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Effect of bio-fertilizer and planting geometry on growth and yield of lentil (*Lens culinaris* L.)

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Abstract

An experiment was conducted during rabi season of 2024, at crop research farm of Department of Agronomy at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) India. The name of the experiment was as follows: The effect of bio-fertilizer and geometry of planting on Growth and Yield of Lentil (*Lentils culinaris* L.) This experiment was patterned in a randomized block design (RBD) that comprised of treatment of nine and were replicated three times T₁, T₂, and T₃ which pertained to the application of Rhizobium at 20 g/kg of seed with three different spaces 20 x 10 cm, 30 x 10 cm, and 40 x 10 cm, respectively. On the same note, treatments T₄, T₅ and T₆ included Phosphate Solubilizing Bacteria (PSB) at the dosage of 20 g/kg of seed using the same respective spacings of 20 x 10 cm, 30 x 10 cm and 40 x 10 cm. Treatments T₇, T₈ and T₉ included the use of Vesicular Arbuscular Mycorrhizale (VAM) which was at the dosage of 15 g/kg of seed using the same respective spacing. Result of experiment revealed that, plant growth parameter i.e. plant height (47.66 cm) no. of branches (3.93) and plant dry weight (23.43 g) was increased with increasing levels of vermicompost i.e., more nutrient level 1 t/ha. Significantly higher number of pod/plant (14.47), number of seed/pod (7.93), test weight of seed (g) (41.83) and seed yield (1.55t/ha) and straw yield (3.71 t/ha) were recorded maximum with application of vermicompost 30cm x 25cm.

Keywords: Biofertilizer and planting geometry on growth, yield and economics of lentil (KLS09)

Introduction

Pulses form an essential group of leguminous crops with high nutritional value as they contain 20-27% of protein and essential amino acids, Fiber, vitamins and approximately 15 major minerals and thus pulses serve as a good source of proteins particularly in developing nations (Wang *et al.*, 2003). Lentils (*Lens culinaris medik* L.) are one of the oldest and most important pulse crops with over 95.7 million hectares under cultivation and a total annual production of 92.3 million tonnes; this makes it a staple food all around the world as a result of its nutritional value and adaptability (FAO STAT, 2018) [1].

Pulses are also important to sustainable agriculture, they grow in marginal, low fertility soils with pesticide and fertilizer at minimal increments hence are a plausible and economic way to grow them in the hands of small holder farmers especially in the Indian sub-continent. The nitrogen-fixing bacteria they correlate with increases soil fertility and minimizes the need to use artificial fertilizers which help the soil in the long term. Bacteria-based bio-fertilizers which include Rhizobium and phosphate-solubilizing bacteria (PSB) enhance accessibility of nutrients, the root growth multiplication and result, whereas the arbuscular mycorrhizal fungi facilitate the survival of plants in stressful conditions (*Pseudomonas* sp., *Bacillus* sp.). There also have been multifunctional microbial consortia (Rhizobium, PSB, and VAM fungi) demonstrating synergetic effects to many nodulations and yield, which have resulted in commercial products such as Bio-N and Bio-Spark.

The spacing of the plants is also very important in maximizing the production of lentil. Appropriate plant geometry supports light interception, nutrient utilization, and overall productivity because it minimizes inter-and intra-plant competition, positively influences the implementation of intercultural measures (Yeswanth & Debbarma, 2022; Swargiary *et al.*, 2021) [15, 9].

The ability of Lentil to grow in poor soils, tolerance to Yellow Mosaic Virus (YMV), and use as food, fodder, and green manure are the features that render Lentil as an emerging source of replacement of classic pulses such as green gram in South and Southeast Asia.

The high degree of genetic diversity and resistance to pests and diseases therefore underscores the necessity to come up with better agronomic practices that will enable the full expression of yield potential (Singh *et al.*, 2018) ^[10].

