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Effect of Rhizobium culture, PSB with combination of fertilizers on growth and yield of Lentil (*Lens culinaris* Medikus) in Central zone of UP

Sidra Fatima, Ravikesh Kumar Pal, Naveen Kumar Maurya, Jaykar Singh, Suryabhan, Mahendra Yadav and Rajat Yadav

Abstract
An experiment was conducted during *Rabi* season of 2022-23 at Agronomy Research Farm of Faculty of Agricultural Sciences & Allied Industries, Rama University, Kanpur, UP. The experiments was consist of 10 treatments with three replication in RBD design, which are: control (T_1) 100% RDF (T_2), 100% RDF + FYM (10 t/ha) (T_3), 100% RDF + FYM (5 t/ha) + PSB (T_4), 100% RDF + FYM (5 t/ha) + Rhizobium (T_5), 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6), 75% RDF + FYM (10 t/ha) (T_7), 75% RDF + FYM (5 t/ha) + PSB (T_8), 75% RDF + FYM (5 t/ha) + Rhizobium (T_9) and 75% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_{10}). The growth metrics, yield parameters, quality parameters, and soil properties are all subjected to observation and recording.
All growth parameters, with the exception of days to 50% flowering, yield and yield characters, except harvest index, and quality metrics were recorded at their highest levels after the application of 100% RDF mixed with 5 tonnes of FYM, Rhizobium, and PSB per hectare. The treatment with 100% RDF + FYM (5 t/ha) + PSB (T4) produced the highest harvest index. Additionally, the 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T6) treatment had the highest gross returns, the highest net returns, and the highest B:C ratio. The application of 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T6) was found to be the most profitable treatment when compared to the other treatments.

Keywords: Lentil, Rhizobium, PSB and FYM

Introduction
Lentil (*Lens culinaris* Medikus), a wintertime pulse crop, have a wide range of culinary applications. It belongs to the fabaceous, often known as the leguminous, family. In Hindi, lentil is referred to as "masoor dal". The two types of lentils grown in India are red and brown lentils. Along with serving as a reliable source of food for both humans and animals, pulses help India maintain its ecological and economic balance. It yields less frequently than other pulses since it takes less care and is frequently grown on poor soils under rain-fed circumstances. The symbiosis nitrogen fixation process and the plant itself are two ways that nutrients affect the output of lentils. (Sahu *et al*., 2017) [9].
In India, lentils are a typical rabi pulse crop; however, Madhya Pradesh, Uttar Pradesh, Bihar, and West Bengal are the key growing areas. In India, 14.29 million hectares of land are used to grow 13.34 lakh tonnes of lentils. In terms of area and output, Madhya Pradesh came in first (35%), followed by Rajasthan (11%), West Bengal (11%) and Uttar Pradesh (12%). About 98% of the total has been donated by the seven states of Madhya Pradesh, Uttar Pradesh, West Bengal, Bihar, Jharkhand, Rajasthan, and Assam. (DA&FW, Unofficial report 2021-22). After the green revolution, Indian agriculture is facing a number of problems, such as major crop production and productivity growth rates that are flat or even going down, declining factor productivity, declining soil fertility, a lack of diversity in production systems, and rising production costs. Some of these problems have been caused by constant cropping without good nutrient management and the use of agrochemicals on both soil and crops without thinking about what they will do. The natural balance of nutrient components in soils is upset when there aren't enough nutrients other than those that were added by using high-analysis chemical fertilizers everywhere. When high-analysis chemical fertilizers with only one or two mineral components are used, they often cause problems with micronutrients.
Due to the constant loss of soil nutrients, many crops, including lentil, now have problems with not getting enough nutrients.

But relying too much on synthetic chemical fertilizers has led to big risks for the environment, worsening soil quality, and lower food yields over time. (Hepperly *et al*., 2009) [6]. This is true despite the fact that extensive use of chemical fertilizers and advances in genetic technology are credited for raising agricultural production. However, OM's bulky form necessitates labor-intensive application, it contains insufficient and inconsistent amounts of minerals, and it is unable to satisfy the nutritional needs of crops over the broad zones. (Jones *et al*., 2010) [7].

