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Effect of Nitrogen- and Phosphorus-Based Liquid Biofertilizers on Growth and Yield Attributes of Chickpea (*Cicer arietinum* L.)

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Abstract

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops cultivated in India due to its high nutritional value, ability to fix atmospheric nitrogen, and adaptability to diverse agro-climatic conditions. However, declining soil fertility, low phosphorus availability, and excessive dependence on chemical fertilizers have emerged as major constraints to sustainable chickpea production. Liquid bio-fertilizers containing beneficial microorganisms such as Rhizobium and phosphorus-solubilizing bacteria (PSB) offer an eco-friendly and cost-effective alternative for enhancing nutrient availability, improving soil health, and increasing crop productivity. Keeping these aspects in view, a field experiment entitled "Influence of Nitrogen- and Phosphorus-Based Liquid Biofertilizers on Growth, Yield, and Nutrient Uptake of Chickpea (*Cicer arietinum* L.)" was conducted during the rabi season of 2022–23 at the Department of Agronomy, School of Agricultural Sciences, Career Point University, Kota, Rajasthan, India. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising sixteen treatment combinations involving four fertility levels [control (F_0), 10 kg N + 30 kg P_2O_5 ha^{-1} (F_1), 15 kg N + 40 kg P_2O_5 ha^{-1} (F_2), and 20 kg N + 50 kg P_2O_5 ha^{-1} (F_3)] and four liquid biofertilizer treatments [control (LB_0), liquid Rhizobium inoculation (LB_1), liquid PSB inoculation (LB_2), and combined liquid Rhizobium + PSB inoculation (LB_3)]. Chickpea variety GNG-1958 was sown at a spacing of 30 × 10 cm using a seed rate of 80 kg ha^{-1}. Growth parameters, nodulation, yield attributes, seed and haulm yield, nutrient uptake, protein content, chlorophyll content, soil fertility status, and economic returns were recorded and analyzed. The experimental soil was clay loam in texture, slightly alkaline in reaction (pH 8.03), low in available nitrogen, medium in available phosphorus, and high in available potassium. The study aimed to evaluate the influence of integrated nutrient management through nitrogen, phosphorus, and liquid bio-fertilizers on crop growth, productivity, nutrient uptake, and profitability. It was hypothesized that the combined application of recommended nitrogen and phosphorus levels with liquid Rhizobium and PSB inoculation would enhance nodulation, nutrient availability, physiological efficiency, and yield while improving soil fertility and reducing dependence on chemical fertilizers. The investigation provides valuable insights into sustainable nutrient management strategies for chickpea cultivation under the humid south-eastern plain region of Rajasthan. The findings are expected to support the development of economically viable and environmentally sustainable fertilizer recommendations by integrating inorganic fertilizers with liquid bio-fertilizers, thereby contributing to improved productivity, soil health, and long-term agricultural sustainability.

Keywords: Nitrogen, Phosphorus, Bio-fertilizers, Chickpea.

1. Introduction

Chickpea (*Cicer arietinum* L.) is an important cool-season food legume belonging to the family Leguminaceae and subfamily Papilionaceae. It is one of the most widely cultivated pulse crops worldwide and plays a pivotal role in ensuring food and nutritional security, particularly in developing countries. In India, chickpea occupies the largest share among pulse crops, covering approximately 9.44 million hectares with a production of 10.13 million tonnes and an average productivity of 1,073 kg ha^{-1}**.** More than 90% of the country's chickpea production is concentrated in the major growing states of Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka, Chhattisgarh, Andhra Pradesh, Gujarat, Jharkhand, Tamil Nadu, and Telangana**.** Rajasthan is one of the leading chickpea-producing states, where the crop is cultivated over an area of 1.60 million hectares, producing 1.76 million tonnes with an average productivity of 1,103 kg ha^{-1} (Government of India, 2018–19). Chickpea possesses a well-developed and deep taproot system, enabling it to withstand drought and moisture-deficit conditions more effectively than many other pulse crops. This characteristic makes it highly suitable for cultivation under both rainfed and limited-irrigation farming systems. The crop is predominantly grown under tropical and subtropical climatic conditions, where it serves as an important component of sustainable cropping systems due to its adaptability, nitrogen-fixing ability, and relatively low input requirements. Owing to its wide adaptability, economic significance, and substantial contribution to pulse production, chickpea is popularly regarded as the "King of Pulses. Chickpea is cultivated primarily for its

