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Effect of phosphorus, sulphur and bio-inoculants on growth and yield attributes performance of chickpea in central plain zone of Uttar Pradesh

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Abstract

A field experiment was conducted during *Rabi* seasons of 2024-25 and 2025-26 at the Student Instructional Farm (SIF), Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, (U.P.), to studies on the effect of Phosphorus, Sulphur and Bio-inoculants on soil properties, growth and yield of chickpea (*Cicer arietinum* L.) in Central Plain Zone of Uttar Pradesh. The treatments consisted three levels of phosphorus (P₀: control, P₁: phosphorus @ 30 kg ha⁻¹, P₂: phosphorus @ 60 kg ha⁻¹), three levels of sulphur (S₀: control, S₁: sulphur @ 20 kg ha⁻¹, S₂: sulphur @ 40 kg ha⁻¹) and two levels of bio-inoculants (B₀: control, B₁: inoculation with *Rhizobium* + PSB). The experiment was replicated thrice in a factorial randomized block design (FRBD). The results revealed that application of different treatments affect the growth parameters like plant population, dry matter accumulation and yield attributes like number of pods plant⁻¹, number of grains pod⁻¹ of chickpea were improved significantly due to the integration of phosphorus, sulphur and bio-inoculants except plant population at 20 DAS. The significant higher values of final plant population, dry matter accumulation, number of pods plant⁻¹ and number of grains pod⁻¹ under phosphorus @ 60 kg ha⁻¹ compared to control clearly indicate the effect of level of phosphorus. The study concludes that the integrated use of phosphorus, sulphur and bio-inoculants is a sustainable nutrient management approach for improving chickpea growth, yield attributes, and soil fertility, thereby promoting eco-friendly and cost-effective pulse production under Central Uttar Pradesh conditions.

Keywords: Bio-inoculants, chickpea, growth, phosphorus, sustainable nutrient management

1. Introduction

Chickpea (*Cicer arietinum* L.) is a primary leguminous crop cultivated for its edible seeds, belonging to the genus *Cicer*, within the Fabaceae family (Leguminaceae) and the subfamily Papilionaceae. It is predominantly cultivated as a *Rabi* crop in India's regions known for pulse cultivation, Originating from the southeastern region. Known by various names such as Garbanzo (Spanish), pois chiche (French), kichar or chicher (German), chana (Hindi) and gram or Bengal gram (English) in different regions, chickpea is widely regarded as "poor man's meat" (Grewal *et al.* 2009) [3]. Chickpeas serve as a substantial source of energy, protein, soluble and insoluble fiber. In their mature state, chickpea grains consist of roughly 60-65% carbohydrates, 6% fat and 12-25% protein, surpassing other pulse crops in protein content. Through symbiotic nitrogen fixation, chickpeas effectively meet up to 80% of soil nitrogen needs, consequently lessening farmer's reliance on nitrogen fertilizers. It provides protein rich diet to the vegetarian of the Indian and complement the stable cereals in the diets with proteins, essential amino acids, vitamins and minerals (Pingoliya *et al.* 2013) [7].

Phosphorus is regarded as the pioneer plant nutrient needed by the leguminous crops for rapid and proper root development, which later on becomes helpful for better nodulation by *Rhizobium* bacteria. Sufficient supply of phosphorus to plant hastens the maturity and increases the rate of nodulation and pod development. It is also an important constituent of vital substances like phospholipids and phosphoprotein. Since legume is heavy feeder of phosphorus, therefore,

application of phosphatic fertilizer to chickpea promotes the growth, nodulation and the yield. Phosphorus also imparts hardness to shoot, improves the quality and regulates the photosynthesis and covers other physico-biochemical processes. Sulphur is now recognized as major plant nutrient along with nitrogen (N), phosphorus (P), and potassium (K). It is essential for the growth and development of all crops, without exception most of the plant requirement of sulphur is absorbed through the root in the form of sulphate. Sulphur deficiency is becoming more critical with each passing year which is severely restricting crop yield, produce quality, nutrient use efficiency and economic returns on millions of farms. Like any essential nutrient, sulphur also has certain specific functions to perform in the plant. Thus, sulphur deficiencies can only be corrected by the application of sulphur fertilizer (Tandon and Messick 2007) [14].

