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Effect of phosphorus levels and phosphate solubilizing bacteria on greengram (*Vigna radiata*) varieties under stone apple (*Aegle marmelos*) based agri-horti system

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ABSTRACT

The present investigation entitled "Effect of phosphorus levels and phosphate solubilizing bacteria (PSB) on greengram (*Vigna radiata* L.) varieties under stone apple (*Agele marmelos* L.) based agri-horti system" was studied during the rainy (*kharif*) season of 2016 at Agricultural Research Farm, R.G.S.C. (BHU), Barakachha, Mirzapur (U. P.). The experiment was conducted in 9-year old stone apple orchard planted in 7x7 meters spacing. The field experiment was laid out in split plot design with stone apple based agri-horti system. The main plot treatment comprised three phosphorus levels (20, 40 and 60 kg P_2O_5 /ha) whereas two greengram varieties ('SML-668' and 'HUM-16') and biofertilizer PSB were used in sub-plot. Treatments were replicated thrice. Results revealed that the increasing levels of phosphorus up to 60 kg P_2O_5/ha gave higher growth parameters, yield attributes, yields, economics *viz.*, cost of cultivation (57.65x10^3/ ha), net return (84.65x10^3/ ha) and benefit: cost (1.48) and nutrient uptake. Furthermore, the variety 'HUM-16' found superior over 'SML 668' in terms of yield attributers and yield. Moreover, the seed treatment with PSB recorded higher growth characters, plant height (cm), dry matter accumulation (g/plant), trifoliate leaves, branches/ plant and root nodules/ plant as well as yield and yield attributes, pods /plant, grains/ pod, 1000-grain weight and grain yield, stover yield, nutrient uptake and economics. Among rates of phosphorus, application of 60 kg P_2O_5/ ha, to greengram was found optimum to realize the high yield and profit under stone apple based agri-horti system. The greengram variety 'HUM-16' was found highly productive and remunerative as compared to 'SML-668' under agro climatic conditions of *Vindhyan* region of Mirzapur. Seed inoculation with PSB markedly enhanced the yield and net return of greengram as compared to the control under stone apple based agri-horti system.

Key words: *Agri-horti system, Biofertilizer, Greengram, Phosphorus levels, Stone apple.*

Introduction

The agroforestry system creates more integrated, diverse, productive, profitable, healthy and sustainable land use system (Sharma *et al*., 2017). Moreover, agri-horti system (fruit based agroforestry) is a better cropping system in India for full utilization of the cropping season and remarkable increase in the return per unit area per unit time. This type of system have proved to be very successful in regions

receiving less than 1000 mm rainfall with about nine months of dry season (Singh, 1987). The stone apple being subtropical species is good for dryland areas of Mirzapur in *Vindhyan* region and offers through scope for the agri-horti system involving short duration pulses. Stone apple commonly known as Bael contains eugenol, lupeol, citroellal, cuminaldehyd, marmelosin, psoralen, luvengetin, aurapten, and marmelide as phytoconstiuents. Being the major active principal largely useful for the bio-potency of Bael, marmelosim is recognized as the marker compound. Greengram being as a short duration pulse crop having high nutritive value which is grown during rainy as well as summer seasons in arid and semi-arid regions of India. In total pulse production, greengram occupies an area of 40.70 Lakh ha with production of 19.01 Lakh tons in India (Anonymous, 2017-18). Production of greengram is very low due to the several factors but most important factor is phosphorus management. Phosphorus has novel function of special importance in the process of energy storage and transfer, roots proliferation, nodules development, bacterial activity and nitrogen fixation. It is one of the major limiting plant nutrients in *Vindhyan* region of Mirzapur and plays a key role in balanced nutrition. Major part of added water-soluble phosphorus fertilizers soon becomes unavailable due to its fixation with clay particles. Hence, solubilization of fixed phosphorus through use of solubilizing microorganisms is a viable option to augment the availability of its in easily assimilable form by the crop. However, information pertaining combined use of phosphate solubilizing bacteria (PSB) along with phosphorus levels in greengram varieties under the *Vindhyan* region is lacking. Therefore, present field experiment was planned to study the effect of phosphorus levels and PSB on greengram varieties under stone apple based agri-horti system.

