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Economic analysis of application of phosphorus, single and dual inoculation of *Rhizobium* and plant growth promoting rhizobacteria in lentil (*Lens culinaris* Medikus)

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Abstract: This study investigates the economic returns of lentil (*Lens culinaris* Medikus) by the use of phosphorus and biofertilizers [*Rhizobium* and plant growth promoting rhizobacteria (PGPR)] in Indian Punjab. The field experiments were conducted during *Rabi* 2013-14 and 2014-15 with combinations of four levels of phosphorus (0, 20, 30 and 40 kg P_2O_5 ha^{-1}) and two/four biofertilizer treatments [uninoculated control and *Rhizobium* (LLR 12) + PGPR (RB 2)] in 2013-14, and uninoculated control, *Rhizobium*, PGPR and *Rhizobium* + PGPR in 2014-15) by replicating thrice. The use of 40 kg P_2O_5 ha^{-1} provided the highest gross returns whereas net returns and B:C were highest at 30 kg P_2O_5 ha^{-1}. The combination of *Rhizobium* + PGPR + 40 kg P_2O_5 ha^{-1} provided the highest gross returns (Rs. 45902) whereas *Rhizobium* + PGPR+ 20 kg P_2O_5 ha^{-1} provided the highest net returns (Rs 20620). Furthermore, the integrated use of *Rhizobium* + PGPR + 20 kg P_2O_5 ha^{-1} provided higher net returns (Rs 20620) and B:C (1.88) as compared to sole application of 40 kg P_2O_5 ha^{-1} (Rs 18792 and 1.72). Thus, there was a net saving of 20 kg P_2O_5 ha^{-1} with the use of *Rhizobium* + PGPR inoculation without sacrificing the economics returns.

Keywords: B:C, Biofertilizers, Gross returns, Lentil, Net returns, Phosphorus

INTRODUCTION

Lentil (*Lens culinaris* Medikus) is recognised as an important grain legume crop in the world. In India, during the year 2014, lentil was grown on an area of 1.80 million hectares and total production was 1.10 million tonnes, with productivity of 611 kg ha^{-1} (FAOSTAT 2017). Pulses are the wonder crops as these are a rich source of protein for vegetarian inhabitants and also have an ability to reduce the pressure of external inorganic N inputs because of biological nitrogen fixation process. In lentil, estimated nitrogen obtained from N_2 fixation is 51 kg N ha^{-1} year^{-1} (Smil 1999). These crops are used for crop diversification in different cropping systems.

Continuous hike in the prices of non-renewable resources and inorganic fertilizers forced to increase the agriculture production by adopting new strategies including the use of biofertilizers (e.g. *Rhizobium*) and integrated use of organic and chemical fertilizers. Phosphorus fertilizer is considered as the limiting factor in pulse production technology. No doubt the use of some chemical fertilizers (such as phosphorus and potash supplying fertilizers) supply nutrients to the crop plants, however, their overexploitation adversely affects the Indian economy by disturbing foreign exchange via increasing import of fertilizers and, therefore, forces to pay attention to find out the economic doses of fertilizers. For increasing their profits, farmers try to make best investments through farming practices, however, there is a great need to make them aware about the use of microbial inoculations along with fertilizer application (Uddin *et al*. 2014).

Beneficial effects of *Rhizobium* are already known (Singh *et al*. 2006), however, recent research has shown beneficial effects of plant growth promoting rhizobacteria (PGPR) also (Kaur *et al*. 2015). Biofertilizers such as *Rhizobium* and PGPR are eco-friendly, low in cost and also they have an ability to recycle the indigenous or immobile nutrients in sustainable agriculture. *Rhizobium* fixes atmospheric nitrogen and converts it in plant usable form while PGPR augment the plant growth by different ways. Direct promotion of plant productivity by use of PGPR occurs, when rhizobacteria improve the supply of nutrients i.e. nitrogen, production of metabolites such as auxins, cytokinins and gibberellins as well as through the solubilization of phosphate and other minerals. Under indirect plant growth promotion, PGPR eliminate the pathogens by the production of cyanide, siderophores, chitinase etc. Application of nutrients at proper dose helps to achieve profitable and also economically and environmentally best while higher dose not only increases the cost of production but also results in environmental

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pollution. When maximum returns per unit of fertilizer are recorded then fertilizers are considered as the efficiently used (Mortvedt *et al*. 2001). Along with enhancing grain yield and making available soil fixed P, microbial inoculations may also help in lowering the cost of crop production through less input of chemical fertilizers. Therefore, agronomic experiments were conducted to find out the best combinations of inorganic fertilizers and biofertilizers for lentil crop from economics point of view.

