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Effect of vermicompost on soil fertility and crop productivity - beans (*Phaseolus vulgaris*)

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Abstract: *Field experiments were conducted at Sivapuri, Chidambaram, Tamil Nadu to evaluate the efficacy of vermicompost, in comparison to inorganic fertilizers–NPK, on the physio-chemical and biological characteristics of the soils – clay loam soil (CLS) and sandy loam soil (SLS) and on the growth, yield and nutrient content of beans – Phaseolus vulgaris. Results showed that the application of vermicompost @ 5 tonnes ha^{-1} had enhanced significantly the pore space (1.09 and 1.02 times), water holding capacity (1.1 and 1.3 times), cation exchange capacity (1.2 and 1.2 times). It reduced particles (1.2 and 1.2 times), and bulk density (1.2 and 1.2 times), pH (1 and 1.02 times) and electrical conductivity (1.4 and 1.2 times) and increased organic carbon (37 and 47 times), micro (Ca 3.07 and 1.9 times, Mg 1.6 and 1.6 times, Na 2.4 and 3.8 times, Fe 7 and 7.6 times, Mn 8.2 and 10.6 times, Zn 50 and 52 times and Cu 14 and 22 times) and macro (N 1.6 and 1.7 times, P 1.5 and 1.7 times, K 1.5 and 1.4 times) nutrients and microbial activity (1.4 and 1.5 times) in both soil types, particularly more in CLS. The growth, yield (1.6 times) and quality (protein (1.05 times) and sugar (1.01 times) content in seed) of bean were enhanced in CLS than SLS. On the other hand, the application of inorganic fertilizers @ 20:80:40 kg ha^{-1} has resulted in reduced porosity (1.03 and 1.01 times), organic carbon (1.04 and 9.5 times) and microbial activity (1.02 and 1.03 times) in both soil types.*

Key words: *Clay loam soil, Sandy loam soil, Physico-chemical-biological properties, Nutrient contents, Vermicompost, Beans*
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Introduction

The long-term use of inorganic fertilizers without organic supplements damages the soil physical, chemical and biological properties and causes environmental pollution (Albiach *et al.,* 2000). Organic manures act not only as a source of nutrients and organic matter, but also increase size, biodiversity and activity of the microbial population in soil, influence structure, nutrients turnover and many other related physical, chemical and biological parameters of the soil (Albiach *et al.,* 2000). Vermicompost is the microbial composting of organic wastes through earthworm activity to form organic fertilizer which contain higher level of organic matter, organic carbon, total and available N, P, K and micronutrients, microbial and enzyme activities (Edwards and Bohlen, 1996; Ranganathan, 2006; Parthasarathi *et al.,* 2007). Orozco *et al.* (1996) and Parthasarathi (2004) reported that vermicompost contains nutrients in forms that are readily taken up by the plants, such as nitrates, exchangeable phosphorus and soluble potassium, calcium and magnesium. Tomati *et al.* (1990) and Parthasarathi *et al.* (2006) also reported that vermicompost contains higher amount of humic acid content and biologically active substances such as plant growth regulators.

Several workers (Kale *et al*., 1992; Tomati and Galli, 1995; Edwards and Bohlen, 1996; Ghosh *et al.,* 1999; Parthasarathi and Ranganathan, 2002; Ranganathan, 2006; Zaller, 2007; Rajesh Banu *et al.,* 2008) observed that integration of vermicompost with inorganic fertilization tended to increase the yield of crop *viz.* tomato, potato, rapeseed, groundnut, blackgram, paddy, mulberry and marigold. Vasanthi and Kumaraswamy (1999) reported that paddy grain yields were significantly higher in plots treated with vermicompost plus NPK than in the treatment that received NPK alone. Effects of application of vermicompost on different types of soil and the nutritional analysis of plants, particularly in crops raised on different soil types have not been studied so far. Hence this paper deals the effect of influence of vermicompost, vermicompost supplemented with chemical fertilizer (NPK) and inorganic chemical fertilizer on various physical, chemical and biological features of two different soils -clay loam and sandy loam and the growth, yield and nutritional quality of beans - *Phaseolus vulgaris*.