Biofertilizers, also known as microbial inoculants, are substances used to treat soil and seeds that contain living or dormant cells of beneficial microorganism strains. "Biofertilizers may colonize the rhizosphere and promotes growth by increasing the availability and supply of nutrients to crop. Nitrogen fixer and phosphate solubilizing microorganisms play an important role in supplementing nitrogen and phosphorus to plants, allowing a sustainable use of nitrogen and phosphate fertilizer" (Tambekar *et al.* 2009) [13]. Chickpea establishes a symbiotic association with *Rhizobium*. *Rhizobium* is one of the nitrogens fixing bacteria which fix atmospheric nitrogen by the symbiotic association with leguminous plants. *Rhizobium* originally called *Bacillus redicicola* was first isolated by Beijerinck (1901). However, PSB also increase the yield of chickpea by 10-30%. Both *Rhizobium* and PSB inoculation significantly increased the nodules mainly due to the fact that "the nitrogenase enzyme present in the bacteria gets introduced through infection causes nodule formation. Application of PSB facilitates the root development vis-à-vis nodule formation and proper development of nodules by increasing the availability of phosphorus through mobilizing the unavailable phosphorus present in the soil. The use of biofertilizers with reduced quantity of chemical fertilizers is therefore recommended for better yield of chickpea". The inoculation of *Rhizobium* can increase grain yield in pulse crop from 10 to 15% (Ali and Chandra, 1985) [1] while phosphate solubilizing bacteria (PSB) increase the availability of insoluble phosphorus into the soils by mineralizing organic phosphorus compounds. Keeping in view the above points, present investigation was carried out.

2. Materials and Methods

2.1 Experimental Location and Season

The experiment was conducted at "Students' Instructional Farm", Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, (U.P.) which is situated between 25° 26' to 26° 58' North latitude, 79° 31' to 31° 34' East longitude and at the 125.9 meters above sea level in the alluvial tract of Indo - Gangatic Plain zone of central part of Uttar Pradesh, India during the Rabi Season 2024-25 to 2025-26.

2.2 Experimental Design and Treatments Details

The experiment was arranged in a Factorial Randomized Block Design with 54 treatment combinations involving three levels of phosphorus (control, phosphorus @ 30 kg ha⁻¹, phosphorus @ 60 kg ha⁻¹), three levels of sulphur (control, sulphur @ 20 kg ha⁻¹, sulphur @ 40 kg ha⁻¹) and two levels of bio-inoculants (control, *Rhizobium* + PSB) replicated thrice. Chickpea var. Uday (KPG-59) was taken as a test crop to observe direct effect of the treatments. The 100% recommended dose of N and K for

chickpea crop was 25 kg N and 20 kg K₂O ha⁻¹, respectively. Full dose of N and K were applied as basal in the form of urea, DAP and muriate of potash manually by placement method into open furrows, respectively. The collected data were statistically analysed using standard ANOVA techniques as suggested by Gomez and Gomez (1984) [12]. The significance of treatment differences was tested at a 5% probability level.

3. Results and Discussion

Growth parameters

The data pertaining to growth parameters under different treatments are presented in Table 1. A perusal of data on plant population as affected by various treatments significantly under study indicated that application of phosphorus, sulphur and bio-inoculants practices at almost all growth stages except 20 DAS during both years and on pooled basis also. In case of at harvest stages pooled analysis of data showed that level of phosphorus at @ 60 kg ha⁻¹ (P₂) was recorded significantly maximum plant population (26.88 m⁻²) followed by phosphorus @ 30 kg ha⁻¹ (P₁), (25.51 m⁻²) and minimum plant population (24.54) were recorded under the treatment of control (P₀). Sulphur level practices also significantly influenced by application of sulphur @ 40 kg ha⁻¹ (S₂) recorded significantly maximum plant population (26.42) followed by sulphur @ 20 kg ha⁻¹ (S₁), (25.62) minimum plant population (24.89) recorded under the treatment of control (S₀). In case of Bio-inoculants practices significantly maximum plant population (26.01) were recorded under *Rhizobium* + PSB (B₁) as compared to without inoculation (B₀), (25.28). Similar result has been reported by (Kumar *et al.* 2019) [4], (Machehouri 2017) [5].

