Enhancing soil fertility, yield and quality in green gram (*Vigna radiata* L. Wilczek) through integrated nutrient management

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A field experiment was conducted at on clay loam soil. The experiment was laid out according to factorial randomized block design with three replications. The experiment comprised four fertility levels (75% Recommended Dose of Fertilizers (RDF), 75% RDF+Vermicompost (VC) at 2 t ha^{-1}, 100% RDF and 100% RDF+VC at 2 t ha^{-1}) and four biofertiliizers levels (control, *Rhizobium*, Phosphate Solubilizing Bacteria (PSB) and *Rhizobium*+PSB) were applied to the green gram variety SML-668. The RDF was 20 kg Nitrogen (N_2) and 40 kg Phosphorus Pentoxide (P_2O_5) per hectare. The soil of the experimental site was clay loam in texture, slightly alkaline in reaction, medium in available nitrogen and phosphorus, while high in potassium and Diethylene Triamine Pentaacetic Acid (DTPA) extractable micronutrients sufficiently above the critical limits. The main findings of investigation are summarized as: The application of fertility level significantly increased the dry matter accumulation, number of pods per plant, number of seeds per pod, chlorophyll content, seed and haulm yields, nitrogen, phosphorus, potassium, copper, zinc, iron and manganese content and uptake in seed and haulm, protein content in seed, number of total and effective root nodules, fresh and dry weight of root nodules, leghemoglobin content in root nodules and net returns up to 75% RDF+VC at 2 t ha^{-1} however, their further increase with application of 100% RDF+VC at 2 t ha^{-1} was non-significant. The increase in test weight was found non-significant. The organic carbon, available nitrogen, phosphorus, potassium, copper, zinc, iron and manganese in soil increased significantly with the application of fertility levels at harvest of the crop, but Electrical Conductivity (EC) and pH remain non-significant. Seed inoculation with *Rhizobium*+PSB significantly increased the dry matter accumulation, number of pods per plant, number of seeds per pod, chlorophyll content, seed and haulm yields, nitrogen, phosphorus, potassium, copper, zinc, iron and manganese content and uptake in seed and haulm, protein content in seed, number of total and effective root nodules, fresh and dry weight of root nodules, leghemoglobin content in root nodules and net returns and the test weight and harvest index were found non-significant. The organic carbon, available nitrogen, phosphorus, potassium, copper, zinc, iron and manganese in soil significantly increased with inoculation of *Rhizobium*+PSB at harvest stage of the crop, but EC and pH remain non-significant. The interactive effect of fertility levels and biofertilizers significantly influenced the seed and haulm yield, nitrogen, phosphorus, potassium uptake by seed and net returns and maximum being with the application of 100% RDF+VC at 2 t ha^{-1} and *Rhizobium*+PSB combination (F_4B_3), which was at par with 75% RDF+VC at 2 t ha^{-1} and *Rhizobium*+PSB combination (F_2B_3).

Key Words: *Greengram; Integrated nutrient management; Fertility; Biofertilizer;* Rhizobium

INTRODUCTION

Green gram (*Vigna radiate* L. Wilczek) commonly known as mung bean and golden gram, is one of the important kharif pulse crop. It ranks third among all pulses grown in India after chickpea and pigeon pea. It is quite versatile crop grown for seeds, green manure and forage; as mixed or sole crop either on residual moisture of the previous crop or as a catch crop to make use of the land left fallow between two main season crops. It makes a good manure if incorporated into soil. Further, it enriches the soil by atmospheric nitrogen fixation through root nodules. The crop gives such a heavy vegetative growth and covers the ground so well that it checks the soil erosion in problem areas and can later be ploughed down for green manure. It has considerable potential as an alternative pulse crop in dry land farming. This crop is of great importance because of availability of short duration (65-70 days), high yielding and quick growing varieties [1].

In India, mung bean growing states are Rajasthan, Uttar Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Odisha. Rajasthan ranks first in area, while Maharashtra ranks first in production. Kerala is the leading state in productivity with an average of 824 kg ha^{-1} whereas, the national average is 548 kg ha^{-1}. Although green gram is a legume and capable of fixing atmospheric nitrogen, still it responds to small quantity of nitrogenous fertilizers applied as starter dose. In terms of significance, phosphorus is most indispensable mineral nutrient for pulse crops as it helps in better root growth and development and thereby making them more efficient in biological nitrogen fixation. Phosphorus is an essential constituent of nucleic acids such as Ribonucleic Acid (RNA) and Deoxyribonucleic Acid (DNA), Adenosine Diphosphate (ADP) and Adenosine Triphosphate (ATP), nucleoproteins, amino acids, proteins, phosphatides, phytin, several co-enzymes *viz.* thiamine, pyrophosphate and pyrodoxyl phosphate [2,3].

MATERIALS AND METHODS

In order to determine the physico-chemical properties of soil, soil samples (0 cm-15 cm depth) were collected from different spots of the experimental field prior to sowing and fertilization. A representative composite soil sample was prepared by mixing all these samples together. The soil sample after drying was passed through 2.0 mm sieve and then subsequently used for mechanical, physical and chemical analysis. The experimental site soil was clay loam in texture, slightly alkaline in reaction. The soil was medium in available nitrogen, phosphorus while high in potassium and sufficient in DTPA extractable micronutrients.