Materials and Methods

Preparation of vermicompost from sugar mill wastes: One month old pressmud (p), dried and chopped sugarcane trash (12-18 cm) (t) and fine bagasse (0.2-0.5 cm) (b) were obtained from E.I.D Parry (I) Sugar Factory, Nellikuppam, Cuddalore district of Tamil Nadu, India. Ten kilogram of 8:1:1 mixture (w/w) of ptb in cement tanks of dimension 50x35x35 cm, about 200 adult *Eudrilus eugeniae* were introduced and maintained for 50 days, at 65-67% moisture, 30 ± 2^{o}C temperature and 65-70% RH. After 50 days fresh vermicompost was collected by hand from the surface and used for experiments.

Experimental site and design: A microplot (2m^{2}) field experiment was conducted at Sivapuri, Chidambaram, Tamil Nadu. Experiment was laid out in randomized block design with three replications.

Table - 1: Effect of vermicompost and NPK on the physical properties in post-harvest 75 days soils

Physical parameters	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
Pore space (%)	35.41	34.27	38.68	36.87	5.87*	32.51	32.17	33.21	32.28	5.01*
Particle density (Mgm^{-3})	1.69	1.62	1.39	1.44	1.12*	1.68	1.61	1.43	1.56	1.02*
Bulk density (Mgm^{-3})	1.13	1.17	0.98	1.09	0.14*	1.24	1.26	1.01	1.08	0.18*
WHC (%)	83.80	81.60	94.80	92.30	0.68*	59.20	56.40	75.50	67.20	0.65*
CEC (cmol (p^+)kg^{-1})	24.30	24.00	28.70	26.90	0.26*	23.20	23.00	28.10	26.3	0.23*

Values are $\bar{X}$ of six observations; * Significant at $p < 0.01\%$ level; T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5tonnes ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK, WHC =Water holding capacity, CEC= Cation exchange capacity

Table - 2: Effect of vermicompost and NPK on the chemical properties in post-harvest 75 days soils

Chemical parameters	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
pH	7.15	7.19	7.08	7.11	0.02^{NS}	7.14	7.18	6.97	7.09	0.03^{NS}
EC (dsm^{-1})	0.87	0.93	0.61	0.71	0.04*	0.58	0.50	0.49	0.52	0.02^{NS}
OC (%)	0.23	0.22	8.52	3.17	0.12	2.00	0.21	9.42	5.06	1.18*
Available nutrients										
N (kg ha^{-1})	125	190	207	201	0.82	117	188	200	193	1.92*
P (kg ha^{-1})	11.21	13.1	16.8	15.3	0.31	8.5	9.0	14.1	12.2	0.38*
K (kg ha^{-1})	206	240	317	267	3.11	203	235	290	260	4.12*
Total nutrient										
Ca (%)	1.70	1.74	3.07	2.69	0.18	1.59	1.63	2.97	2.08	0.12*
Mg (%)	0.56	0.53	0.87	0.63	0.03^{NS}	0.38	0.37	0.59	0.50	0.02^{NS}
Na (%)	0.07	0.06	0.17	0.11	0.02^{NS}	0.04	0.05	0.15	0.09	0.03^{NS}
Fe (ppm)	11.70	11.48	82.12	50.11	0.31	10.30	10.67	78.69	41.78	0.28*
Mn (ppm)	11.9	11.4	97.6	86.7	2.12	9.5	9.1	96.5	79.5	2.61*
Zn (ppm)	1.17	1.13	58.6	39.4	0.25	1.10	10.09	57.5	39.8	0.34*
Cu (ppm)	1.50	1.61	20.8	15.6	0.28	0.94	0.97	20.6	15.2	0.33*

Values are $\bar{X}$ of six observations; * Significant at $p < 0.01\%$ level; T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5 tonnes ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK

Altogether there were 36 plots, four replicate in each for clay loam soil (CLS) and sandy loam soil (SLS). Beans *(Phaseolus vulgaris)* was grown as test crop. Treatments consisted of T_1 - control (without application of inorganic NPK or vermicompost); T_2 - 100% recommended dose of NPK (20:80:40 kg ha^{-1}); T_3 - 100% recommended dose of vermicompost (5t ha^{-1}) and T_4 - 50% vermicompost supplemented with 50% NPK (W/W). Inorganic NPK was applied through urea, single super phosphate and muriate of potash. Inorganic NPK and vermicompost were applied to the soil by basal application at the time of sowing of beans.

Analysis of physico-chemical and biological properties: Soil samples were collected from each plot from 0-15cm depth in two different periods: Initial (I) - 0 day (before application of NPK and vermicompost and beans sowing) and final (F) - 75 days (after harvesting of beans). Physical properties of the soil like porosity, particle density and bulk density were determined by specific gravity bottle method of Kanwar and Chopra (1980), water holding capacity (WHC) was determined by the procedure of Baruah and Barthakur (1999) and cation exchange capacity (CEC) was estimated by ammonium saturation method of Jackson (1973). Chemical parameters like pH and electrical conductivity (EC) were determined by ISI Bulletin (1982) by using digital pH and conductivity meters, organic carbon (OC) was estimated by following the procedure of Walkley and Black (1934), available nitrogen, phosphorus and potassium were estimated respectively by alkaline potassium permanganate method of Subbiah and Asija (1956), Olsen *et al.* (1954) and neutral normal ammonium acetate method of Standford and English (1949). Sodium, calcium and magnesium content were determined following the method of Tandon (1993). Zinc and copper were estimated by atomic absorption spectrophotometer(AAS) (Tandon, 1993). Iron and manganese were estimated Spectrometrically (Jackson, 1973; Chopra and Kanwar, 1991). Total microbial population was estimated according

Table - 3: Effect of vermicompost and NPK on the biological properties in post-harvest soils

Biological parameters	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
Bacteria (CFU x 10^6 g^{-1})	42.6	40.1	50.4	45.1	1.08*	32.1	29.1	36.2	33.1	1.03*
Fungi (CFU x 10^4 g^{-1})	40.1	32.1	42.1	41.0	0.49*	28.7	26.5	35.1	30.2	0.45*
Actinomycetes (CFU x 10^5 g^{-1})	8.5	7.1	10.7	9.5	0.19*	6.3	6.0	7.5	6.9	0.15*
Total microbial population (CFU x 10^6 g^{-1})	43.8	41.1	51.8	46.5	2.12*	33.0	29.9	37.2	34.1	2.38*
Microbial activity (5ml H/5g)	4.1	4.0	5.9	4.8	0.13*	3.1	3.0	4.6	4.1	0.09*

Values are $\bar{x}$ of six observations; * Significant at $p < 0.01\%$ level; T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5 tonnes ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK

Table - 4: Effect of vermicompost and NPK on growth parameters (after 20 days) of beans (*Phaseolus vulgaris*)

Growth parameters	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
Root length (cm)	9.0	9.4	9.8	11.5	0.72*	7.0	7.9	7.7	10.2	0.87*
Shoot length (cm)	31.0	34.5	34.8	40.3	0.39*	28.1	30.4	31.5	34.2	0.35*
Leaf area index (cm^2)	45.8	52.1	54.2	61.5	0.71*	40.1	48.3	48.5	51.2	0.68*
No. of root nodules (No p^{-1})	18	19	25	29	0.12*	14	16	19	23	0.15*
No. of root branches (No p^{-1})	3	5	5	9	0.11*	3	5	5	9	0.07*
No. of shoot branches (No p^{-1})	4	6	6	8	0.03^{NS}	4	6	6	8	0.02^{NS}
Root dry weight (g p^{-1})	0.131	0.145	0.143	0.172	0.31*	0.123	0.140	0.142	0.165	0.26*
Shoot dry weight (g p^{-1})	1.61	1.65	1.66	1.97	0.52*	1.42	1.53	1.57	1.71	0.43*

Values are $\bar{x}$ of six observations; * Significant at $p < 0.01\%$ level, T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5 tonnes ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK

to the method of Baron *et al.* (1994) and expressed as CFU x 10^6 g^{-1} and microbial activity in terms of dehydrogenase activity by adopting the procedure of Stevenson (1959) and expressed as μl H/5g substrate.

