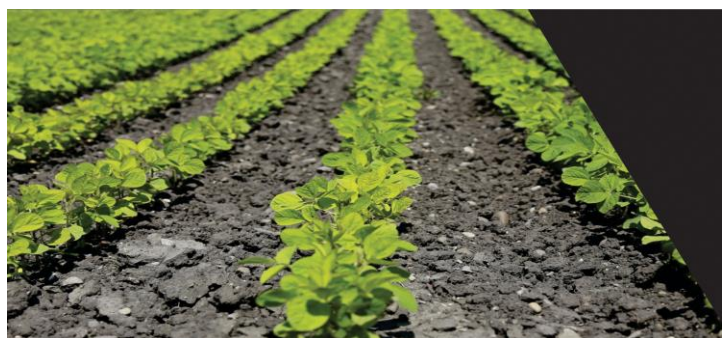




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Gayatri P More
PG Scholar, Department of Soil
science, College of Agriculture,
Latur, Vasantrao Naik
Marathwada Krishi Vidyapeeth,
Parbhani, Maharashtra, India

Dr. Ajit N Puri
Assistant Professor, College of
Agriculture, Latur, Vasantrao Naik
Marathwada Krishi Vidyapeeth,
Parbhani, Maharashtra, India

Dr. Prabhakar B Adsul
Associate Professor, College of
Agriculture, Latur, Vasantrao Naik
Marathwada Krishi Vidyapeeth,
Parbhani, Maharashtra, India

Dr. Mahesh S Waghmare
Assistant Professor, College of
Agriculture, Dharashiv, Vasantrao
Naik Marathwada Krishi
Vidyapeeth, Parbhani,
Maharashtra, India

Dr. Vasant P Suryavanshi
Professor, College of Agriculture,
Latur, Vasantrao Naik
Marathwada Krishi Vidyapeeth,
Parbhani, Maharashtra, India

Aditya S Daware
PG Scholar, Department of Soil
science, College of Agriculture,
Latur, Vasantrao Naik
Marathwada Krishi Vidyapeeth,
Parbhani, Maharashtra, India

Anbarasu R
PG Scholar, Department of Soil
science, College of Agriculture,
Latur, Vasantrao Naik
Marathwada Krishi Vidyapeeth,
Parbhani, Maharashtra, India

Corresponding Author:
Gayatri P More
PG Scholar, Department of Soil
science, College of Agriculture,
Latur, Vasantrao Naik
Marathwada Krishi Vidyapeeth,
Parbhani, Maharashtra, India

Effect of phosphorus solubilizing bacteria on growth and yield of chickpea (*Cicer arietinum* L.)

Gayatri P More, Ajit N Puri, Prabhakar B Adsul, Mahesh S Waghmare, Vasant P Suryavanshi, Aditya S Daware and Anbarasu R

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Abstract

A field experiment entitled “Effect of phosphorus solubilizing bacteria on soil nutrient dynamics, uptake and yield of chickpea (*Cicer arietinum* L.)” was conducted during the rabi season of 2025–2026 at the Research Farm, Department of Soil Science, Latur, using chickpea variety BDNG-797 (Akash). The experiment was laid out in a Randomized Block Design with eight treatments and three replications. The results revealed that application of phosphorus solubilizing bacteria (PSB) significantly influenced the growth and yield attributes of chickpea. The treatment comprising 100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS recorded the highest plant height and leaf area at different growth stages. It also recorded the maximum number of nodules plant⁻¹ (24.50) and pods plant⁻¹ (103.07), indicating better plant growth and nodulation. The highest seed yield (21.60 q ha⁻¹) and straw yield (65.66 q ha⁻¹) were also recorded under this treatment, followed by 100% RDNK + 50% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS and 100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 DAS.

However, seeds pod⁻¹ and test weight were not significantly influenced by the treatments. Overall, the study demonstrated that PSB seed treatment combined with drenching at 20 and 40 DAS along with 75% recommended phosphorus was effective in improving the growth and yield performance of chickpea.

Keywords: Chickpea, phosphorus solubilizing bacteria, growth attributes, yield attributes, seed yield

Introduction

Chickpea, popularly known as Bengal gram (*Cicer arietinum* L.), is an important pulse crop in India, cultivated across diverse agro-climatic conditions. It covers about 9.6 million hectares, producing over 11.04 million tonnes with an average productivity of 1.15 tonnes ha⁻¹. In the northeastern plain region, chickpea occupies nearly 1.2 million hectares. However, its cultivation has declined over the past two decades due to replacement by wheat and other profitable crops, disease incidence, and moisture and heat stress during pod formation and seed filling. Climate change and shortening of the cool season have further intensified heat stress, affecting chickpea productivity (Choudhary *et al.*, 2024) [3].