MATERIALS AND METHODS

The present field research was carried out at Punjab Agricultural University, Ludhiana (30°54′N latitude and 75°56′E longitude), Punjab during *Rabi* season of 2013-14 and 2014-15. The location of the experimental farm is located in Trans-Gangetic agro-climatic zone of India, under the central plain region of Punjab. The soil of experimental farm was loamy sand in textural class with low organic carbon (0.32%) & available N (119.8 kg ha^{-1}) and medium in available P (13.6 kg ha^{-1}) & available K (161 kg ha^{-1}). The experiment comprised combinations of four levels of phosphorus (0, 20, 30 and 40 kg P_2O_5 ha^{-1}) and two/four biofertilizer treatments [uninoculated control and *Rhizobium* + plant growth promoting rhizobacteria (PGPR) in 2013-14] and (uninoculated control, *Rhizobium*, PGPR and *Rhizobium* + PGPR in 2014-15) replicated three times in Randomized Complete Block Design (RCBD).

Sowing of lentil cultivar 'LL 699' was done on 11November 2013 and 6 November 2014. As per the treatments, phosphorus was applied through single superphosphate (16% P_2O_5) at sowing. Seeds were inoculated with *Rhizobium* (LLR 12) and PGPR (RB 2) prior to sowing as per treatments. *Rhizobium* and PGPR were used as single inoculations or as dual inoculation (*Rhizobium* + PGPR) as per the treatments. Inoculated seeds were dried in shade before sowing. A uniform basal dose of N fertilizer at 12.5 kg ha^{-1}through urea (46% N) was broadcasted at the time of sowing. The crop was harvested on 8 April and 14 Aprilin 2014 and 2015, respectively. The crop was raised as per the recommendations (PAU, 2013).

For calculating gross returns, the grain yield was multiplied by minimum support price (MSP) i.e. Rs. 2950 $quintal^{-1}$. The cost of cultivation (i.e. total variable costs) includes different variable costs like human labour, machinery energy, seed, fertilizer, biofertilizers, insecticide, irrigation, etc. The details of the costs involved in different inputs are presented in Table 1.Net returns were calculated by subtracting total variable costs from the gross returns. The benefit cost ratio (B:C) was calculated by dividing the gross returns with total cost of cultivation. The gross returns and net returns were expressed in Rs. ha^{-1}.

RESULTS AND DISCUSSION

Gross returns: Gross returns increased with the successive increase in phosphorus dose from 0 to 40 kg P_2O_5 ha^{-1} (Tables 2 and 3). The lowest gross returns were obtained in the control treatment i.e. where no phosphorus and biofertilizers were applied. Among biofertilizer treatments, higher gross returns were obtained from coinoculated treatment (*Rhizobium* + PGPR) than uninoculated control or sole inoculations of *Rhizobium* and PGPR. Earlier, Jain *et al*. (2006) also reported that the highest net returns from coinoculation might be due to maximum grain and straw yield.

The highest gross returns were fetched by combined application of *Rhizobium* + PGPR + 40 kg P_2O_5 ha^{-1} (Rs 45902) (Table 2), which might be due to higher grain yields. As compared to the sole application of 20, 30 and 40 kg P_2O_5 ha^{-1}, the integrated use of phosphorus and biofertilizers (*Rhizobium*, PGPR and *Rhizobium* + PGPR) improved gross returns. Application of a 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 a 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 (Singh 2004). The application of essential plant

Table 1. Level of input of biofertilizers and phosphorus use for different treatments for lentil cultivation.

Type of input	Cost (Rs ha^{-1})
Rhizobium	50
PGPR	50
Rhizobium + PGPR	100
20 kg P_2O_5 ha^{-1}	2862
30 kg P_2O_5 ha^{-1}	4292
40 kg P_2O_5 ha^{-1}	5725
Labour charges for *Rhizobium* inoculation	50
Labour charges for PGPR inoculation	50
Labour charges for *Rhizobium* + PGPR inoculation	50
General cost of cultivation (except the treatment costs)	20500 (in 2013-14) 22500 (in 2014-15)

Table 2. Effect of phosphorus and biofertilizers on economic returns of lentil in 2013-14.

Treatment	Cost of cultivation (Rs ha^{-1})	Returns (Rs ha^{-1})		B:C*
		Gross	Net	
0 kg P_2O_5 ha^{-1} (unfertilized control)	20500	35400	14900	1.73
20 kg P_2O_5 ha^{-1}	23362	40644	17282	1.74
30 kg P_2O_5 ha^{-1}	24792	43704	18912	1.76
40 kg P_2O_5 ha^{-1}	26225	45015	18790	1.72
Rhizobium + PGPR	20650	41081	20431	1.99
Rhizobium + PGPR + 20 kg P_2O_5 ha^{-1}	23512	44141	20629	1.88
Rhizobium + PGPR + 30 kg P_2O_5 ha^{-1}	24942	44578	19636	1.79
Rhizobium + PGPR + 40 kg P_2O_5 ha^{-1}	26375	45889	19514	1.74
CD (p=0.05)		5281	NS	NS

* B:C = Benefit Cost Ratio

Table 3. Effect of phosphorus and biofertilizers on economic returns of lentil in 2014-15.

