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Research Article

Effect of phosphorus and bio-fertilizers on growth yield and economics of summer green gram [*Vigna radiata* (L.) Wilczek]

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SUMMARY : A field experiment was conducted during summer 2010 at Instructional farm, Junagadh Agricultural University, Junagadh (Gujarat) on clayey soil to study the effect of phosphorus and bio-fertilizers on growth, yield and economics of green gram. Twelve treatments comprising all possible combinations of four levels of phosphorus *viz.*, 0, 20, 40 and 60 and three levels of bio-fertilizers *viz.*, control, with liquid PSB (Phosphate solubilizing bacteria) inoculation and with liquid *Rhizobium* inoculation were tried in factorial Randomized Block Design with three replications. The result of the experiment indicated that application of 60 kg P_2O_5 /ha and seeds inoculated with *Rhizobium* significantly increased the growth parameters *viz.*, plant height, branches per plant, dry weight of nodules, leaf area index and dry matter accumulation as well as yield attributes like number of pods per plant, grain yield per plant, stover yield and test weight. The significantly highest seed (1140 kg/ha) and stover (5890 kg/ha) yields recorded by application of 60 kg P_2O_5 /ha which was at par with 40 kg P_2O_5 /ha level. The highest seed yield (1100 kg/ha) was recorded by application of *Rhizobium* inoculation over liquid PSB inoculation and control.

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BACKGROUND AND OBJECTIVES

Pulses are the most important crops in our country and the main source of vegetable. Green gram is one of the major pulses crop in India for grain, forage and green manure purpose. However, requirement of pulses is going up due to population explosion, while its production is not increasing to that extent. Hence, the production of pulses has to be increased either by increasing the land under these pulses or increasing productivity. Fertilizers, even though comparatively a costly input of production are essential for securing higher yields. The prudent use of fertilizers with appropriate method and time of application are the prime importance in securing higher and economic yield. Phosphorus is the second most important nutrient next to nitrogen. Its deficiency is usually the most important single factor which is responsible for poor yield of pulses on all soils. It is a major constituent of protein and nucleic acids. The cost of nitrogenous and phosphatic fertilizers are increasing day by day, hence, it is required to use some cheaper source of fertilizers like *Rhizobium* and phosphatic solubilizing bacteria etc. Bio-fertilizers like *Rhizobium* and phosphate solubilizing bacteria plays an important role in increasing availability of nitrogen and phosphorus through increase in biological fixation of atmospheric nitrogen and enhanced phosphorus availability to the crop, respectively. Introduction of efficient strain of *Rhizobium* in the soil poor in nitrogen may be helpful in boosting up the production through more nitrogen fixation. The phosphorus solubilizing bacteria as inoculants in the root zone of crop plants partially solubilise the insoluble phosphate and improve the fertilizer

use efficiency and the productivity. Keeping in view the above situation, the present investigation was carried out to study the response of green gram to different levels of phosphorus in conjunction with bio-fertilizers.

RESOURCES AND METHODS

The field experiment was conducted at Instructional farm, Junagadh Agricultural University, Junagadh during summer season of 2010. The soil was moderate in organic carbon (0.83 %), medium in available nitrogen (242.1 kg/ ha) and phosphorus (19.5 kg/ha), high in available potassium (271.2 kg/ha) and slightly alkaline in soil reaction (pH 7.9). The crop variety "GM-4" was taken for this experiment and sowing was done at inter row spacing of 45 cm. The experiment consisted of four levels of phosphorus *viz.*, 0, 20, 40 and 60 and three levels of bio-fertilizers *viz.*, control, with liquid PSB (Phosphate solubilizing bacteria) inoculation and with liquid *Rhizobium* inoculation were tried in factorial Randomized Block Design with three replications. For the study, leaf area index (LAI), relative growth rate (RGR) and net assimilation rate (NAR) was calculated as suggested by Cheema *et al.* (1991).

OBSERVATIONS AND ANALYSIS

The experimental findings obtained from the present study have been discussed in following heads:

Growth attributes:

Different phosphorus treatments significantly increased the growth parameters (Table 1, 2 and 3). Significantly higher branches per plant (6.6) and plant height (43.9 cm) were recorded by application of 60 kg P_2O_5 over 0 and 20 kg P_2O_5 but remained at par with 40 kg P_2O_5. The effective root nodule (13.8) was recorded significantly higher by application of 40 kg P_2O_5 over 0 and 20 kg P_2O_5 but remained at par with 60 kg P_2O_5. The increased number of nodulation with under treatments 40 and 60 kg P_2O_5 which might due to responsible for ascribed to more rapid growth of bacteria and hence, the production of more infected sites resulting in improved nodulation. The highest leaf area index (0.026 at 20 DAS and 0.329 at 40 DAS) was recorded by application of 20 and 60 kg P_2O_5. The highest dry matter accumulation was observed with 60 kg P_2O_5 at 40 and 60 DAS. Application of phosphorus fertilizers not only increased the plant growth but also improved nutrient availability for prolonged period for plant growth. Phosphorus is the main constituent of ADP and ATP which acts as energy currency within plants. Almost every metabolic reaction of any significance proceeds via phosphate derivatives, phosphorus application influences photosynthesis, biosynthesis of proteins and phospholipids, nucleic acid synthesis, membrane transport and cytoplasmic streaming (Mishra, 2003).

