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EFFECT ON PHOSPHORUS AND ZINC EFFICACY WITH PHOSPHATE AND ZINC SOLUBILIZING MICROBES ON YIELD AND ECONOMICS IN LENTIL (*LENS CULINARIS* L.) UNDER *TARAI* REGION OF UTTARAKHAND, INDIA

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ABSTRACT

A field experiment was conducted at N. E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) during *rabi* 2020 on Phosphorus and Zinc efficacy with phosphate and zinc solubilizing microbes in lentil (*Lens culinaris* L.) in *tarai* region. Twelve different doses of phosphorus and zinc with phosphate and zinc solubilizing microbes *viz*. Absolute control (without P and Zn), RDP @ 48 kg per ha, $ZnSO_4$@ 25 kg per hectare, Biophos (5 ml per kg seed), Biozinc (5 ml per kg seed), Biophos and Biozinc (5 ml per kg seed each), 50% RDP @ 24 kg + Biophos (5 ml per kg seed), 12.5 kg $ZnSO_4$+ Biozinc (5 ml per kg seed), 50% RDP@ 24 kg + Biophos + Biozinc (5 ml per kg seed each), 50% RDP @24 +12.5 kg $ZnSO_4$ + Biophos + Biozinc (5 ml per kg seed each), and RDP@ 48kg + nutrient mobilizer (LNm 43a) (20 g per kg seed) were tested in randomized block design taking three replications. Yield characters such as the number of pods per plant, number of grains per pod, grain weight per plant, grain yield and B:C ratio were also highest with the application of 50% RDP @24 kg per hectare +12.5 kg $ZnSO_4$ + Biophos @ 5 ml per kg seed + Biozinc @ 5 ml per kg seed. Yield obtained from 50% RDP @ 24 kg per hectare + Soil of 12.5 kg $ZnSO_4$per ha + nutrient mobilizer @ 20g per kg seed was the second highest.Grain yield and B:C ratio was also highest with the application of 50% RDP @24 kg ha^{-1} +12.5 kg $ZnSO_4$ + Biophos @ 5 ml kg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed.

***Key words*:** Biophos, Biozinc, B: C, Legume, RDP

Introduction

Lentil, a member of the Leguminosae / Fabaceae family, is believed to have originated in the Mediterranean region. Asia, particularly India and Canada, is a significant producer of lentils, with India's Uttar Pradesh leading in production. Total production of lentil in India was 1.23 million tonnes in 2019 with an estimate of 1.44 MT for 2020 (Statista Research Department, 2020). Lentils are rich in protein, with about 30% of their calories coming from this nutrient, making them the third-highest legume. They also contain carbohydrates, fiber, essential amino acids, and various vitamins and minerals, making them a valuable food source for humans and high-quality animal feed. Lentils have a unique ability to fix atmospheric nitrogen through a symbiotic relationship with *Rhizobium* bacteria, reducing the need for nitrogenous fertilizers (Humprey *et al.*, 2001). However, they require adequate phosphorus for root development, seed formation, and overall growth. Phosphorus also influences numerous physiological functions in plants. Applying phosphorus fertilizers enhances lentil yield and soil nitrogen content for subsequent non-legume crops, but excessive phosphorus application can lead to fixation in acidic and alkaline soils. Phosphorus deficiency is a major factor in poor nodulation and low yields of leguminous crops, including lentils (Sammauria *et al.*, 2009). Introducing phosphorus-solubilizing microbes (PSB) to the rhizosphere can improve phosphorus availability to plants by releasing organic acids and enzymes (Gour, 1991). Zinc is another essential micronutrient for plant growth and metabolism, and its deficiency is widespread in many pulse-growing regions (Nijra and Nabwami, 2015). Zinc-solubilizing microorganisms also contribute to better plant growth and zinc content (Deepak *et al.*, 2013). Keeping this view in mind a study was carried out which aims to investigate the impact of phosphorus and zinc solubilizing microbes in the *tarai* region of Uttarakhand, where information on these aspects is currently limited.

