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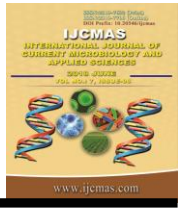

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Effect of Phosphorus, Biofertilizers and Organic Manures on Root Nodulation and Productivity of Green Gram (*Vigna radiata* L.)

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A B S T R A C T

Field experiment was conducted during *kharif*, 2016 on sandy loam soil to study the effect of phosphorus levels, biofertilizers (PSB) and organic manures (vermicompost) on dry matter production at flowering, total root nodule number, effective root nodule number and yield of green gram. The experiment was laid out in randomized block design with three replications having 12 treatment combinations *viz*. 3 levels of phosphorus (0, 75 and 100 % RDP) and its integration with PSB (500 g ha^{-1} seed) and vermicompost (5 t ha^{-1}). A significant increase in dry matter production at flowering was recorded with the application of 100 % RDP along with PSB and vermicompost. Application of 100% RDP ha^{-1} along with vermicompost and PSB seed inoculation (T_{12}) recorded significantly highest number of total and effective root nodules $plant^{-1}$ (12.63, 19.1 and 25.1 total nodules pl^{-1} and 6.83, 10.1 and 12.97 effective nodule pl^{-1} during 3rd, 4th and 5th weeks after sowing, respectively). Combined application of 100 % RDP along with PSB and vermicompost registered significantly highest grain (1626 kg ha^{-1}) and haulm yield (1033 kg ha^{-1}) in green gram. The treatment control (without P fertilization) showed significantly poor performance in dry matter production and yield of green gram as against the rest of the treatments.

Introduction

India is the largest producer of pulses in the world. Green gram is one of the most ancient and extensively grown leguminous crops of India. Green gram is an excellent source of high quality of protein. It also contains high quality of lysine (4600 mg/g N) and tryptophan (60 mg/g N) and consumed as whole grain or as well as in the form of dal for table purpose. Green gram is supposed to be easily digestible, hence preferred by patients. The sprouted seeds of green gram are rich in ascorbic acid (vitamin C), riboflavin and Thiamine (Dhakal *et al.*, 2016). In India, green gram represents 18% (34.4 lakh hectares) of total pulse area and 11.48 % (514 lakh tonnes) of pulse production (CMIE, 2014-15). Despite occupying a greater position both in respect of area and production, the productivity of green gram is low compared to world average. One reason for this could be the imbalanced nutrient management.

Phosphorus is one of the most essential elements for living organism and is the second

largest agricultural chemical needed by plant for growth and development. It is need by leguminous crops for rapid and healthy root development. It hastens the maturity and increases the rate of nodulation and pod development (Rani *et al.,* 2016). Plant utilizes 0.1% of phosphorus present in soil and rest is rapidly fixed as insoluble forms. Beneficial microbes resident to the rhizosphere are receiving greater attention, as they can solubize inorganic phosphate into soluble form through the process of acidification, chelation, exchange reactions and production of organic acids. In addition to these phosphate solubilising microorganisms can also increase the growth of plants by other mechanisms *i.e.* production of phyto hormones such as IAA which promotes plant growth (Vibha *et al.,* 2014). Organic manures like vermicompost stimulate the phosphomonoesterase activity in the crop rhizosphere. Hence, the present work aimed at studying the effect of combined application of organic and inorganic sources of P on yield and nodulation of green gram.

Materials and Methods

A field experiment was conducted during *Kharif,* 2016 at College Farm, Agricultural College, Professor Jayashankar Telangana State Agricultural University, Polasa, Jagtial, Telangana State. The soil of the experimental field was sandy loam in texture and slightly alkaline in reaction (pH 7.84) having an organic carbon content of 0.364%, 157.5 kg available nitrogen ha^{-1}, 18.6 kg available P_2O_5 ha^{-1}, 164.8 kg available K_2O ha^{-1}, and 19.4 kg available sulphur ha^{-1}. The experiment was laid out in randomized block design with three levels of phosphorus (0, 75 and 100 % RDP) and its integration with biofertilizers (PSB) and organic manures (vermicompost), all together 12 treatments replicated thrice. The various treatments were control (T_1- without any P application), seed inoculation of PSB (T_2), application of vermicompost @ 5 t ha^{-1} (T_3), PSB + vermicompost (T_4), 75 % RDP (T_5), 75 % RDPP + PSB (T_6), 75 % RDP + vermicompost (T_7), 75 % RDP + PSB + vermicompost (T_8), 100 % RDP (T_9), 100 % RDP + PSB (T_{10}), 100% RDP + vermicompost (T_{11}) and 100% RDP + PSB + vermicompost (T_{12}). The plots are uniformly basal dressed with 20 kg urea and 20 kg K_2O ha^{-1} and phosphorus applied as per the treatments. PSB and vermicompost applied as per the treatments. *Rhizobium* seed treatment was given to all the treatments. The green gram variety LGG 460 was sown with a spacing of 30 cm X 10 cm. The soil and plant samples from individual treatmental plots were collected and analyzed for dry matter production at flowering, total and effective root nodule number at three stages of crop growth and yield of green gram.