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exceptional nutritional value and is considered one of the most important sources of plant-based protein in human diets. Pulse grains generally contain 20–25% protein, which is nearly twice that of wheat and about three times higher than that of rice, making them an indispensable component of balanced nutrition, particularly in vegetarian populations (Pingoliya *et al.*, 2013). Besides being an excellent source of high-quality protein, chickpea provides essential amino acids, complex carbohydrates, dietary fiber, vitamins, and minerals that contribute significantly to human health. Regular consumption of pulses has been associated with a reduced risk of several non-communicable diseases, including cardiovascular disorders, obesity, diabetes, and certain types of cancer owing to their low glycaemic index and high antioxidant content (Jukanti *et al.*, 2012). Nutritionally, chickpea seeds contain approximately 20% protein**,** 52–70% carbohydrates**,** 4–10% fat**,** 6% crude fibre**,** 49–53 mg phosphorus**,** and 7 mg iron per 100 g of edible portion (Deppe, 2010). They are also rich in vitamins such as thiamine, riboflavin, niacin, biotin, vitamin A, and vitamin C, making them a valuable source of essential micronutrients. Chickpea is consumed in diverse forms, including whole boiled or roasted seeds, sprouted grains, split dal, flour (besan), and various processed food products. In addition to its nutritional importance, chickpea possesses several medicinal properties. Germinated seeds are considered beneficial for preventing vitamin C deficiency-related disorders, while regular consumption has been reported to support blood purification and overall metabolic health. Nitrogen (N) is one of the most essential macronutrients required for optimum plant growth and development. It is a fundamental constituent of amino acids, proteins, nucleic acids, chlorophyll, phospholipids, enzymes, vitamins, and several plant hormones, thereby playing a central role in numerous physiological and biochemical processes. In leguminous crops such as chickpea, atmospheric nitrogen is biologically fixed through a symbiotic association with *Rhizobium* bacteria present in root nodules, reducing dependence on synthetic nitrogen fertilizers. However, a small starter dose of nitrogen at sowing is often recommended to promote early seedling establishment, vigorous vegetative growth, rapid leaf area development, and enhanced photosynthetic efficiency before effective nodulation occurs. Consequently, adequate nitrogen availability during the initial stages of crop growth contributes significantly to improved biomass production, better reproductive development, and higher seed yield. Phosphorus (P) is an essential macronutrient that plays a fundamental role in plant growth, metabolism, and productivity. It is actively involved in several physiological and biochemical processes, including photosynthesis, energy transfer, carbohydrate metabolism, and the

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synthesis of nucleic acids and cellular membranes. Phosphorus is a key constituent of high-energy compounds such as adenosine triphosphate (ATP) and adenosine diphosphate (ADP), as well as phospholipids, phytin, nucleic acids, and nicotinamide adenine dinucleotide phosphate (NADP), all of which are indispensable for normal plant development. Adequate phosphorus nutrition promotes vigorous root growth, enhances root length and biomass, stimulates rhizobial activity and nodule formation, and improves flowering, pod development, seed filling, and test weight, ultimately resulting in increased grain yield (Shahzad *et al.*, 2014). Biofertilizers have emerged as an eco-friendly and sustainable alternative to chemical fertilizers by enhancing nutrient availability through the activity of beneficial microorganisms. These microbial inoculants contain viable strains of nitrogen-fixing bacteria, phosphorus-solubilizing bacteria (PSB), and other plant growth-promoting microorganisms capable of mobilizing essential nutrients into forms readily available for plant uptake. Their application not only improves nutrient use efficiency but also enhances soil biological activity, promotes root growth, and contributes to the maintenance of soil health. In leguminous crops such as chickpea, symbiotic nitrogen-fixing bacteria (*Rhizobium*) establish associations with root nodules to fix atmospheric nitrogen, while phosphorus-solubilizing bacteria convert insoluble soil phosphorus into plant-available forms. The combined use of *Rhizobium* and PSB has been reported to improve nodulation, nutrient uptake, plant growth, grain yield, and overall crop productivity while reducing dependence on synthetic fertilizers, thereby supporting sustainable agricultural production systems (Selvakumar *et al.*, 2012).

