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Potential Utilization of Different Wastes through Vermicomposting in Agriculture

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ABSTRACT

Vermicomposting is an adequate technology for the biooxidation and stabilization of organic material relying on the joint action of earthworms and microorganisms in which organic wastes are converted into rich plant growth media. The aim of this study was to investigate the preparation and potential utilization of vermicomposts (VCs) of different animal dung, agriculture and kitchen wastes and their effect on the growth, flowering period and productivity of three crops namely rice (*Oryza sativa*), maize (*Zea mays*) and pearl millet (*Pennisetum typhoides*). The final VCs obtained from different combinations of three wastes by the help of earthworm *Eisenia foetida* showed a significant increase in total nitrogen, potassium, phosphorus and calcium and a significant decreased in total organic carbon, the C:N ratio, pH and electrical conductivity in comparison with the initial feed mixture. Among all VCs tested, maximum growth of rice (101.50 cm) and maize (998.90 cm) crop was observed when cow dung + vegetable waste (1: 1, w/w) was used. However, maximum growth of millet (120.20 cm) was recorded in the VCs prepared from buffalo dung + vegetable waste (1: 1, w/w). Rice flowered early (62.76 days) when buffalo dung + gram bran (1: 1, w/w) VCs or the combination of horse dung + rice bran VCs for both maize (82.14 days) and millet (80.18 days) were used. The productivity of rice (0.880 kg/m^2) and maize (0.896 kg/m^2) was highest in the cow dung + gram bran and cow dung + vegetable waste VCs, respectively while the productivity of millet was highest (1.92 kg/m^2) in buffalo dung + vegetable waste VCs. This study indicates that VCs based on animal dung, agro and kitchen wastes not only produce a value-added product but also act as a better nutrient source for plants.

Keywords: biofertilizer, crop, *Eisenia foetida*, growth, organic wastes, vermicompositing

Abbreviations: EC, electrical conductivity; **TAP**, total available phosphorus; **TCa**, total calcium; **TKN**, total Kjeldhal nitrogen; **TOC**, total organic carbon; **TP**, total potassium

INTRODUCTION

Environmental degradation is the major threat confronting the world, and the rampant use of chemical fertilizers contributes largely to the deterioration of the environment through depletion of fossil fuels, generation of carbon dioxide (CO_2) and contamination of water resources (Suthar 2007). According to the demand of growing populations, the impact of modern agricultural technology and excessive use of synthetic fertilizers causes loss of diversity, resource degradation and contamination of grain (Krosese 2002). Excessive use of chemical fertilizers to increase crop production is one of the major causing the destruction of soil flora and fauna (Peyvast *et al.* 2008) and will result in a high concentration of some chemicals and metals, which ultimately affect crops and watershed (Egball and Gilley 1999). Such agricultural practices are dangerous for soil fertility and conservation and may lead to desertification. Biological wastes cause environmental hazards and various ill effects on human life and their domesticated animal, if their proper management and disposal practices are not available (Bhattcharya and Chattopadhyay 2004). High rates of industrialization have also increased the problems of solid waste management. These problems start from the rural level i.e. agro, kitchen vegetable and animal wastes moving upwards to the industrial and urban level i.e. solid wastes of textile and sugar mills, vine industries, dairy plant sludge and municipal solid wastes (Suthar 2006).

Organic farming through vermicomposting can convert biowaste into nutrient-rich organic manure (Garg *et al.* 2005). Vermicomposting involves the use of earthworms as natural bioreactors for effective recycling of non-toxic organic wastes into soil. Vermicompost (VC) effectively increases beneficial soil micro-flora, reduces a soil's pathogens and converts organic wastes into valuable products (Suthar 2006, 2007). VC contains a high concentration of nutrients such as nitrates, exchangeable calcium, phosphorus and soluble potassium (Dominguez 2004). Vermicomposting increases the mineralization rate when organic wastes pass through the earthworm gut and nutrients are converted from unavailable to available forms, consequently enriching the worm cast with higher quality nutrients that can be used by plants (Garg *et al.* 2006). The use of VC has many positive effects on soil texture, growth and yield of a variety of plants such as cereals, legumes, vegetables and ornamentals (Atiyeh *et al.* 2002).

The application of VC to improve the stability of pathogen-suppressing resistance and minimize the incidence of pest infestation on plants; in the roots of legume crops, VC increases the biomass of the mycorrhizal population (Bulluck and Restain 2002; Stone 2002). Zaller (2006) studied the effect of vermiwash (VW; a liquid that is collected after the passage of water through gut of worm action and is very useful as a foliar spray) on field-grown tomato (*Lycopersicon esculentum*) resulting in the suppression of late blight disease. The application of VW reduces disease by necrotrophs as well as biotrophs (Ansari 2008). Pearl millet (*Pennisetum typhoides*) is a staple food grain in many parts of India, especially in Gujarat and Rajasthan. Its nutritive value is comparable to that of rice and wheat (Wanyo *et al.* 2009). Maize is an important cereal crop of the world and in terms of area under cultivation and production, its ranks only next to wheat and rice (Hu *et al.* 2009). Maize is extensively used as food forage feed for livestock and as a raw

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material for many industrial products. The grains are nutritious with high percentage of easily digestible carbohydrates, fats and proteins (Wanyo *et al*. 2009).

The aim of this study was to evaluate the different chemical parameters and efficiency of VCs with help of earthworm *Eisenia foetida* prepared from different animal (cow, buffalo, goat, sheep, horse) dung, agriculture or kitchen (rice bran, wheat bran, gram bran, barley bran, straw and vegetable) wastes on certain crops.

MATERIALS AND METHODS

Collection of wastes

The different organic wastes, animal dung (cow, buffalo, sheep, goat, horse) were collected from different animal farms, whereas, agricultural and kitchen waste were collected from garbage and agricultural fields of rural and urban areas of the Gorakhpur district, Uttar Pradesh, India. The Gorakhpur district of Utter Pradesh state has the agriculture based socio-economy of a rural population and it is situated in north-east zone 400 kilometer from the capital of India. The earthworms *Eisenia foetida* were cultured at the Vermiculture Research Centre, Department of Zoology D.D.U. Gorakhpur University Gorakhpur, U.P., India. The cultured adult earthworms (30-40 days old) were used for the experiments.