In a sustainable production system, farmyard manure (FYM), vermin-compost, or other organic manures help to meet the crop's nutrient needs and give high yield. Additionally helpful are biofertilizers like Rhizobium and phosphate solubilizing bacteria (PSB), as well as the combined use of chemical fertilizers. The addition of organic manures boosts the production of lentil grains while also increasing the organic carbon content, aggregate stability, moisture retention capability, and infiltration rate of the surface soil. (Sarkar *et al*., 2003) [10].

Eight plants benefit from Rhizobium, a gram-negative rod-shaped bacteria that coexists with the roots of nitrogen-fixing plants in a symbiotic relationship. In order to fix atmospheric nitrogen in legumes, Rhizobium utilises the nitrogenase enzyme, which eliminates the need for chemical fertilizer and consequently lowers the cost of production. As a result, exogenous Rhizobium inoculation helps to enhance symbiotic traits and boost grain output. Rhizobial inoculations, according to various researchers, can greatly boost yield while saving up to 50% of the nitrogenous fertilizers required (Rewari and Tilak 1988). In addition to fixing nitrogen, rhizobia can improve P nutrition by mobilizing both inorganic and organic P. According to inoculated Rhizobium sp. caused indoleacetic acid (IAA), siderophores, hydrogen cyanate, ammonia, and exo-polysaccharides in lentil**.**

Phosphorus (P) is the second-most significant macronutrient for plant growth, after nitrogen, according to P affects plant physiology and regulates the actions and functions of several enzymes. One of the several plant-growth-promoting rhizobacteria (PGPR) found in rhizosphere soil is phosphate-solubilizing bacteria (PSB), which can promote plant growth and increase plant productivity. These bacteria have the ability to convert insoluble P into an accessible form, according to Hanif *et al*. (2015) [5]. The use of PSB in sustainable agriculture is attracting increasing interest from scientists (Hameeda *et al.*, 2008) [4]. As of right now, the majority of detected PSB come from the genera Pseudomonas, Bacillus, Mycobacterium, and Enterobacter, among others (Hanif *et al*., 2015) [5]. PSB is thought to have two P-solubilization routes. PSB releases malic, lactic, acetic, citric, and succinic acids to dissolve insoluble P. PSB releases enzymes to break down insoluble P. Some PSB produce phytohormones such IAA and GA, which regulate plant growth (Babu *et al*., 2015) [3].

Material and Methods

The experiments was consist of 10 treatments with three replication in RBD design, which are: control (T_1) 100% RDF (T_2), 100% RDF + FYM (10 t/ha) (T_3), 100% RDF + FYM (5 t/ha) + PSB (T_4), 100% RDF + FYM (5 t/ha) + Rhizobium (T_5), 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6), 75% RDF + FYM (10 t/ha) (T_7), 75% RDF + FYM (5 t/ha) + PSB (T_8), 75% RDF + FYM (5 t/ha) + Rhizobium (T_9) and 75% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_{10}) at Research Farm of the University in Chickpea cv. Shekar masoor-2, during *Rabi* 2022-23 following spacing of 30 cm x 10 cm in plot size of 4.50 m x 3.00 m. The experimental site is located at latitude of about 26.57º North, a longitude of approximately 80.21 º East and an elevation of 126 m above mean sea level. The experimental soil was sandy loam in nature having 7.32 pH, 0.34 dSm^{-1} EC, 0.38% Organic Carbon, 210.40 kg ha^{-1} Available N, 10.72 kg ha^{-1} Available P_2O_5 and 208.50 kg ha^{-1} Available K_2O. Experimental field was prepared well for good germination. Fertilizers @ 20 kg N, 40 kg P_2O_5 and 20 kg K_2O ha^{-1} were applied prior to sowing. Quality seed of variety Shekhar masoor-2 was sown @ 45 kg ha^{-1} on Nov. 06, 2022. The pre-emergence herbicides were applied using a Knapsack sprayer that was fitted with a flat fan nozzle, and each hectare received an application of 500 litters of water. In order to cultivate the perfect crop, many additional agronomic and plant protection practices were utilized on occasion.

