Original Research Article

Response of Biofertilizers and Foliar application of Zinc on Yield and Economics of Lentil (Lens culinaris, Fabaceae ~~L.~~)

ABSTRACT

During the Rabi season of 2022, with the objective to establish the effect of biofertilizers and foliar application of zinc on growth and yield of *Lens culinaris*a field trial ~~trail~~ was carried out at the Crop Experimental Farm, Division of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, ~~HUATS,~~ Prayagraj, Uttar Pradesh, India.~~.~~ The trial included two variables with three levels of zinc (0.25%, 0.50%, 0.75%) and biofertilizer (*Rhizobium* spp., *Pseudomonas fluorescens*, *Rhizobium* spp. + *Pseudomonas fluorescens*). The texture of the soil is sandy loam with 7.2 pH, 0.72% organic carbon, 178.48 kg/ha of available N, 27.80 kg/ha of available P, and 233.24 kg/ha of available K. The experiment~~trail~~was conducted in randomized block design with ten treatments and replicated three times. Zinc application and the use of biofertilizers had a big impact on the economics, yield attributes and yield. The outcome showed that treatment eight, *Rhizobium* spp.~~,~~+ *Pseudomonas fluorescens* and foliar spray of zinc at 0.50~~05~~% recorded maximum number of pods/plant (111.33), number of seeds per pod (2.27), seed yield (1530,94~~1025.37~~ kg/ha) andstover yield (3020.00~~76.67~~ kg/ha). Maximum gross returns (91,856.58 INR/ha), net returns (61,406.58 INR/ha) and benefit-cost ratio (2.02). In conclusion the best combination to get maximum economics and yield attributes in *Lens culinaris* using the trialof fertilization performed was *Rhizobium* + *Pseudomonas fluorescens* + Zn (0.50%).~~were also observed in the same treatment eight in lentil crop.~~

Key words: *Biofertilizer, Lentil, Rhizobium* spp., *Pseudomonas fluorescens, Economics, Yield, Yield attributes.*~~*,Economics, Rabi, Lentil.*~~

Introduction

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Lentil (*Lens culinaris* L.) is among the oldest domesticated crop cultivated in the world. Lentil also known as red dhal, masur or split peas is a staple food. It is an excellent source of vitamin A and provides fiber, potassium, vitamin B and iron**(Malik *et al.*, 2022)**.It has the second highest ratio of protein per calorie of any legume, after soybean and contains high levels of protein (20-30%), minerals (2-5%), rich in micronutrients and had the potential to provide adequate dietary amounts, especially iron, zinc, selenium **(Ganesh *et al.*, 2020)**.India is the largest pulse growing country which accounts for nearly one-third of the total world area under pulses and one-fourth of the total world production. India stands second in production of lentil after Canada. The major lentil growing countries of the world include India, Canada, Turkey, Bangladesh, Iran, China, Nepal and Syria.Pulses are the wonder crops as these are rich source of protein and also have an ability of biological nitrogen fixation process. These crops are used for crop diversification in different cropping systems**(Singh *et al.*, 2017)**.Lentil also has an important role in crop rotation and enhancing soil fertility and promote sustainable cereal-based production systems with a potential of fixing free nitrogen up to 107 kg/ha **(Malik *et al.*, 2022)**.