Liquid bio-fertilizers represent an advanced formulation of microbial inoculants that contain highly efficient strains of beneficial microorganisms suspended in a nutrient-rich liquid medium along with suitable protectants and additives that enhance microbial survival during storage and after application to seeds or soil. These additives improve inoculant quality by maintaining high microbial viability, increasing cell population density, and extending shelf life (Tittabutre *et al.*, 2007). Compared with conventional carrier-based formulations, liquid bio-fertilizers offer several advantages, including a longer shelf life of one year or more, higher microbial survival, reduced contamination, and improved field performance. In contrast, carrier-based bio-fertilizers generally have a shelf life of less than six months and are often affected by low water activity, poor survival of inoculated microorganisms, and contamination during storage.

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2. Materials and Methods:

A field experiment entitled "Effect of Nitrogen- and Phosphorus-Based Liquid Biofertilizers on Growth and Yield Attributes of Chickpea (*Cicer arietinum* L.)" was conducted during the rabi season of 2025–26 at the Agricultural Instructional Farm, School of Agricultural Sciences, Career Point University, Kota, Rajasthan, India. The study was undertaken to investigate the influence of varying nitrogen and phosphorus fertility levels in combination with liquid biofertilizer inoculation on the growth, yield attributes, productivity, nutrient uptake, and economic performance of chickpea. The experimental farm is situated in the Humid South-Eastern Plain Agro-climatic Zone (Zone V) of Rajasthan, encompassing approximately 2.443 million hectares, which accounts for nearly 7.71% of the state's total geographical area. Geographically, the region extends between 23°45′ and 26°33′ N latitude and 75°27′ and 77°26′ E longitude. The research farm is equipped with modern infrastructure and essential facilities, including irrigation systems, laboratory facilities, and analytical instruments required for conducting agronomic field experiments. The study area experiences a subtropical climate, characterized by mild winters, moderately warm summers, and relatively high humidity during the southwest monsoon season. The average annual rainfall ranges from 800 to 1000 mm, with approximately 85–90% of the total precipitation received between July and September under the influence of the southwest monsoon. During the rabi season of 2025–26, the maximum air temperature ranged from 21.0 to 30.2°C, while the minimum temperature varied between 4.4 and 17.5°C. The experimental site received a total rainfall of 15.40 mm during the crop-growing period. Overall, the prevailing weather conditions were favourable for the successful establishment, growth, and development of the chickpea crop. Prior to the commencement of the experiment, representative soil samples were collected randomly from the experimental field at a depth of 0–15 cm to assess the initial physico-chemical properties of the soil. The individual samples were thoroughly mixed to obtain a composite sample, which was subsequently air-dried, ground, and passed through a 2-mm sieve for laboratory analysis. The experimental soil was clay loam in texture, containing 37.58% sand, 25.86% silt, and 35.40% clay. The physical properties of the soil included a bulk density of 1.45 Mg m^{-3}, particle density of 2.51 Mg m^{-3}, and porosity of 43.50%. The soil was slightly alkaline in reaction with a pH of 8.03 and an electrical conductivity (EC) of 0.63 dS m^{-1}, indicating non-saline conditions. The soil contained 0.643% organic carbon, 276.25 kg available nitrogen ha^{-1}, 18.62 kg available phosphorus

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ha^{-1}, and 360.70 kg available potassium ha^{-1}, representing low available nitrogen, medium available phosphorus, and high available potassium status.

3. Review of Literature

Khoja *et al.* (2002) conducted a field experiment at Jobner (Rajasthan) and revealed that 20 kg N ha^{-1} + 20 kg P_2O_5 kg ha^{-1} significantly increased the plant height over control and 10 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} . The number of branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$ were increased due to10 kg N + 20 kg $P_2O_5ha^{-1}$ over control in chickpea. Tiwari *et al*. (2005) revealed that application of phosphorus at 50 kg P_2O_5 ha^{-1} significantly increased the number of pods $plant^{-1}$, test weight, seed and haulm yield and harvest index over control and 25 kg P_2O_5 ha^{-1} in chickpea. Dotaniya *et al.* (2014) revealed that seed yield of chickpea significantly increased with increasing level of phosphorus and maximum was at 60 kg P_2O_5 ha^{-1}. Kumar *et al*. (2014) resulted that 100 per cent RDF recorded significantly highest number of pods $plant^{-1}$(44.19), seed yield (1854 kg ha^{-1}) and haulm yield (2722 kg ha^{-1}) over 75 per cent RDF and 50 per cent RDF in chickpea. Badini *et al*. (2015) revealed that 55 kg P_2O_5 ha^{-1} higher yield attributes *viz.*, high number of pods $plant^{-1}$, seeds $plant^{-1}$, seed index and seed yield (1564.15 kg ha^{-1}) over other levels in chickpea. Jat and Ahlawat (2004) revealed that application of phosphorus up to 26.4 kg P_2O_5 ha^{-1} significantly increased the total uptake of nitrogen and phosphorus over control in chickpea. Meena *et al*. (2001) revealed that the protein content in seed was significantly higher with application of 60 kg P_2O_5 ha^{-1} over control in chickpea. Khoja *et al.* (2002) revealed that seed treated with *Rhizobium* + PSB significantly increased the plant height, number of branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$ over control in chickpea. Jat and Ahlawat (2004) revealed that seed inoculation with *Rhizobium* and PSB enhanced seed yield (2.40 ton ha^{-1}) and haulm yield (3.80 ton ha^{-1}) in chickpea.

