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Studies on agricultural waste management through preparation and utilization of organic manures for maintaining soil quality

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Solid waste management has become one of the vital issues to protect health and public safety. Preparation of organic manures like vermicompost, Farm Yard Manure (FYM) etc. from various organic wastes (agricultural wastes) will save our environment from pollution as well as application of these manures in agricultural land prevent those lands from the harmful effect of chemical fertilizers. With these views keeping in background for saving our environment from ill effects of indiscriminate use of chemical fertilizers by substituting them partially or entirely through applying organic manures after converting agricultural wastes into wealth (organic manures), an experiment was carried out in the farmer's field at village Shikarpur (P.O. Bhagirathi Shilpashram, Dist. Nadia, Pin. 741248, W.B., India) during the year 2008 to 2010 with two crops (rice –rainy season and Lentil –winter season). The experiment was laid out in randomized block design with 5 treatments (T_0- without fertilizer or manure, T_1-100% organic through vermicompost, T_2- 100% organic through FYM, T_3-100% chemical through fertilizer and T_4-50% organic through mixed organic manure + 50% chemical through fertilizer) replicated 3 times. It has been found that the vermicompost treated soil showed better result in comparison to that demonstrated by the chemical fertilizers in terms of soil physical and chemical properties as well as productivity of soil.

Key words: Organic waste, vermicompost, farm yard manure, soil quality, chemical fertilizer.

INTRODUCTION

Wastes which arise virtually from all human activities can be classified conveniently with respect to their source. Major categories include household and consumer wastes (for example, municipal wastes), industrial wastes, agricultural wastes, extraction wastes, energy production wastes and sewage sludges. Waste produced by agricultural activities comprises crop residues, stubbles, straws, animal slurries, silage effluents, weeds etc. With the increase in global temperature, weeds which are mostly of C_4 types are sustaining in a better way due to increased rate of photosynthesis with decreasing photorespiration. Thus, these weeds are occupying fallow lands vis-à-vis are encroaching agricultural land in a vigorous way. Huge biomass of these weeds after destruction are being dumped in open site; creating nuisance to environment. India alone produces more than 400 million tones of agricultural wastes annually. It has got a very large percentage of total world production of rice husk, jute, stalk, baggase, groundnut shell and coconut fiber etc. (Raju et al., 2012).

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Increase in cropping intensity results in generation of huge biomass throughout the year from agricultural fields. After harvesting, threshing and post harvest processing bulk amount of crop residues and stubbles remains dumped in the agricultural land or nearby areas. These wastes may cause tremendous environmental pollution which may affect health and wellbeing of living organisms including human. Accumulation and putrefaction of these wastes and consequent adverse effects on surroundings have become a serious issue. To get rid of such situation, proper management of these organic wastes is very essential. In one scenario, there is trouble associated with organic waste management. In the other scenario, there is a problem related to intensive use of chemical fertilizers which is creating toxicity in soil of agricultural fields. Sometimes these toxic chemicals accumulate in plants as a residue of fertilizer added.

Frequent application of chemical fertilizers is deteriorating bio- physico- chemical properties of soil. As a result, soil fertility is being diminished gradually. This in turn is leading to reduction in crop yield per unit area. So it is an urgent need to reduce the use of chemicals in agricultural fields by using organics more and more. Use of organic manures produced/prepared from various organic wastes will save our environment as a whole; simultaneously organic wastes can also be managed properly. Moreover, it enhance soil health which is the balance between soil function for productivity, environmental quality, and plant and animal health (Doran and Zeiss, 2000; Doran, 2002). In this context, use of organic manures such as vermicompost, FYM etc. may supply sufficient amount of micro nutrients in available form to crops and improve the quality of the agricultural produces (Maynard, 1993). Besides supplying various nutrients to the current crop, they often leave substantial residual effect to succeeding crops. Application of organic manures helps to improve health as well as quality of soil. According to Doran et al. (1998), soil quality is the capacity of a living soil to function within natural or managed ecosystem boundaries. Soil health and soil quality are functional concepts which indicate how fit the soil is to support plant and animal productivity, maintain water and air quality, and support plant and animal health. Thus, soil quality can be regarded as soil health (Doran et al., 1996).