India is the largest producer and consumer of pulses. Gram (*Cicer arietinum* L.) is occupying third position among the grain legumes in the world. Among the pulses, gram occupies a predominant position and is considered as a “King of pulses”. It is originated in south eastern Turkey. Chickpea (*Cicer arietinum* L.) is grown in 54 countries with nearly 90% of its area covered in developing countries. The major chickpea (*Cicer arietinum* L.) producing countries are India (64%), Pakistan (8%), Turkey (6%), Iran (3%), Myanmar (3%), Australia (3%), Ethiopia (3%), Canada (2%), Mexico (2%), Iraq (1%), and others (5%) in 2004/05 to 2006/07 (FAOSTAT, 2012) [4].

Macronutrients play important and vital role in soil health and plant growth. They needed in large quantity. P is one of the macronutrient plays important role in leguminous crops like chickpea. P is needed for nodule formation and function, which directly influences N fixation. That’s why macronutrients are essential for nodulation, N fixation, growth, stress resistance and yield in leguminous crops. P is essential for the development and functioning of root nodules in legumes, which house N-fixing bacteria. Adequate P ensures efficient biological fixation. P is also key component of ATP and helps in root development, early maturity and yield, stress resistance, etc. PSB are a group of beneficial soil microorganisms capable of converting insoluble forms of

inorganic phosphate into soluble forms that can be readily utilized by plants.

(Chen *et al.* 2006) ^[2]. The phosphate-solubilizing ability of rhizospheric microorganisms is considered one of the most important traits influencing plant P nutrition.

BDNG 797 (Akash) variety is used for field trial which was developed by the Agricultural Research Station, Badnapur (Maharashtra). It is a desi chickpea variety released in 2007, highly regarded for being resistant to wilt and tolerant to the notorious pod borer (*Helicoverpa armigera*) pest, making it a stable, high-yielding choice for farmers, particularly in Maharashtra.

Materials and method

The experiment was conducted at the research farm of Department of Soil Science, College of Agriculture, Latur, during rabi season of the year 2025-2026, the variety of chickpea used for experiment BDNG 797, and the topography of experimental field was uniform and levelled. The experimental soil was clayey in texture, calcareous in nature, moderately alkaline reaction, low in content of organic carbon (4.60 g kg⁻¹), CaCO₃ (69.20 g kg⁻¹) available nitrogen (222.89 kg ha⁻¹), medium in available phosphorous (26.24 kg ha⁻¹), in available potassium (628.08 kg ha⁻¹). The experiment implemented in randomized block design (RBD) with a plot size of 3.6 × 3 m, and row-to row and plant-to-plant distances of 30 and 10 cm, respectively. Fertilizers used in this experiment include Urea, SSP, MOP and ZnSO₄ by soil application. The seed rate used was 60 kg ha⁻¹. Seed treated with Rhizobium and PSB. Sowing was done by dibbling method. The recommended cultural practices and plant protection measures were taken. Five plants were randomly selected and tagged from each net plot to record biometric observations at various growth stages. These same plants were later harvested individually for post-harvest analysis. The data collected from various observations were organized into tables and analyzed using analysis of variance (ANOVA).

Result and discussion

Plant height (cm)

The results revealed that plant height of chickpea was significantly influenced by different PSB treatments at 30, 45 and 60 DAS. Among the different treatments, T₇ (100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS) recorded the maximum plant height of 18.97, 25.88 and 33.93 cm at 30, 45 and 60 DAS, respectively. This was followed by T₈ (100% RDNK + 50% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS), which recorded 18.67, 25.83 and 33.30 cm, and T₅ (100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 DAS), which recorded 18.63, 25.72 and 33.20 cm at the respective growth stages. Both T₈ and T₅ were statistically at par with T₇. The treatments T₃ and T₆ also recorded significantly higher plant height than T₂ and T₁, indicating the beneficial effect of PSB application on vegetative growth. The lowest plant height was recorded under the control (T₁), with 16.95, 23.49 and 29.84 cm at 30, 45 and 60 DAS, respectively.