The data pertaining to growth parameters under different treatments are presented in Table 2 and figure 2. A perusal of data on dry matter accumulation as affected by various treatments under study indicated that application of phosphorus, sulphur and bio-inoculants have significant effect on dry matter accumulation during both the years and on pooled basis also. Pooled analysis of data showed that level of phosphorus at @ 60 kg ha⁻¹ (P₂) were recorded significantly maximum dry matter accumulation (g plant⁻¹) 0.96, 4.51, 10.70 and 21.48 at 30, 60, 90 DAS and at harvest stage followed by phosphorus @ 30 kg ha⁻¹ (P₁) 0.89, 4.15, 10.11 and 19.99 at 30, 60, 90 DAS and at harvest stage and minimum dry matter accumulation (g plant⁻¹) 0.79, 3.61, 9.58 and 17.48 at 30, 60, 90 DAS and at harvest stage were recorded under the treatment of control (P₀). Sulphur level practices also significantly influenced by application of sulphur @ 40 kg ha⁻¹ (S₂) recorded significantly maximum dry matter accumulation (g plant⁻¹) 0.97, 4.52, 10.61 and 20.67 at 30, 60, 90 DAS and at harvest stage followed by sulphur @ 20 kg ha⁻¹ (S₁) 0.88, 4.08, 10.10 and 19.92 at 30, 60, 90 DAS and at harvest stage and minimum dry matter accumulation (g plant⁻¹) 0.80, 3.66, 9.68 and 18.36 at 30, 60, 90 DAS and at harvest stage recorded under the treatment of control (S₀). In case of Bio-inoculants practices significantly maximum dry matter accumulation (g plant⁻¹) 0.91, 4.20, 10.25 and 20.20 were recorded under *Rhizobium* + PSB (B₁) as compared to without inoculation (B₀) 0.86, 3.97, 10.01 and 19.10 at 30, 60, 90 DAS and at harvest stage. Similar result has been reported by (Singh *et al.* 2018) [11], (Srivastav *et al.* 2024) [12], (Singh *et al.* 2024) [10], (Tewari *et al.* 2022) [15], (Yadav *et al.* 2022) [16].

Yield attributes

The data pertaining to yield attributes under different treatments are presented in Table 3 and figure 3. A perusal of data on yield attributes as affected by various treatments under study indicated that application of phosphorus, sulphur and bio-inoculants have

significant effect on number of pods plant⁻¹ and number of grains pod⁻¹ during both the years and on pooled basis also. Pooled analysis of data showed that level of phosphorus at @ 60 kg ha⁻¹ (P₂) were recorded significantly maximum pods plant⁻¹ and number of grains pod⁻¹ (44.88) and (1.75) followed by phosphorus @ 30 kg ha⁻¹ (P₁), (42.38) and (1.73) and minimum pods plant⁻¹ and number of grains pod⁻¹ (37.51) and (1.50) were recorded under the treatment of control (P₀). Sulphur level practices also significantly influenced by application of sulphur @ 40 kg ha⁻¹ (S₂) recorded significantly maximum pods plant⁻¹ and number of grains pod⁻¹ (42.19) and (1.70) followed by sulphur @ 20 kg ha⁻¹ (S₁), (41.69) and (1.67) minimum pods plant⁻¹ and number of grains pod⁻¹ (40.90) and (1.61) recorded under the treatment of control (S₀). In case of Bio-inoculants practices significantly