Experimental design

The vermicomposting were conducted on a cemented earth surface in bed form. Each vermibed prepared in size of 3 m × 1 m × 9 cm which contain different animal dung and different agricultural/ kitchen wastes in the 1: 1 (w/w) ratio. After formation of vermibed, 2 kg of cultured adult *E. foetida* were inoculated in each bed. The beds were covered with jute pockets and properly moistened the bed daily up to 40 to 50 days for maintaining the moisture content (40-60%) and temperature (25-35°C). After a 7-day interval, mixture of different wastes of each vermibed was manually turned for next 3 weeks. After 50 to 60 days, granular tea like VC appeared on the upper surface of beds. The earthworms were separated from prepared VCs by sieving. The final prepared dry VCs were chemically analyzed and used for experimental field crops.

Chemical analysis

The chemical analysis of water extract of initial feed mixture (mixture of organic wastes just after inoculation of earthworms) and final dry VC, soil of 6 cm depth and mixture of soil with VC were performed by standard methods. Total organic carbon (TOC) was determined by the method of Nelson and Sommers (1982), total nitrogen (TKN) by Bremner and Mulvaney (1982) procedure, available phosphorus (TP) by colorimetric method (Bansal and Kapoor 2000), total potassium and calcium were determined by flame photometer (Bansal and Kapoor 2000), The pH and electrical conductivity (EC) were determined by the method of Garg *et al.* (2006). The sample suspension was made in distilled water where required.

Measurement of growth, flowering and productivity

The following three crop varieties were selected for an experiment field each with six replicates.

Paddy rice (*Oryza sativa*) var. 'Saket 4' is staple food of South-east Asia. It is best suited to the regions which have high temperate, high humidity and assured supply of water and annual rainfall of 60-120 cm is required. It is sown in may-June and is ready for harvest by September-October.

Maize (*Zea mays*) var. 'Hybrid Crown 417' is one of the major cereal crops in India, extensively used as food, forage feed for live stock. Maize is a subtropical crop with temperature range of 20-27°C and annual rainfall of 60-120 cm. The crop matures in about 140 days.

Pearl millet (*Pennisetum typhoides*) var. 'T55' is an important crop in India. It grows well at high temperature and in semi-arid growing conditions. The crop is sown in the middle of July and it matures in October.

Measurement of growth, flowering period and productivity of crops were performed in the experimental field of the Vermiculture Research Center. The different varieties of crops were sowed according to their season. They were sowed directly in the cultivated soil. In the cultivated field, each grid having the size of 1 m^2 (1 m × 1 m) area seeded with different crops were sowed with different seed density according to crops. 2 kg/m^2 VC applied to soil in each experimental grids and control grid also contained no VC. Growth as total length of maize and millet plants was observed at 20, 35 and 50 days whereas, growth of paddy was observed at 45, 60 and 75 days using an auxanometer. Flowering periods (days) were observed when first flower appears in adults plants. After harvesting of each crops, productivity were calculated in kg/m^2.

Statistical analysis

The data given in tables are mean ± standard error (SE) of six replicates of each combination of VC. Two-way analysis of variance (ANOVA) was applied to determine the significant ($P < 0.05$) difference between time and different initial feed mixture and final VC for evaluation of chemical parameter as well as growth of each crop. Student *t*-test was applied to determine the significant ($P < 0.05$) difference between control and different combinations of VC for particularly for flowering period and productivity (Sokal and Rohlf 1973).

RESULTS

There was significant increase in TKN, TK, TP, TCa and decrease in pH, EC, TOC and a C:N ratio was observed in final VC of all the combinations of organic wastes compared to the initial feed mixture and soil mixed with different final VC.

Maximum significant ($P < 0.05$) decrease in TOC was observed in VC prepared from sheep dung + straw (208.0 g/kg) whereas highest TOC was obtained in buffalo dung singly and their different combinations with agriculture/ kitchen wastes was at initial stage (**Tables 1, 2**). TOC level in soil increased after mixing of VC of different animal dung + agriculture/ kitchen wastes. The VC of horse dung+ wheat bran (215.00 g/kg) shows maximum significant increase of TOC among all combination followed by sheep dung + wheat bran (212.66 g/kg), goat dung + wheat bran (205.20 g/kg) and buffalo dung gram bran (200.8 g/kg) after mixed with soil (**Table 3**).

The TKN was significantly increased in all the VC of different combinations of organic wastes when compared to initial feed mixture. The maximum significant ($P < 0.05$) increase of nitrogen was recorded in the VC of goat dung + wheat bran (27.4 g/kg) in the final stage. The highest TKN was observed in soil (3.21 g/kg) after mixing of VC of goat dung + wheat bran (**Table 3**). The highest calcium level was observed in the final VC of buffalo dung + rice bran (5.9 g/kg). The VC of buffalo dung + rice bran (1.92 g/kg) caused highest calcium in soil (**Tables 3, 4**). There was a significant increase in TK was observed in all combinations of the vermicompost of different animal dung and agriculture/kitchen wastes. The highest TK was observed in the final VC of buffalo dung + rice bran (9.8 g/kg) (**Tables 1, 2**). After mixing of different VC caused significant increased of potassium in the soil, the VC of buffalo dung + rice bran (1.58 g/kg) shows highest increased (**Table 3**).

C:N ratio was significantly decreased in all the VC of different animal dung and agriculture/kitchen wastes. The lowest C:N ratio was recorded in VC obtained from cow dung + vegetable wastes (9.6) (**Table 3**). The lowest pH (6.5) was noticed in the VC of goat dung + vegetable wastes. There was significant decrease in electrical conductivity was observed in all VC obtained from sheep dung+ wheat bran (0.59 ds/m) (**Table 3**).

There was significant time dependent effect of VC obtained from different combinations of organic wastes on the, growth, flowering and productivity of paddy, maize and millet **Tables 4-6**). VC of different types caused significant

Table 1 Different physico-chemical parameters in initial feed mixture and final vermicompost of different combinations of animal dung and agriculture /kitchen wastes.

