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Effect of Bio-fertilizer and Phosphorus on Growth and Yield of Green gram (*Vigna radiata* L.)

Chirumella Joharika [a++*], Shikha Singh [b#] and Anu Nawhal [b†]

[a] Department of Agronomy, Sam Higginbottom University of Agriculture Technology and Science (SHUATS), Prayagraj-211007, Uttar Pradesh, India.
[b] Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Science (SHUATS), Prayagraj-211007, Uttar Pradesh, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted at Crop Research Farm, Naini Agriculture Institute, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during Zaid 2022 on sandy loamy soil. The experiment was laid out in Randomized Block Design. The experiment consists of treatments i.e., VAM (20g/kg seed) + Phosphorus 30kg ha^{-1}**,** PSB (20g/kg seed) + Phosphorus 30kg ha^{-1}, VAM + PSB (40g/kg seed) + Phosphorus 30kg/ha, VAM (20g/kg seed) + Phosphorus 40kg ha^{-1}**,** PSB (20g/kg seed) + Phosphorus 40kg ha^{-1}, VAM + PSB (40g/kg seed) + Phosphorus 40kg/ha, VAM (20g/kg seed) + Phosphorus 50kg ha^{-1}**,** PSB (20g/kg seed) + Phosphorus 50kg ha^{-1}, VAM + PSB (40g/kg seed) + Phosphorus 50kg/ha, including control i.e., application of 20-40-20 kg NPK ha^{-1} (Farmer practice), which are replicated thrice. The

++ *M. Sc Scholar;*
\# *Assistant Professor;*
† *Ph.D Scholar;*
**Corresponding author: E-mail: joharika27@gmail.com;*

variety PDM-139 SAMRAT green gram was sown in February 2023. The results of the experiment revealed that the application of VAM + PSB @ (40g/kg seed) along with 50 kg ha^{-1} of phosphorus significantly increased the growth parameters viz., plant height (32.94 cm), plant dry weight (42.73 g $plant^{-1}$), crop growth rate (72.1 g m^{-2} day^{-1}), relative growth rate (2.16 g m^{-1} day^{-1}), branches per plant (6.53), nodules per plant (16.4) and yield parameters viz, pods per plant (19.20), seeds per pod (11.87), test weight (40.0g), seed yield (1,620 kg ha^{-1}), haulm yield (1,022.22 kg ha^{-1}), harvest index (49.30%) over control. This treatment also showed its positive effect on economics viz., gross returns (Rs. 1,45,770 ha^{-1}), net return (Rs. 1,04,120.40 ha^{-1}) and benefit cost ratio (2.50).

Keywords: Green gram; VAM; PSB; phosphorus; growth parameters; yield parameters; economics.

1. INTRODUCTION

Green gram (*Vigna radiata* L.***)*** is popularly known as mung bean or golden gram is one of the most important short duration pulse crops grown in India. It ranks 3rd among all pulses that are grown in India after chickpea and pigeon pea. The seeds are highly nutritious as they contain about 24.7% protein, 57.6% carbohydrates, 0.5% fat, 0.9% fiber and 3.7% ash [1]. In India it is cultivated in area about 300 million hectares. Major states in India which grow green gram are Andhra Pradesh, Orissa, Madhya Pradesh, Uttar Pradesh, Rajasthan, Bihar, and Gujarat. It is grown in about 4.5 million hectares with the total Production of 2.5 million tons with a Productivity of 548 kg/ha and contributing 10% to the total pulse production. According to Government of India 3rd advance estimates, green gram production in 2020-21 is at 2.64 million tons. However, the per capita consumption of pulses was 43.3 g/day and 47.2 g/day in the year 2013-14, respectively [2].

Bio-fertilizers are living microorganisms of bacterial, fungal and algal origin. Their mode of action differs and can be applied alone or in combination. Biofertilizers fix atmospheric nitrogen in the soil and by the help of root nodules of legume crops and make it available to the plant. They solubilize the insoluble forms of phosphates like tricalcium, iron and aluminum phosphates into available forms. They scavenge phosphate from soil layers. They produce hormones and antimetabolites which promote root growth. They decompose organic matter and help in mineralization in soil. When applied to seed or soil, biofertilizers increase the availability of nutrients and improve the yield by 10 to 25% without adversely affecting the soil and environment.

