

Original Research Article

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Soil Quality Parameters and Yield of Green Gram as Affected by the Combined Application of Manures and Biofertilisers

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A field experiment was conducted at the ICAR Research farm Medziphema, Nagaland ($25^{\circ}50'24''\text{N}$ latitude and $93^{\circ}50'26''\text{E}$ longitude) during the summer season of 2017 with green gram as test crop. Organic manures *viz.* Farm Yard Manure (FYM) and vermicompost were combined with biofertilizers *viz.* *Rhizobium* and phosphate solubilizing bacteria (PSB) in different combinations and were evaluated in a Randomized Block Design with three replications. The combination of vermicompost @ 5 t ha^{-1} + co-inoculation with *Rhizobium* + PSB(T₇) proved to be the best treatment in terms of maximum number of nodules (41.33, 44, 18.67 at 30, 45, 60 DAS respectively), the highest grain yield (13.92 q ha^{-1}), total biomass yield (89.77 q ha^{-1}) and nutrient (N, P, K) uptake. No significant variation was recorded in terms of soil physical parameters under study. However, available nitrogen and organic carbon content was significantly influenced in treatment T₇ and T₄ with vermicompost and FYM along with co-inoculation of *Rhizobium* and PSB. Population of *Rhizobium* and PSB (58.33×10^7 and $56 \times 10^4 \text{ CFU g}^{-1}$ soil respectively), soil microbial biomass carbon ($1603.91 \mu\text{g g}^{-1}$ soil), dehydrogenase and acid phosphatase activity was also significantly higher in T₇. However, sole inoculation of nitrogen fixers with either of the manures failed to produce similar effects. Thus combined application of manures and biofertilizers can be recommended as nutrient management strategy for yield enhancement and soil quality maintenance of green gram cultivation in acid soils of north eastern region of India.

Introduction

Green gram [*Vigna radiata* (L.) Wilczek] alternatively known as the mung bean is a plant species belonging to the leguminosae family which is native to the Indian subcontinent. In India, it is grown on an area of 2.75 m ha with average production 1.19 mt and productivity is 432 kg ha^{-1} (Purushottam

and Singh, 2015). The north eastern region also has tremendous potential for increasing pulse production and productivity due to its favourable climatic conditions. The area and productivity of green gram in Nagaland stretches to 330 ha of the total pulse area and 510 tons of the total pulse production (Anonymous, 2013).

Mung bean has an edge over other pulses because of its high nutritive value. It contains about 25% protein which is almost three times that of cereals. In addition to being an important source of human food and animal feed, an important feature of the mung bean crop is its ability to establish a symbiotic relationship with specific bacteria, setting up the biological nitrogen fixation in root nodules that supply the plant needs for nitrogen. The green biomass of the crop as well as residues can be incorporated in the soil for the purpose of replenishing exported plant nutrients and improving fertility status of the soil. The soil microbiological properties were also significantly higher in the soils where mung bean is incorporated in the cropping system (Kumar, 2014).

In the recent years dependence on organic sources of nutrients is increasing as these are effective in promoting health and productivity of the soil. The replenishment of nutrients and soil quality maintenance is dependent on organic materials due to beneficial impacts in terms of soil physical, chemical, and biological properties (Reddy *et al.*, 2003). The ability of the organic materials to supply nutrients differs, as they relate to the rates of decomposition, nutrient release rates and patterns (Kumar and Goh, 1999). There are numerous reports on increased nutrient content in soil, nutrient uptake and yield in green gram due to application of organic manures like vermicompost and FYM. Organic manures enhance soil biological activity which improves nutrient mobilization from organic and chemical sources and decomposition of toxic substances (Rana *et al.*, 2014). Biofertiliser inoculation has always positive effects on nutrient release from the manures. There lies a synergistic relationship between different plant growth promoting micro-organisms. Co-inoculation of nitrogen fixers and phosphorus solubilising micro-organisms could serve dual purpose of

supplying both the nutrients and may benefit plant growth than either group of organisms alone. There is a positive effect on the yield and nutrient uptake of legume crops as well as the increased nodulation due to combined inoculation of PSB and nitrogen fixers (Khan *et al.*, 2007). Co-inoculation of nitrogen fixers and phosphate solubilizers in legumes may have synergistic effects resulting into better crop yield and P uptake. Being a pulse crop, green gram has low nutrient requirement. Hence, organic manures and biofertilisers can serve as an excellent substitute for chemical fertilizers. Adoptions of appropriate strategies hold a great potential in boosting the green gram yield in an effective manner.