Combinations	TOC (g/kg)		TKN (g/kg)		C:N		TK (g/kg)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Cow Dung	468.3±4.21	210.0±0.84*	5.00±.02	13.2±.05*	87.2±2.4	14.2±1.7*	14.8±.07	4.4±.07*
Dung + Gram Bran	588.0±2.21	272.7±1.08*	12.2±.68	19.0±.04*	40.2±.26	12.4±.42*	7.6±.02	7.8±.08*
Dung + Straw	624.0±4.32	218.4±5.46*	7.60±.08	18.0±.25*	79.8±.04	12.1±.62*	6.2±.08	6.4±.02*
Dung + Wheat Bran	653.0±3.04	307.1±4.21*	11.9±1.0	26.5±.22*	55.2±1.0	13.5±.25*	6.3±.10	7.6±.02*
Dung + Rice Bran	560.0±2.32	255.7±5.02*	10.2±.32	20.1±.45*	49.6±.23	10.4±.48*	5.4±.12	7.0±.06*
Dung + Vegetable Wastes	563.02±2.05	245.7±2.25*	9.80±.62	24.1±.08*	58.6±.86	9.60±.01*	6.6±.08	7.9±.12*
Dung + Barley Bran	475.1±2.03	220.5±2.06*	9.89±.04	23.6±.08*	46.3±1.2	9.80±1.1*	5.9±.12	6.1±.02*
Buffalo Dung	504.4±2.20	265.5±1.04*	6.30±.02	9.90±.02*	89.0±1.6	26.0±1.2*	6.5±.16	7.2±.08*
Dung + Gram Bran	637.1±2.42	340.8±2.48*	13.4±.10	24.4±.14*	51.3±.38	11.6±1.1*	7.3±.12	8.0±.13*
Dung + Straw	676.2±3.14	278.4±2.32*	8.70±.06	17.5±.12*	66.1±1.5	16.0±.04*	6.9±.16	8.0±.15*
Dung + Wheat Bran	726.0±2.26	300.1±1.52*	12.9±37	20.3±.40*	56.2±1.6	18.2±.82*	8.4±.17	8.6±.04*
Dung + Rice Bran	615.1±2.06	318.2±2.13*	10.9±.31	23.6±.42*	54.2±.84	12.9±.08*	8.9±.12	9.8±.10*
Dung + Vegetable Wastes	570.3±1.37	324.6±1.23*	10.0±.10	21.8±2.2*	55.2±.82	14.8±.73*	8.6±.18	8.8±.21*
Dung + Barley Bran	509.6±2-32	294.5±2.45*	10.6±.04	20.8±.06*	45.9±1.4	15.3±1.4*	7.8±.13	8.5±.15*
Goat Dung	432.9±3.12	239.2±1.62*	4.30±.20	7.00±.04*	98.5±.13	26.4±1.4*	6.2±.14	6.8±.10*
Dung + Gram Bran	546.0±3.17	298.0±0.08*	11.9±.25	26.0±.60*	43.4±1.2	12.2±.81*	7.0±.14	8.7±.14*
Dung + Straw	585.2±0.62	254.6±1.37*	6.70±.06	18.4±.04*	81.2±.09	14.2±1.2*	6.8±.18	7.2±.05*
Dung + Wheat Bran	599.0±3.05	348.3±1.15*	10.9±.31	27.4±.14*	50.2±.50	13.5±.20*	8.0±.12	8.5±.17*
Dung + Rice Bran	515.0±1.42	300.8±2.80*	10.2±.32	24.6±.12*	48.5±.70	12.4±1.2*	7.6±.20	8.3±.16*
Dung + Vegetable Wastes	530.7±2.58	281.1±3.03*	8.70±.10	22.0±.12*	65.3±1.7	12.4±1.6*	8.0±.16	8.0±.12*
Dung + Barley Bran	460.0±2.87	265.1±2.53*	9.00±.13	22.4±.14*	52.0±1.2	12.0±.81*	7.8±.15	8.2±.13*

Combinations	TP (g/kg)		pH		EC (ds/m)		TCa (g/kg)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Cow Dung	3.4±.03	6.9±.05*	8.0±.02	6.8±.31*	3.4±.03	6.9±.05*	8.0±.02	6.8±.31*
Dung + Gram Bran	4.8±.08	7.0±.40*	8.3±.03	6.9±.06*	4.8±.08	7.0±.40*	8.3±.03	6.9±.06*
Dung + Straw	3.7±.03	5.0±.05*	8.8±.08	7.2±.03*	3.7±.03	5.0±.05*	8.8±.08	7.2±.03*
Dung + Wheat Bran	7.7±.04	6.6±.06*	8.4±.03	7.3±.02*	7.7±.04	6.6±.06*	8.4±.03	7.3±.02*
Dung + Rice Bran	5.9±.08	8.7±.05*	8.7±.04	7.6±.05*	5.9±.08	8.7±.05*	8.7±.04	7.6±.05*
Dung + Vegetable Wastes	4.2±.05	7.3±.10*	8.0±.04	7.3±.02*	4.2±.05	7.3±.10*	8.0±.04	7.3±.02*
Dung + Barley Bran	3.9±.01	7.1±.05*	8.3±.02	7.2±.01*	3.9±.01	7.1±.05*	8.3±.02	7.2±.01*
Buffalo Dung	4.9±.01	6.1±.02*	8.5±.08	7.0±.06*	4.9±.01	6.1±.02*	8.5±.08	7.0±.06*
Dung + Gram Bran	6.9±.04	7.4±.06*	8.6±.02	7.0±.06*	6.9±.04	7.4±.06*	8.6±.02	7.0±.06*
Dung + Straw	4.9±.02	5.6±.04*	8.5±.14	6.7±.04*	4.9±.02	5.6±.04*	8.5±.14	6.7±.04*
Dung + Wheat Bran	8.6±.03	12.2±.01*	8.2±.05	7.5±.06*	8.6±.03	12.2±.01*	8.2±.05	7.5±.06*
Dung + Rice Bran	8.0±.02	8.0±.08*	8.4±.06	6.5±.03*	8.0±.02	8.0±.08*	8.4±.06	6.5±.03*
Dung + Vegetable Wastes	5.4±.06	8.8±.05*	8.5±.04	7.1±.02*	5.4±.06	8.8±.05*	8.5±.04	7.1±.02*
Dung + Barley Bran	6.1±.07	7.9±.08*	8.0±.04	7.5±.07*	6.1±.07	7.9±.08*	8.0±.04	7.5±.07*
Goat Dung	4.0±.04	5.2±.08*	8.5±.03	6.8±.03*	4.0±.04	5.2±.08*	8.5±.03	6.8±.03*
Dung + Gram Bran	5.3±.09	7.1±.04*	8.5±.06	7.2±.01*	5.3±.09	7.1±.04*	8.5±.06	7.2±.01*
Dung + Straw	4.5±.05	4.8±.08*	8.5±.20	7.1±.02*	4.5±.05	4.8±.08*	8.5±.20	7.1±.02*
Dung + Wheat Bran	8.5±.06	8.9±.06*	8.3±.04	6.8±.01*	8.5±.06	8.9±.06*	8.3±.04	6.8±.01*
Dung + Rice Bran	6.6±.02	7.5±.04*	8.5±.04	6.9±.04*	6.6±.02	7.5±.04*	8.5±.04	6.9±.04*
Dung + Vegetable Wastes	5.0±.04	8.2±.04*	9.0±.02	6.5±.02*	5.0±.04	8.2±.04*	9.0±.02	6.5±.02*
Dung + Barley Bran	4.9±.06	6.0±.10*	9.0±.08	7.2±.04*	4.9±.06	6.0±.10*	9.0±.08	7.2±.04*

Each value is the mean ± SE of six replicates.