4. Results and Discussion

The present field experiment entitled "Effect of Nitrogen- and Phosphorus-Based Liquid Biofertilizers on Growth and Yield Attributes of Chickpea (*Cicer arietinum* L.)" was conducted during the rabi season of 2025–26 at the School of Agricultural Sciences, Career Point University, Kota, Rajasthan. The experimental data were statistically analyzed, and the

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significant effects of treatments are presented in the form of tables and graphs, while the analysis of variance (ANOVA) is provided in the appendices. Plant population recorded at 15 DAS and at harvest remained statistically unaffected by different fertility levels as well as liquid bio-fertilizer treatments. Plant height at 30 DAS also did not differ significantly among treatments, although the highest value of 19.89 cm was observed under F_3 (20 kg N + 50 kg P_2O_5 ha^{-1}). However, at 60 DAS, plant height increased significantly with increasing fertility levels, with the tallest plants (43.56 cm) recorded under F_3 and the shortest (37.02 cm) under the control treatment. Similarly, co-inoculation with Liquid Rhizobium + Liquid PSB (LB_3) resulted in the maximum plant height (41.46 cm), significantly outperforming the uninoculated control. At harvest, the highest plant height was recorded under F_3 (54.85 cm) and LB_3 (53.50 cm), indicating that balanced fertilization and bio-fertilizer co-inoculation promoted vigorous crop growth. The number of branches per plant also increased significantly with increasing fertility levels and liquid bio-fertilizer application throughout the crop growth period. At 30 DAS, the highest number of branches was recorded under F_3 (4.33) and LB_3 (4.16). At 60 DAS, F_3 produced 9.51 branches $plant^{-1}$, while LB_3 recorded 8.84 branches $plant^{-1}$, both significantly higher than the control. At harvest, the maximum number of branches was observed under F_3 (12.24 branches $plant^{-1}$) and LB_3 (12.09 branches $plant^{-1}$), confirming that the combined application of nitrogen, phosphorus, and Liquid Rhizobium + Liquid PSB enhanced the vegetative growth of chickpea. Application of increasing fertility levels significantly improved growth characters such as plant height, number of branches, dry matter accumulation, and nodulation, with the highest values recorded under F_3 (20 kg N + 50 kg P_2O_5 ha^{-1}). In contrast, plant population, plant height at 30 DAS, and days to 50% flowering were not significantly influenced by fertility treatments. The enhanced growth under higher fertility levels may be attributed to the role of nitrogen in chlorophyll synthesis and vegetative development, together with the beneficial effects of phosphorus on root development, nodulation, ATP synthesis, nutrient uptake, and energy transfer, supporting earlier findings reported by Khoja *et al*. (2002) and Islam *et al*. (2013). The highest fertility level also significantly increased pods per plant, seeds per pod, seed weight per plant, and consequently seed yield, haulm yield, and biological yield. Improved nutrient availability promoted better source–sink relationships, resulting in enhanced crop productivity. Seed yield showed a strong positive association with branches, dry matter accumulation, pods per plant, seeds per pod, and seed weight, which corroborates the findings of Ali *et al*. (2010). Although nitrogen and phosphorus concentrations in seed and haulm were not significantly

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affected, F_3 significantly enhanced nutrient uptake, soil available nitrogen and phosphorus, chlorophyll content, and seed protein content, thereby improving crop quality and productivity. These results are in accordance with the findings of Singh and Prasad (2008). Economically, the highest net return (₹70,553 ha^{-1}) and benefit–cost ratio (2.32) were obtained with F_3 (20 kg N + 50 kg P_2O_5 ha^{-1}) due to its superior seed yield, which agrees with the observations of Ali *et al*. (2010).