maximum pods plant⁻¹ and number of grains pod⁻¹ (42.74) and (1.70) were recorded under *Rhizobium* + PSB (B₁) as compared to without inoculation (B₀), (40.45) and (1.62). Significant increase in number of grains pod⁻¹ Probably may be due to balanced nutrition and proper vegetative growth which later converted into reproductive phase and resulted might in a greater number of seeds. The results were similar to Significant increase number of pods plant⁻¹ this might be due to more availability of sulphur during these vegetative and reproductive stages of the crop. Sulphur is a part of amino acid (Cystine), which helps in chlorophyll formation, photosynthetic process and activation of enzymes. Similar findings have been reported by (Mitra *et al.* 2006) [6], (Ram *et al.* 2018) [8] and Singh *et al.* 2015) [9].

Table 1: Effect of phosphorus, sulphur and bio-inoculants on growth parameters

Treatments	Plant Population (m ⁻²)					
	Initial (at 20 DAS)			Final (at harvest stage)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Phosphorus						
P ₀	26.12	26.18	26.15	24.41	24.66	24.54
P ₁	27.12	27.32	27.22	25.42	25.60	25.51
P ₂	27.81	28.23	28.02	26.78	26.99	26.88
S.Em±	0.538	0.55	0.174	0.245	0.247	0.162
C.D at 5%	NS	1.58	0.50	0.704	0.709	0.465
Sulphur						
S ₀	26.81	26.87	26.84	24.78	25.00	24.89
S ₁	27.09	27.30	27.19	25.50	25.75	25.62
S ₂	27.16	27.56	27.36	26.34	26.50	26.42
S.Em±	0.538	0.55	0.174	0.245	0.247	0.162
C.D at 5%	NS	NS	NS	0.704	0.709	0.465
Bio-inoculants						
B ₀	27.04	27.19	27.11	25.19	25.36	25.28
B ₁	27.00	27.30	27.15	25.88	26.15	26.01
S.Em±	0.439	0.449	0.142	0.2	0.201	0.132
C.D at 5%	NS	NS	NS	0.575	0.579	0.380

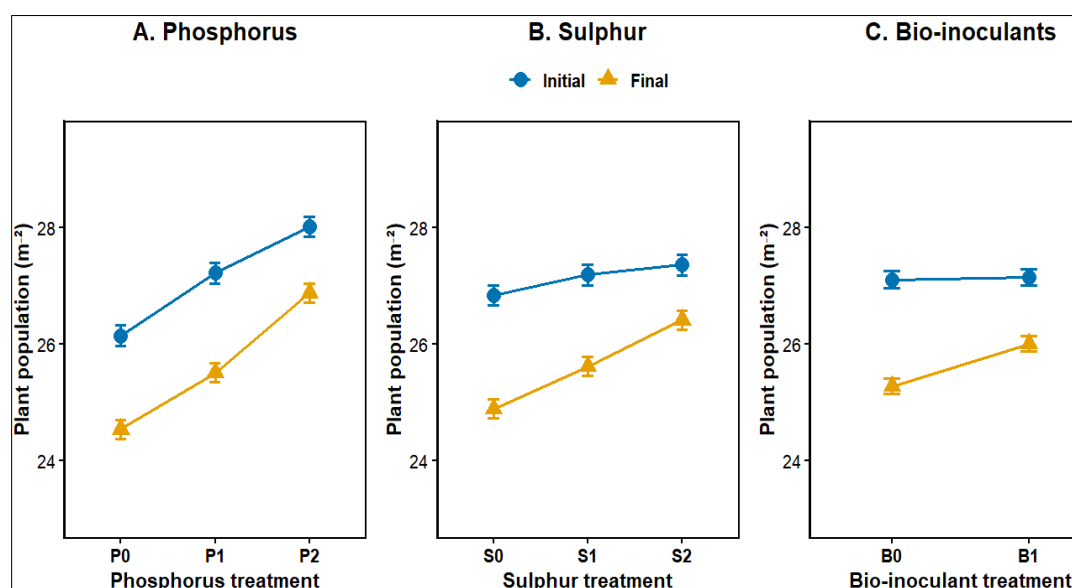
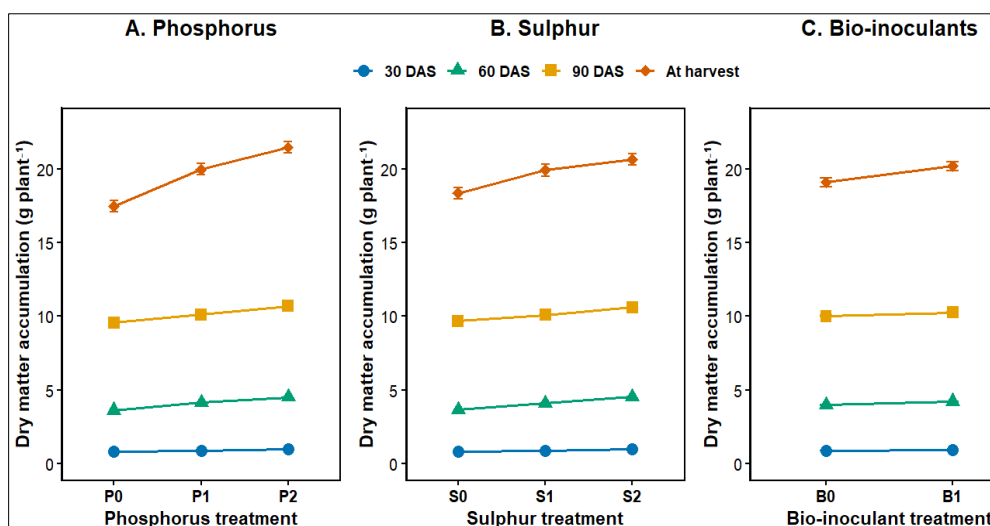