In the era of globalization, time has come to think about organic agriculture or organic farming in India also to sustain in globalized market of quality agricultural products. Vermicomposting is the process of producing compost through the action of earthworm. It is an eco-biotechnological process that transforms energy-rich and complex organic substances into stabilized humus-like product vermicompost. Preparation of vermicompost is an efficient as well as easily adoptable technique of compost preparation. This composting system can not only decompose a huge amount of organic wastes but also help to maintain higher nutrient status in composted materials (Ceccanti and Masciandaro, 1999; Lazcano and Domínguez, 2011; Hema and Rajkumar, 2012). Keeping all these thoughts in background with the broader objective of saving our environment as a whole through proper management of agricultural wastes, a field experiment was carried out at village Shikarpur, Bhagirathi Shilpashram, Nadia- 741248, West Bengal, India to prepare organic manure from low-cost locally available organic waste through vermiculture biotechnology with the intension of substituting chemical fertilizers partially or entirely, augmenting soil quality for sustainability in agricultural production and to study the physical and chemical properties of soil in agricultural fields and also to establish the efficacy of vermicompost in comparison to chemical fertilizers and FYM vis-à-vis other organic manures.

MATERIALS AND METHODS

The name and address of the owner of vermicompost and FYM unit

Mr Animesh Mondal, Shantinagar, Madanpur, Nadia -741245, West Bengal, India (latitude-23° 0' 15.69'' N, longitude-88° 29' 24.32'' E).

Composts preparation and analysis

Vermicompost and FYM were prepared by Heap (Basak et al., 2011) and Trench methods, respectively (Sahai, 2004). The chemical properties (organic carbon, total nitrogen, total phosphorus, and total potash) of these manures were analysed. The organic carbon was determined by Walkley and Black's rapid titration method (Jackson, 1973). Total nitrogen was estimated by modified macro Kjeldahl method (Jackson, 1973). Total phosphorus was determined by Olsen's method (Jackson, 1973) and total potash was determined by the flame photometer method (Jackson, 1973).

Location and soil type of the experimental site

Shikarpur, Bhagirathi Shilpashram, Nadia-741248, West Bengal, India (latitude-23° 1' 53.62'' N, longitude-88° 30' 46.97'' E). According to textural classes proposed by U. S. Bureau of soils (Sahai, 2004), soil of experimental site was sandy loam in texture because it consisted of 73.7% sand, 10% silt and 16.3% clay.

Analysis of soil

After collection (twice- before crop establishment and after harvesting of crops), the soil samples were prepared for analyses in the laboratory. For preparation of soil samples different procedures were involved such as: drying, grinding, mixing, partitioning, sieving etc. Different physical and chemical properties were analysed by using different methods. Bulk density was determined by the method of Blake and Hartge (1986). Total porosity was estimated from the bulk density and particle density. Mechanical analysis of soil samples was determined following the Boyoucous hydrometer method (Gee and Bauder, 1986). The water holding capacity (WHC) of the soil was measured with the help of Keen- Rackzowski box as described by Baruah and Barthakur (1997). Saturated hydraulic conductivity was calculated by Dracy's equation. Water stable aggregates and their distribution in each soil layer under

Table 1. Chemical composition of applied vermicompost and FYM.

Composts	Organic C (%)	Total N (%)	Total P_2O_5 (%)	Total K_2O (%)
Vermicompost	11.9	1.23	2.06	0.78
FYM	5.29	0.53	0.25	0.6

different treatments were determined by wet sieving method as described by Yoder (1936). The pH of the soil sample was measured with the help of Backman's pH meter. Organic carbon was determined by Walkley and Black's rapid titration method (Jackson, 1973). Available nitrogen was estimated by Kjeldahl method (Jackson, 1973). Available phosphorus was determined by Olsen's method (Jackson, 1973) and available potassium was estimated by the flame photometer method (Jackson, 1973).

About crops

Two crops namely rice / *Oryza sativa* L. (rainy season- July to November) and lentil / *Lens culinaris Medik.* (winter season- November to March) were selected and sown. Their varieties were IET-4094 (Khitish) and B-77 (Asha), respectively. The experiment was laid out in randomized block design with 5 treatments (T_0- without fertilizer or manure, T_1-100% organic through vermicompost, T_2- 100% organic through FYM, T_3-100% chemical through fertilizer and T_4-50% organic through mixed organic manure + 50% chemical through fertilizer) replicated 3 times. Yield was recorded and statistically analyzed during two successive cropping years (2008 to 2009 and 2009 to 2010).