Materials and Methods

The field experiment was conducted during rainy (*kharif*) season of 2016-17 at Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Barakachha, Mirzapur, Uttar Pradesh. The experiment was laid out in a split plot design with three main plots for phosphorus levels (20, 40 and 60 kg P_2O_5/ ha) and sub plot treatment was two varieties (SML-668 and HUM-16) and two seed inoculation (No inoculation and inoculation with PSB) replicated three times. The soil of the experimental field was sandy loam in texture with low in available nitrogen (152.36 N kg/ ha), medium in available phosphorus (14.75 kg P_2O_5/ ha) and potassium (213.75 K_2O kg/ ha) having acidic in nature (pH 5.42). The greengram was sown on 1st August in between 9 years old stone apple (*Aegle marmelos* L. variety Narendar Bael-5) planted at a spacing of 7 x 7 meters. The following growth parameters of stone apple, grown at border of the plot, were recorded at the time of sowing and harvesting of greengram:

Plant height (m)	Canopy diameter (m)	Stem girth (cm)	Length (m)	Shading Width (m)	Crown length (m)
		At sowing			
6.20	8.00	50.20	4.7	2.7	4.3
		At harvesting			
6.38	8.20	50.43	4.9	2.9	4.6

Further, entire quantity of phosphorus as per treatment in the form of single super phosphate (16% P_2O_5) was applied in furrow at the time of sowing. The recommended dose of 20 kg N and 40 kg K_2O/ ha was applied through urea (46%N) and murate of potash (60% K_2O), respectively at the time of sowing in every plot. The seed was treated with PSB (*Pseudomonas aeruginosa*, PSBBHU01) on the turpaline sheets, the seeds were heaped. The inoculated seeds were uniformly spread and dried under shade and sown immediately after drying. The seeds were sown manually in the rows operated by *kudal* with a spacing of 30 cm x 10 cm. Relatively higher seed rate (20 kg/ ha) was used for proper maintenance of plant population. The greengram was harvested on 3rd October 2016 from each plot. The Microsoft excel was used as a statistical software package for analyzing the data for the analysis of variance and other statistical parameter (McCullough and Wilson, 2005). Critical difference values at p = 0.05 were used to determine the significance of differences between mean values of treatments (Draper and Smith, 1998).

Results and Discussion

Effect of phosphorus

Growth parameters were significantly influenced by the application of phosphorus levels (Table 1). Application of 60 kg P_2O_5 showed significantly higher

plant height (46.8 cm), trifoliate leaves/ plant (12.8), primary and secondary branches/ plant (9.42, 5.96), number of root nodules/ plant (32.1) and dry matter accumulation/ plant (13.9 g) of greengram over 20 kg P_2O_5 but remained statistically at par with 40 kg P_2O_5/ ha. The magnitude of increase in dry matter accumulation by the application of 60 kg P_2O_5 over 20 kg P_2O_5/ ha was 36.3 per cent. Phosphorus helps in the assimilation of photosynthate into other metabolites and hence acts as an activity zone for CO_2 assimilation. It stimulates cell division and so necessary for meristematic growth (Prasad *et al.* 2014). N, P and K uptake by grain and stover and its total uptake significantly increased with increasing levels of phosphorus application. The highest NPK uptake by grain, stover and total was recorded with 60 kg P_2O_5/ ha except phosphorus uptake by stover which showed non-significant result. This might be due to significantly increased in P availability and uptake resulted profuse nodulation leading to greater symbiotic N fixation which in turn has positive effect on photosynthesis. Patidar and Mali (2001) found that increase in fertility level up to 100% significantly enhanced NPK uptake by sorghum. Response of phosphorus was also reported by Venkatarao *et al.* (2017) in greengram variety 'RMG-492'. The higher removal of nutrients with this treatment might be due to better development of root and shoot with this treatment resulted in higher nutrient uptake. These results are in accordance with the results of those reported by Shankar *et al.* 2014. Further, the higher yield attributes *viz.*, pod length (cm), number of pods/ plant, number of grains/ pod and test weight were recorded significantly with the application of 60 kg P_2O_5 in comparison with 20 and 40 kg P_2O_5/ ha (Table 2). With application of higher rates of phosphorus, the tissue differentiation from somatic to reproductive, meristematic activity and development of floral primordia might have enhanced causing

Table 1. Effect of phosphorus levels and PSB inoculation on growth parameters and nutrient uptake by greengram varieties under stone apple based agri-horti system.