Bio-fertilizer like Rhizobium and PSB takes an important role in enhancing availability of N and P through increase in biological fixation of atmospheric N and increasing the phosphorus availability to plants [3]. Inoculation of Mung bean with PSB increased all the yield attributing characters of Mung bean. The maximum value of all these characters were observed in 80 kg P_2O_5+PSB and minimum values in the control it may be due to fact that the formation of root nodules and atmospheric nitrogen fixation, (Khan et al*.,* 2004) reported that the inoculation of seed with PSB increased seed yield in Mung bean.

VAM greatly improve phosphate supply to the host plant which resulted in increase of nodulation and N_2 fixation in legumes. Many tropical legumes are infact highly mycorrhizal dependent [4]. Among the VAM strains, Glomus fasciculatum recorded maximum dry weight of nodules (33.01 and 21.93mg $plant^{-1}$) and rhizobial population (l6.35 x 102 and 27.91 x 103 cells g^{-1} soil) which was par with Glomus mosseae throughout the growth period due to higher availability of phosphorus by VAM fungi, which leads to better nodulation [5].

Phosphorus is most important nutrients in pulse production, which is responsible for vegetative growth, reproduction and consequently yield of mung bean. In legume crops nitrogen demand is low as compared to phosphorus because atmospheric nitrogen fixation, so P is the major element for improve productivity of legume crops. Pulses crops require a high amount of phosphorus being consumed by plant. Phosphorus helps in production of ATP and other high energy P compounds, results in a buildup of the carbohydrate production through photosynthesis and the development of a dark green leaf color, also involves in carrying the genetic code from one generation to the next, providing the “blueprint” for all aspects of plant growth and development.

Phosphorus encourages initial development of root, increases the movement of rhizobia and enhances the improvement of nodules by such means fixing extra environmental nitrogen. It helps in nodules; root growth and it further accelerate the crop maturity [6]. It plays a vital role in energy movement, stimulation of primary growth and progress, fruiting and seed production.

2. MATERIALS AND METHODS

A field experiment was conducted during Zaid season of 2022 at the crop research farm, department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Sciences (SHUATS), Prayagraj (U.P.) India. The soil of experimental plot was sandy loamy in texture, nearly neutral in soil reaction (pH 7.0), medium in available nitrogen, available phosphorus and available in potassium. The experiments was laid out in Randomized Block Design with 10 treatments each replicated thrice *Viz.,* T1- VAM 20g/kg seed + 30kg P ha^{-1}, T2- PSB 20g/kg seed + 30kg P ha^{-1}, T3- (VAM +PSB) 40g/kg seed + 30kg P ha^{-1}, T4- VAM 20g/kg seed + 40kg P ha^{-1},T5- PSB 20g/kg seed + 40kg P ha^{-1}, T6- (VAM +PSB) 40g/kg seed + 40kg P ha^{-1}, T7- VAM 20g/kg seed + 50kg P ha^{-1}, T8- PSB 20g/kg seed + 50kg P ha^{-1}, T9- (VAM +PSB) 40g/kg seed + 50kg P ha^{-1},T10- 20-40-20 kg NPK /ha (Control).The observations was recorded for plant height (cm), Dry weight (g), Number of nodules, Number of Branches /plant, Crop growth rate (g/m^2/day), Relative growth rate (g/g/day), Number of pods /plant (no.) ,No of seeds/pod, Test weight (g), Seed yield (kg/ha), Haulm yield (t/ha), Harvest index(%). The data were subjected to statistical analysis by analysis of variance method [7].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Plant height: At 60 DAS, inoculation by (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} (T9) has significantly increases the plant height (32.95 cm), whereas inoculation by (VAM + PSB) 40g/kg seed + 40 kg P ha^{-1} (T6), inoculation by PSB 20g/Kg seed + 50 kg P ha^{-1}(T8), inoculation by VAM 20g/Kg seed + 50 kg P ha^{-1} (T7),and inoculation by PSB 20g/Kg seed + 40 kg P ha^{-1} (T5),found to be statistically on par for plant height (31.26 cm, 30.43 cm, 30.14 and 29.41 cm, respectively). Increase in the plant height was due to increasing levels of phosphorus, bio-fertilizers which helped in new cell formation and root development, leading to availability of all nutrients and water from the deeper soil layers for higher photosynthetic activity. thereby promoted vegetative growth; consequently, increased the plant height. Similar findings were also reported by Roy and Rahaman [8], Haque and Khan [9], Rasool and Singh [10].