Inoculation with bio-fertilizers brought about significant improvement in different growth attributes. The maximum plant height (41.7 cm), number of branches per plant (6.6), number of effective root nodule per plant (13.7) and dry weight of root nodule (41.7 g) were recorded by application of *Rhizobium* inoculation over liquid PSB

Table 1 : Effect of phosphorus and bio-fertilizers on growth characters of summer green gram

Treatments	Plant height (cm)	Branches/ plant	Effective root nodule/plant	Dry weight of nodules/plant	Leaf area index			Dry matter accumulation/plant (g)		
					20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Phosphorus levels (P_2O_5 kg/ha)										
P_0 : 0 kg P_2O_5/ha	40.9	6.1	12.3	39.7	0.020	0.223	0.370	1.84	11.06	12.16
P_1: 20 kg P_2O_5/ha	41.2	6.3	12.6	40.6	0.026	0.329	0.303	1.98	11.40	12.72
P_2 : 40 kg P_2O_5/ha	43.7	6.4	13.8	41.5	0.025	0.228	0.370	1.87	11.60	11.27
P_3 : 60 kg P_2O_5/ha	43.9	6.6	13.4	41.4	0.021	0.222	0.409	1.75	12.07	12.84
S. E. ±	0.5	0.1	0.2	0.5	0.0002	0.0002	0.0002	0.10	0.09	0.29
C. D. at 5 %	1.5	0.3	0.5	1.4	0.0006	0.0047	0.0058	NS	0.28	0.87
Bio-fertilizers										
B_0 : Control	39.2	6.2	12.6	39.9	0.025	0.223	0.342	1.80	10.90	11.97
B_1 : PSB inoculation	41.3	6.3	12.8	40.8	0.026	0.301	0.486	1.82	13.38	12.74
B_2: *Rhizobium* Inoculation	41.7	6.6	13.7	41.7	0.027	0.313	0.401	1.83	12.30	15.07
S. E. ±	0.5	0.1	0.1	0.4	0.0002	0.0001	0.054	0.16	0.15	0.62
C. D. at 5 %	1.5	0.2	0.4	1.2	0.0006	0.0005	0.162	NS	0.31	1.31
Interaction (P x B)	NS	Sig.	NS	NS	NS	NS	NS	NS	NS	NS
C. V. (%)	4.1	4.9	4.2	4.1	7.09	6.17	4.18	7.28	4.33	2.88

NS=Non-significant

inoculation and control treatment. Inoculation of seeds with proper strain of *Rhizobium* cultures enhance the N fixation from atmosphere and results in better growth, more active root microbes and consequently enhance proper growth and dry weight of root nodules in green gram. The similar results were also found by Patra and Bhatacharya (1997). Leaf area index and dry matter accumulation per plant were significantly influenced due to bio-fertilizers treatment. Application of *Rhizobium* inoculation produced appreciable higher leaf area index at 20 DAS (0.027 g) and 40 DAS (0.313 g), while liquid PSB inoculation produced appreciable higher leaf area Index at 60 DAS (0.486 g). Application of *Rhizobium* inoculation produced appreciable higher dry matter accumulation per plant at 20 DAS (1.83 g) and 60 DAS (15.07 g), while Liquid PSB inoculation produced appreciable higher dry matter accumulation per plant at 40 DAS (13.38 g).

The interaction effect between phosphorus and bio-fertilizers treatments had significant influence on branches

Table 2 : Effect of phosphorus and bio-fertilizers on growth characters of summer green gram

