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Effect of bio-fertilizer on yield and economics of summer greengram (*Vigna radiata* L.)

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Abstract
The pulses are an integral part of the cropping systems of the farmers all over the country. Pulses are recognized as an indispensable constituent of the Indian diet and an important source of protein for the poor as well as for vegetarians. In participatory mode, On Farm Testing (OFT) was carried out to assess the effect of bio-fertilizers on grain yield and economics of summer green gram during the summer season of 2013-14 and 2014-15 at the farmers' field on ten pre-selected locations in Muzaffarpur district of North Bihar. Each farmer was considered as a replication. The results of the trial explicitly revealed that the effect of bio-fertilizers was found effective to touch the level significance for grain yield production. The grain yield (999.40 kg ha^{-1}) data showed that treatment *i.e.* RDF (N_{20}-P_{40}-K_{00}kgha^{-1}) along with *Rhizobium* + P*hosphorus Solubilizing Bacteria* (PSB) were statistically significant over RDF (N_{20}-P_{40}-K_{00} kgha^{-1}) and Farmers' Practice. A maximum Net Return (Rs. 34690.00 ha^{-1}) and B:C ratio (3.51) was found in the treatmentN_{20}-P_{40}-K_{00} kgha^{-1} along with *Rhizobium* + P*hosphorus Solubilizing Bacteria*-PSB as compared to RDF and Farmers' Practice.

Keywords: B:C ratio, bio-fertilizer, farmers, INM, PSB, soil, yield

Introduction
Green gram (*Vigna radiata* L.) is one of the most important conventional pulse crops cultivated in India. Green gram has an advantage over the other pulse crops owing to its high nutritive value and easy digestibility. The nutritive value of the seed is estimated to be 24.20% protein, 1.30% fat and 60.4% carbohydrates per 100 g of the seed. The seed also contains significant elements such as calcium (Ca) 118 mg and phosphorus (P) 340 mg per 100 g of seed(Imran *et al*., 2015) [7]. Moreover, green gram possesses a significant position in our daily diet as well as an important component in ouragricultural production system. In India, the low productivity of this crop is due to the unavailability of healthy seeds, high cost of seeds, pesticides, fertilizers and scarcity of labors at the time of peak agricultural operations as well as wide gap in adoption of recommended production technology for green gram(Pardava *et al.*,2019) [12].

Bio-fertilizer such as *Rhizobium* are used for growing good quality pulse produce. Most of bio-fertilizers are found beneficial in the crop production, they are named as *Azotobactor*, *Azospirillum, Blue Green Algae (BGA)* and *Rhizobium*(Hedge, 1999) [6].Continuous use of chemical fertilizers has led to a declination in the yield and deterioration of soil fertility indicating that sole dependence on chemical-based fertilizer is unsuitable for achieving sustainable crop production. Only chemical fertilizer application to meet the nutrient requirement of crop is negatively affect the environment as well as human health. Whatever chemical fertilizers used in soil to meet the N demand of crop is by and large in large quantities exceeding the recommended dose of fertilizer, they are highly costly and contaminating the environment severely (Dai *et al*, 2004) [3]. Bio-fertilizers fix the atmospheric nitrogen and make readily available form to the plants (Chen, 2006) [1]. Bio-fertilizers are low cost, renewable source of plant nutrients which supplement chemical fertilizers. The bio-fertilizers known as the kingpin of modern agriculture have not only boosted food production and productivity but are also accredited for the positive changes inphysico-chemical properties of soil, nitrogen transformation, macro and micronutrients uptake along with nutritional composition (Mahesh and Hosmani, 2004) [9] as well as nutrient use efficiency. Bio-fertilizers are known to fix atmospheric nitrogen through *Rhizobium sp*. This bacterial inoculation has ability to fix atmospheric nitrogen in association with plants forming nodules in roots.

Rhizobium sp. in the presence of phosphorus not only fixes more nitrogen through an increased number of nodules but also considerably enhances the protein content, dry matter, and seed yield of various legume crops. They belong to the family of *Rhizobiaceae* which are symbiotic in nature and fixes nitrogen @ 50-100 kg/ ha in association with legumes only (Mishra *et al*., 2012) [10]. Green gram is a crop that naturally forms nodules, but the degree of nodulation varies with the area and culture being used. Being a legume crop, it necessitates less nitrogen, but phosphorus application is an important input for higher yields per unit area. Keeping these above facts in view, the present study was designed to evaluate the response of bio-fertilizer *i.e. Rhizobium* and *phosphorus-solubilizing bacteria* (PSB)for realizing the maximum yield and economics as well as the soil status in the Muzaffarpur district of North Bihar, India.