Plant dry weight: At 60 DAS, inoculation by (VAM + PSB) 40g/kg seed + 50 kg P ha^{-1} (T9) showed significantly higher dry weight per plant (42.73 g $plant^{-1}$) over control (RDF only), with Significant result. Phosphorus encourages the formation of new cells, promote plant vigour and hastens leaf development, which helps in harvesting of more solar energy and better utilization of nitrogen. As the result growth attributes increased with increase in doses of phosphorus. Higher dry weight was may be due to the cumulative effect of increased plant height and number of branches which resulted in more dry matter production by plant. These findings were found relevant to Mashi et al. (2020) and Venkatarao et al. [11].

Plant crop growth rate: During 45-60 DAS, with inoculation by (VAM+PSB) 20g/kg seed + 50 kg P ha^{-1} (T9) significantly higher crop growth rate (72.11 g m^{-2} day^{-1}) has been recorded over control (only RDF), whereas crop growth rate in inoculation by (VAM+PSB) 20g/kg seed + 40 kg P ha^{-1} (T6), (59.33 g m^{-2} day^{-1}) found to be statistically on par T9. The inoculation of bio-fertilizers and Phosphorus resulted in higher crop growth rate, this might be due to direct and higher availability and translocation of nutrients during development phase of crop growth, which enhances the physiological and metabolic activities of plant and put up more growth by assimilating the available nutrients at higher rate and facilitate more photosynthesis.

Plant relative growth rate: During 45-60 DAS, with co-inoculation of (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} (T9) significantly higher crop growth rate (2.16 g g^{-1} day^{-1}) has been recorded over (T10) control (only RDF), whereas crop growth rate in inoculation of T6-(VAM +PSB)40g/kg seed + 40 kg P ha^{-1} (1.78 g g^{-1} day^{-1}) found to be statistically on par with highest treatment.

Number of Branches per plant: At 60 DAS, co-inoculation by T9 - VAM and PSB + 50 kg P ha^{-1} has significantly increased the number of branches per plant (6.53), whereas in T6 co-inoculation (VAM+PSB) 40g/kg seed + 40 kg P ha^{-1} was found on par for number of branches per plant (6.26) with T9. More number of branches per plant was found in T9 over control (only RDF). This result might be due to better availability of nutrients during the crop growth period by the action of bio-fertilizers and phosphorus. Similar findings were also reported by Haque and Khan [9] and Rasool and Singh [10].

Number of Nodules per plant: At 60 DAS, co-inoculation by T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} had significantly increased the number of nodules per plant (20.93) over control (only RDF), whereas, co-inoculation by (VAM+PSB) 40g/kg seed along with application of 40 kg P ha^{-1} (20.26) found to be statistically on par with T9. Application of phosphorus helped in efficient utilization of nutrients, which resulted in attaining better crop canopy and further increased absorption and utilization of radiant energy resulting in higher effective and total number of nodules. Phosphorus also enhanced the activity of rhizobia and increased the formation of root nodule and there by helped in fixing more of atmospheric nitrogen in root nodule. Similar results were confirmed by Masih et al. (2020). Interaction of VAM was synergistic for nodulation of the plant. Results were confirmed by Chaudhary [12].

3.2 Yield Attributes

Pods/plant: The number pods per plant was significantly higher in co-inoculation by T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} (19.20 pods $plant^{-1}$), whereas pods per plant in co-inoculation of by T6 (VAM+PSB) 40g/kg seed + 40 kg P ha^{-1} (18.87 pods $plant^{-1}$), found to be statistically on par with the T9. This result might be due to more availability of N, P, K in the soil because of the bio-fertilizers, also reported by Sharma et al. (1998), Togay et al. (2008), and Namvar et al. [13]. Moreover, the growth promoting hormones are produced by these organisms, which further promote plant growth reported by Jat et al. [14] and Geneva et al. [15].