Material and Methods

The experiment evaluation field experiment was aimed at investigating the consequence of planting geometry and biofertilizer on the growth and yield of lentils (*Lentils culinaris* L.) conducted during the Rabi season of 2024-2025 at the Crop Research Farm (CRF) of the department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (U.P.). The pH level of the soil was 6.5, organic carbon was 0.4%, and available nitrogen, phosphorus and potassium were 125, 75 and 217 kg/ha respectively. It was loamy sand soil. Randomized Block Design (RBD) experiment had nine treatments in three replications. The treatments that will be utilized are the combinations as follows: (T₁) Rhizobium 20 g/Kg Seed + 20 x 10 cm, and (T₂) Rhizobium 20 g/Kg Seed + 30 x 10 cm, and (T₃) Rhizobium 20 g/Kg Seed + 40 x 10 cm, and (T₄) PSB 20 g/Kg Seed + 20 x 10 cm, (T₅) PSB 20 g/Kg Seed + 30 x 10 cm, (T₆) PSB 20 g/Kg Seed + 40 x 10 cm, (T₇) VAM 15 g/Kg Seed + 20 x 10 cm, (T₈) VAM 15 g/Kg Seed + 30 x 10 cm, (T₉) VAM 15 g/Kg Seed + 40 x 10 cm.

Chemical analysis of soil

Before designing the experiment, a composite soil sample was taken to find out what the first soil characteristics are. We got this soil sample from a depth of 0 to 15 cm. We dried it in the shade, ground it up with a wooden pestle and mortar, and then filtered it through a 2mm filter to use in the analysis. Jackson (1973) ^[3] describes the available organic carbon and black p technique; Subbaih and Asija (1956) ^[8] describe the available nitrogen by the alkaline permanganate method; Oslen *et al.*, (1954) ^[6] describe the available phosphorus by the Olsen colorimeter method; and Jackson (1973) ^[3] and Toth and Prince (1949) ^[12] describe the available potassium by the flame photometer technique.

Statistical analysis

The statistical analysis of variance (ANOVA) of this experimental data was then carried out following what has been described by Gamez and Gomez (2010) ^[2]. Upon computation of the values of the Critical Difference (CD), the value of the F test turned out to be significant at 5 percent.

Result and Discussion Growth and Yield attributes:

Plant height (cm)

The experiment shows that the lentil plants height was highly affected by different biofertilizer management and planting geometries at various lentil plant growth stages. At 25 DAS, the highest plant height was observed in T₄ (PSB @ 20 g/kg seed + 20 x 10 cm), which could be attributed to the increased root growth which was brought about by PSB. Maximum plant height at 50 DAS was recorded in T₂ (Rhizobium @ 20 g/kg seed + 30 x 10 cm) and then followed by T₃ (12.15 cm). The minimum plant height was below T₄. Such a significant difference in performance of Rhizobium-treated plots can be explained by the fact that it favours nitrogen fixation, which, in turn, stimulates vegetative growth. T₂ exhibited the tallest plants at 75 DAS (25.59 cm), then T₆ (24.33 cm), and T₃ (23.43 cm). The

Rhizobium was more widely spaced in order to reduce inter-plant competition, promoting growth and a superior level of nutrient uptake and root development. At 100 DAS, the plant height was the highest in T₂ (40.48 cm) and then T₃ (38.31 cm) and T₄ (38.78 cm). The lowest plants were T₉ (VAM @ 15 g/kg seed + 40 x 10 cm). These results justify the findings of other authors who have stated that rhizobium (biofertilizer) when used together with appropriate planting geometry tend to improve growth and development of lentil. (Kumar *et al.*, 2008) ^[4].

Number of nodules per plant

It can be found in this study that the number of nodules per plant in lentil was also significantly affected by various treatments of biofertilizer and geometries of planting at different growth stages. With 25 DAS, the most nodules were recorded with Rhizobium 20 g/kg seed + 40 x 10 cm (T₃), and PSB 20 g/kg seed + 20 x 10 cm (T₄). The numbers under Rhizobium, 20 g/kg of seed + 20 x 10 cm (T₁) and 30 x 10 cm (T₂) were least. The data shows that there is an early nodulation response in the PSB and VAM-treated plants also. The number of nodules was highest with Rhizobium 20 g/kg seed + 40 cm (T₃) at 50 DAS and it was followed by VAM 15 g/kg seed + 30 x 10 cm (T₈) with 13.78 nodules. The minimum number of nodules was recorded when VAM 15 g/kg seed + 20 x 10 cm (T₇) was used. At 75 DAS, the nodulation was still on the rise with the most nodules being found in Rhizobium 20 g/kg seed + 40 x 10 cm (T₃), followed by VAM 15 g/kg seed + 30 x 10 cm (T₈) and VAM 15 g/kg seed + 40 x 10 cm (T₉). (Kumawat *et al.*, 2019) ^[5].

