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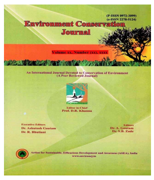

# Inoculation with PSB (phosphate-solubilizing bacteria) *or Rhizobium* in combination with NPK influenced the yield, quality and soil parameters of field pea

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## ABSTRACT

**The yield and quality of field pea are directly influenced by inoculation of *Rhizobium* and PSB with NPK, which increase various parameters, such as the yield and quality of field pea. This research was conducted during the Rabi season in 2022-2023 at Lovely Professional University in the Punjab region of India. The yields of pea grain and stover are greatly increased by the use of 100% RDF (the recommended dose of fertilizer) with PSB and *Rhizobium*. In addition to the combination of *Rhizobium*, PSB and NPK increased the harvest index of field pea. The protein content and number of nodules were strongly affected by this treatment, which was more beneficial than the other treatments. Overall, the net return was greater in T7 (100% RDF+ PSB + *Rhizobium*). In addition, in comparison with the other treatments, available nitrogen, phosphorus and potassium also had positive effects on T7.**

## Introduction

Pea (*Pisum sativum* L.) belongs to the family *Fabaceae*. In the eleventh century, it was cultivated by the Romans and Greeks, and it has become a significant crop in farming systems. (Sajid *et al.,* 2013). It is a self-pollinating, annual crop. The crop's green seeds and pods are what are grown. The immature green seeds are the most popular frozen vegetable food and can be eaten fresh, canned, or in dehydrated jars. (Negi *et al.,*2006) India produces 21% of the world's peas, making it the second-largest producer in the world. Punjab produces 6.7% of all peas in India and is the fifth-largest producer in the nation. This crop is a leguminous plant and has a minimal need for nitrogen. *Rhizobium* has the capacity to fix atmospheric nitrogen (Mishra *et al.,* 2013). The use of legumes such as peas, beans, chickpeas, lentils, and red grammes is helpful. It colonizes the roots of some legumes to produce nodules, which resemble tumors and function as factories for the production of ammonia. The need

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for nitrogen fertilization in successive crops may be reduced by nitrogen cycling from plant waste. The use of traditional cultivars and an uneven application of fertilizers are the reasons for the low productivity of pea in the Punjab region. *Rhizobium* and phosphate solubilizing bacteria (PSB) have been proven to be beneficial in boosting pea yield in such circumstances (Jain P. C *et al*.,1999; D. L. Rudresh *et al.,*2005). The use of microbial inoculants is an economical source of plant nutrients that are sustainable and renewable (Khan M. S *et al.,*2007). Therefore, *Rhizobium* and PSB are extremely important because of their crucial functions in N2 fixation and P solubilization. Therefore, to examine the effect on pea quality parameters, the favorable effects of N-fixing *Rhizobium* and phosphate-solubilizing bacteria with NPK were thoroughly investigated. The purpose of this research was to investigate the influence of two biofertilizers inoculated with NPK on pea yield and quality and soil parameters.

## Material and Methods

The study of the inoculation of PSB, Rhizobium and the combination of NPK with field pea utilized an RBD (randomized block design) with three replications and included seven treatments, including T1- Control (no fertilizer), T2-100% RDF (recommended dose of fertilizers), T3-*Rhizobium*, T4-PSB (phosphate solubilizing bacteria), T5-100% RDFF + *Rhizobium*, T6-100% RDF + PSB and T7-100% RDFF + PSB+*Rhizobium*. The pH of the sandy loam soil in the experimental field was 8.2, and its organic carbon content was 0.38. The field pea variety used was PB-89, which employs 75 kg of seed per hectare, and the Kera technique was used on ridges. At the time of sowing, the field received the full dosage of fertilizer prescribed by the treatments. Chemical plant protection methods, such as the removal of infected plants and the application of copper oxychloride at a rate of 2 g per liter of water to control bacterial infection, are required to control pests and disease infestation. The following information was collected: grain yield (q/ha), yield recovery (q/ha), harvest index (%) and protein content (%). Information such as the number of nodules per plant was also analyzed for different nutrient sources. The yield of the crop was determined by calculating its economic value, which plays a vital role in estimating the production of plants. Moreover, soil analysis was performed to determine the contents of available nitrogen, phosphorus and potassium.