Treatment	Plant height (cm)	Trifoliate leaves/ plant	No. of Primary branches/ plant	No. of secondary branches/ Plants	Root nodules/ plant (Nos.)	Dry matter accumulation (g/plant)	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	At harvest	60 DAS	At harvest	At harvest	40 DAS	At harvest	Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
Phosphorus levels (kg P_2O_5/ ha)															
20	46.8	7.75	6.60	3.61	25.5	10.2	24.7	28.9	53.6	3.36	3.45	6.81	6.12	26.7	32.8
40	47.5	10.6	8.19	5.05	29.8	12.0	30.1	29.0	59.1	3.97	3.73	7.70	6.43	27.3	33.8
60	48.0	12.8	9.42	5.96	32.1	13.9	37.5	31.2	68.7	4.26	4.15	8.41	7.79	29.9	37.7
SEm±	0.48	0.69	0.41	0.21	1.03	0.58	0.59	0.32	0.91	0.103	0.18	0.28	0.32	0.49	0.81
CD (P= 0.05)	1.89	2.71	1.63	0.84	4.33	2.31	2.34	1.28	3.62	0.40	NS	0.40	1.25	1.95	3.2
Varieties															
SML-668	46.7	9.83	7.64	4.49	27.8	11.4	29.4	28.5	57.9	3.75	3.49	7.24	6.31	27.5	33.8
HUM-16	48.1	10.9	8.50	5.25	30.5	12.6	30.6	31.0	61.6	3.97	4.06	8.03	7.29	29.8	37.0
SEm±	0.46	0.27	0.26	0.17	0.87	0.29	0.38	0.345	0.725	0.16	0.16	0.32	0.13	0.73	0.86
CD (P= 0.05)	1.36	0.82	0.78	0.52	2.58	0.86	1.12	1.02	2.14	NS	0.48	0.48	0.39	2.17	2.56
Biofertilizer															
Control (No PSB)	46.0	9.87	7.64	4.45	27.6	11.2	29.2	28.6	57.8	3.72	3.53	7.25	6.65	27.2	33.9
PSB (Seed treatment)	48.8	10.9	8.50	5.30	30.7	12.8	30.9	30.8	61.6	4.00	4.02	8.02	6.93	30.0	36.9
SEm±	0.46	0.27	0.26	0.17	0.87	0.29	0.38	0.34	0.72	0.16	0.16	0.32	0.131	0.73	0.86
CD (P= 0.05)	1.37	0.82	0.78	0.52	2.59	0.86	1.13	1.02	2.15	NS	0.48	0.48	NS	2.17	2.17

NS: Not significant

greater production of flowers which latter developed to pods (Hamza *et al*., 2016). Moreover, adequate supply of phosphorus helps in higher sink filling process due to its role in photosynthesis, being an essential element in energy-transformation process of plants. Thus phosphorus is found to maintain better source-sink relationship by improving in yield contributing characters. Similar results have also been reported by Venkatarao *et al.* (2017). Application of phosphorus gave significant effect on grain and stover yield of greengram and the per cent increase in grain and stover yield by the application of 60 kg P_2O_5 over 20 kg P_2O_5/ ha was 31.8 and 13.9, respectively. The application of 60 kg P_2O_5/ ha showed the highest harvest index (33.6%). This might be attributed to better performance of yield attributes in the respective treatment. Net returns and benefit-cost ratio were affected significantly by phosphorus application, 60 kg P_2O_5/ ha gave the highest and an average of 25.11 and 17.46% higher net return and B: C, respectively over 20 kg P_2O_5/ ha. The higher net return and B: C was the result of more grain and stover yields, recorded under the treatment.

Effect of varieties

A critical analysis of data indicated that the growth parameters of greengram grown under stone apple based agri-horti system exhibited significant variation due to different varieties (Table 1). There was a significant improvement in the growth parameters of greengram *viz*., plant height (48.1 cm), trifoliate leaves/ plant (10.9), primary and secondary branches (8.5, 5.25)/ plant, root nodules/ plant (30.5) and dry matter accumulation / plant (12.6 g) with the variety 'HUM-16', which produced significantly better growth parameters than the variety 'SML-668'. The marked variation in growth could be ascribed on account of their genetic capabilities to exploit available resources for their growth and development. Differential response of different

Table 2. Effect of phosphorus levels and PSB inoculation on yield attributes, yield and relative economics of greengram varieties under stone apple based agri-horti system.

