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Effect of Different Levels of Macronutrients and Rhizobium on Soil Health and Yield Attributes of Field Pea (*Pisum sativum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment was carried out at the central research farm in the Department of Soil Science and Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during Rabi season 2023-24. The soil texture in the experimental region was sandy loam. The design was set up using randomized block design, with two levels of sulphur (50 and 100%),

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Rhizobium, and NPK (20:60:40) at different levels. The treatment T9 (@100% NPKS +@100% Rhizobium+ 100% Sulphur) gave the best results in terms of plant height, number of pods plant$^{-1,}$ and total Field Pea yield. It also showed a slight decrease in pH, bulk density, and particle density; however, there was a significant increase in pore space, water holding capacity, EC, organic carbon, available nitrogen, phosphorus, and potassium, as well as plant growth and yield attributes. There was no discernible difference in the growth and production of Field Pea under control. The use of Biofertilizer, as well as their blend with complete NPK and S, significantly increased the characteristics of growth and total yield attributes of Field Pea.

Keywords: Field pea; NPK; Sulphur; rhizobium.

1. INTRODUCTION

"Pea (*Pisum sativum L.*) is the most important legume crop, which had its origin in Ethiopia. One of the main pulse crops is field pea, a grain legume that belongs to the Leguminosae family. Due to its high protein, carbohydrate, vitamin C, calcium, and phosphorus content, it is a staple food that is enjoyed by people all over the world" [1]. Notably, lysine and tryptophan are also abundant in field peas (Sharma et al., 2023). "Symbiotic Rhizobium bacteria within its root nodules enable nitrogen fixation, a process critical to soil fertility preservation" [2]. "Peas are commonly small spherical seeds present inside the pod. Each pod contains several seeds, which develop from the ovary of the flower and can be green or yellow in colour. It is used as a fresh vegetable or can even be canned or processed. Pea occupies an area of 5,49,000 hectares with an annual production of 56,80,000 metric tons in India" (NHB, 2021-22). In Himachal Pradesh, it occupies an area of 22,855.17 hectares with an annual production of 2,88,994 metric tons [3].

"Long term sustainability of agriculture is a matter of today's agriculture. The most intensive agriculture shows signs of soil deterioration in the quality and quantity of soil nutrients as well as physical soil properties, which is associated to stagnation and yield decline. Imbalance use of inorganic fertilisers and lack of organic fertilization are the related causal factors for decline of their properties" [4]. "The use of organic manures along with chemical fertilizers on a regular basis is usually thought to be useful in the long run for maintaining and increasing fertility of the soil. Organic manures improve soil quality indicators such as physical, chemical, and biological as well as provide plant nutrients" [5].

"Rhizobium is a genus of Gram-negative soil bacteria that fix nitrogen. Rhizobium species from an endosymbiotic nitrogen-fixing association with roots of legumes and other flowering plants" [6,7]. The bacteria colonize plant cells within root nodules, where they convert atmospheric nitrogen into ammonia using the enzyme nitrogenase and then provide organic nitrogenous compound such as glutamine or ureides to the plant. The beneficial effects of Rhizobium inoculation on cluster bean grain yield resulting in saving of 13.37 to 21.73kg/ha nitrogen and an enhanced seed yield ranging from 2.34 to 8.05q/ha along with nitrogen application compared to control.

"Phosphate solubilizing bacteria (PSB) are beneficial bacteria capable of solubilizing inorganic phosphorus from insoluble compound. P-solubilization ability of rhizosphere microorganisms is one of the most important traits associated with plant phosphate nutrition. PSB have been introduced to the Agricultural community as phosphate Biofertilizer. Phosphorus is one of the major essential macronutrients for plants and is applied to soil in the form of phosphate fertilizers. However, a large portion of soluble inorganic phosphate which is applied to the soil as chemical fertilizer is immobilized rapidly and becomes unavailable to plants" [7]. PSB have attracted the attention of agriculturists as soil inoculums to improve the plant growth and yield. Many different strains of these bacteria have been identified as PSB, including *Pantoea agglomerans* (P5), *Microbacterium laevaniformans* (P7) strains are highly efficient insoluble phosphate solubilizers.