*Significant (P‹ 0.05) 't' test was applied in between treated and control group

($P < 0.05$) increase in the growth of paddy (**Table 4**). Mixing of VC obtained from buffalo dung + vegetable wastes and cow dung + vegetable wastes 58.70 and 56.00 cm, respectively with respect to control group (30.39 cm), after 45 days of sowing.

VC of cow dung (CD) + vegetable wastes (103.40 cm) followed by buffalo dung + vegetable wastes (102.5 cm) and CD + wheat bran (101.50 cm) caused significant growth after 75 days of sowing with respect to control group (75.00 cm) (**Table 4**). Combination of CD + vegetable wastes (98.90 cm) followed by buffalo dung + vegetable wastes (97.70 cm) and horse dung + vegetable wastes (95.50 cm) were highly effective for the growth of maize plant after 50 days with respect to control (78.80 cm) (**Table 4**). Treatments of different VC caused a significant growth of millet. Soil mixed with VC obtained from buffalo dung + vegetable wastes caused maximum significant growth of millet plant (120.20 cm) after 50 days of growth followed by buffalo dung + straw (118.70 cm) and CD + vegetable wastes (117.90 cm) with respect to control. VC prepared from combinations of CD + vegetable wastes show highest significant growth (98.80 cm) after 35 days of sowing of millet with respect to control (48.00 cm) (**Table 4**).

Significant early flowering of paddy, maize and millet was observed in the all combinations of VC of different animal dung and agro/kitchen wastes. **Table 5** shows that treatments of VC obtained from buffalo dung+ gram bran caused maximum significant effect on early flowering for paddy (62.76 days) and combination of horse dung+ rice bran was highly effective for early flowering of maize (82.14 days) and millet (80.18 days). The VC of horse dung + vegetable wastes and horse dung + barley bran was also effective for the early flowering of maize (83.36 days) and millet (83.77 days), respectively.

Significant productivity of paddy, maize and millet was observed in the all combinations of VC of different animal dung and agro/kitchen wastes. The highest productivity of paddy (0.880 kg/m^2) was observed in the VC obtained from CD + gram bran. The highest productivity of maize and millet was observed in the combination of CD + vegetable wastes (0.896 kg/m^2) and buffalo dung + vegetable wastes (1.92 kg/m^2), respectively. The control value of maize and millet was 0.360 kg/m^2 and 0.60 kg/m^2, respectively (**Table 6**).

Table 2 Different physico-chemical parameters in initial feed mixture and final vermicompost of different combinations of animal dung and agriculture /kitchen wastes.

Combinations	TOC (g/kg)		TKN (g/kg)		C:N		TK (g/kg)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Sheep Dung	316.±1.8	236.1±2.6*	4.10±.08	7.8±.06*	85.81±0.8	27.8±0.6*	6.9±.12	7.1±.13*
Dung + Gram Bran	538.0±1.3	244.2±2.6*	12.3±.13	22.2±.20*	42.65±0.3	14.8±1.2*	6.9±.12	7.3±.17*
Dung + Straw	612.0±1.4	208.0±2.3*	7.40±.04	16.0±.25*	83.0±1.4	13.8±1.5*	7.3±.14	7.8±.14*
Dung + Wheat Bran	580.1±3.3	372.3±2.7*	10.2±.04	21.4±.14*	57.8±1.2	16.2±.80*	7.4±.12	8.0±.12v
Dung + Rice Bran	498.6±1.6	212.4±2.5*	8.30±.05	21.6±.32*	58.4±.60	9.8±.09*	7.8±.13	8.2±.16*
Dung + Vegetable Wastes	438.1±2.5	289.7±1.4*	9.30±.08	21.8±.32*	42.9±.80	9.8±.09*	7.7±.06	8.1±.08*
Dung + Barley Bran	429.0±1.4	235.1±2.4*	7.10±.01	18.5±.20*	54.8±1.2	11.8±1.3*	7.2±.08	8.0±.17*
Horse Dung	472.2±1.4	226.5±2.2*	4.00±.08	7.50±.14*	118.3±1.2	29.4±1.4*	7.2±.08	7.5±.06*
Dung + Gram Bran	621.1±1.4	252.1±1.8*	12.5±.62	20.2±.25*	50.2±.02	13.1±.60*	7.3±.06	7.6±.02*
Dung + Straw	650.1±3.1	210.7±1.3*	7.20±.12	16.7±.42*	899.3±.12	13.3±.22*	7.2±.08	8.1±.10*
Dung + Wheat Bran	710.1±3.1	375.0±2.4*	9.90±.05	21.8±.42*	65.5±1.4	17.2±1.3*	7.8±.09	8.0±.12*
Dung + Rice Bran	584.4±3.4	280.4±1.6*	8.9±.16	22.0±.83*	56.7±1.8	11.8±.71*	8.0±.08	8.3±.06*
Dung + Vegetable Wastes	555.2±1.1	235.6±1.4*	7.80±.21	20.4±.14*	89.1±.60	14.8±.30*	8.1±.04	8.6±.06*
Dung + Barley Bran	489.1±1.4	240.2±3.2*	8.10±.13	21.4±.06*	60.0±.80	14.9±.20*	8.0±.05	8.4±.06*