Material and Methods

The field experiment was carried out during the *rabi* season of 2020 in Pulse Agronomy Block located at N.E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The experiment was conducted with twelve treatments and three replications in Randomised block design. Variety Pant L8 was taken for experiment with R × R spacing of 23 cm with net plot size of 7.32 m^2 in 812 m^2 area. Details of treatments are given below:

Table 1: Details of the treatments.

S. No.	Treatment
T_1	Absolute Control (without P and Zn)
T_2	RDP application (Control) @ 48 kg ha^{-1}
T_3	Soil application of $ZnSO_4$ @ 25 kg ha^{-1}
T_4	Application of Biophos @ 5ml kg^{-1} seed
T_5	Application of Biozinc @ 5ml kg^{-1} seed
T_6	Application of Biophos and Biozinc @ 5 ml each kg^{-1} seed
T_7	50% RDP application @ 24 kg per hectare + Biophos@ 5 ml per kg seed
T_8	12.5 kg $ZnSO_4 ha^{-1}$ + Biozinc @ 5 ml kg^{-1} seed
T_9	50% RDP application @ 24 kg ha^{-1}+Biophos @ 5ml kg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed
T_{10}	50% RDP application @ 24 kg per hectare + Biophos @ 5 ml per kg seed + Biozinc @ 5 ml kg^{-1} seed
T_{11}	RDP application @ 48 kg ha^{-1} + nutrient mobilizer (LNm 43a) @ 20 g kg^{-1} seed
T_{12}	50% RDP application @ 24 kg ha^{-1} + Soil application of 12.5 kg $ZnSO_4$ ha^{-1} + nutrient mobilize @ 20g kg^{-1} seed

Yield attributes

Total number of pods borne by five tagged plants were counted and the averaged for each plant. Ten representative pods were randomly selected from tagged plants and then the grains per pod was averaged. The number of grains per pod were multiplied to the total number of pods in each plant. A random sample of 200 grains was taken from net plot produce of each plot and their weight was recorded. This weight was multiplied by five to obtain the thousand grain weight.

Yield

Total produce of each net plot (excluding the root biomass) was dried in the sun in the field after harvest and weighed. Yield ha^{-1} was computed by multiplying this with suitable conversion factor. After threshing, the grain yield from each net plot was weighed and then multiplied with suitable conversion factor to get yield (kg ha^{-1}). Straw yield was calculated by deducting the grain yield from the biological yield. Harvest index (HI) was calculated using the formula (grain yield / biological yield) x100. Grain: Straw Ratio was calculated by dividing the grain yield by straw yield.

Economic studies

Selling price of grain and straw were multiplied to the grain and straw yield to obtain the gross return. The cost was deducted from the gross return to obtain the net return. The net return was divided by the cost to obtain Benefit cost (B: C) ratio.

Statistical analysis of data

The experimental data were analyzed using OPSTAT for Randomised Block Design which is programmed by HAU, Hisar, Haryana.

Result and Discussion

Yield attributing characters

The data pertaining to number of pods $plant^{-1}$ have been presented in Table 2. The results presented in the table shows that the treatment receiving 50% RDP @48 kg ha^{-1} +12.5 kg ZnSO4 + Biophos@ 5 ml kg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed (T_{10}) produced the maximum number of pods $plant^{-1}$ being significantly superior to other treatments except the treatment receiving 50% RDP @ 24 kg per hectare + Soil of 12.5 kg ZnSO4 ha-^{1} + nutrient mobilizer @ 20g kg-^{1} seed (T_{12}) which did not differ significantly. This suggests that plant nutrient availability plays a role in pod production, with moderate nutrient levels leading to increased pod production. Phosphorus was found to positively influence plant reproduction, including flowering and fruiting, resulting in a higher number of pods $plant^{-1}$. Additionally, the number of pods $plant^{-1}$ was positively correlated with the number of branches $plant^{-1}$. (Ali *et al.*, 2017) and (Nadergoli *et al.*, 2011), support the role of phosphorus and zinc in increasing pod production through various mechanisms, such as improved source-sink relationships, regulation of plant growth, and stamen and pollen formation.

Table 2 present the data pertaining to the number of

Table 2: Yield attributing characters and yield as influenced by phosphorous and zinc treatments.