2. MATERIALS AND METHODS

The research work was carried out at the Soil Science Research Farm, Department of Soil Science and Agricultural Chemistry Sam Higginbottom University of Agriculture, Technology and Sciences, Naini Agricultural Institute, Prayagraj, during Rabi Season of 2023-2024. Agro-climatically, Prayagraj district represents the subtropical belt of the Southeast of Uttar Pradesh and is endowed with extremely hot summer and fairly cold winter. The maximum temperature of the location reaches up to 46'C-48'C and seldom falls as low as 4'C -5'C. The relative humidity ranged between 20 to 94 percent. The average rainfall of this area is around 1100mm annually. The experiment was carried out in a Randomized Block Design (RBD) with three levels of inorganic fertilizer N, P, K (40, 80, 40 ha^{-1}), Levels Of Sulphur and Levels of Rhizobium, the treatments were replicated three times. Treatments were T_1 -(control), T_2 -RDF @ 0% + S @ 0% + @ Rhizobium 50%, T_3 -RDF @ 0% + S @ 0% + @ Rhizobium 75%, T_4 -RDF @ 0% + S @ 0% + @ Rhizobium 100%, T_5 -RDF @ 50% + S @ 0% + @ Rhizobium 50%, T_6 -RDF @ 50% + S @ 50% + @ Rhizobium 75%, T_7 -RDF @ 50% + S @ 50% + @ Rhizobium 100%, T_8 -RDF @ 100% + S @ 100% + @ Rhizobium 75% and T_9 -RDF @ 100% + S @ 100% + @ Rhizobium 100%. During the experimentation, growth and yield characters were recorded. The source of inorganic nutrients was Urea, SSP, MOP, micronutrient and rhizobium respectively.

3. RESULTS AND DISCUSSION

After harvesting the shows that soil bulk density was found to be non-significant by organic and inorganic. The maximum soil bulk density at 0-15 to 15-30 cm soil depth was recorded in T_9[NPK @ 100% + S @ 100% + @ Rhizobium 100%] which was 1.32 and 1.33 Mg m-3 and minimum soil bulk density was recorded in T_1[(Control)] which was 1.24 and 1.25 Mg m-3. The maximum bulk density was recorded in treatment T9. Similarfindings were recorded by Verma and Baigh, (2012), Kumar et al. [8]. The maximum soil particle density at 0-15 to 15-30 cm soil depth was recorded in T_9[NPK @ 100% + S @ 100% + @ Rhizobium 100%], which was 2.51and 2.52 Mg m-3 and minimum soil particle density was recorded in T_1[(Control)], which was 2.43 and 2.44 Mg m-3. Similar findings were recorded by Kumaret al. [8], Reddyet al. (2005), Gupta et al. (2000). The maximum soil %pore space at 0-15 to 15-30 cm soil depth was recorded in T_9[NPK @ 100% + S @ 100% + @ Rhizobium 100%], which was 46.63and 41.98% and minimum soil %pore space was recorded in T_1[NPK @ 0% + S @ 0% + @ Rhizobium 0%], which was 41.10 and 36.80%. The maximum soil water holding capacity (%) at 0-15 to 15-30 cm soil depth was recorded in T_9[NPK @ 100% + S @ 100% + @ Rhizobium 100%], which was 40.96 and 36.71% and minimum soil water holding capacity (%) was recorded in T_1[(Control)], which was 35.55 and 31.48%

The table shows the interaction between NPK fertilizers in conjunction with Rhizobium on water holding capacity in soil was significant. Similar findings were recorded by Kumar et al. [8], Reddy et al. (2005). The maximum soil pH w/v (1:2.5) at 0-15 to 15-30 cm soil depth was recorded in T_9[NPK @ 100% + S @ 100% + @ Rhizobium 100%], which was 7.12 and 7.16 and minimum soil pH was recorded in T_1[(Control)], which was 6.71 and 6.75. The maximum soil pH was recorded 7.35 in treatment T0(control) Similar findings were recorded by Verma and Baigh, (2012), Takase et al. [9]. The maximum soil EC (dS m^{-1}) at 0-15cm soil depth was recorded in T_9[NPK @ 100% + S @ 100% + @ Rhizobium 100%], which was 0.43 and 0.42 Mg m^{-1} and minimum was recorded in T_1[(Control)], which was 0.29 and 0.26 Mg m^{-1}.The maximum EC of the soil was recorded in treatment T9 [RDF @100% + S @100%+ Rhizobium @100%]. Similar findings were recorded by Takase et al.[9].Kumar [8],Gupta et al. (2000).