Measurement of growth and yield parameters: Ten competitive plants were randomly selected on 20, 40 and 60th days for the measurement of various morphological growth parameters (root and shoot length, leaf area index, number of root nodules, number of root and shoot branches, root and shoot dry weight) and biochemical constituents - chlorophyll in the leaves (Arnon, 1949), sugar (Nelson, 1944) and protein (Lowry *et al.,* 1951) in the leaf, shoot, root at 45 days and seed and the yield (pod length, number of seeds/pod, number of pods/plant and pod weight) were determined on the 75th day. The results were statistically analyzed as critical differences (CD values) at $p<0.01$ level using Analysis of Variance with interaction effect (ANOVA-RBD).

Results and Discussion

The effects of application of NPK(T_2), ptb vermicompost (T_3) and ptb vermicompost supplemented with NPK (T_4) on the physical, chemical and biological properties of CLS and SLS, of post harvest of beans were represented in the Tables 1-3.

Effect on physical properties of soils: The porosity, WHC and CEC of CLS and SLS were significantly increased in soil treated with 100% ptb vermicompost (T_3), followed by 50% ptb vermicompost supplemented with 50% NPK (T_4) when compared to control (T_1). On the contrary these qualities were observed to be decreased significantly in soil treated only with 100% NPK (T_2). Further, the decrease in particle density and bulk density was more both in CLS and SLS treated with ptb vermicompost (T_3) and ptb vermicompost supplemented with NPK (T_4) when compared to soil treated with only NPK (T_2) (Table 1). The long-term application of inorganic fertilizers without organic supplements damages the soil's physical properties (Goyal *et al.,* 1999). Earthworms play an important role in the process of soil formation and soil aggregation, mainly through the production of casts. Edwards and Bohlen (1996) reported that earthworm cast contains more water stable aggregate than the surrounding soil. Earlier studies have shown that vermicast appears to be enriched with polysaccharides which act in the soil as cementing substances causing aggregate stability, contributing to create and maintain the soil structure and causing better aeration, water retention, drainage and aerobic conditions, very useful for root development and nutrient availability to plants (Tomati and Galli, 1995). In the present study indicated that there was increased porosity in T_3 and T_4 plots which might be due to aggregation of the

Table - 5: Effect of vermicompost and NPK on growth parameters (after 40 days) of beans (*Phaseolus vulgaris*)

Growth parameters	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
Root length (cm)	14.0	17.3	17.7	21.1	0.73	12.1	15.0	15.6	19.2	0.81*
Shoot length (cm)	37.5	41.1	43.5	55.0	0.41	35.4	39.2	39.7	50.2	0.31*
Leaf area index (cm^2)	80.05	112.8	134.0	180.0	0.69	71.05	113.4	111.2	162.4	0.67*
No. of root nodules (No p^{-1})	21	29	34	39	0.18	19	26	29	32	0.14*
No. of root branches (No p^{-1})	11	12	13	15	0.02^{NS}	11	13	12	14	0.04^{NS}
No. of shoot branches (No p^{-1})	8	10	10	14	0.13	7	9	9	12	0.14*
Root dry wt. (g p^{-1})	0.154	0.287	0.331	0.427	0.39	0.134	0.282	0.291	0.386	0.41*
Shoot dry wt. (g p^{-1})	1.90	3.4	3.9	5.2	0.42	1.82	3.0	3.1	4.9	0.37*

Values are $\bar{x}$ of six observations; * Significant at p < 0.01% level, T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5 tonnes ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK

Table - 6: Effect of vermicompost and NPK on growth parameters (after 60 days) of beans (*Phaseolus vulgaris*)

Growth parameters	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
Root length (cm)	15.7	17.6	19.2	22.4	0.92*	13.3	15.4	16.1	20.2	0.85*
Shoot length (cm)	40.0	48.1	54.2	69.1	0.38*	35.1	41.2	43.2	61.2	0.41*
Leaf area index (cm^2)	91.77	140.2	155.1	210.7	0.51*	80.2	115.4	107.2	181.0	0.59*
No. of root branches (No. p^{-1})	12	14	14	17	0.08*	11	14	14	17	0.02^{NS}
No. of shoot branches (No. p^{-1})	9	11	11	13	0.17*	9	10	11	13	0.15*
Root dry wt. (g.p^{-1})	0.871	1.42	1.45	2.01	0.28*	0.801	1.12	1.10	1.95	0.35*
Shoot dry wt. (g.p^{-1})	3.8	4.9	4.7	5.8	0.51*	2.9	3.5	3.2	4.9	0.42*

Values are $\bar{x}$ of six observations; * Significant at p < 0.01% level, T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5 tonnes ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK

soil particles by the action of microorganisms in the ptb vermicompost that are known to produce polysaccharides that provide a cementing action between the soil particles. Edwards and Bohlen (1996) and Zaller (2007) suggested the polysaccharides to stabilize the soil aggregates and also the fungal mycelia could contribute to soil aggregation.

In the present study particle and bulk density were found to be significantly decreased in T_3 and T_4 treatments. Earlier Vasanthi and Kumaraswamy (1999) reported reduction in bulk density of the soil treated with vermicompost supplemented with NPK. The decreased particle and bulk density in the present study was mainly due to the enhanced microbial population and activity that resulted in the formation of aggregates and increased porosity. Aggregation of soil and its water use efficiency improved with increasing dose of vermicompost upto a particular level (Bhattacharjee *et al.,* 2001). The increased WHC in T_3 and T_4 treatments, in the present study, was due to increased porosity and decreased bulk density of the soil due to vermicompost application and these in turn provide greater aeration and drainage. Similarly the significantly increased CEC in T_3 and T_4 plots in the present study might be due to higher amount of organic matter in the ptb vermicompost. Vasanthi and Kumaraswamy (1999) also reported that there was a significant increase in CEC of the soil treated with vermicompost supplemented with NPK.

Effect on chemical properties of soils : The application of NPK (T_2) was found to enhance slightly the pH of the CLS and SLS. On the contrary, a very slight decrease in pH was observed in both soils treated with ptb vermicompost (T_3) (Table 2). Application of ptb vermicompost (T_3) revealed that EC had been reduced in CLS than the control (T_1). But EC in SLS was slightly decreased in all the treatments (Table 2). OC had been phenomenally enhanced in both the soils but especially in SLS, treated with ptb vermicompost (T_3) and ptb vermicompost plus NPK (T_4) (Table 2). There was a significantly increase in the available N, P, K, total Ca and micronutrients such as Zn, Fe, Cu and Mn in both CLS and SLS of T_3 and T_4 than the plots treated only with NPK (T_2), as well as T_1 (Table 2).

pH range between 6-7 seems to promote the availability of nutrients to the plants (Brady, 1988). Decreased pH 6.41 and 6.66 were observed in the soils treated with enriched compost of industrial wastes, after harvest of ragi and cowpea (Srikanth *et al.,* 2000). Similarly in the present study due to application of ptb vermicompost (T_3) to CLS and SLS, a very slight decrease from 7.15 to 7.08 in CLS and 7.14 to 6.97 in SLS in pH was observed which might be due to the acidifying effects of organic acids produced during the course of decomposition of organic amendments and or the increased permeability and leaching of salts. Similarly low EC was observed in the soils treated with vermicompost which is similar to

Table - 7: Effect of vermicompost and NPK on chlorophyll, sugar and protein content in different plant parts of beans at (flowering stage on 45th day)