	Treatment	Yield attributes				Yield (kg/ha)				
		Pods Plant^{-1}	Grains Pod^{-1}	1000 -Grain weight (g)	Grain weight Plant^{-1} (g)	Grain	Straw	Biolo-gical	Grain straw ratio	Harvest index
T_1	Absolute Control (without P and Zn)	69	1.7	14.0	1.2	1318	2591	3909	0.52	0.34
T_2	RDP @ 48 kg per ha	82	1.9	17.0	1.4	1418	2894	4271	0.49	0.35
T_3	$ZnSO_4$ @ 25 kg per hectare	80	1.8	16.8	1.4	1381	2880	4198	0.52	0.33
T_4	Biophos (5 ml per kg seed)	79	1.7	16.6	1.4	1363	2731	4179	0.49	0.34
T_5	Biozinc (5 ml per kg seed)	75	1.7	16.0	1.4	1322	2668	4049	0.49	0.35
T_6	Biophos and Biozinc (5 ml per kg seed each)	81	1.8	16.9	1.3	1363	2816	4216	0.48	0.33
T_7	50% RDP @ 24 kg + Biophos (5 ml per kg seed)	82	1.9	18.1	1.7	1522	2890	4298	0.53	0.31
T_8	12.5 kg $ZnSO_4$ + Biozinc (5 ml per kg seed)	74	1.7	16.4	1.6	1341	2708	4094	0.49	0.37
T_9	50% RDP@ 24 kg + Biophos + Biozinc (5 ml per kg seed each)	84	1.9	18.7	1.8	1531	2930	4475	0.53	0.33
T_{10}	50% RDP @24 +12.5 kg $ZnSO_4$ + Biophos + Biozinc (5 ml per kg seed each)	98	2.1	20.3	2.6	1735	3424	5063	0.53	0.35
T_{11}	RDP@ 48 kg + nutrient mobilizer (LNm 43a) (20 g per kg seed)	89	2.0	19.3	2.1	1544	2980	4502	0.52	0.32
T_{12}	50% RDP @ 24 kg + 12.5 kg $ZnSO_4$ + nutrient mobilizer (20 g per kg seed)	94	2.0	19.4	2.2	1563	3333	4544	0.47	0.33
	S.Em$\pm$	3	0.1	0.7	0.1	65	177	130	0.03	0.01
	LSD (P=0.05)	9	0.2	2.0	0.4	191	NS	383	NS	NS

grains pod^{-1}. The treatment getting 50% RDP @48 kg ha^{-1} +12.5 kg $ZnSO_4$ + Biophos@ 5 ml kg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed (T_{10}) had significantly more number of grains pod^{-1} over that of the others except RDP @ 48 kg ha^{-1} + nutrient mobilizer (LNm 43a) @ 20 g kg^{-1} seed (T_{11}) and 50% RDP @ 24 kg ha^{-1} + Soil of 12.5 kg $ZnSO_4$ ha^{-1} + nutrient mobilizer @ 20g kg^{-1} seed (T_{12}) which did not differ significantly. Increasing phosphorus and zinc increased all the yield characters. The number of grains per pod enhanced with successive increase in phosphorus levels (Choubay *et al.,* 2013).

The data regarding 1000-grain weight have been presented in Table 2. The 1000-grain weight was significantly influenced due to the different treatments of phosphorus and zinc. The treatment receiving 50% RDP @24 kg ha^{-1} +12.5 kg $ZnSO_4$ + Biophos@ 5 mlkg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed (T_{10}) recorded significantly highest 1000-grain weight. Applying various nutrients reduced interplant competition, resulting in bolder seeds. Higher phosphorus application extended crop maturity and increased grain yield by improving seed weight. (Khorgamy *et al.*, 2009) and (Rathi *et al.*, 2009) attributed the increase in 1000-grain weight to factors like cell division, phosphorus content, and the formation of fats and albumin. Zinc, when optimally applied also enhanced cell division, sugar and starch formation, and seed size, leading to a higher thousand grain weight in lentil.