Green gram has of late emerged as one of the best bets for enhancing farm productivity as well as soil quality in north east India. Its introduction into the cropping systems as a quick growing summer crop has immense potential in augmenting the farmer's income apart from boosting of the soil fertility, health and quality. However, a well thought out nutrient management plan has to be in place so as to help the crop perform to its full potential. The present study, therefore, have been conducted to explore potential role of organic manures and biofertilizers in order to devise a viable nutrient management plan for green gram to fit in the nutrient starved agricultural production systems of north east India, especially Nagaland.

Materials and Methods

The experimental farm was located at 25°50'24"N latitude and of 93°50'26"E longitude. The climate of the Medziphema area represents sub tropical with annual rainfall of 2000-2500 mm. The maximum rainfall is received during May to October while the remaining period from November to April remains comparatively dry. The average maximum and minimum temperature and

relative humidity recorded during the period of investigation was 33.7°C and 11.7°C and 92% respectively.

The soil of the experimental plot was sandy loam in texture. The texture and initial fertility status of the soil was ascertained and determined by collecting representative soil samples randomly from different locations with soil auger at 0-15 cm depth. The collected samples were air dried and ground to pass through a 2 mm sieve and analyzed for physical, chemical and biological parameters following standard analytical procedures. pH of initial samples was 4.90, OC 0.51%, available N, P₂O₅ and K₂O was 150.53, 56.43 and 268.8 kg ha⁻¹ respectively. Maximum water holding capacity of soil was 36.21% with mean weight diameter 2.11mm and bulk density 1.39 g cm⁻³. Initial microbial population was 12.0 x 10⁴ and 11.3 x 10⁴ CFU g⁻¹ soil for *Rhizobium* and PSB respectively. Dehydrogenase enzyme activity was recorded as 8.23 µg TPF g⁻¹ hr⁻¹ and acid phosphatase activity was 59.52 µg p-nitrophenol g⁻¹ hr⁻¹. Soil Microbial Biomass Carbon of initial soil sample was 481.41 µg g⁻¹ soil.

Summer green gram variety "Pratap" was grown following recommended cultivation practices. Seven treatments consisting of T₁: Control, T₂: FYM @ 5 t ha⁻¹, T₃: FYM @ 5 t ha⁻¹ + seed inoculation with *Rhizobium*, T₄: FYM @ 5 t ha⁻¹ + seed inoculation with *Rhizobium* + PSB, T₅: vermicompost @ 5 t ha⁻¹, T₆: vermicompost @ 5 t ha⁻¹ + seed inoculation with *Rhizobium*, T₇: vermicompost @ 5 t ha⁻¹ + seed inoculation with *Rhizobium* and PSB were evaluated in a Randomized Block Design with three replications. The individual plot size was 22.5 m². Vermicompost and FYM were procured from production unit of ICAR, Nagaland Centre whereas the biofertilisers were procured from the state biofertiliser

laboratory, Medziphema, Dimapur, Nagaland. *Rhizobium* and PSB were applied as seed treatments just before sowing @ 30 g *Rhizobium*/ PSB per kg seed.

Growth attributes viz. root volume and numbers of nodules were recorded at 30, 45 and 60 DAS. Grain yield and Biomass yield was also recorded. Nutrient (N, P, K) uptake was calculated for both grain and stover from the yield and nutrient contents.

Soil quality parameters viz pH, organic carbon, available N, P₂O₅ and K₂O, mean weight diameter, bulk density, water holding capacity, microbial (*Rhizobium* and PSB) population, enzyme (dehydrogenase and phosphatase) activity, SMBC and basal respiration were assessed during the investigation adopting standard procedures as mentioned in the table 1. *Rhizobium* cell count was done in Yeast Extract Mannitol Agar while PSB cell count was done in Pikovskaya's medium.

Mean data of each quantitative trait were statistically analysed by the technique of analysis of variance. The significant difference was tested by 'f' test and difference between mean by using CD at 5% level (Gomez and Gomez, 1984).

Results and Discussion

Growth and yield of plants

Significant variation in root volume and number of nodules at different time interval was recorded over control (Table 2). The highest root volume / maximum number of effective nodules (2.33 cc/ 41.33; 2.67 cc / 44.0; and 2.50 cc / 18.67 at 30 DAS, 45 DAS and 60 DAS respectively) was recorded in T₇ (vermicompost @ 5 t ha⁻¹ + seed inoculation with *Rhizobium* + PSB) followed by T₄ and the lowest was observed in control (T₁).