Biochemical contents	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
Chlorophyll (mg g^{-1} fresh wt.)	223	320	360	389	0.17*	213	290	322	361	0.18*
Sugar (mg g^{-1} fresh wt.)										
Root	150	185	210	235	0.05*	147	165	197	218	1.01*
Shoot	135	168	199	209	1.71*	135	147	185	201	1.87*
Leaf	165	179	181	208	1.19*	140	162	180	203	1.18*
Protein (mg g^{-1} fresh wt.)										
Root	115	126	135	147	0.72*	112	123	134	142	0.81*
Shoot	118	127	130	149	0.41*	109	120	130	147	0.23*
Leaf	123	134	142	151	0.19*	113	125	138	149	0.17*

Values are $\bar{x}$ of six observations; * Significant at $p < 0.01\%$ level, T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5 tonnes ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK

Table - 8: Effect of vermicompost and NPK on yield parameters of beans (*Phaseolus vulgaris*)

Growth parameters	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
Pod length (cm)	11.0	14.5	15.5	18.5	0.72*	10.5	15.0	14.5	17.5	0.61*
No. of seeds pod^{-1}	5.0	6.0	6.0	9.0	0.08*	5.0	6.5	6.0	10	0.04^{NS}
No. of pods $plant^{-1}$	9	17	19	24	0.48*	7	15	18	21	0.42
Pods weight (kg ha^{-1})	6750	9625	11259	14375	0.21*	4750	7250	7100	11300	0.37

Values are $\bar{x}$ of six observations; * Significant at $p < 0.01\%$ level, T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5 tonnes ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK

Table - 9: Effect of vermicompost and NPK on the sugar and protein content in the beans (*Phaseolus vulgaris*) after harvesting at 75 days

Biochemical contents	Clay loam soil					Sandy loam soil				
	T_1	T_2	T_3	T_4	CD values	T_1	T_2	T_3	T_4	CD values
Sugar (mg g^{-1} dry wt.)	210	240	262	290	0.21*	201	235	259	285	0.18*
Protein (mg g^{-1} dry wt.)	290	310	321	382	0.32*	262	295	307	329	0.23*

Values are $\bar{x}$ of six observations; * Significant at $p < 0.01\%$ level, T_1 = Control (without application of inorganic fertilizer or manure), T_2 = Recommended dose of NPK (20:80:40 kg ha^{-1}), T_3 = Recommended dose of vermicompost (5 tons ha^{-1}), T_4 = Application of 50% vermicompost + 50% NPK

the observation where enriched compost, FYM and vermicompost applications were made where ragi and cowpea were grown (Srikanth *et al.,* 2000).

The deficiency in OC reduces the storage capacity of soil nutrients and reduction in soil fertility (Kale *et al.* 1992). Vasanthi and Kumaraswamy (1999) and Srikanth *et al.* (2000) reported that the incorporation of various enriched compost, FYM and vermicompost have been shown to increase OC content in the soil. In the present study OC content had been phenomenally enhanced in CLS and SLS treated with vermicompost (T_3) and vermicompost plus NPK (T_4). Hervas *et al.* (1989) reported that the organic fraction of vermicompost is upto over 50% of the total weight. So it can be concluded that increased OC content in the soil, in the present study, is mainly due to higher amount of OC content in the ptb vermicompost. Also available N, P, K, total Ca, Mg, Na, Zn, Fe, Cu and Mn were significantly increased in CLS and SLS treated with ptb vermicompost (T_3) and ptb vermicompost plus NPK (T_4). Bhattacharjee *et al.* (2001) reported that application of vermicompost reduces the loss of nutrients through leaching from the soil by changing the soil's physicochemical properties. Increased available NPK in the soils was observed where the soils were treated, respectively, with enriched compost from different organic wastes, FYM, vermicompost and vermicompost plus NPK after the harvest of rice, ragi and cowpea (Vasanthi and Kumaraswamy, 1999; Srikanth *et al.,* 2000; Chaoui *et al.,* 2003).