It was decided to tag five plants from each plot using a random selection. The average values for the height in centimeters and the number of branches on each plant were computed. The number of days till the lentil plant reached fifty percent flowering was recorded for each treatment after the seed was sown. After counting the days, the average number of days was calculated and expressed as the number of days till 50% flowering.

By adjusting the net plot area of each treatment replication-wise to a moisture content of 12% in q/ha, grain yield was calculated. Utilizing Donald's (1962) formula of Economic yield/Biological yield x 100, the harvest index was calculated. By subtracting the cultivation costs from the particular treatment's gross return, the net return was calculated. Furthermore, the net return was divided by the expense of growing each specific therapy to arrive at the benefit:cost ratio. Finally, data were analyzed using accepted statistical techniques.

Results and Discussion

The application of FYM, seed inoculation with rhizobium, and the use of PSB have all had noteworthy effects on the growth parameters of initial plant population, plant height, and the number of branches produced by each plant. The availability of nitrogen to plants can be increased through seed inoculation with rhizobium, while the availability of phosphorus for crop growth can be increased through seed inoculation with PSB.

Plant population

The experimental data on IPP is shown in Table-1. At 30 days after sowing, there was no substantial difference in the plant populations that had been managed differently regarding nutrients. The control treatment yielded the lowest plant population of all the treatments tested (20.04 and 19.35, respectively), while the 100% RDF + FYM (5 t/ha) + Rhizobium + PSB (T_6) treatment produced the highest plant population at 30 DAS and maturity (22.23 and 21.72, respectively).

Plant height (cm): At 30 days after seeding, it was discovered that the height of the plants ranged from 10.53 to 14.82 centimetres and demonstrated substantial differences across all of the treatments of the experiment. Rhizobium culture, PSB, and a combination of fertilisers had a substantial impact on the plant height at both the 60 and 90 days after seeding time points. The application of 100% RDF + FYM (5 t/ha) + Rhizobium + PSB (T6) resulted in the highest plant height (33.06 cm and 44.34 cm respectively) when compared to the other treatments. This was followed by the application of 100% RDF + FYM (5 t/ha) + Rhizobium T_5, which resulted in plant heights that were comparable to one another. Control had the lowest recorded plant height of 22.83 centimetres, compared to the experimental group's 32.41 centimetres. At the time of harvest, the plant height was dramatically altered by a number of various treatments. The tallest plant was produced by the lentil crop that was given 100% RDF + FYM (5 t/ha) + Rhizobium + PSB (T_6). This plant's height was comparable to that of the lentil crop that was given 100% RDF + FYM (5 t/ha) + Rhizobium T_5 (43.92 cm). The result of plant height was following the result of Sankar *et al*., 2003 and Sahu *et al*.,2017) [10, 9].

Number of branches per plant: The number of branches per lentil plant was measured at 30, 60, and 90 days after sowing and is depicted in Table-1. The treatment containing 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6) had the highest number of observed branches per plant (4.53/plant), which was comparable to the treatment containing 100% RDF + FYM (5 t/ha) + Rhizobium (T_5) (4.13/plant) and 75% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_{10}) (4.02/plant). The T_4, T_9, T_8, T_3, T_7, and ultimately the T_2 followed. The control group had the fewest branching structures (1.74 per plant) recorded.

Days taken to 50% flowering: The application of 100% RDF + FYM (5 t/ha) + PSB (T_4) required considerably more days (62.59) to reach 50% flowering than did 100% RDF + FYM (5 t/ha) + Rhizobium (T_5), according to data on days to 50% flowering. 75% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_{10}) followed these. Control (T_1) (52.99) had the earliest 50% flowering, according to observations.