Results and Discussion

Dry matter production

Significant increase in dry matter production at flowering was observed with the combined application of inorganic P, vermicompost and PSB (Table 1). Application of 100 % RDP along with PSB and vermicompost (T_{12}) increased the drymatter production by 43.14 percent as against control (T_1), which was recorded the drymatter production of 596 kg ha^{-1}. The drymatter recorded in T_{12} treatment (853 kg ha^{-1}) was statistically on par with the treatments of T_9 (100 % RDP), T_{10} (100 % RDP + PSB) and T_{11} (100 % RDP + Vermicompost) treatments. Plant dry matter production is a result of growth and environment interaction through leaves, stems and reproductive parts which contributes to dry matter. Increasing inorganic P levels from) to 75 % RDP significantly increased the dry matter production. This is due to better utilization of P in the presence of higher dose of P. Phosphorus is known to play a beneficial

role in legume growth by promoting extensive root development and nodulation and thereby increasing the supply of nutrients to growing parts of plant resulting in an increased photosynthetic area and dry matter accumulation. These results are in accordance with earlier reports of Dhewa *et al.*, (2015) and Das *et al.*, (2015).

Significant differences in dry matter production were not observed between T_9 and T_8 treatments. The dry matter production in 100% RDP (813 kg ha^{-1}) was statistically on par with the dry matter production of 75% RDP + PSB + vermicompost (795 kg ha^{-1}). The results indicate that 25% P fertilizer may be saved by applying PSB and vermicompost. This may be attributed to inorganic P when applied to soil get transformed to various reaction products mainly remaining in sparingly soluble orthophosphates. On the contrary, if it is applied with vermicompost and PSB, fixed P will be dislodged thus resulting in the enhanced P availability to the plants (Kadam *et al.*, 2014). These results in support with those of Tak *et al.*, (2013) and Jat *et al.*, (2012).

Nodule number

The data of root nodule number (Table 2) revealed application of phosphorus, vermicompost and seed inoculation of PSB significantly increased the total and effective root nodules. Total number of nodules $plant^{-1}$ were significantly higher under the treatment T_{12} (12.63, 19.1 and 25.1 total root nodules pl^{-1} were recorded during 4^{th}, 5^{th} and 6^{th} weeks after sowing, respectively). In contrast, the control plot (T_1) was recorded lowest number of total root nodules pl^{-1} during 4^{th}, 5^{th} and 6^{th} weeks after sowing which were 7.9, 13.5 and 16.0 respectively. Increasing the inorganic P level from 0 to 100 % RDP significantly increased the root nodule number during entire crop growth.

Table.1 Dry matter production and yield of green gram as influenced by inorganic P levels, organic manures and PSB treatments

Treatments	Dry matter production at flowering (kg ha^{-1})	Haulm yield (kg ha^{-1})	Grain yield (kg ha^{-1})
T_1- Control (without application of P)	596	993	703
T_2- PSB	615	1037	724
T_3-Vermicompost	621	1067	750
T_4-PSB + Vermicompost	631	1157	771
T_5-75 % RDP ha^{-1}	778	1259	831
T_6-T_5+PSB	753	1275	853
T_7-T_5+Vermicompost	782	1380	869
T_8-T_5+ PSB+ Vermicompost	795	1412	929
T_9-100 % RDP ha^{-1}	813	1457	957
T_{10}-T_9+PSB	822	1518	985
T_{11}-T_9+Vermicompost	830	1566	996
T_{12}- T_9+ PSB+ Vermicompost	853	1626	1033
CD(0.05)	47	88	56
SE(D)	22.76	42.37	27.17

Table.2 Total and effective root nodule number of green gram as influenced by inorganic P levels, organic manures and PSB treatments