RESULTS AND DISCUSSION

In present research, following chemical analysis of organic manures (Table 1), it was found that the applied vermicompost contained 11.9% organic carbon, 1.23% total nitrogen, 2.06% total phosphorus and 0.78% total potash. Similar results were observed by Purohit (2006) and Palaniappan and Annadurai (2008). They opined that depending upon the nature of substrate, on an average the vermicompost contained 10.12 to 11.98% organic carbon, 1.09 to 2.75% total nitrogen, 2 to 2.45% total phosphorus and 0.78 to 1.39% total potash. Chemical compositions of applied FYM in current study were 5.29% organic carbon, 0.53% total nitrogen, 0.25% total phosphorus and 0.6% total potash. This result is also in agreement with those observed by Sahai (2004) and Roychoudhury et al. (2010). In their study, FYM contained on an average of 5.1 to 5.4% organic carbon, 0.52 to 0.56% total nitrogen, 0.23 to 0.28% total phosphorus and 0.58 to 0.63% total potash. Table 2 exhibits the comparison of various physical properties of soil for different treatments (T_i- initial property of soil or property of soil before crop establishment,T_0- without fertilizer or manure, T_1- 100% organic through vermicompost, T_2- 100% organic through FYM, T_3-100% chemical through fertilizer and T_4-50% organic + 50% chemical). From this table, it is clear that the bulk density value was found to be insignificantly ($p>0.05$) increased while results of treatment T_0 was compared with initial state of the soil before crop establishment (Ti). For all the treatments except T_3 (100% chemical through fertilizer), bulk density values significantly ($p \leq 0.05$) reduced in comparison to control that is, T_0 (without fertilize or manure). This value significantly ($p \leq 0.05$) reduced in case of T_1 comparison to T_3. This reduction in the values of bulk density might be due to the presence of organic materials in all those treatments (T_1, T_2, and T_4).

According to Miller et al. (2002) and Shirani et al. (2002), application of organic materials (manure and/or crop residues) can increase soil organic matter concentration and decrease bulk density. The value of porosity was significantly ($p \leq 0.05$) decreased in case of T_0 when compared with T_i. There was no significant ($p>0.05$) increase in porosity value while result of treatment T_0 (without fertilize or manure) was judged against the treatment T_3 (100% chemical through fertilizer). Significant ($p \leq 0.05$) increase in porosity values were found in case of treatment T_1 (100% organic through vermicompost) in comparison to both T_3 (100% chemical through fertilizer) and T_0 (without fertilize or manure). This indicates that treatment with 100% vermicompost is very much beneficial for enhancing porosity of soil. According to Sahai (2004), organic manure increases percentage of pore space in soil. Jadhav et al. (1993) noticed that application of vermicompost increased soil porosity. Table 2 also depicts that percentage of maximum water holding capacity was found to be significantly ($p \leq 0.05$) decreased while result of treatment T_0 (without fertilize or manure) was evaluated against treatment Ti (initial state of the soil before crop establishment). This value was increased significantly ($p \leq 0.05$) when T_1 (100% organic through vermicompost), T_2 (100% organic through FYM), T_3 (100% chemical through fertilizer) and T_4 (50% organic + 50% chemical) were compared with T_0 (without fertilize or manure). Percentage of maximum water holding capacity significantly ($p \leq 0.05$) increased in case of T_1 (100% organic through vermicompost) in comparison to T_3 (100% chemical through fertilizer). According to Biswas and Khosla (1971), addition of organic manures significantly improved water holding capacity of soil, compared to sole inorganic fertilizer application. Change was found to be insignificant ($p>0.05$) while saturated hydraulic conductivity of initial state of the soil before crop establishment (Ti) was compared with treatment T_0 (without fertilize or manure). Value of saturated hydraulic conductivity was significantly ($p \leq 0.05$) reduced for treatments T_1 (100% organic through vermicompost), T_2 (100% organic

Table 2. Comparison of various physical properties of soil for different treatments.