The data recorded on % organic carbon was recorded at 0-15cm and 15-30cm soil depth. The result of the data shows that soil % organic carbon was found to be significant by organic and inorganic. The maximum soil % organic carbon at 0-15cm and 15-30cm soil depth was recorded in T9 [NPK @ 100% + S @ 100% + @ Rhizobium 100%] which was 0.53 and 0.44 minimum was recorded in T1[(Control)] which was 0.30 and 0.28. Similar findings were recorded by Verma and Baigh, (2012), Kumar et al. [8] and Reddy et al. (2005). The maximum soil Available Nitrogen (kg ha^{-1}) at 0-15and 15-30cmsoildepth was recorded in T9 [NPK @ 100% + S @ 100% + @ Rhizobium 100%] which was 285.42 and 283.93 minimum was recorded in T1[(Control)] which was 258.15 and 256.82. Similar findings have been reported by Malavet al. (2018), Patel et al. [10], Patel et al. (2010), Manohar et al. (2018). The maximum soil Available Phosphorus(kgha^{-1}) at 0-15and 15-30cmsoildepth was recorded in T9 [NPK @ 100% + S @ 100% + @ Rhizobium 100%] which was 25.01 and 24.08 minimum was recorded in T1[(Control)] which was 12.25 and 11.32. These findings corroborate with the results reported by Katkar et al., (2011). Moharana et al., (2012) also found the maximum increase in available

Table 1. Physical properties of soil sample after harvesting of Pea (*Pisum sativum* L.)

Treatment Combination		Bulk Density (Mg m-3)		Particle Density (Mg m-3)		Pore Space (%)		Water Holding Capacity (%)		pH w/v (1:2.5)		EC (dS m-1)	
		0 – 15 cm Depth	15 – 30 cm Depth	0 – 15 cm Depth	15 – 30 cm Depth	0 – 15 cm Depth	15 – 30 cm Depth	0 – 15 cm Depth	15 – 30 cm Depth	0 – 15 cm Depth	15 – 30 cm Depth	0 – 15 cm Depth	15 – 30 cm Depth
T1	(Control)	1.24	1.25	2.43	2.44	41.10	36.8	35.55	31.48	6.71	6.75	0.29	0.26
T2	NPK @ 0% + S @ 0% + Rhizobium@50%	1.24	1.25	2.44	2.45	41.56	37.43	35.97	31.7	7.23	7.27	0.31	0.28
T3	NPK @ 0% + S @ 0% + Rhizobium@ 75%	1.25	1.26	2.45	2.46	42.18	38.46	36.07	32.18	7.25	7.29	0.33	0.3
T4	NPK @ 0% + S @ 0% + Rhizobium@100%	1.26	1.26	2.45	2.46	42.43	39.21	36.84	32.72	6.80	6.84	0.37	0.34
T5	NPK @ 50% + S @ 0% + Rhizobium@50%	1.26	1.27	2.46	2.47	43.38	39.87	37.61	33.92	7.27	7.31	0.38	0.35
T6	NPK @ 50% + S @ 50% + Rhizobium@75%	1.28	1.29	2.47	2.48	43.98	40.06	38.3	34.22	7.28	7.32	0.38	0.35
T7	NPK @ 50% + S @ 50% + Rhizobium @100%	1.29	1.3	2.48	2.49	44.5	40.86	38.84	35.09	7.16	7.20	0.39	0.36
T8	NPK @ 100% + S @ 100% + Rhizobium@75%	1.3	1.31	2.51	2.52	45.48	41.67	40.51	35.85	6.73	6.77	0.43	0.42
T9	NPK @ 100% + S @ 100% + Rhizobium@100%	1.32	1.33	2.51	2.52	46.63	41.98	40.96	36.71	7.12	7.16	0.43	0.42
F- test		**NS**	**NS**	**NS**	**NS**	**S**	**S**	**S**	**S**	**NS**	**NS**	**NS**	**NS**
S. Ed. (±)		**-**	**-**	**-**	**-**	**0.62**	**0.48**	**0.68**	**0.55**	**-**	**-**	**-**	**-**
C. D. (P = 0.05)		**-**	**-**	**-**	**-**	**1.32**	**0.99**	**2.06**	**1.65**	**-**	**-**	**-**	**-**