Combinations	TP (g/kg)		pH		EC (ds/m)		TCa (g/kg)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Sheep Dung	2.1±.05	6.0±.08*	9.0±.1	7.3±.8*	1.9±.04	1.78±.02*	1.3±0.3	3.0±0.1*
Dung + Gram Bran	4.0±.06	7.1±.05*	8.3±.1	7.2±.5*	2.1±.06	1.70±.03*	1.5±0.5	5.5±0.2*
Dung + Straw	4.3±.03	4.8±.04*	8.2±.3	7.0±.1*	2.2±.03	1.71±.03*	1.3±0.4	5.2±0.1*
Dung + Wheat Bran	8.4±.06	8.8±.08*	8.5±.2	6.5±.2*	2.1±.05	1.59±.04*	1.2±0.1	4.6±0.2*
Dung + Rice Bran	4.7±.02	5.9±.03*	9.0±.4	7.4±.4*	2.0±.20	1.64±.03*	1.5±0.4	3.4±0.3*
Dung + Vegetable Wastes	7.3±.06	6.3±.09*	8.4±.1	7.1±.5*	2.2±.09	1.73±.04*	1.8±0.3	3.6±0.4*
Dung + Barley Bran	4.8±.06	6.1±.01*	8.2±.2	6.9±.2*	2.2±.18	1.88±.01*	1.5±0.3	3.6±0.5*
Horse Dung	6.8±.03	9.1±.05*	7.8±.6	6.9±.2*	2.1±1.1	1.27±.08*	1.3±0.5	3.9±0.4*
Dung + Gram Bran	7.9±.05	9.2±.06*	7.8±.1	6.8±.5*	2.8±.31	1.07±.04*	1.5±0.3	4.8±0.2*
Dung + Straw	5.5±.07	7.0±.03*	8.5±.1	7.3±.5*	2.8±.22	1.37±.04*	1.3±0.2	5.6±0.3*
Dung + Wheat Bran	9.8±.10	12.3±.08*	8.0±.2	6.9±.4*	2.6±.27	2.20±.08*	1.6±0.8	5.0±0.4*
Dung + Rice Bran	8.6±.02	11.6±.07*	8.2±.5	6.5±.3*	2.5±.11	1.23±.03*	1.1±0.2	5.2±0.1*
Dung + Vegetable Wastes	7.7±.05	9.0±.20*	8.6±.2	7.2±.3*	2.8±.21	1.35±.04*	1.8±0.3	5.4±0.2*
Dung + Barley Bran	6.9±.06	9.9±.10*	8.3±.5	6.8±.5*	2.7±.37	1.64±.07*	1.4±0.1	3.9±0.3*

Each value is the mean ± SE of six replicates.

*Significant (P‹ 0.05) 't' test was applied in between treated and control group

DISCUSSION

The significant decrease in pH, TOC, EC and C: N ratio and increase in TKN, TAP, TK and TCa in final VC than initial feed mixture indicates that inoculated earthworms in the vermibed altered the physico-chemical properties of VC. The vermicomposting of organic matter stabilization gives chelating and phyto-hormonal elements, which have a high content of microbial matter and stabilized humic substance (Venkatesh and Eevera 2008).

Maximum significant ($P < 0.05$) decrease in TOC was observed in VC prepared from sheep dung + straw. It is because the significant decrease in TOC is due to the feedings of earthworm as well as simultaneous microbial degradation of organic matter. Elvira *et al*. (1998) stated that a large fraction of organic matter in initial substrate was lost as CO_2 during vermicomposting. Micro-organisms that use the carbon as source of energy and nitrogen for building cell structure bring about decomposition of organic matter (Suthar 2007, 2008; Venkatesh and Eevera 2008). Straw of wheat have a content of nitrogen, ash, lignin, cellulose, hemicelluloses, residual ash, calcium, magnesium, sodium, potassium and phosphorus (You *et al.* 1982).

The TKN was significantly increased in all the VC of different combinations of organic wastes when compared to the initial feed mixture. The maximum significant increase in TKN was observed in VC obtained from goat dung + wheat bran (27.40 g/kg) followed by CD + wheat bran (26.50 g/kg). The decay of organic carbon might be responsible for nitrogen addition in the form of micro-nutrient, excretory substance, growth hormone, resume from the earthworm gut (Tripathi and Bharadwaj 2004). Decreased in pH may also be an important factor in nitrogen retentions, as this is lost as volatile ammonia at higher pH volume (Hartenstein and Hartenstein 1981).

C:N ratio was significantly decreased in all the VC of organic wastes. The lowest C:N ratio was recorded in VC obtained from CD + vegetable wastes (9.6). The lowest C:N ratio was obtained in soil with VC of horse dung + straw (79.72). Microbial decomposition is one of the major factors that caused a significant decrease in the C:N ratio of vermiwash obtained from the VC of different animal dung + agriculture/kitchen wastes (Senapati *et al.* 1980). The lowest (8.8) C:N ratio in the combination of CD + vegetable wastes may be due to the acceleration of organic matter mineralization, stabilization and maturity of organic wastes (Suthar 2008).

A significant increase in TK was observed in all combinations. The highest potassium was observed in buffalo dung + gram bran (9.8 g/kg), whereas, VC obtained from buffalo dung + rice bran caused highest TK (1.58 g/kg). Microbial activity during vermicomposting enhanced the rate of exchangeable K^+ mineralization (Suthar 2007). The earthworms prime its symbiotic gut micro flora with secreted mucous and water to increase degradation of ingested organic matter and release of metabolites (Suthar 2008).

Significant TP was observed in VC of horse dung + vegetable wastes (12.6 g/kg) followed by buffalo dung + wheat bran (12.2 g/kg). The significant increase in the level of total available phosphorus is due to the physical breakdown of feed mixture through earthworms as well as due to vermic activity attributed to the phosphorus-solubilizing and stabilizing micro-organism present in earthworm guts (Suthar 2008). The highest level of TP in the combination of horse dung + vegetable waste and followed by buffalo dung + wheat bran was because wheat bran has organic phosphorus compound, it is possible that the breakdown of these organic compounds in vermicactivity enhanced the total phosphorus (Suthar 2008).

The lowest pH (6.5) was noticed in the VC of goat dung + vegetable wastes. It is because microbial decomposition during the process of vermicomposting lowers the pH of

Table 3 The physio-chemical parameters of the soil before and after mixing of vermicomposts of animal dung and agro/kitchen wastes.