### Study area

The present study was performed at Lovely Professional University, Punjab, India, from 2022–2023 at the School of Agriculture Research Field at Lovely Professional University, Phagwara, Punjab, India, which is located in the northern plain zone between 31.2690°N and 75.7021°E.

## Results and Discussion

### Effect of different nutrient sources on the grain yield (q/ha) of field pea

The results of the field pea seed yield per hectare were obtained for the various treatments. The field pea grain yield per hectare varied dramatically, as shown in Figure 1. An analysis of the data showing that the use of 100% RDF in combination with inoculation of *Rhizobium* and PSB (T7) resulted in the highest yield of seeds (34.6 q/ha), followed by the application of 100% RDF in combination with phosphate-solubilizing bacteria (33.0 q/ha) in T6, as shown in Table 1. The absolute control (T1) treatment produced the least amount of seed (12.8 q/ha). The plots treated with *Rhizobium* (T3) had the highest seed output of the various biofertilizer treatments, with a yield of 14.1 q/ha, followed by the plots treated with PSB (T4). The increase in seed yield at higher phosphorus levels may be related to the involvement of phosphorus in energizing processes, abundant nodulation, and status as a component of ribonucleic acid. Deoxyribonucleic acid, ATP, and acid control key metabolic processes in plants, aiding in nitrogen fixation and root development, which has a favorable impact on photosynthetic organs, and the rate favors greater crop growth and output. These results are consistent with those of Erman *et al.* (2006). However, there was a statistically significant difference between the treatments used in the present study. There are a number of reasons why the pea yield increased significantly when chemical fertilizers were applied alone or in conjunction with biofertilizers. The use of chemical fertilizers for treatments T3 and T4 provided the plant with all the nutrients needed,

**Table 1: Grain yield of field pea after seed inoculation with biofertilizers**

| Treatments | Grain Yield (q/ha) |
|---|---|
| T1- Control | 12.8 |
| T2- 100% RDF | 27.0 |
| T3- *Rhizobium* @20 g/kg | 14.1 |
| T4- PSB @20 g/kg | 16.7 |
| T5- 100% RDF + *Rhizobium* | 28.8 |
| T6- 100% RDF + PSB | 33.0 |
| T7 - 100% RDF + *Rhizobium* + PSB | 34.6 |
| **S.Em±** | 0.6 |
| **C.D@ 5%** | 1.4 |

resulting in a quick boost in nutrition and general plant growth. Later, the biofertilizers provided more nutrients to the plants, promoting healthy plant growth and ultimately leading to increased crop yields. Similar findings have been reported by Tyagi (2003), Mishra *et al.* (2010), Patel (2006) and Kumari *et al*. (2012).

**Effects of different nutrient sources on stover yield in field pea**

Information regarding the impact of biofertilizer inoculation on field pea stover yield is provided in Figure 1. There are a number of reasons why the combined application of NPK and biofertilizers increased pea stover output. Treatment T7, which applied 100% RDF and inoculated rhizobium and phosphate-solubilizing bacteria, produced the highest yield of all the treatments (41.0 q/ha), which was comparable to treatment T6, which applied 100% RDF and inoculated phosphate-solubilizing bacteria (39.4 q/ha). The control (T1) treatment had the lowest stover yield (22.1 q/ha). When fertilizer was applied at the full recommended rate (T2), the yield of stover was 37.1 q/ha greater than that of the absolute control treatment. The plots treated with phosphate-solubilizing bacteria (24.5 q/ha) exhibited the highest stover production across the individual biofertilizer applications, followed by the *Rhizobium*-treated plots (23 q/ha), even though the difference was not statistically significant, as shown in Table 2. The high stover yield is due to a well-balanced and ample supply of nutrients, including nitrogen, phosphorus, and potash, which encourage optimal plant growth. Additionally, it enhances the soil's qualities, which can strengthen the root system and allow for greater nutrient and water absorption.