To assess the fertility status of soil, the soil sample (0 cm-15 cm depth), from each plot at harvest of crop was taken. The samples were passed through 2 mm plastic sieve to avoid metallic contamination. The soil sample were analysed for EC, pH and Organic Carbon (OC) and available Nitrogen, Phosphorus, Potassium (NPK) and cationic micronutrients (Copper (Cu), Zinc (Zn), Iron (Fe) and Manganese (Mn)) content as per methods [4].

The experiment was laid out in factorial randomized block design with three replications. The treatment combinations were randomized with the help of randomization technique.

Treatment application

<u>Fertility levels:</u> Nitrogen and phosphorus were applied through urea and Diammonium Phosphate (DAP), respectively as per treatments as basal doses at the time of sowing. Whole amount of vermicompost as per treatment was broadcasted uniformly at the time of sowing and incorporated in the soil.

<u>Biofertilizer levels:</u> The required seeds were treated with bavistin at 2 g/kg

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of seed to control seed borne diseases. Later on seeds were inoculated with *Rhizobium* and PSB culture or both as per treatments, using standard method and dried in shade.

Seed rate and sowing

The seeds were sown by 'kera' method with row spacing of 30 cm by hand plough at a depth of 5 cm using a seed rate of 20 kg ha^{-1}. The variety of green gram (SML-668) was used as the test crop and the sowing was done on 18 July 2015.

Thinning, hoeing and weeding

To maintain uniform plant, stand at an intra-row spacing of 10 cm, extra plant was thinned out 10 days after sowing (DAS). In order to minimize weed competition, weeding and hoeing was done manually 19 and 28 days after sowing to facilitate aeration and removal of weeds.

Harvesting

The crop was harvested from net plot area separately from each plot. The harvested material of each plot was tied up in bundles and tagged.

Statistical analysis

Analysis of variance and test of significance: In order to test the significance of variation in experimental data obtained for various treatment effects. The critical differences were calculated to assess the significance of treatment mean wherever the 'F' test was found significant at 5% level of probability. To elucidate the nature and magnitude of treatment effects, summary tables along with Standard Error of the mean (SEm) ± Critical Difference (CD) (p=0.05) were prepared and are given in the text of the chapter "results" and their analyses of variance are given in appendices at the end.

Economics of treatments: The economics of treatments is the most important consideration making any recommendation to the farmers for its wide adoption. For calculation of economics, the average treatment yield along with prevailing market rates for inputs and outputs were used. Hence, to evaluate the effectiveness and profitability of the treatments comprehensive economics including net returns and Benefit cost (B/C) ratio was calculated so that most effective and remunerative treatment could be recommended. The details of calculation are given in appendices at the end [5-7].

RESULTS AND DISCUSSION

The data related to various criteria used for treatment evaluation were analysed statistically using standard statistical methods to test their significance. The data regarding the effect of fertility and biofertilizer levels on net return and benefit cost ratio of green gram are being summarized in Table 1.

Net return

Effect of fertility levels: A perusal of data in Table 1, revealed that with the application of fertility levels, the net return under 75% RDF+vermicompost (2 t ha^{-1}), 100% RDF and 100% RDF+vermicompost (2 t ha^{-1}) treatments significantly increased as compared to 75% RDF. However, the increase in net return with 100% RDF+vermicompost (2 t ha^{-1}) was statistically at par with 75% RDF+vermicompost (2 t ha^{-1}). The application of 75% RDF+vermicompost (2 t ha^{-1}), 100% RDF and 100% RDF+vermicompost (2 t ha^{-1}) increased the net return to the tune of 28.98%, 14.51% and 36.63% respectively, over 75% RDF [8-10].

Effect of bioferilizers: A critical examination of data in Table 1, revealed that due to inoculation of green gram seed with *Rhizobium*, PSB and *Rhizobium*+PSB, the net returns significantly increased in comparison to control. Further, the increase in net returns with *Rhizobium*+PSB was statistically significant over *Rhizobium* as well as PSB inoculations. However, the increase in net returns with inoculation of *Rhizobium* was statistically at par with that of PSB. The extent of increase in net return of green gram with *Rhizobium*, PSB and *Rhizobium*+PSB inoculation was 38.31%, 33.14% and 54.57% respectively over control.

Interactive effective of fertility and biofertilizer levels: The interactive effect of fertility and biofertilizer levels on the net returns was found significant (Table 2). The significantly highest net returns were obtained under treatment combination F_4B_3, which was at par with the treatment combinations of F_2B_3. Minimum net returns were recorded under F_1B_0 treatment.