The application of liquid bio-fertilizers also exerted a significant influence on crop performance. Co-inoculation of Liquid Rhizobium + Liquid PSB (LB_3) significantly improved plant height, number of branches, dry matter accumulation, and nodulation compared with the control treatment. These improvements can be attributed to enhanced biological nitrogen fixation, phosphorus solubilization, increased nutrient availability, and the production of plant growth-promoting substances, as also reported by Togay *et al*. (2008). Among the bio-fertilizer treatments, LB_3 recorded the highest number of pods per plant, seed weight per plant, seed yield, biological yield, and harvest index. The improved nutrient availability and synthesis of plant growth regulators enhanced both yield attributes and overall productivity, while seed yield remained positively associated with major growth and yield components, confirming the findings of Sahai and Chandra (2011). Co-inoculation with Rhizobium and PSB significantly increased nitrogen and phosphorus uptake, soil nutrient availability, chlorophyll content, and seed protein content, although nutrient concentrations in seed and haulm remained statistically unchanged. Similar observations were reported by Gupta and Gangwar (2012). From an economic perspective, LB_3 (Liquid Rhizobium + Liquid PSB) produced the highest net return (₹68,457 ha^{-1}) and benefit–cost ratio (2.32) owing to higher yield and improved nutrient use efficiency. The interaction between fertility levels and liquid bio-fertilizer treatments significantly influenced dry matter accumulation, nodulation, pods per plant, and seed weight per plant. The combined application of F_3 (20 kg N + 50 kg P_2O_5 ha^{-1}) with LB_3 (Liquid Rhizobium + Liquid PSB) produced the highest values for these parameters, resulting in superior crop growth, enhanced nutrient availability, increased nitrogen fixation and phosphorus solubilization, improved source–sink relationships, and ultimately higher productivity. These findings are in close agreement with those reported by Kumar *et al*. (2014).

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Table 1.1: Effect of fertility levels and liquid bio-fertilizers inoculation on yield attributes and yield of chickpea

Treatments	Number of pods plant^{-1}	Number of seeds pod^{-1}	Weight of seeds plant^{-1} (g)	Seed index (100 seeds weight)	Yield (kg ha^{-1})			HI (%)
					Seed	Haulm	Biological	
Fertility levels								
Control	55.17	2.15	23.98	20.00	1490	2264	3754	39.62
10 kg N + 30 kg P_2O_5 ha^{-1}	74.26	2.16	34.99	20.13	1713	2409	4129	41.50
15 kg N + 40 kg P_2O_5 ha^{-1}	85.08	2.30	36.34	21.22	1790	2431	4222	42.38
20 kg N + 50 kg P_2O_5 ha^{-1}	91.25	2.51	39.65	21.16	1912	2577	4489	42.58
SEm±	1.03	0.08	1.07	0.43	26	32	35	0.58
CD (P= 0.05)	2.97	0.22	3.10	NS	76	94	102	1.69
Liquid bio-fertilizers								
Control	57.67	1.95	26.90	19.95	1550	2375	3925	39.42
Liquid *Rhizobium* inoculation alone	80.92	2.42	34.41	20.72	1781	2441	4221	42.11
Liquid PSB inoculation alone	76.08	2.32	33.37	20.65	1718	2413	4130	41.51
Liquid *Rhizobium* + liquid PSB inoculation	91.08	2.43	40.28	21.20	1856	2454	4310	43.03
SEm±	1.03	0.08	1.07	0.43	26	32	35	0.58
CD (P= 0.05)	2.97	0.22	3.10	NS	76	NS	102	1.69

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5. Conclusion:

The present study demonstrated that integrated application of 20 kg N + 50 kg P_2O_5 ha^{-1} (F_3) along with Liquid Rhizobium + Liquid PSB (LB_3) significantly improved the growth, yield attributes, seed yield, nutrient uptake, chlorophyll content, seed protein content, and economic returns of chickpea under the agro-climatic conditions of South-Eastern Rajasthan. The combined application of balanced nitrogen and phosphorus fertilization with liquid bio-fertilizer inoculation enhanced nutrient availability, biological nitrogen fixation, phosphorus solubilization, and overall crop productivity. Therefore, the use of 20 kg N + 50 kg P_2O_5 ha^{-1} along with Liquid Rhizobium + Liquid PSB is recommended as an efficient, economical, and sustainable nutrient management practice for chickpea cultivation.

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