Biofertilizer is one of the most important factors that will increase the yield significantly. Seed inoculation with *Rhizobium* play a vital role in the formation of nodules to fix atmospheric nitrogen by symbiotic process in the root system of legume crop making the nutrient available to the plant **(Siddiqui *et al.*, 2013)**. Living microorganisms of bacterial, fungal, and algal origin are called biofertilizers. Atmospheric nitrogen fixed in the root nodules with the help of biofertilizers and make it available to the plant. They convert phosphates from their insoluble forms into ones that can be used. They create hormones and antimetabolites that encourage the growth of roots. When applied to seeds or soil, biofertilizers make nutrients more readily available and enhance the productivity by 10% to 25% without damaging the soil or the environment **(Kumar and Chandra, 2008)**.An aerobic, gram-negative bacterium Pseudomonas fluorescens that present in agricultural soils, is well suited to flourish in the rhizosphere. Besides promoting plant development, it functions as a biocontrol agent. It colonizes and thrives quickly in the rhizosphere, using seed and root exudates. It produces a diverse range of bioactive metabolites, such as antibiotics, siderophores, volatiles, and growth-promoting compounds in the plant rhizosphere engage in aggressive competition with other microbes, and responds to environmental challenges **(Rakesh and Mehera, 2022)**. Biofertilizers such as Rhizobium and PGPR are eco-friendly, low in cost and also, they have an ability to recycle the indigenous or

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immobile nutrients in sustainable agriculture. Improvement in plant productivity by use of PGPR occurs, when rhizobacteria supply nutrients and produce auxins, cytokinin's and gibberellins. Application of nutrient at proper dose helps to achieve profitable and also economically and environmentally best. Along with enhancing grain yield, microbial inoculations may also help in lowering the cost of production through less input of chemical fertilizers **(Singh *et al.*, 2017)**.

The role of micronutrients is also very important in growth and development of all the crops. Zinc is very important in reproductive phase like fertilization and pollen grain formation as pollen grain contains a high amount of zinc. Most of the zinc is translocated to seeds during fertilization **(Ali et al., 2017)**. Micronutrients are important for maintaining soil health and also increasing productivity of crops **(Swargiary*et al.*, 2021)**. Zinc role is as multifaceted as the interface that reduces its availability. Physiologically its role in a plant is either as a metal constituent in enzymes or as a functional co-factor of number of enzyme reactions. Zinc is necessary for the synthesis of tryptophan, which is a precursor for tryptophan production. High levels of zinc enhance cell differentiation in post flowering stage **(Singh and Bhatt~~*et al.*~~, 2013).**

The current study was conducted to determine **"Response of Biofertilizers and Foliar Application of Zinc on Growth and Yield of Lentil (*Lens culinaris* L.)"** while keeping the previously mentioned factors in consideration

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Materials and methods

The experiment was conducted during *Rabi* season of 2022, at Crop research farm of Ddepartment of Agronomy at Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS), Prayagraj, U.P., India. The soil had a sandy loam texture, with a pH of 7.2, organic carbon (0.72%), available N (178.48 kg/ha), available P (27.80 kg/ha) and available K (233.24 kg/ha). The experiment was laid out in randomized block design (RBD) with ten treatments each replicated thrice. The experiment comprised of three biofertilizer treatments and three levels of zinc when applied in combinations as follows, T_1: *Rhizobium* spp. + Zinc (0.25%), T_2: *Rhizobium* spp. + Zinc (0.50%), T_3: *Rhizobium* spp. + Zinc (0.75%), T_4: *Pseudomonas fluorescens* + Zinc (0.25%), T_5: *Pseudomonas fluorescens* + Zinc (0.50%), T_6: *Pseudomonas fluorescens* + Zinc (0.75%), T_7: *Rhizobium* spp. + *Pseudomonas fluorescens* + Zinc (0.25%), T_8: *Rhizobium* spp. + *Pseudomonas fluorescens* + Zinc (0.50%), T_9: *Rhizobium* spp. + *Pseudomonas fluorescens* + Zinc (0.75%), T_{10}: Control (NPK 20-40-20 kg/ha).

Five plants were tagged randomly at third week of germination for recording observations. At maturity of the pods, the lentil crop was harvested treatment wise. Followed by bundles were sun dried and weighed by balance for calculating biological yield. The seed yield was recorded after threshing of plants from each treatment and then converted into kg/ha. The Observations like number of pods per plant, number of seeds per pod, seed yield and stover yield were recorded from each plot**(Ahmad *et al.*, 2017)**. Net returns, Gross returns and benefit cost ratio were computed based on cost of cultivation with their prevailing market price. The dData wereas statistically analyzed by using (**Gomez and Gomez, 1984)**.