Treatment	Pod length (cm)	No. of pods/ plant	No of grains/ pod	Test weight (1000-seed) (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Cost of cultivation (x10³₹/ha)	#Net return (x10³₹/ha)	B-C ratio
Phosphorus levels (kg P_2O_5/ ha)											
20	8.45	11.0	10.4	32.2	779	1780	2559	30.3	54.1	67.7	1.26
40	9.08	12.2	11.6	34.2	852	1907	2759	30.7	55.7	72.1	1.30
60	10.3	14.7	12.5	35.2	1027	2028	3055	33.6	57.3	84.7	1.48
SEm±	0.16	0.21	0.26	0.43	8.0	11.00	5.60	0.27			
CD (P= 0.05)	0.64	0.86	1.04	1.28	31.5	43.50	22.2	1.06			
Varieties											
SML-668	8.29	11.6	10.6	32.3	816	1834	2650	30.5	55.1	69.8	1.27
HUM-16	10.20	13.6	12.5	35.4	956	1976	2932	32.5	56.3	79.9	1.42
SEm±	0.20	0.50	0.20	0.50	16.7	30.90	33.80	0.54			
CD (P= 0.05)	0.52	1.41	0.66	1.42	50.4	91.90	100.5	1.63			
Biofertilizer											
Control (No PSB)	8.65	11.4	10.9	33.1	807	1857	2665	30.1	55.6	68.6	1.23
PSB (Seed treatment)	9.89	13.9	12.2	34.6	965	1952	2917	33.0	55.8	81.1	1.45
SEm±	0.18	0.47	0.22	0.47	16.7	30.90	33.8	0.54			
CD (P= 0.05)	0.53	1.42	0.67	1.42	50.4	91.90	100.5	1.63			

#included cost production of stone apple

varieties of greengram has also been observed by Rathod and Gawande (2014). The uptake of nitrogen, phosphorus and potassium by grain, stover and total differed significantly due to varieties of greengram except phosphorus uptake by stover and it was highest with the variety 'HUM-16' as compared to 'SML-668'. The uptake of nutrient is part a function of dry matter production and partly due to increase in its concentration. Perusal of data (Table 2) clearly indicates that different cultivars brought significant variation on yield attributes and yield of greengram. The highest pod length, pods/ plant, grains/ pod, test weight, grain and stover yield produced by variety 'HUM-16' as compared to 'SML-668'. The per cent increase in grain yield by 'HUM-16' over 'SML-668' was 17.2. Further, variety 'HUM-16' exhibited significantly the highest harvest index (32.5%). The increase in grain yield with variety 'HUM-16' was also largely due to high harvest indices that show high partitioning of the plant assimilates towards the sink. Significant increase in stover yield could be attributed to the increased vegetative growth possibly a result of effective utilization of nutrients absorbed through extensive root system developed under phosphate fertilization (Kumar and Kushwaha, 2006). Greengram variety 'HUM-16' also showed the maximum net return ($79.90x10^{3}$ / ha) and B: C (1.42).

Effect of biofertilizer

Greengram plants showed various responses to inoculation with PSB (Table 1). Generally inoculated plants with PSB were taller, had more trifoliate leaves/ plant, primary and secondary branches/ plant, higher number of root nodules/ plant and dry matter accumulation/ plant. Uptake of NPK by grain, stover and total were higher compared to uninoculated control. The marked improvement under inoculation could be ascribed to pivotal role of PSB in solubilization of insoluble phosphorus through production of organic acids. Kumawat *et al*. (2010) found significantly higher growth parameters, yield attributes, yield and nutrient uptake by greengram variety 'RMG 268' under seed inoculated with PSB over the uninoculated control. Yield attributes, grain and stover yield of greengram were more under seed inoculated with PSB over uninoculated control (Table 2). PSB inoculated crop increased pods/ plant, grains/ pod, test weight and grain yield by 21.9, 11.9, 4.5 and 19.6%, respectively over the control. Beneficial effect of PSB on the yield attributing characters might be due to supplementation of nutrients in relatively more amount which caused in better growth and development of crop. Gajera *et al*. (2014) found similar results in summer greengram. The highest harvest index of 33% was observed under PSB inoculation. Further, the maximum net return ($81.1x10^{3}$ / ha) and B: C (1.45) was calculated under seed inoculation with PSB. Higher yield of the crop has turned into higher net return and B: C. Kudi and Singh (2016) recorded higher net return and B:C by the dual inoculation of *Rhizobium* and PSB in blackgram grown under agri-hori system.

Thus, it can be concluded that greengram variety 'HUM-16' inoculate with phosphate solubilizing bacteria along with application of 60 P_2O_5/ ha proved optimum for producing higher growth, yield parameters, yield and net return under stone apple based agri-horti system of *Vindhyan* region.

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