Choudhary *et al.*, (2011) also reported that organic manures result in better growth and consequently exploitation of greater soil volume for nodulation. These findings are also in close conformity with Naveen *et al.*, (2012) who reported positive influence of vermicompost and biofertilisers on growth and nodulation of the plant. Enrichment of rhizospheric N by vermicompost could stimulate nodule development (Shukla and Tyagi, 2009). The increased growth parameters may be attributed to increased cell division due to sufficient supply of nitrogen and phosphorus by dual inoculation of *Rhizobium* + PSB (Singh *et al.*, 2013).

The maximum grain yield (13.92 q ha^{-1}) was recorded from the treatment T₇. This is followed by the treatments T₄ (12.10 q ha^{-1}) and T₆ (12.05 kg ha^{-1}). The lowest grain yield was recorded in control (7.90 q ha^{-1}). Similar trend was observed in case of stover yield too (Table 2). Increased grain yield might be attributed to increased availability of nitrogen and phosphorus in soil that resulted in higher growth and development and finally the yield (Tagore *et al.*, 2013).

Soil quality parameters

Maximum Mean weight diameter (3.61 mm) and water holding capacity (38.83%) was recorded in treatment T₇, however the difference was non-significant (Table 3). Negi and Gulshan (2000) also reported that manure application enhances soil organic carbon and aggregate stability and decreases bulk density.

pH of soils ranged between 4.97-5.23. The effect of the treatment on soil pH was found to be non-significant. This is in accordance with the findings of Parvathi *et al.*, (2013) who reported that soil pH did not differ significantly with the application of organic manures. Soil pH was found non-significant because of release of organic acids that

maintain the buffering capacity of the soil during the mineralization of organic manures (Srikanth *et al.*, 2000). However, significantly higher OC (0.59%) was recorded in treatment T₇. Available fraction of soil nitrogen was found to be the highest under treatment T₇ ($275.96 \text{ kg ha}^{-1}$), followed by T₄ ($250.88 \text{ kg ha}^{-1}$) and T₆ ($242.51 \text{ kg ha}^{-1}$). Available potassium though found maximum in T₇, the treatment effect was non-significant (Table 3).

The application of vermicompost @ 5 t ha^{-1} + seed inoculation with *Rhizobium* + PSB (T₇) recorded significantly highest *Rhizobium* population ($58.33 \times 10^4 \text{ CFU g}^{-1}$ soil) and PSB population ($56 \times 10^4 \text{ CFU g}^{-1}$ soil) (Table 4). The co-inoculation of the biofertilisers probably supported the growth of *Rhizobium* due to their role in the synthesis of extracellular polysaccharides. This is in accordance with the findings of Tagore *et al.*, (2013) who reported the effectiveness of co-inoculation of *Rhizobium* + PSB in increasing microbial population in soil. Application of organic manures along with *Rhizobium* + PSM resulted a marked increase in PSB population in soil over the other treatments (Singh *et al.*, 2014). Further, it is known that organic manure like vermicompost stimulates soil microbial populations by supplying large amounts of readily available carbon (Das and Dkhar, 2011).

Highest microbial biomass carbon in soil ($1603.91 \mu\text{g g}^{-1}$ dry soil) was recorded in the soils of treatment T₇ was followed by T₄ ($1157.94 \mu\text{g g}^{-1}$ soil) and the lowest was recorded in control T₁ ($689.85 \mu\text{g g}^{-1}$ soil). The application of vermicompost in conjunction with biofertilisers was found to be superior over the sole application of vermicompost due to the synergistic effect of the co-inoculation of biofertilisers with vermicompost. The results are in agreement with the findings of Singh *et al.*, (2015).

Addition of organic manures increases the microbial biomass carbon because the organic manures act as a good substrate that provides a congenial environment for the microbial growth. Supply of readily available C resulted in higher microbial activity and ultimately higher microbial biomass in soil (Das and Dkhar, 2012). The results are also in close conformity with the findings of Das and Dkhar (2011) who have reported that the application of organic manures enhanced the microbial biomass carbon as compared to inorganic fertilisers and control. Similar trend was observed in case of soil basal respiration, highest ($6.87 \mu\text{g C g}^{-1} \text{ hr}^{-1}$) being under treatment T₇ followed by T₄ ($6.72 \mu\text{g C g}^{-1} \text{ soil hr}^{-1}$). However, lowest soil basal respiration ($3.81 \mu\text{g C g}^{-1} \text{ soil hr}^{-1}$) was recorded under control treatment (Table 4).