Overall, the results indicated that combined application of PSB through seed treatment and split drenching, particularly with 75% recommended phosphorus, promoted vigorous vegetative growth of chickpea. The improved plant height may be attributed to enhanced phosphorus solubilization and availability in the rhizosphere, better nutrient uptake, root development and physiological activity. Singh *et al.* (2021) ^[9] reported that PSB seed inoculation significantly enhanced plant height of mungbean

at 30, 45, 60 DAS and at harvest compared with the control. The maximum plant height (78.9 cm) was recorded with 60 kg P₂O₅ ha⁻¹, which was at par with 40 kg P₂O₅ ha⁻¹, indicating the beneficial interaction of PSB and P in improving crop growth. Sumanth *et al.* (2021) ^[10] observed that application of PSB @ 1% + P @ 20 kg ha⁻¹ recorded the highest plant height (40.17 cm) at 75 DAS in greengram, which was significantly superior to most other treatments.

Leaf area (cm²) plant⁻¹

At 30 DAS, leaf area was significantly influenced by PSB treatments, ranging from 150.44 cm² in T₁ (Control) to 229.18 cm² in T₇, followed by T₈ (221.01 cm²) and T₅ (216.85 cm²). At 45 DAS, the same trend was observed, with the maximum leaf area in T₇ (377.36 cm²), followed by T₈ (366.90 cm²) and T₅ (356.08 cm²), while the minimum was recorded in T₁ (245.40 cm²).

The increased leaf area with PSB application may be attributed to improved phosphorus availability, which promotes root development, cell division and photosynthetic activity. The superior performance of T₇ may be due to the combined effect of 75% RDP, PSB seed treatment and drenching at 20 and 40 DAS, ensuring better phosphorus availability throughout crop growth. Similar results were observed by Chattha *et al.* (2017) ^[1] reported that fertilizer application and inoculation significantly ($P \leq 0.05$) improved the growth attributes of mungbean. Application of 20:50 kg N:P ha⁻¹ recorded the maximum leaf area index, leaf area duration and dry matter accumulation, whereas the lowest values were observed without fertilizer application. Among inoculants, combined application of Rhizobium and PSB resulted in the highest leaf area index, leaf area duration and dry matter accumulation, demonstrating the positive effect of microbial inoculation on mungbean growth.

Number of nodules plant⁻¹

Among the different treatments, T₇ (100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS) recorded the maximum number of nodules (24.50 plant⁻¹), followed by T₈ (100% RDNK + 50% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS) and T₅ (100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 DAS), which recorded 24.25 and 24.20 nodules plant⁻¹, respectively. The higher nodule formation under these treatments might be due to improved P availability through PSB activity, which enhanced root development and created favourable conditions for symbiotic N fixation.

The treatments T₃ (100% RDNK + 75% RDP + PSB seed treatment) and T₄ (100% RDNK + 50% RDP + PSB seed treatment) recorded 22.50 and 22.70 nodules plant⁻¹, respectively, indicating the positive influence of PSB seed inoculation on nodulation compared to fertilizer alone treatments. The lowest number of nodules was recorded under T₁ (Control) and T₂ (100% RDF) with 16.83 and 16.87 nodules plant⁻¹, respectively. Similar results were found by Nabati *et al.* (2025) ^[8] reported that biofertilizer application significantly enhanced nodulation in chickpea. The combined application of SPO + SOB + NFB + PSB + KSB increased the number of nodules from 32.3 to 109 nodules plant⁻¹ compared with the control and also recorded the highest percentage of active nodules, with a 77% increase over the control. The improvement in nodulation was attributed to the synergistic effect of plant growth-promoting rhizobacteria and nutrient-solubilizing microorganisms, which enhanced nutrient availability and supported better plant growth.

Number of pods plant⁻¹ and Number of seeds pod⁻¹

The number of pods plant⁻¹ was significantly influenced by different PSB treatments, whereas the effect on number of seeds pod⁻¹ was non-significant. Treatment T₇ (100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS) recorded the maximum number of pods (103.07 plant⁻¹) and seeds (1.60 pod⁻¹), followed by T₈ (101.80 pods plant⁻¹ and 1.57 seeds pod⁻¹). Treatment T₅ recorded 94.10 pods plant⁻¹ and 1.50 seeds pod⁻¹, followed by T₆ with 93.67 pods plant⁻¹ and 1.30 seeds pod⁻¹. Treatments T₃ and T₄ also showed better performance than T₂ (100% RDF), indicating the beneficial effect of PSB application along with appropriate phosphorus management on yield-contributing characters.