Replication	Treatments						Significance of differences (p-values)					
Bulk density ($g.cm^{-3}$)												
	T_i	T_0	T_1	T_2	T_3	T_4	Ti/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	1.61	1.65	1.42	1.46	1.64	1.5	0.19	0.00	0.00	0.57	0.01	0.00
R_2	1.65	1.69	1.46	1.42	1.66	1.48						
R_3	1.66	1.67	1.41	1.52	1.68	1.57						
mean	1.64	1.67	1.43	1.47	1.66	1.52						
sd	0.026	0.020	0.026	0.050	0.020	0.047						
Porosity (%)												
	T_i	T_0	T_1	T_2	T_3	T_4	Ti/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	39.01	36.9	46.1	40.12	37.01	39	0	0	0	0.11	0	0
R_2	39.09	37	46.4	40.1	37.03	39.02						
R_3	39.11	36.8	46.1	40.02	37.02	39.01						
mean	39.07	36.9	46.2	40.08	37.02	39.01						
sd	0.053	0.1	0.173	0.053	0.01	0.01						
Maximum water holding capacity (%)												
	T_i	T_0	T_1	T_2	T_3	T_4	Ti/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	38.94	36.4	46.05	44.13	38.39	43.07	0.01	0	0	0.01	0	0
R_2	38.89	37.6	46.07	44.2	38.41	43.15						
R_3	38.93	37	46.09	44.12	38.46	43.14						
mean	38.92	37	46.07	44.15	38.42	43.12						
sd	0.026	0.6	0.02	0.044	0.036	0.044						
Saturated hydraulic conductivity ($cm.h^{-1}$)												
	T_i	T_0	T_1	T_2	T_3	T_4	Ti/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	1.3	1.5	0.02	0.02	0.47	0.35	0.85	0.00	0.00	0.01	0.00	0
R_2	1.1	1.1	0.04	0.03	0.5	0.4						
R_3	1.2	1.09	0.03	0.07	0.5	0.39						
mean	1.2	1.23	0.03	0.04	0.49	0.38						
sd	0.1	0.234	0.01	0.026	0.017	0.026						
Aggregate ratio												
	T_i	T_0	T_1	T_2	T_3	T_4	Ti/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	0.6	0.61	0.75	0.3	0.24	0.53	0.39	0.00	0.00	0	0.01	0
R_2	0.62	0.67	0.79	0.35	0.27	0.55						
R_3	0.64	0.64	0.8	0.31	0.27	0.56						
mean	0.62	0.64	0.78	0.32	0.26	0.55						
sd	0.02	0.03	0.026	0.026	0.017	0.015						
Percentage aggregate stability (%)												
	T_i	T_0	T_1	T_2	T_3	T_4	Ti/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	37.15	37.03	38.24	27.6	20.07	32.1	0.10	0	0.00	0	0	0
R_2	37.2	37.12	38.25	27.4	20.14	32.8						
R_3	37.22	37.15	38.26	27.5	20.09	32.6						
mean	37.19	37.1	38.25	27.5	20.1	32.5						
sd	0.036	0.062	0.01	0.1	0.036	0.361						
Mean weight diameter (mm)												
	T_i	T_0	T_1	T_2	T_3	T_4	Ti/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	1.1	1.02	0.56	0.5	0.32	0.52	0.02	0	0	0	0	0.00
R_2	1.12	1.06	0.59	0.55	0.37	0.57						
R_3	1.17	1.04	0.59	0.51	0.39	0.56						
mean	1.13	1.04	0.58	0.52	0.36	0.55						
sd	0.036	0.02	0.017	0.026	0.036	0.026						

T_i- Initial property of soil or property of soil before crop establishment, T_0- without fertilizer or manure, T_1- 100% organic through vermicompost, T_2- 100% organic through FYM, T_3- 100% chemical through fertilizer and T_4- 50% organic + 50% chemical.

through FYM), T_3 (100% chemical through fertilizer) and T_4 (50% organic + 50% chemical) in comparison to treatment T_0 (without fertilize or manure). This value significantly ($p \leq 0.05$) reduced in case of T_1 comparison to T_3.

Change was found to be insignificant ($p > 0.05$) while soil aggregate ratios of initial state of the soil before crop establishment (Ti) was compared with treatment T_0 (without fertilize or manure). Apparent decrease in values of soil aggregate ratios (after two years) was statistically significant ($p \leq 0.05$) for all treatments except the treatment T_1 (100% organic through vermicompost) in comparison to treatment T_0 (without fertilize or manure). Significant ($p \leq 0.05$) increase was observed in case of treatment T_1 (100% organic through vermicompost) in comparison to the treatment T_3 (100% chemical through fertilizer). Significant ($p \leq 0.05$) changes in soil aggregate stability was found for any treatment under present study following two years in comparison to treatment T_0 (without fertilize or manure) except initial state of the soil before crop establishment (Ti). This value significantly ($p \leq 0.05$) reduced in case of T_3 comparison to T_1. The value of mean weight diameter was significantly ($p \leq 0.05$) decreased in case of T_0 (without fertilize or manure) comparison to treatment Ti (initial state of the soil before crop establishment). Significant ($p \leq 0.05$) decrease were observed in case of treatments T_1 (100% organic through vermicompost), T_2 (100% organic through FYM), T_3 (100% chemical through fertilizer) and T_4 (50% organic + 50% chemical) in comparison to T_0 (without fertilize or manure). In case of treatment T_1 (100% organic through vermicompost), this value was significantly ($p \leq 0.05$) increased compared with T_3 (100% chemical through fertilizer).