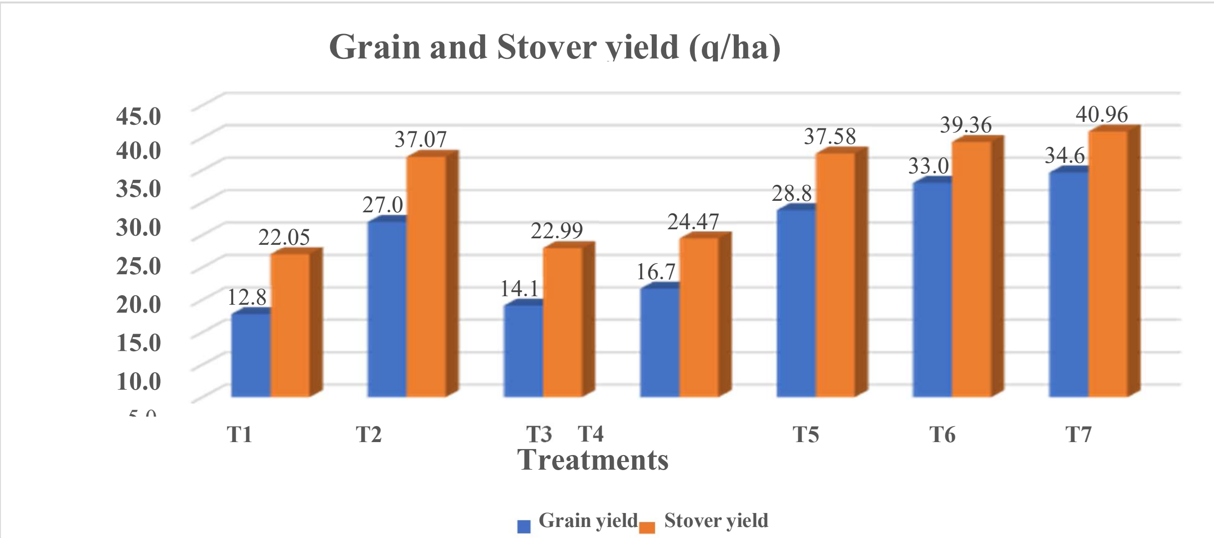


**Figure 1. Grain yield (kg/ha) and stover yield (kg/ha) of field pea influenced by varying phosphorus levels and *Rhizobium* inoculation in combination with NPK**

**Table 2: Effect of the use of biofertilizers for seed inoculation on the stover yield of field pea**

| Treatments | Stover yield (q/ha) |
|---|---|
| T1- Control | 22.1 |
| T2- 100% RDF | 37.1 |
| T3- *Rhizobium* @20 g/kg | 23.0 |
| T4- PSB @20 g/kg | 24.5 |
| T5- 100% RDF + *Rhizobium* | 37.6 |
| T6- 100% RDF + PSB | 39.4 |
| T7 - 100% RDF + *Rhizobium* + PSB | 41.0 |
| **S.Em±** | 1.4 |
| **C.D@ 5%** | 2.9 |

Together, these elements support enhanced plant growth, which increases crop productivity. Bhat *et al.* (2012), Kumari *et al.* (2012) reported similar findings. Similarly, Negi *et al.* (2006) reported that *Rhizobium* and PSB may have had a synergistic effect that boosted growth, yield characteristics, and eventually yield because of the increased nitrogenase activity of field pea and the accessible phosphorus status of the soil.