Combinations	TOC (g/kg)	TKN (g/kg)	C:N	TK (g/kg)	TP (g/kg)	pH	EC (ds/m)	TCa (g/kg)
Soil	54.21±1.4	.68±.05	79.72±2.60	0.51±.01	0.42±.02	7.2±2.3	1.98±.10	0.56±.23
Soil+ following vermicomposts								
Cow Dung	132.9±1.3*	1.24±.01*	107.23±1.3*	1.20±.01*	0.98±.01*	6.9±.02*	1.10±.01*	0.96±.38*
Dung + Gram Bran	160.2±2.6*	1.93±.03*	82.90±1.5*	1.18±.02*	1.22±.02*	6.9±.09*	0.98±.04*	1.12±.85*
Dung + Straw	133.6±1.4*	1.80±.04*	73.88±1.8*	1.45±.01*	0.97±.05*	6.7±.06*	0.99±.01*	1.35±.25*
Dung + Wheat Bran	180.7±1.7*	2.05±.01*	87.80±1.3*	1.42±.03*	1.30±.06*	6.8±.04*	1.20±.02*	1.34±1.2*
Dung + Rice Bran	154.3±1.5*	2.74±.04*	56.29±.89*	1.48±.01*	1.00±.04*	6.6±.05*	1.30±.02*	1.05±.63*
Dung + Vegetable Wastes	149.2±2.3*	2.96±.09*	50.33±1.5*	1.24±.04*	1.06±.01*	6.6±.03*	0.92±.03*	1.39±.44 *
Dung + Barley Bran	136.7±1.4*	1.92±.03*	71.56±2.3*	1.07±.02*	1.00±.01*	6.9±.02*	0.95±.02*	1.66±.24*
Buffalo Dung								
Buffalo Dung	161.5±1.6*	1.15±.20*	140.51±1.5*	1.06±.02*	0.95±.03*	6.4±.08*	1.10±.04*	0.98±.35*
Dung + Gram Bran	200.8±2.3*	3.02±.01*	66.49±1.8*	1.35±.02*	1.06±.02*	6.9±.04*	1.00±.03*	1.36±.56*
Dung + Straw	166.5±2.0*	2.23±.01*	75.45±2.3*	1.42±.02*	1.24±.02*	6.5±.03*	0.99±.03*	1.55±.74*
Dung + Wheat Bran	172.5±2.1*	2.45±.02*	70.28±1.2*	1.54±.03*	1.42±.05*	6.6±.02*	1.30±.01*	1.65±.22*
Dung + Rice Bran	136.1±1.9*	2.97±.05*	46.93±2.6*	1.58±.02*	0.90±.06*	6.2±.09*	0.97±.02*	1.92±.52*
Dung + Vegetable Wastes	192.2±2.4*	2.10±.05*	96.96±1.4*	1.25±.03*	1.15±.04*	6.4±.04*	0.96±.04*	1.82±.52*
Dung + Barley Bran	169.5±3.0*	2.94±.04*	58.27±2.7*	1.34±.01*	1.08±.01*	6.8±.04*	1.00±.02*	1.73±.45*
Goat Dung								
Goat Dung	144.4±1.5*	1.21±.01*	120.00±1.9*	1.04±.02*	1.16±.01*	6.9±.08*	0.87±.04*	0.90±.60*
Dung + Gram Bran	172.4±2.7*	3.00±.02*	57.35±2.3*	1.55±.05*	1.22±.01*	6.5±.09*	0.86±.01*	1.22±.38*
Dung + Straw	152.4±1.6*	2.21±.04*	69.27±1.9*	.97±.03*	1.14±.02*	6.8±.08*	1.00±.01*	1.45±.12*
Dung + Wheat Bran	205.2±2.2*	3.21±.04*	97.61±2.6*	1.11±.01*	1.00±.03*	7.1±.05*	1.00±.02*	1.65±.24*
Dung + Rice Bran	164.3±1.5*	1.96±.06*	86.47±2.5*	1.24±.01*	1.03±.03*	6.9±.04*	0.98±.03*	1.77±.77*
Dung + Vegetable Wastes	152.9±2.1*	2.96±.01*	52.41±1.4*	1.22±.01*	1.02±.03*	6.2±.05*	1.02±.02*	1.80±.23*
Dung + Barley Bran	112.2±1.3*	1.59±.01*	70.59±2.6*	1.15±.05*	1.10±.04*	6.9±.06*	0.99±.01*	1.66±55*
Sheep Dung								
Sheep Dung	144.25±1.4*	1.76±.01*	81.96±1.2*	1.01±.01*	1.24±.01*	6.9±0.2*	1.30±.09*	0.92±.22*
Dung + Gram Bran	149.29±1.5*	2.79±.03*	53.50±1.3*	0.99±.03*	1.23±.06*	7.0±.96*	1.30±.03*	1.12±.65*
Dung + Straw	136.87±1.7*	2.80±.02*	48.88±2.6*	1.08±.03*	1.02±.08*	7.1±.56*	1.40±.05	1.89±.35*
Dung + Wheat Bran	212.66±2.3*	2.96±.01*	71.84±1.3*	1.25±.03*	1.00±.04*	7.0±.23*	0.99±.06*	1.44±.36*
Dung + Rice Bran	132.87±1.5*	2.87±.02*	45.99±1.9*	1.08±.04*	1.10±.02*	7.1±.14*	1.10±.02*	1.48±.53*
Dung + Vegetable Wastes	167.53±2.7*	1.75±.01*	95.73±2.7*	1.32±.05*	1.05±.01*	6.2±.12*	0.98±.01*	1.78±.64*
Dung + Barley Bran	144.94±1.0*	2.35±.04*	61.67±1.7*	1.22±.04*	1.00±.02*	6.8±.45*	1.25±.03*	1.62±.27*
Horse Dung								
Horse Dung	141.65±3.0*	1.22±.05*	118.04±1.9*	0.92±.11*	0.97±.22*	6.8±.22*	0.90±.02*	0.91±.55*
Dung + Gram Bran	151.81±2.4*	2.63±.01*	57.72±2.3*	1.12±.01*	1.32±.02*	6.5±.25*	0.87±.05*	1.24±.88*
Dung + Straw	131.80±1.9*	2.89±.04*	45.60±1.5*	1.21±.22*	1.20±.03*	6.6±.23*	1.10±.06*	1.90±.74*
Dung + Wheat Bran	215.04±1.4*	2.34±.01*	91.88±1.8*	0.96±.11*	1.42±.01*	6.9±.24*	0.81±.02*	1.65±.41*
Dung + Rice Bran	164.87±2.0*	1.89±.03*	87.24±2.5*	1.00±.09*	1.08±.04*	6.8±.78*	0.98±.03*	1.77±.63*
Dung + Vegetable Wastes	142.84±1.4*	1.98±.02*	72.14±1.4*	1.24±.01*	1.15±.30*	6.5±.49*	1.20±.02*	1.89±.63*
Dung + Barley Bran	143.06±1.5*	2.20±.04*	65.02±2.4*	1.15±.02*	1.11±.08*	7.1±.25*	0.81±.02*	1.72±.25*

Each value is the mean ± SE of six replicates.