Application of vermicompost to soil gives a tremendous boost to soil physical health by improving water-holding capacity, structure formation and also by enhancing fertility (Jeyabal and Kuppuswamy, 2001; Edwards, 1998). Table 3 indicates the chemical properties of soil after harvesting of crops. This table enumerates the pH of soil was decreased insignificantly ($p > 0.05$) while pH value of soil before crop establishment (Ti) was compared with treatment T_0 (without fertilize or manure). Values of pH were decreased insignificantly ($p > 0.05$) for treatments T_1 and T_2 and increased insignificantly ($p > 0.05$) in case of T_3 contrasted with treatment T_0. In case of treatment T_1 (100% organic through vermicompost), this value was insignificantly ($p > 0.05$) decreased compared with T_3 (100% chemical through fertilizer). From this study, it was evident that organic manure alone can decrease the alkalinity of soil rapidly than chemical fertilizer. A study to know effect of FYM on soil pH showed that there was decrease in pH from 7.99 to 7.65 and each increment of FYM reduced the soil pH significantly due to organic acid production during its decomposition (Patil et al., 2003).

There was significant ($p \leq 0.05$) decrease in percentage of organic carbon while result of treatment T_0 (without fertilizer or manure) was judged against initial state of the soil before crop establishment (Ti).

Significant ($p \leq 0.05$) increase in percentage of organic carbon was found in case of treatments T_1, T_2 T_3 and T_4 when it was evaluated against the treatment T_0. The percentage of organic carbon was significantly ($p \leq 0.05$) increased in case of treatment T_1 (100% organic through vermicompost) compared with T_3 (100% chemical through fertilizer). Reduction in percentage of total nitrogen was found to be insignificant ($p > 0.05$) in case of treatment T_0 (without fertilizer or manure) when it was compared with initial state of the soil before crop establishment (Ti). Percentages of total nitrogen was significantly ($p \leq 0.05$) increased for treatments T_1 (100% organic through vermicompost), T_3 (100% chemical through fertilizer) and T_4 (50% organic + 50% chemical) in comparison to treatment T_0 (without fertilizer or manure). These results indicate that in general organic manures as well as chemical fertilizers have positive impact on total nitrogen of soil. The percentage of total nitrogen was significantly ($p \leq 0.05$) higher in case of T_1 in comparison to treatment T_3 (100% chemical through fertilizer). From this table, it is clear that the significant ($p \leq 0.05$) reduction was found while amount of available phosphorus was compared between soil before crop establishment (Ti) and soil after two years following crop establishment with treatment T_0 (without fertilizer or manure). The amount of available phosphorus was significantly ($p \leq 0.05$) increased for treatments T_1 (100% organic through vermicompost), T_2 (100% organic through FYM), T_3 (100% chemical through fertilizer) and T_4 (50% organic + 50% chemical) in comparison to treatment T_0 (without fertilizer or manure). There was significant ($p \leq 0.05$) decrease in amount of available K while result of treatment T_0 (without fertilizer or manure) was compared with initial state of the soil before crop establishment (Ti).

In case of treatment T_1 (100% organic through vermicompost), this value was significantly ($p \leq 0.05$) increased compared with T_3 (100% chemical through fertilizer). The value of available K was found to be increased significantly ($p \leq 0.05$) for all the treatments (T_1, T_2, T_3 and T_4) compared to treatment T_0. Value of available K was significantly low for treatment T_3 in comparison to T_1. Thus, it is clear that both organic manures and chemical fertilizers can increase the amount of available K but efficacy is more in case of organics. Magdoff (1992) and Sahai (2004) reported that organic manure served as a reservoir of different types of nutrients which were essential for plant growth. According to Sudhakar et al. (2002), vermicompost contains micro sites rich in available carbon and nitrogen. Worm cast injected soils are also rich in water soluble phosphorous (Gratt, 1970) and contains two to three times more available potassium than surrounding soils (Sudhakar et al., 2002) which encourage better plant growth. Table 4 represents the pooled data of rice yield for consecutive two years of studies. Following statistical analysis, it was found that rice crop productions were significantly ($p \leq 0.05$) more in case of every treatment (T_1, T_2, T_3 and T_4) in

Table 3. Comparison of various chemical properties of soil for different treatments.