Fig 1: Effect of phosphorus, sulphur and bio-inoculants on growth parameters

Table 2: Effect of phosphorus, sulphur and bio-inoculants on growth parameters

Treatments	Dry matter accumulation (g plant ⁻¹)											
	At 30 DAS			At 60 DAS			At 90 DAS			At harvest		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Phosphorus												
P ₀	0.78	0.81	0.79	3.54	3.69	3.61	9.49	9.68	9.58	17.18	17.78	17.48
P ₁	0.88	0.91	0.89	4.07	4.23	4.15	10.01	10.22	10.11	19.52	20.46	19.99
P ₂	0.94	0.97	0.96	4.42	4.60	4.51	10.59	10.81	10.70	20.82	22.14	21.48
S.Em±	0.005	0.005	0.005	0.027	0.023	0.019	0.055	0.058	0.059	0.382	0.401	0.392
C.D at 5%	0.015	0.015	0.015	0.078	0.065	0.054	0.159	0.166	0.169	1.097	1.153	1.126
Sulphur												
S ₀	0.78	0.81	0.80	3.59	3.74	3.66	9.58	9.78	9.68	17.94	18.78	18.36
S ₁	0.86	0.89	0.88	4.00	4.17	4.08	10.00	10.21	10.10	19.45	20.40	19.92
S ₂	0.95	0.98	0.97	4.44	4.61	4.52	10.51	10.72	10.61	20.13	21.21	20.67
S.Em±	0.005	0.005	0.005	0.027	0.023	0.019	0.055	0.058	0.059	0.382	0.401	0.392
C.D at 5%	0.015	0.015	0.015	0.078	0.065	0.054	0.159	0.166	0.169	1.097	1.153	1.126
Bio-inoculants												
B ₀	0.84	0.87	0.86	3.89	4.05	3.97	9.92	10.11	10.01	18.60	19.61	19.10
B ₁	0.89	0.92	0.91	4.12	4.29	4.21	10.15	10.35	10.25	19.75	20.65	20.20
S.Em±	0.004	0.004	0.004	0.022	0.019	0.015	0.045	0.047	0.048	0.312	0.328	0.320
C.D at 5%	0.012	0.012	0.012	0.064	0.053	0.044	0.13	0.136	0.138	0.896	0.942	0.919