The data on grain weight per plant have been presented in Table 2. The grain weight per plant significantly differed ascribable to different treatments of phosphorous and zinc. The treatment getting 50% RDP @48 kg per hectare +12.5 kg $ZnSO_4$ + Biophos@ 5 ml kg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed (T_{10}) had significantly more grain weight per plant over that of the others. Grain weight per plant is determined by attributes such as grains pod^{-1}, pods plant^{-1} and 1000-grain weight. Thus, phosphorus and zinc application which improved these attributes also increased the grain weight per plant. (Hussain *et al.,* 2015) also concluded that phosphorus and zinc played important role in enzymes activation, photosynthesis, fertilization and translocation of assimilates to the seeds which might be the cause for increased seed size and grain weight plant^{-1}.

Yield, Harvest Index and Grain: Straw ratio

Table 2 presents data on grain yield per hectare influenced by various treatments, with a significant impact observed due to variations in phosphorus and zinc

Table 3: Cost of cultivation, net returns and B:C ratio as influenced by the different phosphorus and zinc application practices.

Treatment		Net return (Rs/ha)	Cost of cultivation (Rs/ha)	B:C ratio
T_1	Absolute Control (without P and Zn)	40231	22058	1.82
T_2	RDP @ 48 kg per ha	43906	23183	1.89
T_3	$ZnSO_4$ @ 25 kg per hectare	42005	23308	1.80
T_4	Biophos (5 ml per kg seed)	42091	22103	1.90
T_5	Biozinc (5 ml per kg seed)	40123	22103	1.82
T_6	Biophos and Biozinc (5 ml per kg seed each)	41791	22148	1.89
T_7	50% RDP @ 24 kg + Biophos (5 ml per kg seed)	49161	22666	2.17
T_8	12.5 kg $ZnSO_4$ + Biozinc (5 ml per kg seed)	40410	22728	1.78
T_9	50% RDP@ 24 kg + Biophos + Biozinc (5 ml per kg seed each)	49293	22711	2.17
T_{10}	50% RDP @24 +12.5 kg $ZnSO_4$ + Biophos + Biozinc(5 ml per kg seed each)	58460	23336	2.51
T_{11}	RDP@ 48 kg + nutrient mobilizer (LNm 43a) (20 g per kg seed)	53399	24183	2.21
T_{12}	50% RDP @ 24 kg + 12.5 kg $ZnSO_4$ + nutrient mobilizer (20 g per kg seed)	55101	24246	2.27

application. Among these treatments, the one receiving 50% RDP @24 kg ha^{-1}+12.5 kg $ZnSO_4$ + Biophos@ 5 ml kg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed (T_{10}) yielded the highest grain production, significantly surpassing other treatments. The balanced nutrient supply and the timely availability of these nutrients, facilitated by nutrient-solubilizing microbes, enhanced plant growth and, consequently, grain yield. The combined and optimal application of phosphorus and zinc exhibited a synergistic effect, leading to a significant increase in grain yield, a finding consistent with Hussain and Ahmad (2015).

Table 2 presents data related to straw yield per hectare, which was not significantly affected by varying phosphorus and zinc treatments. Nevertheless, the treatment with 50% RDP @24 kg ha^{-1} +12.5 kg $ZnSO_4$ + Biophos@ 5 ml kg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed (T_{10}) resulted in the highest straw yield. Proper nutrient availability enhanced plant growth, with zinc playing a role in chlorophyll production and contributing directly to plant growth. (Meena *et al.*, 2017) noted that applying phosphorus with zinc led to higher grain and straw yields in soybean.

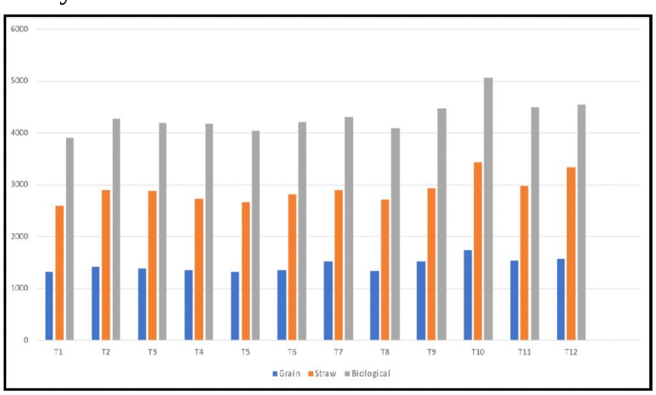

Fig. 1: Grain, straw and biological yield as influenced by phosphorus and zinc treatments.