Materials and Methods

An On-Farm Testing (OFT) was conducted during the summer seasons of 2013-14 and 2014-15 at ten pre-selected locations in Muzaffarpur district that are situated at the Indo-Gangetic- North-West Alluvial Plans of North Bihar. The experiment was laid out in Randomized Block Design (RBD). Each farmer was considered as a replication and ten farmers were selected, thereby the experiment had ten replications. The current experiment was comprising three treatments *viz*. T_0 -Farmers practice, T_1- Recommended Dose of Fertilizer (RDF) *i.e*. N_{20}-P_{40}-K_{00} (kgha^{-1}) and T_2– RDF (N_{20}-P_{40}-K_{00}) along with *Rhizobium* + *Phosphorus Solubilizing Bacteria* (PSB). The packets of *Rhizobium* and PSB containing 200gm inoculums were obtained from the Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India. Seeds of green gram were treated with Bio-fertilizers prior to sowing @ 200 g/10kgseed. For the seed treatment, the slurry was prepared by boiling 50gmjaggery in 500ml of water. The slurry was then cooled down to room temperature and 200g each of *Rhizobium* and PSB bio-fertilizers were added to it. The mixture was thoroughly homogenized and mixed with the green gram seeds. The treated green gram seeds were shade dried for 30 minutes after which the seeds were sown. Seeds were sown with a row to row spacing of 30 cm and plant to plant spacing of 7 cm. Before sowing, soil samples from each of the plots under trial were collected and analyzed for available nitrogen by alkaline potassium permanganate method (Subbiah and Asija, 1956) [16], available phosphorus using 0.5 M$NaHCO_3$ extractable colorimetric methods (Olsen *et al.* 1954) [11] and available potassium by Jackson (1973) [8] method. The fertilizer was applied in the experimental plots as per the treatments. Invariably, according to treatments, a full dose of nitrogen and phosphorus was applied as the basal dose. The data were subjected to statistical analysis of Gomez and Gomez (2010) [5]. Net return, benefit-cost ratio and harvest index was calculated using the following formula:

Net return = Gross return (ha^{-1}) – Cost of cultivation (ha^{-1})

$$\text{Benefit cost ratio} = \frac{\text{Gross return (ha}^{-1})}{\text{Total cost of cultivation (ha}^{-1})}$$

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

Results and Discussion

Grain yield

The effect of seed treatment with bio-fertilizers on grain and straw yield was recorded after harvesting (Table. 1). Application of N_{20}-P_{40}-K_{00} (kg ha^{-1}) along with *Rhizobium* + P*hosphorus Solubilizing Bacteria* (PSB) significantly enhanced the grain yield and recorded the highest grain yield (999.40kg ha^{-1})as compared to other experimental variables. The minimum grain yield of 711.00 kg ha^{-1} was obtained in the case of farmers practice (T_0).While the treatment T_1 showed its statistical superiority over T_0in respect to grain and straw yield, this might be due to the fact that green gram has utilized the artificial and natural resources available below and above the ground very effectively thereby exhibiting better growth and yield parameters. However, the marked increase in seed yield in treatment of T_2 may be attributed to the increase in P availability by the solubilization of phosphate-rich compounds. Several organic acids are secreted by PSB which may form chelates resulting in the effective solubilization of phosphate assisting in higher nitrogen fixation, dry matter accumulation, rapid plant growth, higher absorption and utilization of P and other plant nutrients and ultimately leading to a positive resultant effect on growth and subsequently on yield and yield attributes (Rathour *et al*., 2015) [13].

Biological yield and Harvest index

A perusal of the pooled data indicated that biological yield and harvest index (%) were significantly enhanced in the application of bio-fertilizer when compared to the other treatments *i.e.* RDF and farmers practice (Table-1). The result showed that application of RDF (N_{20}-P_{40}-K_{00}) along with *Rhizobium* + *phosphorus-solubilizing bacteria* (PSB) (T_2) produced maximum biological yield (2729.43 kg ha^{-1}) and harvest index per cent (36.63) followed by the other treatments T_1 and T_0. The minimum biological yield and harvest index of 2313.89kg ha^{-1} and 31.06 respectively were recorded of the farmers' practice (T_1).This result is supported by the findings of Tomar *et al.* (1993) [17] and Freitas (2000) [4].

Economics

Applications of N_{20}-P_{40}-K_{00} along with *Rhizobium* + Phosphorus Solubilizing Bacteria (PSB) have shown to give the highest gross return (Rs.48500 ha^{-1}), net returns (Rs.34690.00 ha^{-1}) and B: C ratio of 3.51 followed byN_{20}-P_{40}-K_{00} (RDF) and farmers' practice (Table 2). The lowest net return of Rs. 16705.00 ha^{-1}and B:C ratio of 2.44were observed under T_0.These results were conformity by the findings of Toma r*et al.* (1993) [17].