	CGR (mg cm^{-1} day)			RGR (mg / day)			NAR (mg cm^{-1} day)		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Phosphorus levels (P_2O_5 kg/ha)									
P_0 : 0 kg P_2O_5/ha	0.036	0.091	0.155	0.138	0.107	0.077	0.573	0.514	0.720
P_1: 20 kg P_2O_5/ha	0.033	0.093	0.247	0.145	0.114	0.101	0.604	0.626	0.751
P_2 : 40 kg P_2O_5/ha	0.026	0.071	0.172	0.156	0.110	0.098	0.605	0.506	0.884
P_3 : 60 kg P_2O_5/ha	0.027	0.069	0.183	0.146	0.107	0.101	0.658	0.437	0.836
S.E. ±	0.0026	0.0026	0.0026	0.0083	0.0018	0.0018	0.0019	0.0026	0.0169
C. D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bio-fertilizers									
B_0 : Control	0.031	0.103	0.134	0.150	0.106	0.062	0.607	0.679	0.524
B_1 : PSB inoculation	0.044	0.102	0.220	0.161	0.099	0.093	0.846	0.549	0.825
B_2: *Rhizobium* inoculation	0.042	0.113	0.233	0.163	0.114	0.090	0.849	0.641	0.899
S.E. ±	0.0001	0.0002	0.0011	0.0054	0.0026	0.0006	0.0263	0.0151	0.0054
C. D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (P x B)	NS	NS	NS	NS	NS	NS	NS	NS	NS
C. V. (%)	4.06	3.24	4.11	4.23	2.98	4.02	3.55	3.39	2.57

NS=Non-significant

Table 3 : Effect of phosphorus and bio-fertilizers on yield and yield characters of summer green gram

	Pods/ plant	Pod length (cm)	Seeds/ pod	Test weight (g)	Seed yield /plant (g)	Yield (kg/ha)		Harvest index (%)
						Seed	Stover	
Phosphorus levels (P_2O_5 kg/ha)								
P_0 : 0 kg P_2O_5/ha	21.67	7.08	8.38	42.00	33.6	760	5130	12.90
P_1: 20 kg P_2O_5/ha	22.30	7.00	9.03	44.02	38.0	885	5616	13.61
P_2 : 40 kg P_2O_5/ha	23.08	7.30	9.38	45.11	37.2	1110	5700	16.21
P_3 : 60 kg P_2O_5/ha	22.85	7.02	9.20	46.00	40.7	1140	5890	16.29
S. E. ±	0.28	0.08	0.23	0.596	0.15	42.27	155.78	0.67
C. D. at 5 %	0.81	0.23	0.65	1.54	0.44	115.21	448.22	NS
Bio-fertilizers								
B_0 : Control	21.49	6.83	8.49	44.91	3.57	800	5189	13.35
B_1 : PSB inoculation	22.90	7.20	9.04	45.43	3.75	1075	5753	15.74
B_2: *Rhizobium* inoculation	23.03	7.28	9.48	45.98	4.08	1100	5800	16.40
S. E. ±	0.24	0.07	0.20	0.23	0.13	36.60	134.91	0.58
C. D. at 5 %	0.70	0.20	0.56	0.66	0.38	105.32	388.17	NS
Interaction (P x B)	Sig.	Sig.	NS	NS	NS	NS	NS	NS
C. V. (%)	4.35	3.91	8.75	4.57	14.04	14.04	9.73	14.66

NS=Non-significant

per plant (Table 5). Application of 60 kg P_2O_5/ha along with *Rhizobium* inoculation registered significantly higher length of pods (6.90) than other treatment combinations except application of 60 kg P_2O_5/ha along with liquid PSB inoculation. The CGR, RGR and NAR growth parameters were found non-significant with all treatments and their combinations.

Yield attributes:

Different phosphorus levels had significantly influenced various yield attributes (Table 3). The numbers of pods per plant and pod length at harvest were significantly influenced due to application of different treatments. The application of 40 kg P_2O_5/ha recorded significantly higher number of pods per plant over control which was at par with 60 kg P_2O_5 level. The 40 kg P_2O_5 level recorded significantly higher pod length which was at par with 0 kg P_2O_5 level. The 40 kg P_2O_5 level recorded significantly higher number of seeds per pod (9.3) which was at par with 20 and 60 kg P_2O_5 levels. It might be due to phosphorus fertilizer application provide better nourishment to the plant for better partitioning dry matter and in turn, it results in increased number of seeds per pod. These findings are in close conformity to those of reported by Kumar *et al*. (2002). Application of 60 kg P_2O_5/ ha recorded significantly higher test weight (46.00 g) which was at par with 40 kg P_2O_5/ha level. This might be due the fact that test weight of seed is governed by genetically characters of plants. The harvest index was also not influenced significantly due to different phosphorus treatments.

Inoculation with bio-fertilizers brought about significant improvement in different growth attributes (Table 3). The higher number of pods per plant (23.03), pod length (7.28 cm) and number of seeds per pod (9.48) were recorded by application of *Rhizobium* inoculation over control which was at par with application of liquid PSB inoculation. This might be due to more nitrate reductase and nitrogenase activity in root nodules and more availability of N and P to the plant for better growth and development and hence, more number of pod, pod length and more number of seeds per pod. The findings are in close vicinity with the findings of Thakur and Panwar (1997). The result pertaining to the test weight and harvest index showed non-significant response to different bio-fertilizers treatment.