Table 2. Chemical properties of soil sample after harvesting of Pea (*Pisum sativum* L.)

Treatment combination		Organic Carbon (%)		Available Nitrogen (kg ha^{-1})		Available Phosphorous (kg ha^{-1})		Available Potassium (kg ha^{-1})	
		0 – 15 cm Depth	15 – 30 cm Depth	0 – 15 cm Depth	15 – 30 cm Depth	0 – 15 cm Depth	15 – 30 cm Depth	0 – 15 cm Depth	15 – 30 cm Depth
T1	(Control)	0.30	0.28	258.15	256.82	12.25	11.32	184.41	182.48
T2	NPK @ 0% + S @ 0% + Rhizobium @50%	0.37	0.35	260.97	259.64	12.93	12.00	189.33	187.51
T3	NPK @ 0% + S @ 0% + Rhizobium @75%	0.39	0.37	268.65	267.32	16.21	15.28	192.85	190.12
T4	NPK @ 0% + S @ 0% + Rhizobium@100%	0.42	0.40	273.18	271.72	16.22	15.29	193.19	191.26
T5	NPK @ 50% + S @ 0% + Rhizobium@50%	0.43	0.41	274.91	273.58	16.93	16.00	196.83	194.90
T6	NPK @ 50% + S @ 50% + Rhizobium@75%	0.47	0.45	282.05	280.26	17.97	17.04	201.15	199.22
T7	NPK @ 50% + S @ 50% + Rhizobium@100%	0.52	0.50	282.26	280.93	19.96	19.03	205.83	203.90
T8	NPK @ 100% + S @ 100% + Rhizobium@75%	0.43	0.51	284.59	283.26	20.65	19.72	212.83	210.90
T9	NPK @ 100% + S @ 100% + Rhizobium@100%	0.53	0.44	285.42	283.93	25.01	24.08	218.10	216.17
F- test		**NS**	**NS**	**S**	**S**	**S**	**S**	**S**	**S**
S. Ed. (±)		**-**	**-**	**2.18**	**1.8**	**1.10**	**0.68**	**1.75**	**1.41**
C. D. (P = 0.05)		**-**	**-**	**4.42**	**3.62**	**2.23**	**1.40**	**3.28**	**1.85**

phosphorus in the surface soil with the incorporation of PS Balong with NPK through chemicals overcontrol. The maximum soil Available Potassium(kgha^{-1}) at 0-15and 15-30cmsoildepth was recorded in T9 [NPK @ 100% + S @ 100% + @ Rhizobium 100%] which was 218.10 and 216.17 minimum was recorded in T1[Control)] which was 184.41 and 182.48. The lowest available potassium was recorded in the treatment T0 which might be due to continuous cropping and no addition of organic and inorganic fertilizers in the soil (Katkar et al.,2011). In the sub-surface layer(15-30cm), the available potassium was found low as compared to the surface soil, but the pattern was same. This might be due to lower SOM and higher fixation of potassium ions in the sub surface soil. Similar findings were reported by Moharana et al., (2012).

4. CONCLUSION

From trial it was concluded that the various level of Nitrogen, Phosphorous, Potassium, Sulphur and Rhizobium used in the experiment gave the best result in the treatment T9(NPK@100%+S@100% +Rhizobium@100%) and the soil health parameters retained the suitable soil properties, yield attributes and yield of Field Pea.Therefore, it can be recommended for farmers to obtain the best combination Treatment (T9) for higher farm income.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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