**Effects of different nutrient sources on the harvest indices of field pea plants**

The harvest index measures the economic yield as a share of the total biological production (grain plus straw) in terms of dry matter. The application of 100% RDF in combination with *Rhizobium* and phosphate-solubilizing bacteria (45.8%) improved the harvest index. It was comparable to 100% RDF (42.1%), 100% RDF with seed inoculation of *Rhizobium* (43.4%), and 100% RDF (45.6) with regard to phosphate-solubilizing bacteria. The lowest harvest index (36.2%) was obtained with the absolute control treatment, as shown in Table 3. Chethan *et al.* (2018) and Sakya *et al.* (2018) reported the same findings.

**Effect of different nutrient sources on the protein content in field pea**

The protein content was greatly enhanced by using several biofertilizers and the recommended amount of fertilizer, either separately or in combination. T6 application of 100% RDF along with phosphate-solubilizing bacteria (18.7%) and T7 (100% RDF along with seed inoculation by Rhizobium and phosphate-solubilizing bacteria) yielded the highest field pea protein content readings of 19.8% and 11.5%, respectively. The protein content dramatically increased as a result of the use of synthetic fertilizers in T2 compared to that in the control, as shown in Table 4. *Rhizobium* produced the highest protein concentration when compared to PSB in biofertlizers. The protein content increased by 19.8% and 11.5% when *Rhizobium* and PSB were used as inoculants, respectively; therefore, the NPK dosage may need to be increased because phosphate- and rhizobium-solubilizing bacteria are converted into unavailable phosphorus in the soil and atmospheric nitrogen that plants may utilize, resulting in greater nitrogen levels in the seeds and other plant components. Additionally, phosphorus likely plays a role in increasing protein content by encouraging plants to use nitrogen. Similar results are noted for Kumar *et al. (*2012).

**Table 3: Effect of different treatments on the harvest index percentage of field pea**

| Treatment | Harvest index(%) |
|---|---|
| T1- Control | 36.8 |
| T2- 100% RDF | 42.1 |
| T3- *Rhizobium* @20 g/kg | 38.2 |
| T4- PSB @20 g/kg | 40.6 |
| T5- 100% RDF + *Rhizobium* | 43.4 |
| T6- 100% RDF + PSB | 45.6 |
| T7 - 100% RDF + *Rhizobium* + PSB | 45.8 |
| **S.Em±** | 1.4 |
| **C.D@ 5%** | 3.0 |

**Table 4: Influence of different nutrient sources during seed inoculation on the protein content (%) of field pea**

| Treatments | Protein content (%) |
|---|---|
| T1- Control | 11.5 |
| T2- 100% RDF | 18.0 |
| T3- *Rhizobium* @20 g/kg | 12.9 |
| T4- PSB @20 g/kg | 14.1 |
| T5- 100% RDF + *Rhizobium* | 18.0 |
| T6- 100% RDF + PSB | 18.7 |
| T7 - 100% RDF + *Rhizobium* + PSB | 19.8 |
| **S.Em±** | 0.9 |
| **C.D@ 5%** | 2.1 |

**Effect of different nutrient sources on the number of nodules per field pea plant**

The nodule density per plant at 60 DAS for the various treatments is shown in Table 5. Treatment T7 resulted in the highest average number of nodules (37.7), which was statistically comparable to that resulting from the application of 100% RDF along with the inoculation of phosphate-solubilizing bacteria (35.7). The same observations were recorded by Gupta and Namdeo (2000) and Barea *et al.* (2005). The treatment with the lowest number of nodules, the absolute control (T1), had 15.3 nodules, as shown in Figure 2. The most notable positive effect on nodulation was associated with the combination of NPK fertilizers and biofertilizers, demonstrating a synergistic interaction between NPK fertilizers, *Rhizobium* and PSB. These outcomes are consistent with those of Rather *et al.* (2010) and Bansal (2009).

**Effects of different nutrient sources on field pea economics**

An economic experiment has the main objective of maximizing profit while minimizing production costs. Therefore, it seems sensible to think about implementing therapies that have produced better revenues. Based on current prices for various commodities, economic analysis involves computing the average cost of manufacturing. We calculate the net return, cost of production, and net profit per rupee by using different treatments to establish whether it is economically feasible to implement the recommendations shown in Figure 3.