**Fig 2:** Effect of phosphorus, sulphur and bio-inoculants on growth parameters**Table 3:** Effect of phosphorus, sulphur and bio-inoculants on yield attributes

Treatments	Yield Attributes					
	Number of Pods Plant ⁻¹			Number of Grains Pod ⁻¹		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Phosphorus						
P ₀	37.32	37.71	37.51	1.47	1.53	1.50
P ₁	41.88	42.88	42.38	1.70	1.76	1.73
P ₂	44.49	45.28	44.88	1.73	1.78	1.75
S.Em±	0.28	0.269	0.214	0.009	0.011	0.009
C.D at 5%	0.806	0.772	0.616	0.027	0.032	0.025
Sulphur						
S ₀	40.54	41.26	40.90	1.58	1.64	1.61
S ₁	41.36	42.02	41.69	1.64	1.69	1.67
S ₂	41.78	42.59	42.19	1.67	1.73	1.70
S.Em±	0.28	0.269	0.214	0.009	0.011	0.009
C.D at 5%	0.806	0.772	0.616	0.027	0.032	0.025
Bio-inoculants						
B ₀	40.15	40.74	40.45	1.59	1.66	1.62
B ₁	42.31	43.17	42.74	1.67	1.72	1.70
S.Em±	0.229	0.219	0.175	0.008	0.009	0.007
C.D at 5%	0.658	0.63	0.503	0.022	0.026	0.020

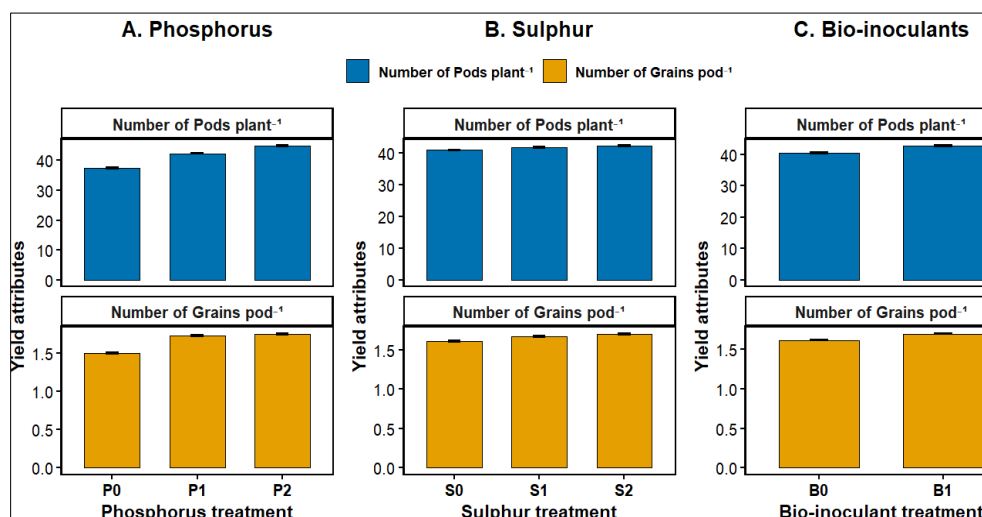


Fig 3: Effect of phosphorus, sulphur and bio-inoculants on yield attributes

Conclusion

The combined application of phosphorus, sulphur and bio-inoculants significantly enhanced plant growth and yield attributes parameters in terms of final plant population, dry matter accumulation and number of pods plant⁻¹ and number of grains pod⁻¹. Final plant population, dry matter accumulation and number of pods plant⁻¹ and number of grains pod⁻¹ showed marked improvement with increasing phosphorus levels, particularly when combined with sulphur and bio-inoculants. The treatment level of phosphorus at @ 60 kg ha⁻¹ (P₂) consistently produced superior results across all growth stages and yield attributes, indicating its effectiveness in promoting plant vigor and productivity compared to lower phosphorus doses or control treatments.

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