Days taken to maturity: The treatment of 100% RDF + FYM (5 t/ha) + PSB (T_4) took substantially longer (116.42 days) to reach maturity than 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6), according to data on days to 50% flowering. 75% RDF + FYM (5 t/ha) + Rhizobium (T_9) came next in order. Control (T_1) (96.38) displayed the earliest maturity.

Number of pods per plant: The results shown in Table 2 made it very evident that the Rhizobium, PSB, and FYM applications significantly affected how many pods each plant produced. The highest number of pods produced by the treatment combination of 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6) (50.04), followed by T_5, T_{10}, T_4, T_9, T_8, T_3, T_7, and T_2. The control plant has 32.17 lower pods than any other plant. Both Butter *et al.*, (2008) and Rana (2013) reported the same type of response to the nutrient management methods they had previously used.

Length of pod (cm): The table-2 clearly depicted that the Rhizobium, PSB and FYM application had a considerable impact on the length of pods produced by each plant. The combination of 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6) (2.34 cm) produced the maximum pod length of all the treatments, followed by T_5, T_{10}, T_4, T_9, T_8, T_3, T_7, and T_2. The control plant had the lowest pod length, 1.47 cm.

Number of grains per pod: According to the data shown in Table-2, all treatments were determined to be significantly better than the control. The total number of seeds per pod under 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6) was counted at 1.71, which was comparable to 100% RDF + FYM (5 t/ha) + Rhizobium (T_5) at 1.67 and 75% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_{10}) at 1.62. The control (0.96) had the fewest seeds per pod. Singh *et al.*, (2003), *Vaishya et al.*, (2005), and Butter *et al.*, (2008) all discovered techniques of nutrition management that resulted in responses that were analogous to the ones described above.

Seed index (g): Data on seed index are shown in Table-2 as a effect of various treatments. Treatments had a considerable impact on the seed index. The highest test weight was found in 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6) (2.52 g), which was at par with 100% RDF + FYM (5 t/ha) + Rhizobium (T_5) (2.49 g) among the various treatments. Treatments T_5, T_{10}, T_4, T_9, T_8, T_3, T_7, and T_2 came next. The control sample (1.80 g) had the lowest seed index measurement.

Grain yield (q/ ha): When compared to the control group, the experiment's findings demonstrated that increasing the amount of fertilizer applied to the crop, either on its own or in conjunction with FYM and bio fertilizers, resulted in a significant increase in the amount of grain harvested per hectare (Table-2). Application of 100% RDF + FYM (5 t/ha) + Rhizobium (T_6) (1855 kg) considerably increased grain yield while application of 100% RDF + FYM (5 t/ha) + Rhizobium (T_5) (1803 kg) was statistically equivalent. After this, treatments T_5, T_{10}, T_4, T_9, T_8, T_3, T_7, and T_2 were carried out in descending order of intensity. The control group had the lowest grain output per hectare (822 kilogrammes). There is a high degree of concordance between the findings of Dheer and Yadav (2017) [11].

Harvest index: Table 2 displays information regarding the harvest index as well as how it alters by the various treatments. The 100% RDF + FYM (5 t/ha) + Rhizobium (T_5) treatment had the greatest harvest index among the various treatments (44.68%), and it was closely followed by 100% RDF + FYM (5 t/ha) + PSB (T_4) and 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6). The lowest harvest index was recorded in control plot (40.05%).

Net monitory return (Rs ha^{-1}): Reading the data in Table-2 made it clear that integrated nutrition management had a big impact on net returns. Significantly, 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6) produced the highest net returns (92,979 Rs. /ha), which was at par with 100% RDF + FYM (5 t/ha) + Rhizobium (T_5) (89,427 Rs. /ha). T_{10}, T_4, T_9, T_8, T_3, T_7, and T_2 came after both. Both Meena *et al.*, (2016) [8] came to the same conclusions, and those conclusions are consistent with these observations.