The higher pod formation under PSB treatments may be attributed to improved phosphorus availability through PSB activity, which enhanced nutrient uptake, photosynthetic efficiency, flower retention and translocation of assimilates towards reproductive growth. The repeated application of PSB under T₇ and T₈ may have ensured a more continuous supply of available phosphorus during the reproductive phase, resulting in better pod formation. In contrast, the lowest number of pods (59.47 plant⁻¹) and seeds (1.07 pod⁻¹) was recorded under T₁ (Control), which may be attributed to limited phosphorus availability, restricted vegetative growth and lower nutrient uptake, ultimately resulting in poor reproductive development.

The present findings are in agreement with Meena *et al.* (2025) [7], who reported that phosphorus application significantly improved the yield attributes of chickpea by enhancing photosynthetic activity and efficient translocation of assimilates towards reproductive parts. Application of 65 kg P₂O₅ ha⁻¹ recorded significantly higher plant population (35 m⁻²), number of seeds plant⁻¹ (45.66) and seeds pod⁻¹ (2.10). The same treatment also recorded the highest number of pods plant⁻¹ (45.66), seed yield (2166 kg ha⁻¹), straw yield (3396 kg ha⁻¹) and harvest index (38.95%), demonstrating the beneficial effect of phosphorus application on chickpea productivity.

Seed yield (q ha⁻¹)

Among the different treatments, T₇ (100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS) recorded the maximum seed yield (21.60 q ha⁻¹), followed by T₈ (100% RDNK + 50% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS) with 21.51 q ha⁻¹. The higher seed yield under these treatments might be due to the combined effect of PSB seed inoculation and repeated drenching, which improved P availability, nutrient uptake and P use efficiency. Enhanced P nutrition resulted in better growth, increased yield contributing characters such as number of pods plant⁻¹ and seeds pod⁻¹, and efficient translocation of assimilates towards seed development. Treatment T₅ (100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 DAS) recorded 21.29 q ha⁻¹, followed by T₆ with 21.11 q ha⁻¹ seed yield. The treatments T₃ and T₄ also recorded higher seed yield (20.80 and 20.43 q ha⁻¹, respectively) compared to T₂ (100% RDF), indicating the positive influence of PSB inoculation in improving P availability and crop productivity. The present findings are in conformity with Laharia *et al.* (2019) [5], who observed that phosphorus levels combined with PSB inoculation significantly increased seed yield of chickpea. The highest seed yield (15.10 q ha⁻¹) was recorded with 125% RDP along with PSB inoculation, which was attributed to improved phosphorus availability, enhanced nutrient uptake and efficient utilization of applied phosphorus.

Straw yield (q ha⁻¹)

The maximum straw yield was recorded under T₇ (100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS) with 65.66 q ha⁻¹, followed by T₈ with 65.14 q ha⁻¹. The higher straw yield under these treatments might be due to improved vegetative growth, greater leaf area development, enhanced nutrient uptake and increased dry matter accumulation resulting from continuous P availability through PSB activity. Treatment T₅ and T₆ recorded comparable straw yields of 64.88 q ha⁻¹, whereas T₃ and T₄ recorded 64.78 and 64.63 q ha⁻¹, respectively. These treatments showed improvement over T₂ (100% RDF), indicating that PSB application enhanced P utilization and promoted better biomass production. The lowest straw yield was recorded under control (T₁) with 61.56 q ha⁻¹, which may be due to insufficient P availability and reduced vegetative growth. The significant variation among treatments (CD at 5% = 2.07) indicates the effectiveness of PSB inoculation and P management in improving straw production. Waghmare *et al.* (2024) [6] reported that phosphorus-solubilizing microorganisms and phosphorus application significantly improved straw yield of chickpea. Seed inoculation with *A. awamori* recorded the highest straw yield (1803.2 kg ha⁻¹), followed by *A. niger* (1688.0 kg ha⁻¹) and *B. megaterium* (1613.4 kg ha⁻¹). Among phosphorus levels, application of 75 kg P₂O₅ ha⁻¹ recorded the highest straw yield (1741.19 kg ha⁻¹), indicating that improved phosphorus availability through PSB inoculation and adequate P application enhanced plant growth and biomass production.