Table 2 presents data on biological yield per hectare. The application of phosphorus and zinc to plants increased both grain and straw yield, consequently boosting the biological yield. The highest biological yield was achieved in the treatment featuring 50% RDP @24 kg ha^{-1} +12.5 kg $ZnSO_4$ + Biophos@ 5 mlkg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed (T_{10}), statistically superior to all other treatments. (Singh *et al.*, 2008) similarly found that the biological yield increased significantly with up to 50 kg P_2O_5 ha^{-1}.

The data in Table 2 showing the grain-to-straw ratio for various treatments revealed non-significant variations. The highest ratio was found in the treatment involving 50% RDP @24 kg ha^{-1} +12.5 kg $ZnSO_4$ + Biophos@ 5 ml kg^{-1} seed + Biozinc @ 5 ml kg^{-1} seed (T_{10}), as well as in treatments T_9 and T_7.

Table 2 presents data on harvest index, where variations in this index due to different phosphorus and zinc treatments were non-significant. The highest harvest index was obtained from 12.5 kg $ZnSO_4$ + Biozinc (5 ml kg^{-1} seed) (T_8). These substantial variations in the harvest index are not influenced by the given treatments and may

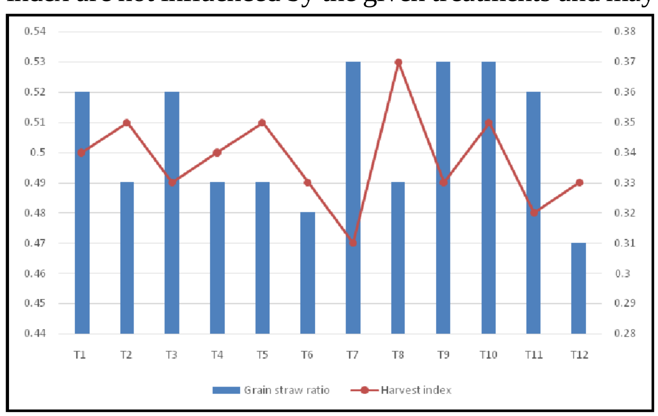

Fig. 2: Grain: straw ratio and harvest index as influenced by phosphorus and zinc treatments.

be associated with the genetic makeup of the crop, as suggested by (Singh *et al*., 2011). (Fatima *et al*., 2013) also observed that each increment of phosphorus from 25 to 75 kg ha^{-1} resulted in a superior harvest index value for lentil.

Economic returns

Gross returns: The gross return was highest in the case of T_{10} followed by the T_{12}. These returns may be ascribed to the higher yield of the treatments due the balanced application of the nutrients. The higher growth parameters and yield attributes resulted in higher gross returns.

Net returns : The data (Table 3) on economic studies reveals that the highest net return was obtained in the case of the T_{10} whereas the minimum net return was in case of T_1. Yadav *et al*., (2017) found that the application of phosphorus at 40 kgha^{-1} gave significantly higher net returns.

B:C ratio : The data regarding the benefit cost ratio is detailed in Table 3. The data shows that the highest B:C ratio was obtained in the case of T_{10} followed by the T_{12} at 2.27. The minimum was in the case of T_1. This indicates amount of money earned from investment of a unit amount of money. The higher B:C ratio may be ascribed to higher net return rupee^{-1} of cost. The nutrients applied caused better output when both phosphorus and zinc were combined along with the solubilizing microbes and led to higher gross and net returns which also led to higher B:C ratio (Singh *et al*., 2019).

Conclusion

On the basis of the experimental findings from the investigation it could be deduced that the application 50% RDP @24 kg per hectare +12.5 kg $ZnSO_4$ + Biophos@ 5 ml per kg seed + Biozinc @ 5 ml per kg seed may be made along with the recommended dose of potassium and nitrogen for getting higher yield attributing characters and yields of lentil in tarai conditions of the Himalayan terrain. The highest benefit to cost ratio was obtained in this nutrient doses.

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