B: C ratio: Reading the data in Table-2 made it clear that integrated nutrient management had a big impact on benefit-cost ratio. Significantly, the highest B: C ratio (2.24) was found in the 100% RDF + FYM (5 t/ha) + PSB + Rhizobium

(T_6), which was comparable to the 100% RDF + FYM (5 t/ha) + Rhizobium (T_5) (2.17) and the 75% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_{10}) (2.17). After them came T_9, T_4, T_8, T_2, T_3, and T_7. The control plot having B:C ratio was the lowest (0.88). Ankita *et al.*, (2014) and Ram *et al.*, (2014) have both reported findings that are very similar to our own.

Table 1: Effect of Rhizobium culture, PSB and FYM with combination of fertilizers on growth parameters of lentil

Treatments	Plant population		Plant height (cm)				Number of branches per plant			Days to 50% flowering	Days to crop maturity
	30 DAS	At maturity	30 DAS	60 DAS	90 DAS	At maturity	30 DAS	60 DAS	90 DAS		
T_1	20.04	19.35	10.53	22.83	32.41	32.52	1.74	3.12	3.15	52.99	96.38
T_2	20.10	19.62	11.10	28.41	35.22	36.03	2.73	4.14	4.20	57.07	101.38
T_3	20.82	20.25	11.82	29.31	36.27	36.90	3.03	4.53	4.62	56.18	106.16
T_4	21.72	21.30	13.62	30.75	39.33	40.11	3.75	4.92	4.98	62.59	116.42
T_5	22.05	21.63	14.62	32.40	43.05	43.92	4.13	5.10	5.22	58.81	108.28
T_6	22.23	21.72	14.82	33.06	44.34	45.21	4.53	5.58	5.67	56.39	114.62
T_7	20.40	20.01	11.31	29.10	35.64	36.15	2.91	3.90	4.11	55.10	104.40
T_8	21.03	20.70	12.24	29.64	37.53	37.92	3.27	4.71	4.77	56.89	106.49
T_9	21.60	21.06	13.02	29.97	38.64	39.15	3.32	4.83	4.92	57.63	110.41
T_{10}	21.90	21.60	14.31	31.74	41.13	42.33	4.02	5.01	5.13	57.95	106.86
S.Em+	0.59	0.56	0.35	0.81	1.04	1.06	0.09	0.12	0.13	1.48	2.76
C.D. (P=0.05)	NS	NS	1.02	2.39	3.07	3.13	0.26	0.35	0.37	4.39	8.19

Table 2: Effect of Rhizobium culture, PSB and FYM with combination of fertilizers on yield and yield attributes of lentil

Treatment	No. of pod/ plant	Pod length (cm)	No. of grain/pod	Seed index (g)	Grain yield (kg ha^{-1})	Harvest index (%)	Net monitory return (Rs. ha^{-1})	B:C ratio
T 1	32.17	1.47	0.96	1.80	822	40.05	28,841	0.88
T 2	40.56	1.83	1.35	2.20	1351	43.37	61,517	1.65
T 3	43.32	1.92	1.44	2.34	1506	43.57	65,377	1.46
T 4	46.53	2.16	1.56	2.47	1704	44.65	82,089	1.98
T 5	48.06	2.28	1.67	2.49	1803	44.68	89,427	2.17
T 6	50.04	2.34	1.71	2.52	1855	44.60	92,979	2.24
T 7	42.12	1.89	1.41	2.23	1425	42.18	61,573	1.41
T 8	44.01	2.01	1.50	2.43	1563	43.85	73,545	1.83
T 9	45.33	2.13	1.54	2.43	1671	44.28	81,243	2.02
T_{10}	47.31	2.21	1.62	2.48	1764	44.14	87,825	2.17
S.Em+	1.12	0.05	0.04	0.06	39.79	1.12	-	-
CD (5%)	3.34	0.15	0.11	0.18	118.20	NS	-	-

Conclusion

In accordance with the findings presented above, it can be assumed that the use of 100% RDF + FYM (5 t/ha) + PSB + Rhizobium (T_6) could be put to use in lentil cultivation during the Rabi season to achieve the maximum grain yield (1855 kg ha^{-1}), revenue generation (net return Rs.92,979 ha^{-1}) and (2.24) B:C ratio.

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