The treatment effect on soil basal respiration was not significant probably because of reduction in number of actively respiring microorganisms in soil after the harvest of the crop.

The effect of different sources of organic manures and biofertilisers was found to have significant influence on reactivity of dehydrogenase enzyme in soil. The highest dehydrogenase activity ($32.23 \mu\text{g TPF g}^{-1} \text{ soil h}^{-1}$) was recorded under T₇ followed by T₄ ($28.90 \mu\text{g TPF g}^{-1} \text{ soil h}^{-1}$) and the lowest was recorded in T₂ ($7.22 \mu\text{g TPF g}^{-1} \text{ soil h}^{-1}$). The trend clearly demonstrated the positive influence of biofertiliser and organic manures on the abundance of microorganisms in soil (Table 4).

Table.1 Parameters analyzed

Sl. No	Parameters	Methods followed
I	Physical parameters	
	a. Mean weight diameter	Wet sieving method (Yoder, 1936)
	b. Bulk density	Core method (Black, 1965)
	c. Maximum water holding capacity	Keen-Rackzowski box (Piper, 1966)
II	Chemical parameters	
	a. pH	Glass electrode pH meter (Jackson, 1973)
	b. Soil organic carbon	Wet oxidation method (Walkley and Black, 1934)
	c. Available nitrogen	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
	d. Available phosphorus	Bray's method (Bray and Kurtz, 1945)
	e. Available potassium	Neutral normal ammonium acetate method (Jackson, 1973)
III	Biological parameters	
	a. Microbial population	Serial dilution method (Johnson and Curl, 1972)
	b. Microbial biomass carbon (MBC)	Fumigation extraction method (Vance <i>et al.</i> , 1987).
	c. Soil basal respiration (SBR)	Alkali entrapment method (Anderson, 1982)
	d. Dehydrogenase activity	2-3-5-triphenyl tetrazolium chloride reduction technique (Casida, 1977)
	e. Acid phosphatase activity	p-nitrophenyl phosphate method (Tabatabai and Bremner, 1969)

Table.2 Growth parameters and yield of green gram as affected by the application of manures and biofertilisers

Treatments	Root volume (cc)			Nodule no. per plant			Grain yield (q ha ⁻¹)	Stover yield		
	Days After Sowing (DAS)									
	30	45	60	30	45	60				
T ₁ : Control	0.8	1.27	0.93	8.33	9.67	4.0	7.90	17.71		
T ₂ : FYM @ 5 t ha ⁻¹	1.03	1.37	1.23	12.33	11.33	3.67	8.90	39.04		
T ₃ : FYM @ 5 t ha ⁻¹ + Rhizobium,	1.23	1.47	1.33	21.33	20.33	5.33	9.85	47.23		
T ₄ : FYM @ 5 t ha ⁻¹ Rhizobium + PSB	1.90	2.17	1.93	34.67	35.33	13.67	12.10	60.44		
T ₅ : vermicompost @ 5 t ha ⁻¹	1.53	1.73	1.43	24.33	25.0	9.33	11.33	52.52		
T ₆ :vermicompost @ 5 t ha ⁻¹ + Rhizobium	1.87	2.13	1.87	34.0	35.67	14.0	12.05	57.32		
T ₇ : vermicompost @ 5 t ha ⁻¹ + Rhizobium +PSB	2.33	2.67	2.5	41.33	44.0	18.67	13.92	75.86		
SEm±	0.06	0.06	0.06	1.40	1.12	0.62	0.20	0.62		
CD(P=0.05)	0.22	0.23	0.23	5.07	4.06	2.26	0.72	2.24		

Table.3 Physicochemical properties of soil as affected by the application of manures and biofertilisers