Benefit cost ratio

Effect of fertility levels: The benefit cost ratio under 75% RDF+vermicompost (2 t ha^{-1}), 100% RDF and 100% RDF+vermicompost (2 t ha^{-1}) treatments significantly increased as compared to 75% RDF treatment. The highest B/C ratio (1.80) was recorded with 100% RDF+vermicompost (2 t ha^{-1}). The application of 75% RDF+vermicompost (2 t ha^{-1}), 100% RDF and 100% RDF+vermicompost (2 t ha^{-1}) increased the B/C ratio to the extent of 9.32%, 8.07% and 11.80% respectively, over 75% RDF.

Effect of bioferilizers: Due to inoculation of green gram seed with *Rhizobium*, PSB and *Rhizobium*+PSB, the B/C ratio significantly increased in comparison to control. The highest B/C ratio (2.08) was obtained with B_3 (*Rhizobium*+PSB). However, the increase in B/C ratio with inoculation of *Rhizobium* was statistically at par with that of PSB. The extent of increase in B/C ratio with *Rhizobium*, PSB and *Rhizobium*+PSB inoculation was 36.23%, 31.16% and 50.72% respectively, over control [11,12].

The application of 100% RDF+VC at 2 t ha^{-1} to green gram crop significantly increased the net return (38837) and B/C ratio (1.80) over others levels of RDF and vermicompost. Likewise, inoculations of greengram seeds with *Rhizobium*+PSB also significantly increased net returns (40102) and B/C (2.08) ratio over *Rhizobium*, PSB and control (Table 1). It is clear that in both the treatments there was significant increase in seed and haulm yield which ultimately gave more net returns and B/C ratio over the input cost incurred in these treatments in comparison to others treatments. These results are in close conformity with those of Meena et al., [13].

Interactive effect of fertility and biofertilizer levels: The significantly highest net returns (48109 ha^{-1}) and B/C ratio (2.22) were obtained with combined use of 100% RDF+VC at 2 t ha^{-1} and *Rhizobium*+PSB (F_4B_3), which were significantly higher as compared to other treatment combinations (Table 2). However, it is at par with F_2B_3 (44987 ha^{-1}). It is obvious because the seed and haulm yield of green gram also increased significantly under this treatment which is main contributor to net returns and thus resulted in higher net returns under application of 100% RDF+VC at 2 t ha^{-1} and *Rhizobium*+PSB. These results are in close conformity with those of Meena et al., [13].

TABLE 1

Effect of fertility and biofertilizer levels on net returns and benefit cost ratio

Treatments	Net returns (ha^{-1})	B/C ratio
	Fertility levels	
F_1: 75% RDF	28424	1.61
F_2: 75% RDF+VC (2 t ha^{-1})	36661	1.76
F_3: 100% RDF	32549	1.74
F_4: 100% RDF+VC (2 t ha-1)	38837	1.8
SEm ±	1422	0.04
CD (p=0.05)	4108	0.12
	Biofertilizer levels	
B_0: Control	25944	1.38
B_1: *Rhizobium*	35882	1.88
B_2: PSB	34543	1.81

B_3: *Rhizobium*+PSB	40102	2.08
SEm±	1422	0.04
CD (p=0.05)	4108	0.12

Note: RDF: Recommended Dose of Fertilizers; VC: Vermicompost; SEm: Standard Error of the mean; CD: Critical Difference; PSB:Phosphate Solubilizing Bacteria; B/C: Benefit cost.

TABLE 2

Interactive effect of fertility and biofertilizer levels on net returns (ha^{-1})

Treatments	F_1	F_2	F_3	F_4
B_0	24455	26563	25778	26980
B_1	29507	38570	34274	41178
B_2	29106	36524	33462	39081
B_3	30630	44987	36681	48109
SEm ±	2845	-	-	-
CD (p=0.05)	8216	-	-	-

Note: SEm: Standard Error of the mean; CD: Critical Difference.

CONCLUSION

On the basis of one-year field experimentation, it can be concluded that under agro climatic condition of Kanpur, application of 100% RDF+VC at 2 t ha^{-1}+*Rhizobium*+PSB (F_4B_3), is the better option for realizing higher productivity, content and uptake of nutrients, net returns and B/C ratio of green gram and is the better option for improved fertility status of soil. A significant response to the application of aforesaid treatment was observed. However, highest economic green gram seed yield (1386.07 kg ha^{-1}) and net return (48109 ha^{-1}) was observed in treatment combination of F_4B_3 (100% RDF+VC at 2 t ha^{-1}+*Rhizobium*+PSB) with B/C ratio of 2.22, which was at par with F_2B_3 (75% RDF+VC at 2 t ha^{-1}+*Rhizobium*+PSB). The result of the present investigation reveals the significance of fertility levels with the combination of vermicompost and biofertilizer levels in green gram crop for maximization of yield and profits.

However, the highest available nitrogen, phosphorus, potassium, copper, zinc, iron and manganese status of soil after harvesting of green gram crop were observed under fertility level 100% RDF+VC at 2 t ha^{-1} (F_4) and inoculation of *Rhizobium*+PSB (B_3) treatment as compared to 75% RDF (F_1) and control (B_0), respectively.

However, these results are only indicative and require further experimentation for confirmation before making final recommendation to the farmers.

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