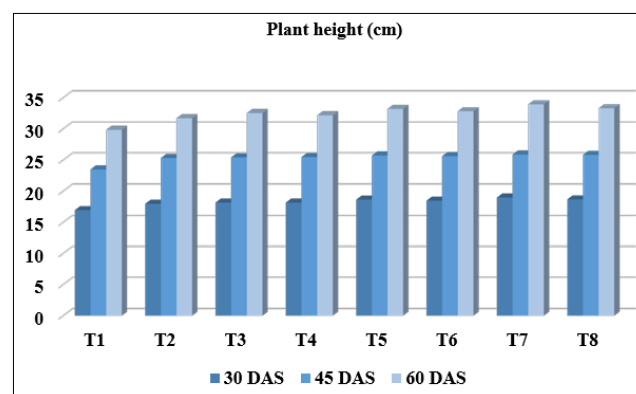


Fig 1: Effect of PSB on plant height (cm) of Chickpea at 30, 45, 60 DAS.

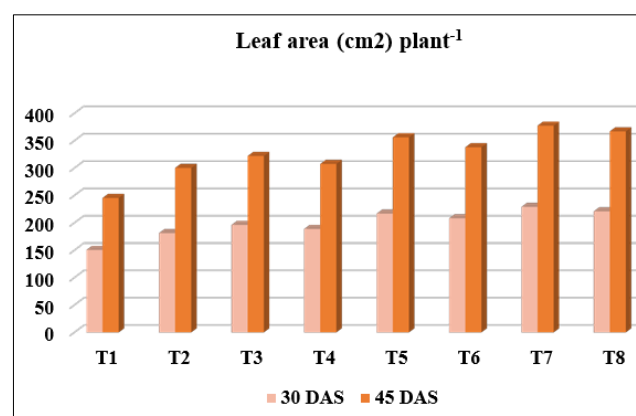


Fig 2: Effect of PSB on leaf area plant⁻¹ (cm²) of Chickpea at 30 and 45 DAS.

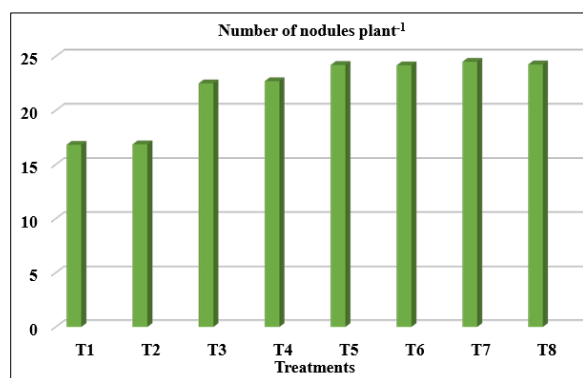


Fig 3: Effect of PSB on nodulation of Chickpea at flowering stage.

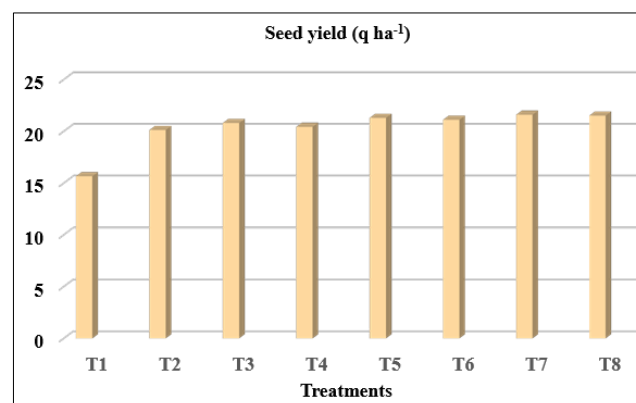


Fig 6: Effect of PSB on seed yield of Chickpea crop.

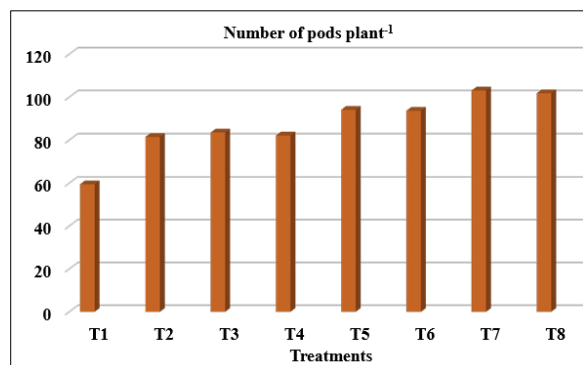


Fig 4: Effect of PSB on number of pods plant⁻¹ of Chickpea at harvest.