Soil fertility status

The two years pooled data (Table 3) of current trial showed that treatment N_{20}-P_{40}-K_{00} along with *Rhizobium* + *Phosphorus Solubilizing Bacteria* (T_2) has a net higher positive gain of available nitrogen and phosphorus as compared to the other two treatments *i.e.*, N_{20}-P_{40}-K_{00} (RDF) and farmers' practice. Similar findings were reported by Singh *et al*. 2020 [14]. Application of N_{20}-P_{40}-K_{00} along with *Rhizobium* + *Phosphorus Solubilizing Bacteria* registered highest available nitrogen of 313.25 kg ha^{-1}, whereas the lowest value of 284.50 kg ha^{-1} was recorded in the case of farmers' practice. The maximum available phosphorus value of 22.15 kg ha^{-1} was registered in the application of N_{20}-P_{40}-

K_{00} along with bio-fertilizers followed by N_{20}-P_{40}-K_{00} (RDF) and the lowest value of 18.50 kg ha^{-1} was observed in the farmers' practice in post-harvest observation. It indicates that uses of *Rhizobium* and *Phosphorus Solubilizing Bacteria* together in the present experiment were cumulatively translated into a net gain of available nitrogen and phosphorus. Similar finding was reported by Singh *et al*., 2019 [15]. The role of micro-organisms including PSB (*Phosphate Solubilizing Bacteria*) in solubilizing and mobilizing inorganic phosphate in soil and making them available to plants is crucial. The PSBs convert the insoluble phosphate into soluble forms by acidification, chelation, exchange reaction and production of gluconic acid (Chung *et al*., 2005) [2].

Table 1: Effect on biological yield of summer green gram treated with bio-fertilizer (*Rhizobium and PSB*) (Pooled data of 2 years)

Treatment	Biological Yield (kg ha^{-1})			
	Grain	Straw	Biological	HI
T_0: Farmers Practice	711.00	1602.89	2313.89	31.06
T_1:RDF (N_{20}-P_{40}-K_{00})	890.20	1677.44	2567.64	34.65
T_2: N_{20}-P_{40}-K_{00} + *Rhiz.*+PSB	999.40	1730.03	2729.43	36.63
S.Em±	14.94	8.55	17.16	0.52
C D ($P \leq 0.05$)	44.39	25.40	50.97	1.54

HI-Harvest index, RDF-Recommended dose of fertilizer, significant at $P \leq 0.05$

Table 2: Effect on economics of summer green gram treated with bio-fertilizer (*Rhizobium and PSB*) (Pooled data of 2 years)

Treatment	Cost of Cultivation (Rs. ha^{-1})	Gross Return (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	B:C ratio
T_0: Farmers' Practice	11620	28325	16705	2.44
T_1:RDF (N_{20}-P_{40}-K_{00})	13710	35075	21365	2.56
T_2: N_{20}-P_{40}-K_{00} + *Rhiz.*+PSB	13810	48500	34690	3.51

RDF-Recommended Dose of Fertilizer, Rhiz.- Rhizobium, PSB- Phosphorus Solubilizing Bacteria

Table 3: Effect on soil fertility status of summer green gram treated with bio-fertilizer (Pooled data of 2 years)

Treatment	Available Nutrients (Kg ha^{-1})								
	Initial			Post-harvest			Net Change (Net gain/loss)		
	N	P	K	N	P	K	N	P	K
T_0:Farmers' Practice	284.00	18.25	234.50	284.50	18.50	235.00	0.50	0.25	0.50
T_1:RDF (N_{20}-P_{40}-K_{00})	294.25	19.50	240.25	294.50	20.00	240.50	0.25	0.50	0.25
T_2: N_{20}-P_{40}-K_{00} + *Rhiz.*+PSB	294.50	19.75	245.00	313.25	22.15	245.50	18.75	2.40	0.50

RDF- Recommended Dose of Fertilizer, Rhiz.- Rhizobium, PSB- Phosphorus Solubilizing Bacteria

Conclusion

Bio-fertilizers are small microbes which can be preparedto contain living cells of nitrogen fixing and phosphate solubilizing microorganisms for treatment of seed or soil. The seed treated with *Rhizobium* and PSB showed significantly higher biological yield as compared to other treatments. Hence, bio-fertilizers *i.e. Rhizobium and Phosphorus Solubilizing Bacteria* along with a recommended dose of fertilizers can be best to the farmers in the case of green gram crop to obtain higher yield and return without any negative impact on soil fertility status.

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