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RESULTS AND DISCUSSION

Pods and seeds y~~Y~~ield ~~attributes~~

According to yield attributes data that was collected and analyzed at harvest (see Table 1)~~,~~ significantly higher number of pods/plant (111.33), seeds/pod (2.27) were recorded in treatment-8 with the combined application of *Rhizobium* spp.~~,~~+ *Pseudomonas fluorescens* along with zinc (0.50%).Zinc enhanced the transfer of photosynthates towards the reproductive system, increasing the crop's productivity. Due to less crop competitiveness among the plants resulted increase in photosynthetic activity and also photosynthates may have been transported from source to sink more effectively **(Swargiary *et al.,* 2021).** Zinc produces auxin and IAA which regulates plant growth that in turn resulted in more number of pods per plant **(Ali *et al.*, 2017).**This could occur as an outcome of the stimulatory effect on cell division, cell elongation, and background structure of cells. In addition, higher levels might be responsible for increased leaf area and chlorophyll content which resulted in higher photosynthesis and assimilation, metabolic activities responsible for overall reproductive phase, and ultimately improved seed yield**(Kasuhik and Singh, 2022).**Due to zinc's role in seed setting, treatment with zinc resulted in more seeds per pod**(Praveena *et al*., 2018).**

Seed and stover y~~Y~~ield (kg/ha)

In Table 1, may be seenthe~~After evaluated the~~ data recorded post harvesting of crop. They show that significantly maximum seed yield (1530.94 kg/ha) and stover yield (3020.00 kg/ha) were recorded in treatment eight with the combined application of *Rhizobium* spp.~~,~~+ *Pseudomonas fluorescens* along with zinc (0.50%). *Rhizobium* and zinc interact to significantly boost yield. Growthhormones produced by *Rhizobium* encourage the development of roots.By increasing the quantity of these microorganisms, the microbial process swiftly speeds up, increasing the amount of nutrients available in forms that the plant can readily absorb**(Mounika *et al*., 2022)**. *Pseudomonas* spp.produces siderophores in addition to phosphorus solubilizing capacity, thus builds symbiotic efficiency, growth, and the productivity of lentil**(Khanna and Sharma~~*et al.*~~, 2011).** The effect of zinc treatment on straw yield may be attributed to its direct impact on auxin production, which in turn accelerate plant growth elongation processes**(Praveena*et al.*,**

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2018).Zinc foliar spray results in adequate nutrient availability forlush crop growth as well as efficient assimilation partitioning from source to sink**(Lakshmi *et al.*, 2017).**

Economics

In Table 2 are shown the economics data recorded. Maximum gross returns (91,856.58 INR/ha), net returns (61406.58 INR/ha) and benefit cost ratio (B: C= 2.02) were obtained in treatment eight ~~T_9~~ with application of *Rhizobium*~~,~~+*Pseudomonas fluorescens* and zinc at 0.50%. Integrated use of biofertilizers (~~Rhizobium, Pseudomonas fluorescens,~~+*Rhizobium* + *Pseudomonas fluorescens*) improved gross returns. Application of unit fertilizer is economical, if the value of the increase in the crop yield due to the quantity of fertilizer added is greater than the cost of fertilizer used. If the unit of fertilizer does not increase the yield enough to pay for its cost, its application will not be economical and will not return profit even after a constant increase in the yield. The application of essential element in optimum quantity and right proportion is the key to increase the profit **(Singh *et al*., 2017)**. Because of the enhanced seed yield, highest netreturns, and best benefit-cost ratio, the foliar spray of zinc twice at 40 and 60 days after sowing (DAS) appeared to be the most cost-effective**(Gourav*et al*., 2018)**. The benefit-cost (B:C) ratio has increased compared to the uninoculated control, and this is due to the low cost of biofertilizers**(Singh *et al*., 2017)**. In comparison to single inoculation and uninoculated control, net returns and gross returns and benefit cost ratio were higher with dual inoculation of *Rhizobium* and plant growth promoting rhizobacteria(PGPR)**(Biswas *et al*., 2012)**.