The interaction effect between phosphorus and bio-fertilizers treatments has significant influence on number of pods per plant and length of pods (Table 5). Application of 40 kg P_2O_5/ha along with *Rhizobium* inoculation registered significantly higher length of pods (7.6 cm), whereas application of 60 kg P_2O_5/ha along with liquid PSB inoculation registered significantly higher number of pods

Table 4: Effect of phosphorus and bio-fertilizers on economics of summer green gram

Treatments	Seed (kg/ha)	Stover (kg/ha)	Gross realization (Rs./ha)	Net return (Rs./ha)	BCR
Phosphorus levels (P_2O_5 kg/ha)					
P_0 : 0 kg P_2O_5/ha	760	5130	25365	18309	2.59
P_1: 20 kg P_2O_5/ha	885	5616	29358	22227	3.11
P_2 : 40 kg P_2O_5/ha	1110	5700	36150	28850	4.00
P_3 : 60 kg P_2O_5/ha	1140	5890	38145	30664	4.21
Bio-fertilizers					
B_0 : Control	800	5189	26594	19538	2.77
B_1 : PSB inoculation	1075	5753	35127	27423	3.29
B_2: *Rhizobium* inoculation	1100	5800	35900	27548	3.65

Selling price : Seed : Rs. 30/kg, Stover ; Rs. 0.50/kg

Table 5: Interaction effect between phosphorus and bio-fertilizers

Treatments	Branches/plant			Pods/plant			Pod length (cm)		
	B_0 : Control	B_1 : PSB inoculation	B_2: *Rhizobium* inoculation	B_0 : Control	B_1 : PSB inoculation	B_2: *Rhizobium* inoculation	B_0 : Control	B_1 : PSB inoculation	B_2: *Rhizobium* inoculation
P_0 : 0 kg P_2O_5/ha	5.50	6.15	6.50	21.20	20.85	22.95	6.45	7.30	7.50
P_1: 20 kg P_2O_5/ha	6.60	6.10	6.30	22.20	22.40	22.30	6.90	7.00	7.10
P_2 : 40 kg P_2O_5/ha	6.40	6.40	6.50	22.95	23.40	22.80	7.00	7.30	7.60
P_3 : 60 kg P_2O_5/ha	6.40	6.40	6.90	19.60	24.95	24.00	6.95	7.20	6.90
S. E. ±		0.155			0.49			0.12	
C. D. at 5 %		0.447			1.41			0.34	
C. V. (%)		4.90			4.35			3.33	

per plant (24.95) than other treatments combination.

Seed and stover yield:

The seed and stover yields were remarkably influenced due to different phosphorus treatments (Table 3). The significantly highest seed (1140 kg/ha) and stover (5890 kg/ha) yields were recorded by application of 60 kg P_2O_5 /ha which was at par with 40 kg P_2O_5/ha level was to the tune of 44.0 and 13.2 per cent, respectively over control. The improvement in seed and stover yield could be attributed to the combined effect of significantly increase in growth and yield attributing characters. The increase in seed and stover yields due to phosphorus treatments may be attributed to solubilization of native or applied phosphorus in soil thus, making it available for plant use which in turn helps to put profuse growth and produced more seed yield, which ultimately increased the seed and stover yields. Similar observations were earlier reported by Oad and Burio (2005).

The seed and stover yields were remarkably influenced due to different bio-fertilizers treatments (Table 3). The highest seed (1100 kg/ha) and stover (5800 kg/ha) yields was recorded by application of *Rhizobium* inoculation over liquid PSB inoculation and control. The increase in yield of green gram might be due to increased growth and yield parameters. This was due to the fact that application of bio-fertilizer treatments enhanced the activity of absorption of N, P and other plant nutrients and fixation of N leading to better synthesis and metabolic activities in plant parts and ultimately higher dry matter accumulation and translocation of photosynthesis resulting higher biomass yield with bolder seeds. Similar observation was also made by Maiti *et al*. (1998).

Economics:

Application of 60 kg P_2O_5/ha gave the highest net return of Rs. 30664/ha and B:C ratio of 4.21 followed by 40 kg P_2O_5/ha (Net return Rs. 28850/ha and B:C ratio of 4.00). Seed inoculation with *Rhizobium* was found superior by recording the highest value of net return (Rs. 27548/ha) and B: C ratio of 3.65 followed by 40 kg P_2O_5/ha (Net return Rs. 27423/ha and B : C ratio of 3.29) (Table 4).

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