**Table 5: Number of nodules per plant of field pea (*Pisum sativum* L.) influenced by seed inoculation with biofertilizers**

| Treatments | Number of nodules per plants at 60 days after sowing |
|---|---|
| T1- Control | 15.3 |
| T2- 100% RDF | 31.3 |
| T3- *Rhizobium* @20 g/kg | 23.0 |
| T4- PSB @20 g/kg | 25.7 |
| T5- 100% RDF + *Rhizobium* | 32.0 |
| T6-100% RDF + PSB | 35.7 |
| T7 -100% RDF + *Rhizobium* +PSB | 37.7 |
| **S.Em±** | 0.9 |
| **C.D@ 5%** | 2.0 |

**Cost of cultivation** (per **ha)**

In the agricultural industry, crop yield is greatly influenced by the cost of cultivation. It involves a variety of costs, including the costs of hired labor, machine labor, irrigation, fungicides, seeds, manures, and land preparation. It also includes land revenue, depreciation costs, other costs, and interest. It is critical to assess whether the applied inputs result in benefits that outweigh their costs. The benefits are considered when the returns outweigh the cost of cultivation. Table 6 (T7) shows that the highest cost of cultivation was ₹41606, followed by T6 (100% RDF along with seed inoculation by PSB) at Rs.40766. The lowest cultivation cost (T1) was obtained for the absolute control ₹ 34587.

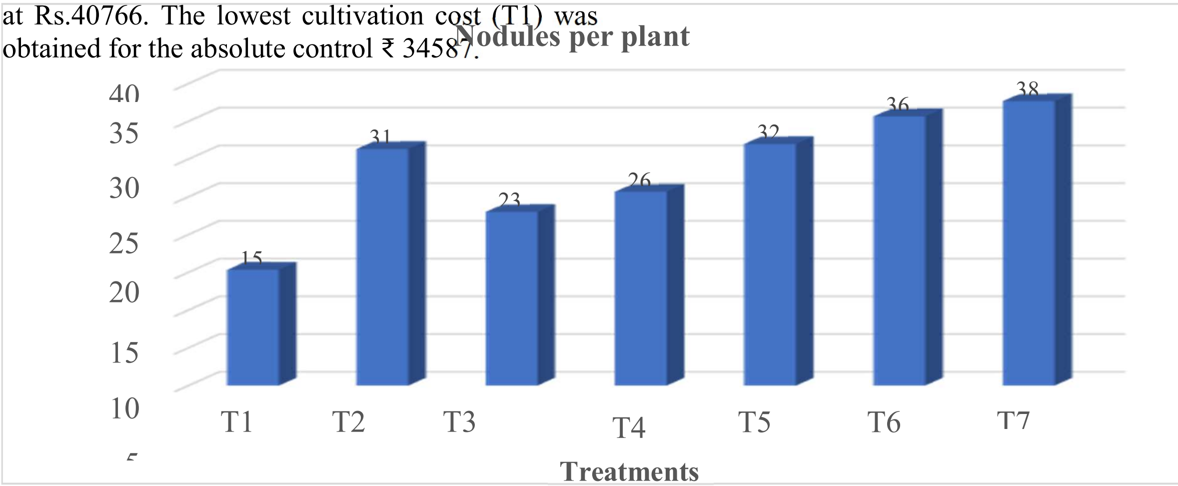


**Figure 2 Number of nodules in field pea plants as influenced by varying phosphorus levels and *Rhizobium* inoculation in combination with NPK**