Number of branches per plant

The effects of treatments with biofertilizers and geometries in the planting of lentil plants in terms of the number of branches per plant can be significantly determined at various stages of plant growth. At 25 DAS, there was no significant difference in treatments recorded, meaning there was minimal effect towards branching. The greatest number of branches per plant is observed at 50 DAS under VAM 15 g/kg seed + 20 x 10 cm (T₇) followed by PSB 20 g/kg seed + 30 x 10 cm (T₅) and Rhizobium 20 g/kg seed + 30 x 10 cm (T₂) (4.63). At 75 DAS, the results yielded a significant difference whereby the T₂ had the highest number of branches and T₈ had the lowest number of branches. (Verma *et al.*, 2017) ^[13].

Plant dry weight (g)

Biofertilizer treatment and planting geometries at 50, 75 and 100 days after sowing significantly affected with the number of branches per plant in lentil plants. Early branch development was witnessed at 25 DAS and it showed that the optimal branching was recorded under PSB 20 g / kg seed + 20 x 10 cm (T₄). At 50 DAS major distinctions were registered where VAM 15 g/kg seed + 20 x 10 cm (T₇) showed the highest number of branches (4.67). The highest number of branches was recorded in Rhizobium 30 x 10 cm (T₂) at 75 DAS and similarly Rhizobium 30 x 10 cm (T₂) had the highest number of branches at 100 DAS. (Rai *et al.*, 2020) ^[7].

Number of Pods/ Plant

The insertion of biofertilizers and planting geometry had a huge influence on the number of pods per plant. Rhizobium

20 g/kg seed + 30 x 10 cm (T₂) treatment showed the maximum number of pods (89.19) followed by Rhizobium 20 g/kg seed + 40 x 10 cm (T₃) which had 84.71 pods per plant. The minimum pod number of (78.06) was found. (Kumar *et al.*, 2008) [5].

Number of Seeds/ Plant

The paper has shown that there were slight important disparities in seed pod number, T₂ having a greatest amount (1.73) followed by PSB (1.70) and lowest (1.27) by VAM (15 g/kg seed, 20 times 10 cm). This difference can be attributed to effective nodulation and better seed setting. (Singh *et al.*, 2015) [11].

Test Weight

There was no significant difference between the treatments in the 100-seed test weight. The values of metal ranged at 27.37 g to 27.89 g. Rhizobium 20 g/kg seed + 30 x 10 cm (T₂) was found to have the highest test weight (27.89 g) whereas Rhizobium 20 g/kg seed + 20 x 10 cm (T₄) gave a low-test weight (27.37 g). This shows that biofertilizer treatment and spacing had a less effect on seed size, and weight.

Grain Yield

The analysis indicated that yield of grains differed significantly among treatments with the highest yield of 1.45 t/ha recorded under Rhizobium 20 g/kg seed + 30 x 10 cm (T₂) as compared to low yield of 1.22 t/ha when PSB 20 g/kg seed + 20 x 10 cm (T₄) and T₅ used. The increased yield can be attributed to better nodulation and availability of nitrogen.

Straw Yield

The patterns in Straw yield and grain yield were the same,

the Straw yield was highest in T₂ at 4.01 t/ha, and grain yield was least in T₉ at 3.40 t/ha. The increase of straw biomass was achieved by increasing the spacing and enhancing nutrient availability.

Harvest Index

There was no significant difference in harvest index between the treatments. But, VAM 15 g/kg seed + 40 x 10cm (T₉) had the maximum harvest index percentage (27.47%) and Rhizobium 20 g/kg seed + 30 x 10cm (26.49 percent). PSB 20 g/kg seed + 20 x 10 cm (T₄) had the lowest harvest index of (24.04).

Economic Analysis

It provides results of cost of cultivation, gross return, net return, benefit-cost ratio (B:C ratio) of bio-fertilizer and planting geometry on lentil. The cost of the treatments ranged between 45, 010.75 to 45, 094.00 per hectare when PSB and VAM treatment are involved, and 45, 062.50 per hectare when Rhizobium treatments are involved. The maximum gross return was realized under treatment of Rhizobium 20 g/kg seed and 30 x 10 cm (T₂) and Rhizobium and 40 x 10 cm (T₃) and PSB 20 g/kg seed and 20 x 10 cm (T₄). The maximum net income was realized in the combination T₂ (Rhizobium + 30 x 10 cm), followed by T₃ (Rhizobium + 40 x 10 cm) and VAM 15 g/ kg seed + 20 x 10 cm (T₇). The lowest net benefit was that of the treatment T₄ (PSB + 20 x 10 cm). As indicated by the results, the application of Rhizobium at a rate of 30 x 10 cm was highly economical. The enhanced economical returns with Rhizobium treatments agree with the earlier findings that indicate that wider spacing can be used to ensure that plants individualize on the available soil nutrients and soil moisture.