*Significant (P‹ 0.05) 't' test was applied in between treated and control group

VC in acidic condition was attributed to mineralization of nitrogen and phosphorus in to nitrates/nitrites and ortho-phosphates. The decreasing trend of pH was noticed in the combination of goat dung + vegetable waste, buffalo dung + rice bran, sheep dung + wheat bran and horse dung + rice bran. Jadia and Fulekar (2008) found that pH was enhanced initially during vermicomposting and then, was reduced. In the case of vermicomposting, the decrease in pH may be due to production of CO_2, ammonia NO_3^- and organic acid by microbial decomposition during vermicomposting (Suthar 2009).

There was significant decrease in electrical conductivity was observed in all VC obtained from sheep dung + wheat bran (0.59 ds/m). The soil mixed with VC of horse dung + barley bran (0.81 ds/m) caused lowest electrical conductivity. The decrease in EC might have been due to the loss of organic matter and release of different minerals salts in available forms. Lowest electrical conductivity in combination of sheep dung + wheat bran may be due to the increased rate of loss of organic matter, consequently there was release of different minerals salts (Kaviraj and Sharma 2003). The highest calcium level was observed in the VC of buffalo dung+ rice bran because it was possible that the gut process associated with Ca^{++} metabolism was primarily responsible for enhanced content of inorganic Ca^{++} in worm cast. Highest Ca^{++} level was noticed in combination of buffalo dung + rice bran is due to the higher rate of Ca^{++} mineralization (Garg *et al.* 2006; Suthar 2008).

There was a significant time dependent effect of VC obtained from different combinations of organic wastes on the growth, flowering and productivity of paddy, maize and millet. The highest (103.40 cm) growth of paddy has been observed after 75 days in VC of CD + vegetable wastes. VC prepared from CD+ vegetable wastes mixed with soil was highly effective for the growth of millet (120.20 cm) plant. It may be due to the increased amount of Ca^{++} in CD + vegetable wastes and TKN in buffalo dung+ vegetable wastes which affects the growth of plants. VC of different organic wastes are a rich source of enzymes, vitamins, plant growth hormones such as IAA, gibberellins, cytokinins, biocontrol agents, phosphorus, potassium and calcium (Pathak and Ram 2004). These micronutrients, hormones etc. are beneficial for growth of different plants.

The essential nutrients present in the combination of CD + vegetable wastes give better growth of paddy plant. It indicates that the synthesis of hormones, enzymes, vitamins and microorganism like nitrogen fixing bacteria are present in sufficient amount, which affect the growth of paddy plants. Dhawan *et al*. (1991) reported that protein (albumin and globulin) is the most important part for the well growth of crops. Recent research has provided evidence that earthworm activity on organic matter lead to production of plant growth influencing substances which significantly influence crop growth (Edwards *et al.* 2004). Canellas *et al.* (2000)

Table 4 Effect of vermicomposts of different combination of animal, agro/kitchen wastes on the growth (cm) of different crops.

Combinations	Crops								
	Paddy			Maize			Millet		
	Days after sowing								
	45	60	75	20	35	50	20	35	50
Control	30.39±.59	50.02±2.21	75.00±.59	24.6±2.5	39.40±3.1	58.80±4.3	29.50±2.3	48.00±3.1	60.00±4.00
Cow Dung	*32.60±1.3	59.51.40	84.8±2.24	*35.30±1.5	56.23±4.5	74.80±4.3	*41.40±1.4	63.60±.98	92.70±3.2
Dung + Gram Bran	32.00±.78	62.50±.32	88.00±.86	44.60±.98	68.6±2.61	83.5±1.25	48.40±3.5	75.60±1.8	8.40±.44
Dung + Straw	47.00±.24	84.17±.58	101.5±.54	46.80±2.6	72.40±3.1	90.9±2.60	55.40±1.6	83.60±1.8	102.45±2.3
Dung + Wheat Bran	43.70±3.1	74.8±3.19	92.67±.34	48.40±1.6	70.70±.88	92.30±.34	63.30±2.4	94.40±3.3	108.80±3.6
Dung + Rice Bran	56.00±2.5	89.8±3.84	103.4±.48	55.80±2.8	78.8±1.28	98.90±2.6	70.70±1.8	98.80±4.1	117.90±.54
Dung + Vegetable Wastes	46.10±2.2	79.67±1.96	90.83±1.7	49.90±3.0	75.0±1.00	94.40±1.4	59.90±2.9	70.70±3.5	92.80±1.22
Dung + Barley Bran	53.60±1.1	87.6±2.11	100.8±1.55	52.10±1.5	71.2±2.10	93.30±2.7	60.70±1.5	79.90±4.4	100.10±3.2
Buffalo Dung	*50.30±.28	57.3±1.80	72.00±.46	*23.70±1.6	55.50±1.5	77.90±3.1	*42.20±3.4	66.40±1.8	94.40±3.65
Dung + Gram Bran	48.60±1.7	63.00±1.55	78.90±.55	38.80±2.5	69.90±2.6	86.80±1.3	49.80±4.1	78.60±.44	99.40±2.57
Dung + Straw	47.10±1.4	83.50±.92	95.60±2.2	46.60±.70	75.20±2.8	88.80±3.6	52.20±.88	84.40±2.4	110.50±2.2
Dung + Wheat Bran	49.80±2.8	85.8±3.12	92.80±1.5	48.80±1.8	73.30±.98	90.30±1.8	61.10±.45	90.90±.44	118.70±2.4
Dung + Rice Bran	58.70±.70	90.05±2.64	102.5±1.2	50.50±2.7	75.50±1.8	97.70±2.4	76.60±1.87	96.60±3.9	120.20±3.5
Dung + Vegetable Wastes	44.60±.58	84.03±.53	92.95±1.4	56.60±1.4	79.60±1.6	93.90±1.8	60.78±.92	88.60±2.4	105.50±.69
Dung + Barley Bran	48.80±.79	86.5±3.40	99.83±1.8	46.6±2.7	71.10±3.1	91.40±2.8	58.80±2.6	83.70±.98	101.80±1.5
Sheep Dung	*40.90±2.3	51.50±2.98	62.25±1.47	65.4±2.83	54.40±.67	*38.78±.31	55.30±.90	80.56±.54	80.56±.54
Dung + Rice Bran	46.60± 1.7	53.26±1.77	67.50±.83	24.40±1.8	53.30±.33	55.80±1.6	40.80±1.5	69.30±.44	90.90±1.6
Dung + Wheat Bran	40.90±.99	65.50±1.68	75.66±.53	30.30±.44	40.60±2.41	63.32±3.5	46.30±2.5	70.70±2.6	96.70±2.3
Dung + Straw	38.90±.88	68.68±.43	66.83±1.10	29.40±3.1	44.70±.66	64.84±1.2	50.41±1.7	78.80±.85	103.30±3.4
Dung + Vegetable Wastes	44.10±2.61	68.00±.89	80.33±.92	32.34±2.88	53.40±3.60	66.29±.34	61.20±3.4	83.40±2.6	95.80±.98
Dung + Barley Bran	38.00±1.60	62.19±3.14	75.16±2.64	26.60±3.4	50.30±.31	59.80±1.3	68.70±2.8	80.70±1.2	95.50±.98
Dung + Gram Bran	39.50±2.33	67.16±2.61	80.83±2.48	24.40±.88	47.70±1.92	64.84±1.2	55.80±3.1	76.6±1.37	98.90±.24
Goat Dung	*40.80±.14	52.83±2.44	61.00±1.2	*20.22±1.8	34.60±2.5	56.60±.56	*36.70±.85	54.40±.92	84.60±.66
Dung + Rice Bran	49.16±2.26	53.30±3.39	67.00±.48	32.3±3.16	50.50±1.5	70.20±2.8	46.70±.18	70.20±.22	92.80±1.7
Dung + Wheat Bran	40.17±3.46	67.00±2.70	76.00±.78	41.4±4.15	53.20±1.8	66.18±.92	50.21±2.1	73.4±1.51	98.90±2.2
Dung + Straw	36.34±2.50	69.84±3.60	66.5±1.64	45.40±2.6	52.40±.92	69.68±3.1	58.80±3.6	80.80±.90	4.50±3.1
Dung + Vegetable Wastes	77.30±.62	89.90±2.3	48.80±1.6	52.50±2.4	70.70±1.6	55.40±2.3	85.40±2.41	85.40±2.41	106.45±.84
Dung + Barley Bran	39.00±.88	65.50±.87	79.60±.70	42.40±4.3	50.50±1.7	64.4±2.20	46.44±.84	82.20±1.86	98.90±.59
Dung + Gram Bran	38.80±.86	65.17±.98	85.60±2.7	45.60±2.5	50.10±2.7	66.60±.75	51.28±3.3	80.10±2.36	95.50±3.3
Horse Dung	*33.00±3.30	62.60±3.47	72.5±2.41	*23.80±.54	55.40±1.40	77.10±.98	*41.30±4.4	64.60±2.8	90.94±3.61
Dung + Rice Bran	42.66±1.16	36.83±2.63	76.50±.55	31.70±2.5	60.80±1.29	84.60±1.6	49.90±3.2	74.40±.64	94.60±1.20
Dung + Wheat Bran	40.9±.64	75.00±3.46	99.00±3.18	29.80±1.4	70.50±3.40	90.98±2.6	50.50±.94	80.40±1.6	105.50±.32
Dung + Straw	36.00±.48	62.16±.84	97.33±1.19	37.70±.29	71.10±4.00	89.40±1.7	63.30±.46	86.60±2.4	107.70±2.84
Dung + Vegetable Wastes	42.17±.75	67.66±.74	100.8±.77	44.56±2.6	72.43±2.33	95.50±.36	70.60±2.81	94.50±3.9	114.40±3.44
Dung + Barley Bran	39.83±2.8	68.50±.29	91.80±3.54	36.84±1.4	58.24±3.84	85.87±.54	59.40±.99	84.50±.55	103.30±.70
Dung + Gram Bran	40.16±1.5	69.67±1.76	99.17±2.83	40.80±.80	72.80±0.79	91.98±2.6	59.90±3.40	80.79±.46	98.80±2.84