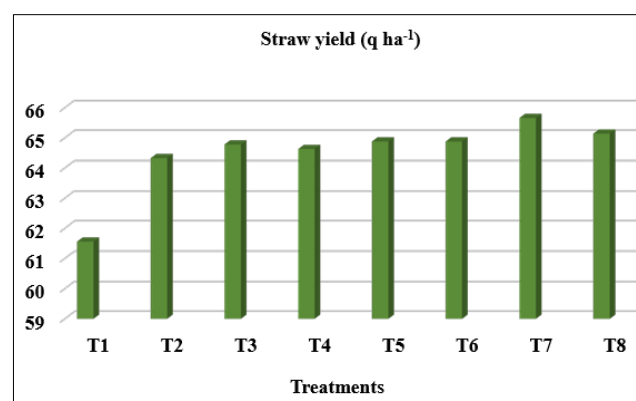


Fig 7: Effect of PSB on straw yield of Chickpea crop.

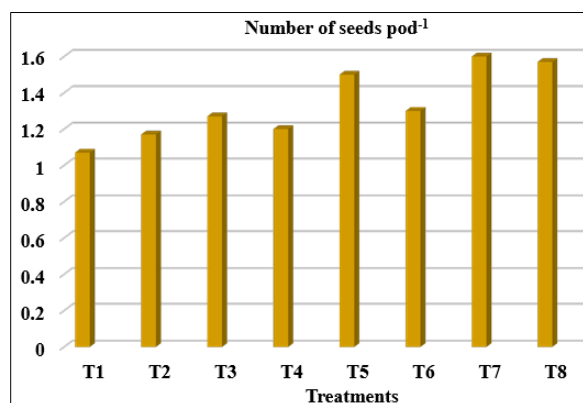


Fig 5: Effect of PSB on number of seeds pod⁻¹ of Chickpea at harvest.

Conclusion

Overall, 100% RDNK + 75% RDP + PSB seed treatment + PSB drenching at 20 and 40 DAS (T₇) recorded the highest plant height, leaf area, number of nodules, pods plant⁻¹, seeds pod⁻¹ and straw yield. T₇ was at par with T₅ and T₈ for major growth and yield attributes, while differences in nodules and seeds pod⁻¹ were non-significant. Thus, T₇ proved to be the most promising treatment for improving growth and yield parameters of chickpea, mainly due to enhanced phosphorus availability, nutrient uptake and efficient utilization of applied nutrients.

Table 1: Mean of growth and yield parameters of soybean as influenced by various treatments.

Treatments	Plant height (cm)			Leaf area (cm ²)		No. of nodules plant ⁻¹	No. of pods plant ⁻¹	No. of seeds pod ⁻¹	Seed yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS					
T1 - Control	16.95	23.49	29.84	150.44	245.40	16.83	59.47	1.07	15.66	61.56
T2 - RDF	17.97	25.32	31.70	181.22	300.25	16.87	81.47	1.17	20.12	64.33
T3 - 100% RDNK+ 75% RDP+ PSB seed treatment	18.17	25.43	32.53	196.20	322.00	22.50	83.53	1.27	20.80	64.78
T4 - 100% RDNK + 50% RDP + PSB seed treatment	18.17	25.48	32.17	188.75	307.52	22.70	82.13	1.20	20.43	64.63
T5 - 100% RDNK + 75% RDP + PSB seed treatment + Drenching of PSB at 20 DAS.	18.63	25.72	33.20	216.85	356.08	24.20	94.10	1.50	21.29	64.88
T6 -100% RDNK + 50% RDP + PSB seed treatment +	18.47	25.62	32.83	208.35	337.97	24.17	93.67	1.30	21.11	64.88

Drenching of PSB at 20 DAS.										
T7 - 100% RDNK + 75% RDP + PSB seed treatment + Drenching of PSB at 20 and 40 DAS.	18.97	25.88	33.93	229.18	377.36	24.50	103.07	1.60	21.60	65.66
T8 - 100% RDNK + 50% RDP + PSB seed treatment + Drenching of PSB at 20 and 40 DAS.	18.67	25.83	33.30	221.01	366.90	24.25	101.80	1.57	21.51	65.14
SE ±	0.25	0.44	0.50	5.10	9.14	1.97	3.40	0.16	0.43	0.68
CD @ 5%	0.77	1.33	1.51	15.47	27.73	NS	10.32	NS	1.29	2.07

*DAS- days after sowing

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