Table 1: Effect of Bio fertilizer and Planting Geometry on growth attributes of Lentil.

S. No	Treatment combination	Plant height (cm)	No. of Nodules/plant	No. of Branches/plant	Dry Weight (g)
1	Rhizobium 20 g/kg Seed + 20 x 10 cm	38.08	12.25	11.53	9.24
2	Rhizobium 20 g/kg Seed + 30 x 10 cm	40.48	14.10	12.93	10.39
3	Rhizobium 20 g/kg Seed + 40 x 10 cm	38.31	11.96	11.87	9.40
4	PSB 20 g/kg Seed + 20 x 10 cm	38.78	12.93	11.60	9.27
5	PSB 20 g/kg Seed + 30 x 10 cm	36.31	13.80	11.87	9.40
6	PSB 20 g/kg Seed + 40 x 10 cm	37.28	12.06	11.33	9.05
7	VAM 15 g/kg Seed + 20 x 10 cm	37.07	13.47	11.27	9.13
8	VAM 15 g/kg Seed + 30 x 10 cm	36.63	13.78	11.53	9.43
9	VAM 15 g/kg Seed + 40 x 10 cm	36.02	12.96	11.39	9.29
	F-test	S	S	S	S
	S.Em (±)	1.09	0.48	0.27	0.24
	CD (p = 0.05)	3.27	1.42	0.81	0.73

Table 2: Effect of Bio fertilizer and Planting Geometry on Post Harvest Observation of Lentil.

S. No	Treatment combination	Post-Harvest Observations					
		Number of Pods / Plant	Number of Seed / Pod	Test Weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
1.	Rhizobium 20 g/Kg Seed + 20 x 10 cm	78.06	1.33	27.40	1.30	3.65	26.16
2.	Rhizobium 20 g/Kg Seed + 30 x 10 cm	89.19	1.73	27.89	1.45	4.01	26.49
3.	Rhizobium 20 g/Kg Seed + 40 x 10 cm	84.71	1.37	27.63	1.38	3.90	26.15
4.	PSB 20 g/Kg Seed + 20 x 10 cm	79.52	1.60	27.37	1.22	3.86	24.04
5.	PSB 20 g/Kg Seed + 30 x 10 cm	79.53	1.40	27.59	1.22	3.84	24.18
6.	PSB 20 g/Kg Seed + 40 x 10 cm	82.22	1.40	27.44	1.26	3.99	23.96
7.	VAM 15 g/Kg Seed + 20 x 10 cm	78.89	1.27	27.51	1.32	3.95	25.03
8.	VAM 15 g/Kg Seed + 30 x 10 cm	79.89	1.40	27.62	1.26	3.83	24.75
9.	VAM 15 g/Kg Seed + 40 x 10 cm	79.02	1.33	27.55	1.28	3.40	27.44
	F-Test	S	S	NS	S	S	NS
	S.Em (±)	2.05	0.05	0.15	0.05	0.11	0.99
	CD (p = 0.05)	6.14	0.16	-	0.14	0.34	-

Table 3: Effect of Bio fertilizer and Planting Geometry on economic of Lentil.

S. No	Treatment combination	Economics			
		Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C ratio
1	Rhizobium 20 g/Kg Seed + 20 x 10 cm	45062	139246	94183	2.09
2	Rhizobium 20 g/Kg Seed + 30 x 10 cm	45062	150016	104953	2.33
3	Rhizobium 20 g/Kg Seed + 40 x 10 cm	45062	145316	100253	2.22
4	PSB 20 g/Kg Seed + 20 x 10 cm	45094	134561	89467	1.98
5	PSB 20 g/Kg Seed + 30 x 10 cm	45094	134731	89637	1.99
6	PSB 20 g/Kg Seed + 40 x 10 cm	45094	137264	92170	2.04
7	VAM 15 g/Kg Seed +20 x 10 cm	45010	141357	96347	2.14
8	VAM 15 g/Kg Seed +30 x 10 cm	45010	136861	91850	2.04
9	VAM 15 g/Kg Seed +40 x 10 cm	45010	137347	92337	2.05

Conclusion

It is concluded that the combination of (Rhizobium 20 g/kg; seed spacing 30 x 10 cm) has given better results in growth parameters, yield attributes and benefit cost ratio of lentil, and may therefore be recommended in case of higher productivity and profitability.

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