Seeds/pod: The number seeds per pod was significantly higher with co-inoculation of T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} (11.87 seeds $pods^{-1}$). Phosphorus deficiency limits N-fixation mainly by reducing the growth of host plant. Thus, the application of phosphorus and seed treatment with both microorganisms might have resulted in the increased carbohydrate accumulation and their remobilization, reproductive parts of the plants, being the closest sink and hence, resulted in increased flowering, fruiting and seed formation [16,17].

Test weight: The test weight was significantly higher in co-inoculation by T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1}(40.0 g), whereas in co-inoculation of T6 (VAM+PSB) 40g/kg seed + 40 kg P ha^{-1} test weight (39.6 g), was found to be statistically on par with T9. This is because of regulatory functions of phosphorus in photosynthesis and carbohydrate metabolism of leaves can be considered to be one of the major factors limiting plant growth particularly during reproductive phase. The level of phosphorus during this period regulates starch or sucrose ratio in the source leaves and the reproductive organs [18].

Seed yield: The seed yield was significantly higher in co-inoculation by T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} (1620 kg ha^{-1}). This might be due to the combined increase in number of pods per plant, number of seeds per pod under this treatment. This might be the fact that excess assimilates stored in the leaves and later then trans-located into seeds at the time of senescence, ultimately led to the higher seed yield. These findings are in line with the results obtained by Sepat [17] and Kumawat [19].

Haulm yield: The haulm yield was significantly higher with the co-inoculation by T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} (1022.22 kg ha^{-1}), whereas with co-inoculation by T6 (VAM+PSB) 40g/kg seed + 40 kg P ha^{-1}haulm yield (1009.12 kg ha^{-1}), was found to be statistically on par with T9. This might be due to the increased growth and development in terms of plant height, branches and dry matter by improving nutritional environment of rhizosphere and plant system leading to the higher plant metabolism and photosynthetic activity. These findings are similar to the results of Ram and Dixit [20], Patel et al*.* [21] in moth bean, Yadav [22] in green gram, Kumar [23] in chickpea, Sepat [17] and Kumawat [19] in moth bean and Kumar and Kushwaha [24] in pigeon pea.

Harvest index: The harvest index was significantly higher with co-inoculation by T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} (49.30 %), whereas harvest index with co-inoculation by T6 (VAM+PSB) 40g/kg seed + 40 kg P ha^{-1} (47.33 %) was found to be statistically on par with T9. Better performance of crop from vegetative to reproductive stage is due to optimum spacing and higher dose of phosphorus which increased the nutrient uptake of the crop.

Table 1. Effect of Bio-fertilizers and phosphorus on growth attributes of green gram

S. No	Treatments	Plant height	Dry weight	No. of. nodules	No. of. Branches	CGR	RGR
1.	VAM 20g/Kg Seed + Phosphorus 30 kg/ha	26.96	20.17	14.40	5.33	32.14	0.96
2.	PSB 20g/Kg Seed + Phosphorus 30 kg/ha	27.57	21.70	15.00	5.33	34.37	1.03
3.	VAM+PSB 40g/Kg Seed + Phosphorus 30 kg/ha	28.39	23.93	15.00	5.66	38.81	1.16
4.	VAM 20g/Kg Seed + Phosphorus 40 kg/ha	29.09	25.97	15.00	5.66	42.22	1.27
5.	PSB 20g/Kg Seed + Phosphorus 40 kg/ha	29.41	26.50	14.93	5.66	42.96	1.29
6.	VAM+PSB 40g/Kg Seed + Phosphorus 40 kg/ha	31.26	36.57	15.86	6.26	59.33	1.78
7.	VAM 20g/Kg Seed + Phosphorus 50 kg/ha	30.14	26.93	14.80	5.66	43.85	1.32
8.	PSB 20g/Kg Seed + Phosphorus 50 kg/ha	30.43	29.20	15.33	6.00	46.95	1.41
9.	VAM+PSB 40g/Kg Seed + Phosphorus 50 kg/ha	32.95	42.73	16.45	6.53	72.11	2.16
10.	Control:20-40-20	26.80	18.28	13.66	4.82	29.17	0.88
	S. Em (±)	1.22	1.60	0.22	0.11	6.11	0.18
	CD (p = 0.05)	3.63	4.77	0.67	0.35	18.16	0.54