Effect on biological properties of soils: The total microbial population and activity had been significantly enhanced in both the kinds of soils treated with ptb vermicompost (T_3) and ptb vermicompost was supplemented with NPK (T_4) (Table 3). A very striking feature of the application of NPK (T_2) to these soils is the significant reduction in total microbial population and activity and the reduction was even lesser than the values observed in the control field (T_1) where neither organic or inorganic fertilizer was applied. Organic residues were found to increase the size, biodiversity and activity of the microbial population in soil (Albiach *et al.,* 2000). Zink and Allen (1998) found that the application of the composts enhanced microbial population and activity in the soil. Further, Goyal *et al.* (1999) observed that soil organic matter level, soil microbial biomass and activities were increased with the use of organic fertilizer. In the present study, total microbial population and activity had been significantly enhanced in both CLS and SLS where vermicompost (T_3) and vermicompost plus NPK (T_4) were applied. The greater pore volume in vermicompost amended soils increased the availability of both water and nutrients to microorganisms in soils (Scott *et al.,* 1996). On the contrary, application of NPK had resulted in the reduction of microbial population in T_2 plots which is due to reduction of OC content in the soil, compaction, reduced porosity, reduced WHC and reduced micronutrients.

Effect on growth, grain and yield quality: The effects of application of NPK and ptb vermicompost on the growth, biochemical parameters and yield of beans were represented in the Tables 4-9. Conspicuous effects were observed on the growth and yield of beans in plots fertilized with 50% vermicompost supplemented with 50% NPK (T_4). Growth parameters such as shoot and root length, leaf area index and number of root nodules were all enhanced (Tables 4-6). Enhanced sugar, protein and chlorophyll contents of root, shoot and leaf (flowering stage - 45th day) were also observed (Table 7). Similarly the highest yield (Table 8), enhanced sugar and protein contents in the beans (pods) (Table 9) were observed in T_4 treatments than plants treated either with vermicompost (T_3) or NPK (T_2). Pod length, number of seeds/pod, number of pods/plant and pod weight were more in T_4 plots. Especially these effects were more in CLS than SLS. Effect of vermicompost (T_3) on all these parameters was only slightly lesser than the T_4 application.

Vermicompost could serve as a naturally produced, slow release source of plant nutrients and their amendment has been shown to increase plant dry weight (Edwards, 1995) and plant N uptake (Tomati *et al.,* 1990). Application of vermicompost in combination with chemical fertilizer resulted in larger leaf area index (Jeyabal and Kuppuswamy, 2001). With a higher leaf area index, plants become photosynthetically more active, which would contribute to improvement in yield attributes (Sharma and Mittra, 1988). Kale *et al.* (1992) reported increase in the rates of uptake of nutrients with increase in the symbiotic microbial association in cereal and ornamental plants with the use of vermicompost. Vasanthi and Kumaraswamy (1999) also reported that vermicompost at the rate of 5t ha^{-1} would be sufficient for production of rice crop when applied with recommended doses of N, P and K. Falling in line with these observations, the present study showed, significantly higher growth, yield and biochemical contents in the beans harvested from soil treated with vermicompost supplemented with NPK (T_4), followed by soil treated with 100% vermicompost (T_3) than the soil treated only with NPK (T_2).

In conclusion, the increased growth, yield and quality of beans are due to application of ptb vermicompost which improved the physical conditions of the soil which support better aeration to plant root, drainage of water, facilitation of cations N^+, P^+ and K^+ exchange, sustained availability of nutrients, and thereby the uptake by the plants resulting in better growth. The T_4 treatment supplies higher macro and micronutrients to the soil and plants in the available form which results in better growth, yield and quality of beans. Among the two types of soil, CLS seems to be better than SLS because CLS has better physical, chemical and biological properties and hence the growth, yield and quality of beans were also better. Hence the use of ptb vermicompost alone or in combination with chemical fertilizers is recommended for improving the long-term soil fertility and crop productivity.

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