Replication	Treatments						Significance of differences (p-values)					
pH												
	T_i	T_0	T_1	T_2	T_3	T_4	T_i/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	7.1	6.9	6.9	6.9	7.2	7	0.13	0.21	0.06	0.49	1.00	0.07
R_2	7.2	7.1	6.8	6.8	7.1	7						
R_3	7.3	7.1	7	6.8	7	7.1						
mean	7.2	7.0	6.9	6.8	7.1	7.0						
sd	0.100	0.115	0.100	0.058	0.100	0.058						
Organic C (%)												
	T_i	T_0	T_1	T_2	T_3	T_4	T_i/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	0.47	0.4	0.95	0.98	0.56	0.73	0.01	0	0	0.00	0	0
R_2	0.48	0.42	0.99	0.96	0.58	0.75						
R_3	0.52	0.41	0.97	0.88	0.63	0.74						
mean	0.49	0.41	0.97	0.94	0.59	0.74						
sd	0.026	0.01	0.02	0.053	0.036	0.01						
Total N (%)												
	T_i	T_0	T_1	T_2	T_3	T_4	T_i/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	0.046	0.048	0.094	0.009	0.053	0.08	0.28	0.00	0.00	0.01	0.00	0
R_2	0.048	0.04	0.093	0.01	0.057	0.083						
R_3	0.045	0.041	0.098	0.011	0.058	0.083						
mean	0.05	0.043	0.095	0.01	0.056	0.082						
sd	0.002	0.004	0.003	0.001	0.026	0.003						
Available P ($Kg.ha^{-1}$)												
	T_i	T_0	T_1	T_2	T_3	T_4	T_i/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	40.82	38.08	48.02	46.9	41.08	46.03	0	0	0	0	0	0
R_2	40.83	38.06	48.05	46.5	41.03	46.07						
R_3	40.87	38.05	48.04	46.8	41.09	46.05						
mean	40.84	38.06	48.04	46.73	41.07	46.05						
sd	0.026	0.015	0.015	0.208	0.032	0.020						
Available K ($Kg.ha^{-1}$)												
	T_i	T_0	T_1	T_2	T_3	T_4	T_i/T_0	T_0/T_1	T_0/T_2	T_0/T_3	T_0/T_4	T_1/T_3
R_1	144.1	141.8	152.03	150.04	148.01	150.2	0	0	0	0	0	0
R_2	144.6	141.84	152	150.1	148.04	150.27						
R_3	144.8	141.79	152	150.13	148.04	150.25						
mean	144.5	141.81	152.01	150.09	148.03	150.24						
sd	0.361	0.026	0.017	0.046	0.017	0.036						

T_i-Initial property of soil or property of soil before crop establishment, T_0- without fertilizer or manure, T_1- 100% organic through vermicompost, T_2- 100% organic through FYM, T_3- 100% chemical through fertilizer and T_4- 50% organic + 50% chemical.

comparison to control (T_0). It was also found that production was not significantly higher for T_1 compared to T_3. The maximum rice yield was recorded under treatment T_1 where the lowest grain yield was observed in crop without fertilizer (T_0). It was found that the application of 100% vermicompost (T_1), 100% FYM (T_2), 100% chemical (T_3) and 50% organic + 50% chemical (T_4) increased the rice yield by 31.41, 30.56, 29.93 and 30.33%, respectively over control (the crop without fertilizer that is, T_0). Similarly, it was noticed that the application of 100% vermicompost (T_1), 100% FYM (T_2) and 50% organic + 50% chemical (T_4) increased rice yield by 2.12, 0.9 and 0.57%, respectively over 100% chemical through fertilizer (T_3). This may be due to the fact that organic manure, like vermicompost, is a nutritive plant food rich in NPK.