Treatment	Cost of cultivation (Rs ha^{-1})	Returns (Rs. ha^{-1})		B:C*
		Gross	Net	
P_2O_5 (kg ha^{-1})				
0	22587	47140	24553	2.08
20	25449	53534	28085	2.10
30	26879	56402	29523	2.09
40	28312	57377	29065	2.02
CD (p=0.05)		1607	1607	NS
Biofertilizers				
Uninoculated	25719	50454	24735	1.96
Rhizobium	25819	53845	28026	2.08
PGPR	25820	52838	27018	2.04
Rhizobium + PGPR	25869	57316	31447	2.21
CD (p=0.05)		1607	1607	0.06

* B:C = Benefit Cost Ratio

nutrients in optimum quantity and right proportion is the key to increase the profit.

Net returns: Among different phosphorus levels, 30 kg P_2O_5 ha^{-1} provided the highest net returns (Tables 2 and 3). Among biofertilizer treatments, the coinoculated treatment gave higher net returns than uninoculated control (Table 2) and uninoculated control as well as single inoculations of *Rhizobium* and PGPR (Table 3). Similarly in chickpea, higher net returns (Rs 11312ha^{-1}) with the application of *Rhizobium* + phosphorus solubilising bacteria over the uninoculated control (Rs 8282 ha^{-1}) and single inoculations of *Rhizobium* (Rs 9883 ha^{-1}) and PGPR (Rs 9697 ha^{-1}) were reported by Jain *et al*. (2006).

The highest net returns were fetched by integrated use of *Rhizobium* + PGPR + 20 kg P_2O_5 ha^{-1} (Rs 20620) (Table 2), which might be due to high grain yield and less cost of cultivation. Earlier, Jain *et al*. (2006) reported that improvement in net returns (Rs 22067 ha^{-1}) was due to higher gross returns (Rs 30538 ha^{-1}) in chickpea. Application of 20 kg P_2O_5 ha^{-1} with consortium (*Rhizobium* + PGPR) was more profitable over 40 kg P_2O_5 ha^{-1} + *Rhizobium* + PGPR, that might be due to low cost of single superphosphate and biofertilizers in comparison to the additional grain yield obtained (Kanwar *et al*. 2013). Thus, there was a net saving of 20 kg P_2O_5 ha^{-1} with the useof *Rhizobium* + PGPR+ 20 kg $P_2O_5$$ha^{-1}$over *Rhizobium* + PGPR + 40 kg P_2O_5 ha^{-1}or 40 kg P_2O_5 ha^{-1} alone without sacrificing the economic returns.

Benefit cost ratio: Among different phosphorus levels, 20 and 30 kg P_2O_5 ha^{-1} provided higher B:C than 0 and 40 kg P_2O_5 ha^{-1} (Tables 2 and 3), though the results differed non significantly in 2014-15. Among biofertilizer treatments, coinoculation treatment resulted in significantly higher B:C than uninoculated control (Table 2) and uninoculated control as well as single inoculation of *Rhizobium* or PGPR (Table 3).

Higher B:C was obtained in combined use of *Rhizobium*+ PGPR + 20 kg P_2O_5 ha^{-1} (1.88) than all other treatments except *Rhizobium* + PGPR (Table 2). These results are similar with the findings of Jain *et al*. (2006) who reported that this was due to more uptake of nutrients (N and P) that increased the grain yield. Minimization in dose of phosphorus and subsequently reduction of cost per unit production through higher yield helps to get maximum benefits. Application of either phosphorus or biofertilizers was unable to give better B:Cthan that given by combined application of both. It shows the importance of both biofertilizers and fertilizers. In chickpea, compared to phosphorus fertilizers, the low cost of biofertilizers is responsible to improve the B:C ratio in PGPR (4.33) over the uninoculated control (3.54) (Tanwar *et al*. 2010).

Conclusion

It may be concluded that to obtain the higher profit it is necessary to use the fertilizers as efficiently as possible without any wastage or losses. The use of 40 kg P_2O_5 ha^{-1} provided the highest gross returns (Rs. 45015 ha^{-1} for 2013-14 and Rs. 57377 ha^{-1} for 2014-15) where as net returns (Rs. 18912 ha^{-1} for 2013-14 and Rs. 29523 ha^{-1} for 2014-15) and B:C (1.76 for 2013-14 and 2.09 for 2014-15) were highest at 30 kg P_2O_5 ha^{-1}. Dual inoculation with *Rhizobium* and PGPR was better over uninoculated control or single inculcations. As compared to sole application of chemical fertilizer or inoculation, the integrated use of 20 kg P_2O_5 ha^{-1}+ *Rhizobium* + PGPR was found to be the most promising treatment. The saving in 20 kg P_2O_5 ha^{-1} was possible because of the use of biofertilizers which increased the efficiency of applied phosphorus.

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