Treatments	MWD (mm)	BD (gcm ⁻³)	MWHC (%)	pH	OC(%)	AvN	AvP ₂ O ₅	AvK ₂ O
						(kg ha ⁻¹)		
T ₁ : Control	2.20	1.31	35.53	5.17	0.51	188.16	20.52	232.96
T ₂ : FYM @ 5 t ha ⁻¹	2.39	1.38	37.70	5.20	0.55	200.70	27.36	277.76
T ₃ : FYM @ 5 t ha ⁻¹ + Rhizobium,	2.83	1.38	36.26	5.17	0.53	221.61	27.36	304.64
T ₄ : FYM @ 5 t ha ⁻¹ Rhizobium + PSB	3.26	1.42	36.89	4.97	0.58	250.88	39.33	328.52
T ₅ : vermicompost @ 5 t ha ⁻¹	3.10	1.37	35.80	5.20	0.54	213.24	30.78	328.52
T ₆ :vermicompost @ 5 t ha ⁻¹ + Rhizobium	3.32	1.39	38.29	5.23	0.56	242.51	25.65	313.60
T ₇ : vermicompost @ 5 t ha ⁻¹ + Rhizobium +PSB	3.61	1.36	38.83	5.13	0.59	275.96	32.49	349.44
SEm±	0.03	0.02	1.46	0.14	0.01	14.08	6.56	29.78
CD(P=0.05)	0.12	NS	NS	NS	0.05	50.97	23.77	107.82
Initial value	2.11	1.39	36.21	4.90	0.51	150.33	15.51	268.80

Table.4 Soil biological properties as affected by manures and biofertilizers

Treatments	Soil biological properties					
	Microbial population ($\times 10^4$ CFU g ⁻¹ soil)		SMBC ($\mu\text{g g}^{-1}$ soil)	Soil Basal Respiration ($\mu\text{g C g}^{-1}$ soil hr ⁻¹)	Enzyme activity	
	Rhizobium	PSB			Dehydrogenase ($\mu\text{g TPF g}^{-1}$ soil h ⁻¹)	Phosphatase ($\mu\text{g p-nitrophenol g}^{-1}$ soil h ⁻¹)
T ₁ : Control	11.67	11.33	689.85	3.81	7.22	60.34
T ₂ : FYM @ 5 t ha ⁻¹	27.33	17.33	1046.40	6.37	13.89	58.91
T ₃ : FYM @ 5 t ha ⁻¹ + Rhizobium,	20.33	14.0	794.26	5.0	10.0	120.27
T ₄ : FYM @ 5 t ha ⁻¹ Rhizobium + PSB	33.67	27.0	1157.94	6.72	28.90	169.36
T ₅ : vermicompost @ 5 t ha ⁻¹	26.33	19.33	862.75	6.37	15.0	141.44
T ₆ : vermicompost @ 5 t ha ⁻¹ + Rhizobium	15.67	17.0	741.16	4.54	13.34	167.80
T ₇ : vermicompost @ 5 t ha ⁻¹ + Rhizobium +PSB	58.33	56.0	1603.91	6.87	32.23	185.28
SEM \pm	1.69	2.79	133.88	0.91	2.31	2.10
CD(P=0.05)	6.12	10.09	484.71	NS	8.38	7.61
Initial value	10.2	3.5	481.41	0.44	8.23	59.52

The application of vermicompost enhances dehydrogenase activity which reflects the total range of oxidative activity of soil microflora and is consequently used as an indicator of soil microbial activity. Marinari *et al.*, (2000) reported that the enzymatic activities in soil were higher in organically amended soils than in control and soils treated with mineral fertilizer. Acid phosphatase activity was also found to be the highest under T₇ (185.28 µg *p*-nitrophenol g⁻¹ soil h⁻¹) followed by T₄ (169.36 µg *p*-nitrophenol g⁻¹ soil h⁻¹) and the lowest was recorded in T₂ (58.91 µg *p*-nitrophenol g⁻¹ soil h⁻¹) (Table 4). The plots receiving only vermicompost showed a significantly lower phosphatase activity as compared to that received vermicompost in conjunction with PSB. The phosphatase activity was stimulated by the application of biofertilisers. These findings are in agreement with Singh *et al.*, (2015).

From the above discussion it can be concluded that introduction of green gram into the cropping systems as a quick growing summer crop has immense potential in augmenting the farmer's income apart from boosting of the soil fertility, health and quality. Green gram can be grown successfully with judicious use of organic manures and biofertilisers. Combined inoculation of nitrogen fixers and phosphate solubilisers can bring about even better improvement in productive performance of green gram than either group of organisms alone due to synergistic effect, which was obvious in the present investigation. The application of vermicompost @ 5 t ha⁻¹ + seed inoculation with *Rhizobium* + PSB was found to be the best treatment which resulted 76.2% increase in yield over control, besides contributing substantially to other growth attributes as well as improving physical, chemical and biological properties of soil. Hence, application of vermicompost along with co-inoculation of seed with *Rhizobium*

and PSB can be a nutrient management strategy for improving the productivity of green gram in phosphorus deficient acid soils of north eastern region.

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