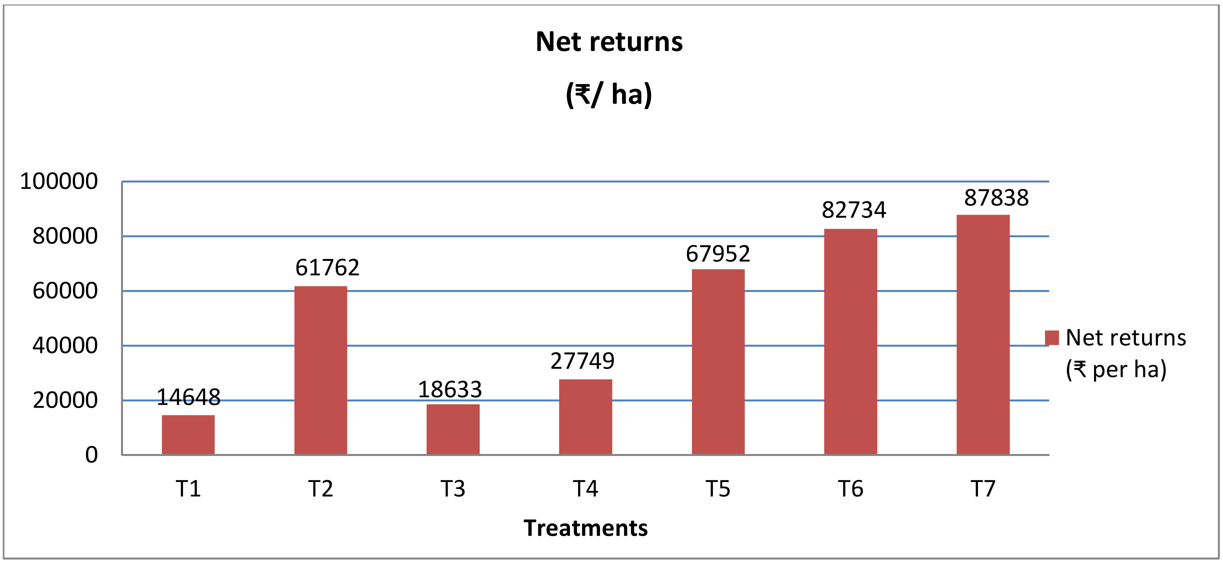


**Figure 3 Net return (₹/ha) of field pea plants influenced by varying phosphorus levels and Rhizobium inoculation at different NPK concentrations**

**Gross Return (₹ per ha)**

Gross returns, which do not include cultivation costs, are the overall income from grain and stover yield. Higher gross returns that are more than the cost of production point to favorable outcomes for agricultural farmers. Table 6 contains information on gross income after harvesting grain, straw, and stover. The T7 treatment produced the greatest gross return ₹137636, followed by the T6 treatment (100% RDF along with seed inoculation by PSB) ₹ 131371. The absolute control (T1) had the lowest gross return, which was recorded at ₹ 34587.

**Net returns**

The money obtained after subtracting the cost of cultivation from the gross returns is represented by net returns. These net returns closely reflect the initial gain or loss that farmers incurred while working in the fields. Farmers benefit from higher net returns relative to the expense of cultivation. The statistics on the net returns shown in Table 6 indicate that the highest net returns were observed at 100% RDF with Rhizobium and PSB (T7) seed inoculation, followed by T6 (100% RDF with PSB seed inoculation), which had net returns of ₹90605 and ₹96030, respectively. The control treatment (T1) had the lowest net returns (approximately 19059).

**Table 6: Field pea economics after inoculation of nutrient sources with biofertilizers**

| Treatments | Cost of cultivation (₹ per ha) | Gross returns (₹ per ha) | Net returns (₹ per ha) | B: C (Benefit cost Ratio) |
|---|---|---|---|---|
| T1- Control | 34587 | 49234 | 14648 | 0.4 |
| T2- 100% RDF | 40165 | 101927 | 61762 | 1.5 |
| T3- *Rhizobium* @20 g/kg | 35403 | 54036 | 18633 | 0.5 |
| T4- PSB @20 g/kg | 35688 | 63437 | 27749 | 0.8 |
| T5- 100% RDF + *Rhizobium* | 40481 | 108433 | 67952 | 1.7 |
| T6-100% RDF + PSB | 40766 | 123500 | 82734 | 2.0 |
| T7 - 100% RDF + *Rhizobium* + PSB | 41606 | 129444 | 87838 | 2.1 |