Treatments	4th week		5th week		6th week	
	Total nodules	Effective nodules	Total nodules	Effective nodules	Total nodules	Effective nodules
T_1- Control (without application of P)	7.90	4.03	13.50	6.07	16.00	6.97
T_2- PSB	8.27	4.37	14.60	6.60	16.67	8.17
T_3-Vermicompost	8.60	4.50	14.80	6.77	17.23	8.40
T_4-PSB + Vermicompost	8.77	4.60	15.30	7.20	17.80	8.80
T_5-75 % RDP ha^{-1}	8.93	4.75	15.73	7.70	18.83	9.10
T_6-T_5+PSB	9.00	5.10	16.33	7.97	20.30	9.40
T_7-T_5+Vermicompost	10.17	5.60	16.93	8.07	21.70	10.17
T_8-T_5+ PSB+ Vermicompost	11.43	5.97	17.57	8.53	22.50	10.53
T_9-100 % RDP ha^{-1}	11.63	6.23	18.10	8.93	23.10	10.70
T_{10}-T_9+PSB	11.90	6.37	18.40	9.00	24.07	11.50
T_{11}-T_9+Vermicompost	12.13	6.63	18.77	9.37	24.50	12.07
T_{12}- T_9+ PSB+ Vermicompost	12.63	6.83	19.10	10.10	25.10	12.97
CD	0.245	0.139	0.159	0.135	0.167	0.181
SE(D)	0.118	0.06	0.077	0.065	0.080	0.08

Phosphorus helps in increase in various metabolic processes, such as cell division, cell development and cell enlargement which increase the root length and nodule number (Ahamad *et al.,* 2014). Similar results have been reported by Kumawat *et al.,* (2010) in green gram and Kumar *et al.,* (2014) in black gram crop. Combined application of PSB or/and vermicompost further improved root nodule number during nodule formation period.

Integration of 100 % RDP, PSB and vermicompost (T_{12}) significantly increased the active root nodule number to 6.83, 10.10 and 12.97 as against 4.03, 6.07 and 6.97 nodules $plant^{-1}$ with control (T_1) during 4th, 5th and 6th weeks after sowing respectively.

Seed inoculation with PSB also significantly increased the total and active nodule $plant^{-1}$ over uninoculated treatments. This increase is due to PSB release of growth promoting substances by PSB which provide favorable environment for rhizobium, which promotes root nodulation (Rathour *et al.,* 2014) and also PSB solubilises the native P and enhance its availability to the plants. The increased availability might have helped in better nodulation. These results are similar to the findings of Kumawat *et al.,* 2010. Vermicompost decreases P fixation and enhances P availability, thus resulting in better growth and consequently exploitation of greater soil volume for root nodulation (Choudary *et al.,* 2011). These results are in agreement with finding of Tak *et al.,* (2013) and Singh *et al.,* (2013).

Yield of green gram

The grain yield and haulm yield significantly influenced by different phosphorus management practices (Table 1). The seed yield was the highest when vermicompost and PSB were combined applied with inorganic P

at 100 % RDP (T_{12}), the yield being 1033.33 kg ha^{-1} and it was found to be on par with T_{11} (996 kg ha^{-1}) and T10 (985.00 kg ha^{-1}) treatments. Integrated application of inorganic P along with vermicompost and PSB significantly increased the seed yield by 46.92% (T_{12} on T_1), 11.75% (T_8 on T_5) and 8 % (T_{12} on T_9) at P_0. P_{75} and P_{100} levels, respectively over inorganic P application at their respective level. Application of 75 % RDP alone (T_5) significantly increased the seed yield to 831.00 kg ha^{-1} over 703.33 kg ha^{-1} in control (T_1). The increased seed yield with P application might be due to increased P availability and uptake resulted profuse nodulation leading to greater symbiotic nitrogen fixation which in turn has positive effect on photosynthesis, then on yield (Rani *et al.*, 2016 and Kumar *et al.*, 2014). Haulm yield was increased from a value of 993.33 kg ha-1 in the control (T_1) to 1625.66 kg ha^{-1} in the treatment (T_{12}) which was receiving 100 % RDP along with vermicomost and PSB and it was on par with T_{11} treatments. However, addition of 75 % RDP alone (T_5) significantly increased the haulm yield to 1259.33 kg ha^{-1} over control (T_1). Rathour *et al.*, (2014) reported that phosphorus involves in cell division, increases various metabolic processes and cell enlargement, application of phosphate solubilising bacteria releases growth promoting substances which improves the haulm yield.

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