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CONCLUSION

It is concluded that the maximum yield, gross returns, net returns, and benefit cost ratio were obtained in treatment $T_8$with combined application of *Rhizobium* spp.~~,~~ + *Pseudomonas fluorescens* at a rate of 20 g/kg seed and foliar zinc application of zinc 0.50~~05~~%.

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Ethical paper: This article does not contain any studies with human participants or animals performed by any of the authors.

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Table1.Responseofb~~B~~iofertilizersandf~~F~~oliarapplicationofz~~Z~~incony~~Y~~ieldattributes and y~~Y~~ieldofl~~L~~entil *(Lens culinaris)*.

S.No	Treatments	Numberofpods/plant	Numberofseeds/pod	Seedyield (kg/ha)	Stoveryield (kg/ha)
1.	*Rhizobium*spp.+Zinc -0.25%	103.00	1.73	1025.37	2076.67
2.	*Rhizobium*spp.+Zinc -0.50%	103.67	1.73	1038.44	2216.67
3.	*Rhizobium*spp.+Zinc -0.75%	104.00	1.80	1082.46	2346.67
4.	*Pseudomonasfluorescens*+Zinc -0.25%	105.33	1.93	1192.33	2463.33
5.	*Pseudomonasfluorescens*+Zinc-0.50%	105.67	2.00	1257.02	2570.00
6.	*Pseudomonasfluorescens*+Zinc-0.75%	107.00	2.07	1309.93	2676.67
7.	*Rhizobium* spp. + *Pseudomonasfluorescens*+Zinc -0.25%	107.33	2.13	1378.94	2843.33
8.	*Rhizobium* spp. + *Pseudomonasfluorescens*+Zinc -0.50%	111.33	2.27	1530.94	3020.00
9.	*Rhizobium* spp. + *Pseudomonasfluorescens*+Zinc -0.75%	109.33	2.20	1451.81	2920.00
10.	Control(20-40-20NPKkg/ha)	101.00	1.73	997.02	2036.67
	F-test	S	S	S	S
	SEm(±)	0.912	0.06	39.13	45.98
	CD(p=0.05)	2.710	0.17	116.27	136.61

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Table2.Responseofbiofertilizersandfoliarapplicationofzinconeconomics oflentil *(Lens culinaris)*.

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S.No	Treatments	Cost of cultivation(INR/ha)	Grossreturns(INR/ha)	Netreturns(INR/ha)	B:C ratio
1.	*Rhizobium spp* +Zinc -0.25%	30440.00	61522.42	31082.42	1.02
2.	*Rhizobium spp* +Zinc -0.50%	30470.00	62306.16	31836.16	1.04
3.	*Rhizobium spp* +Zinc -0.75%	30510.00	64947.39	34437.39	1.13
4.	*Pseudomonasfluorescens*+Zinc -0.25%	30400.00	71539.72	41139.72	1.35
5.	*Pseudomonasfluorescens*+Zinc-0.50%	30430.00	75421.04	44991.04	1.48
6.	*Pseudomonasfluorescens*+Zinc-0.75%	30470.00	78595.99	48125.99	1.58
7.	*Rhizobium spp + Pseudomonasfluorescens*+Zinc -0.25%	30420.00	82736.65	52316.65	1.72
8.	*Rhizobium spp + Pseudomonasfluorescens*+Zinc -0.50%	30450.00	91856.58	61406.58	2.02
9.	*Rhizobium spp + Pseudomonasfluorescens*+Zinc -0.75%	30490.00	87108.67	56618.67	1.86
10.	Control(20-40-20NPKkg/ha)	29750.00	59820.92	30070.92	1.01