**Cost–benefit analysis**

The fundamental indicator of how farmers gain from their inputs used in crop production and how returns are obtained is the benefit–cost ratio. There will be a higher B:C ratio and thus more benefits for growers if the returns are greater than the expense of production. According to the benefit–cost statistics in Table 6, T7 (100% RDF plus seed inoculation by PSB) had the highest benefit–cost ratio (2.3), followed by T6 (100% RDF plus seed inoculation by *Rhizobium)* (2.2). The control treatment (T1) had the lowest benefit–cost ratio (0.6).

**Effects of biofertilizers combined with NPK on the soil properties of field pea crops**

**Available nitrogen in the soil**

The data in Table 7 demonstrate that in comparison with plots treated with biofertilizers, the plots treated with 100% RDF +PSB+*Rhizobium (*T7) exhibited a greater accessible nitrogen content of 244.4 kg/ha. The nitrogen delivered from these sources and the decrease in nitrate loss through soil leaching, resulting in a balanced nitrogen supply, can be attributed to the increase in available nitrogen with the addition of seed inoculation using biofertilizers. These conclusions are in line with the study performed by Dhiman *et al.* (2016).

**Available phosphorus**

Table 7 shows that the available phosphorus content following crop harvesting, which ranged from 18 kg/ha to 27.3 kg/ha, was considerably impacted by the various seed inoculation procedures. The plot receiving T7 had the maximum available phosphorus content of 27.3 kg/ha, while the control plot (T1) had the lowest concentration of 18 kg/ha. Comparing the plots infected with only biofertilizers to the plots treated with 100% RDF (T2), the accessible phosphorus level in the latter was greater at 25.7 kg/ha.

**Available potassium**

Table 7 shows that the available potassium content, which ranged from 169.2 kg/ha to 227.1 kg/ha, was significantly impacted by the various seed inoculation regimens. The plot with T7 had the maximum available potassium content of 227.1 kg/ha, while the control plot with T1 had the lowest amount, at 169.2 kg/ha. Comparing the plots infected with only biofertilizers to the plots treated with 100% RDF (T2), the latter had a greater accessible potassium content of 222.4 kg/ha.

**Table 7: Analysis of the soil properties of field pea plants inoculated with biofertilizers**

| **Treatments** | **Available N (kg/ha)** | **Available P (kg/ha)** | **Available K (kg/ha)** |
|---|---|---|---|
| T1- Control | 143.8 | 18.0 | 169.2 |
| T2- 100% RDF | 220.4 | 25.7 | 222.4 |
| T3- *Rhizobium* @20 g/kg | 158.9 | 19.0 | 183.2 |
| T4- PSB @20 g/kg | 150.4 | 24.4 | 180.1 |
| T5- 100% RDF + *Rhizobium* | 223.6 | 25.3 | 224.6 |
| T6- 100% RDF + PSB | 218.0 | 26.0 | 223.0 |
| T7 - 100% RDF + *Rhizobium* + PSB | 244.4 | 27.3 | 227.1 |
| **S.Em±** | 6.5 | 1.2 | 8.7 |
| **C.D@ 5%** | 14.0 | 2.4 | 19.0 |

## Conclusion

According to one study, the contribution of biofertilizers with NPK to yield and quality parameters is evident. Both the increase in field pea production and protein content as a result of rhizobium interactions with PSB and NPK, Rhizobium and PSB combined with NPK improved the grain yield, harvest index, and stover yield, all of which are indicators of increased productivity. In addition, the protein content of the peas improved their quality. In light of this, using biofertlizers such as rhizobium and PSB together with NPK encourages farmers to use them in the field with the aim of sustainability and profitability.

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### Conflict of interest

The authors declare that they have no conflicts of interest.

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