Table 2. Effect of Bio-fertilizers and phosphorus on yield attributes of green gram

S. No	Treatments	Pods/plant	Seeds/pod	Test weight	Seed yield	Harvest index	Haulm yield
1.	VAM 20g/Kg Seed + Phosphorus 30 kg/ha	17.73	10.13	38.1	1051	42.28	584.22
2.	PSB 20g/Kg Seed + Phosphorus 30 kg/ha	17.80	10.20	38.2	1087	40.28	644.15
3.	VAM+PSB 40g/Kg Seed + Phosphorus 30 kg/ha	18.20	10.33	38.3	1164	45.26	722.71
4.	VAM 20g/Kg Seed + Phosphorus 40 kg/ha	18.20	10.40	38.6	1255	42.13	737.09
5.	PSB 20g/Kg Seed + Phosphorus 40 kg/ha	18.13	10.87	38.0	1295	43.41	783.47
6.	VAM+PSB 40g/Kg Seed + Phosphorus 40 kg/ha	18.87	11.20	39.6	1546	47.33	1009.12
7.	VAM 20g/Kg Seed + Phosphorus 50 kg/ha	18.07	10.47	38.4	1380	41.89	862.75
8.	PSB 20g/Kg Seed + Phosphorus 50 kg/ha	18.13	10.93	38.6	1497	43.43	926.45
9.	VAM+PSB 40g/Kg Seed + Phosphorus 50 kg/ha	19.20	11.87	40.0	1620	49.30	1022.22
10.	Control:20-40-20	16.73	10.00	38.0	957	41.33	556.89
	S. Em (±)	0.12	0.16	0.37	13.68	1.39	31.14
	CD (p = 0.05)	0.36	0.48	1.12	40.66	4.13	92.55

Table 3. Effect of Bio-fertilizers and phosphorus on economics of green gram

	Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C
1	VAM 20g/Kg Seed + Phosphorus 30 kg/ha	40115.6	94620.00	54504.40	1.36
2	PSB 20g/Kg Seed + Phosphorus 30 kg/ha	40335.6	97860.00	57524.40	1.43
3	VAM +PSB 40g/Kg Seed + Phosphorus 30 kg/ha	40599.6	104790.00	64190.40	1.58
4	VAM 20g/Kg Seed + Phosphorus 40 kg/ha	40640.6	112950.00	72309.40	1.78
5	PSB 20g/Kg Seed + Phosphorus 40 kg/ha	40860.6	116550.00	75689.40	1.85
6	VAM +PSB 40g/Kg Seed + Phosphorus 40 kg/ha	41124.6	139110.00	97985.40	2.38
7	VAM 20g/Kg Seed + Phosphorus 50 kg/ha	41165.6	124200.00	83034.40	2.02
8	PSB 20g/Kg Seed + Phosphorus 50 kg/ha	41385.6	134730.00	93344.40	2.26
9	VAM +PSB 40g/Kg Seed + Phosphorus 50 kg/ha	41649.6	145770.00	104120.40	2.50
10	Control (20:40:20) NPK Kg/ha	38276.6	86160	47883.4	1.25

3.3 Economic

Cost of cultivation: The Cost of cultivation of green gram (*Vigna radiata* L.) was discussed in Table 3. The Total Cost cultivation INR 41,649.6 ha^{-1} was found to be highest in T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1}.

Gross returns: The Gross return of green gram was discussed in Table 3. The higher Gross return of INR 1,45,770.00 ha^{-1} found with co-inoculation of T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1}.

Net returns: The Net return of green gram was discussed in Table 3. The higher Net return INR 1,04,120.40 ha^{-1} was found with co-inoculation of T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1}.

Benefit-cost ratio: The benefit- cost ratio of green gram was discussed in Table 3. The higher B:C (2.50) was found with co-inoculation of T9 (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1}.

4. CONCLUSION

It can be concluded that the co-inoculation by (VAM+PSB) 40g/kg seed + 50 kg P ha^{-1} (Treatment 9) recorded higher yield and benefit cost ratio in green gram.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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