Comparing over all pool data of lentil crop productions (Table 5) under study, it was found that productions were significantly ($p \leq 0.05$) more in case of every treatment (T_1, T_2, T_3 and T_4) in comparison to control (T_0). It was also noted that production was significantly higher for T_1 compared to T_3. The highest seed yield was obtained

Table 4. Effect of nutritional management on grain yield of rice.

Replication	Treatments					Significance of differences (p-values)				
2008	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**	**T_0/T_1**	**T_0/T_2**	**T_0/T_3**	**T_0/T_4**	**T_1/T_3**
R_1	2380	3400	3394	3356	3382	**0**	**0**	**0**	**0**	0.32
R_2	2398	3420	3410	3374	3385					
R_3	2389	3425	3411	3377	3403					
2009										
R_1	2460	3659	3589	3558	3575					
R_2	2462	3674	3600	3566	3586					
R_3	2485	3671	3584	3568	3588					
mean	2429	3541.5	3498	3466.5	3486.5					
sd	45.051	138.917	102.186	107.099	106.047					

T_0- Without fertilizer or manure, T_1- 100% organic through vermicompost, T_2- 100% organic through FYM, T_3- 100% chemical through fertilizer and T_4-50% organic + 50% chemical.

Table 5. Effect of nutritional management on seed yield of lentil.

Replication	Treatments					Significance of differences (p-values)				
2008	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**	**T_0/T_1**	**T_0/T_2**	**T_0/T_3**	**T_0/T_4**	**T_1/T_3**
R_1	448	775	779	732	760	**0**	**0**	**0**	**0**	**0.04**
R_2	460	792	781	749	762					
R_3	460	797	795	733	785					
2009										
R_1	502	861	823	796	819					
R_2	522	877	847	819	817					
R_3	524	872	841	806	848					
mean	486	829	811	772.5	798.5					
sd	34.035	45.795	30.067	38.960	35.241					

T_0- Without fertilizer or manure, T_1- 100% organic through vermicompost, T_2- 100% organic through FYM, T_3- 100% chemical through fertilizer and T_4-50% organic + 50% chemical.

from the treatment T_1 and lowest seed yield was observed in crop without fertilizer (T_0). Application of 100% vermicompost (T_1), 100% FYM (T_2), 100% chemical (T_3) and 50% organic + 50% chemical (T_4) increased seed yield by 41.38, 40.07, 58.95 and 39.14%, respectively over control. Similarly, it was manifested that application of 100% vermicompost (T_1), 100% FYM (T_2) and 50% organic + 50% chemical (T_4) has increased the seed yield by 6.82, 4.75 and 3.26%, respectively over 100% chemical through fertilizer (T_3). These results are in accordance with those observed by Bwamiki et al. (1998) and Maynard (1993). They noticed that increase in productivity in the plots receiving organic manure/matter might be due to the fact that organic manure/matter not only provided additional nutrients other than N, P and K but also caused improvement in physical properties of soil. According to Suhane et al. (2008), vermicompost showed better results because exchangeable potassium (K) was over 95% higher in vermicompost compared to conventional compost. There were also over 60% higher amounts of calcium (Ca) and magnesium (Mg) which increased crop yield. In Guyana, an investigation into the recycling of sugar cane bagasse and rice straw to produce compost, using vermitechnology and using the compost on *Phaseolus vulgaris*, was conducted by Ansari (2011). He concluded that physiochemical properties of rice straw and the combinations (bagasse with rice straw) were beneficial and enhanced growth and yield of *P. vulgaris*. His soil chemical analysis also indicated improvement in nutrient content.

Conclusion

Following results obtained from the period of two years of experimentation, it can be concluded that the application of vermicompost showed better result in comparison to chemical fertilizers in terms of soil physical and chemical properties as well as productivity of soil. Long-term use of chemical fertilizers which deteriorates the soil quality as well as diminishes the productivity of soil can be checked by using vermicompost. It may surely be concluded that recycling of organic wastes through vermicomposting is an effective and quick process for preparing organic manures. Application of vermicompost improves the soil quality as a whole which may be reflected through better crop production and use of vermicompost is better from all environmental aspects if compared with chemical fertilizer. It is envisaged that the problem of extensive use of chemical fertilizer can be solved to a great extent by increasing the use of organic manure produced from organic wastes by vermicomposting technology. Thus, one problem (generation and accumulation of organic wastes) can be used for solving another problem (toxicity of agricultural land and its reduction of crop production toward infertility) through proper management approach.

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