Each value is the mean ± SE of six replicates.

*Significant (P‹ 0.05) 't' test was applied in between treated and control group

extracted humic acid from VC and found that increases the root growth and number of fruits of marigold and pepper plants. Supplementation of NPK and humic acid production during vermicomposting had a positive effect on plant growth (Atiyeh *et al.* 2002; Ramamoorthy 2004).

The significant early flowering of paddy (62.76 days) was observed in the VC obtained from buffalo dung + gram bran and sheep dung + rice bran. Early flowering of maize was observed in VC prepared from horse dung + rice bran. The treatment of VC of horse dung + rice bran caused early flowering of millet. VC and its extract consistently improved early flowering much more than was possible from more conversion of mineral nutrients in to more plant available forms (Atiyeh *et al.* 2002). It has been suggested that the dramatic increase in microbial action in the organic matter by earthworms could result in the production of significant quantities of plant growth regulators such as indole-3-acetic acid, gibberellins and cytokinines and hormone like activity in the VC. The highly significant concentration of TKN and TP stimulate the starting of early flowering period in wheat (Atiyeh *et al.* 2002). It may be possible that the growth hormones (gibberellins) present in significant amounts in VC of buffalo dung + gram bran stimulated the early flowering of the plant. Phosphorous is the most important content required in much quantity for better flowering (Davis *et al.* 2002). The nitrogen, phosphorus, sulphur and hormones are the important factors which stimulate the starting of early flowering and yield of grains (Farahbakhsh *et al.* 2006).

Significant productivity of paddy, maize and millet was observed among all combinations of VC mixed with soil. The VC of CD + gram bran caused highest productivity of paddy crops. The highest productivity of maize and millet was observed in the VC prepared from CD + vegetable wastes and buffalo dung + vegetable wastes respectively. It indicates that the increased productivity of plants may be due to the presence of essential nutrients in VC which enhanced the productivity of crops. Large amount of humic acid was produced during vermicomposting which increase the productivity (Ramamoorthy 2004; Gupta 2005). Phosphorous is the most important content required in much quantity for better flowering and yield of any crops (Davis *et al.* 2002). Gibberellins, auxin increases the bio availability of phosphorus and more exchangeable nutrients by the organic inputs (Erich *et al.* 2002). The application of VC improves the cation exchange capacity and uptake of nutrient by plants which are necessary for better yield of rice (Vansanthi and Kumaraswamy 1999). The NPK had enhanced the growth and yield of black gram (*Vigna munga*) and ground nut, *Arachis hypogea* (Parthsarthi and Ranganathan 2002).

CONCLUSION

A properly designed vermicomposting system will process organic wastes in to vermicomposting in 50-60 days. It was clear from the results that during vermicomposting, there was significant increase of TKN, TP, TCa, TK and decrease

Table 5 Effect of vermicomposts of different animal dung's with combination of agro/kitchen wastes (1:1 ratio) on the flowering period (days) of different crops.

	Paddy rice	Maize	Millet
Control	75.00±0.16	112.24±0.58	110.34±0.55
Cow Dung	70.18±0.25*	96.83±1.67*	97.70±1.25*
Dung + Rice Bran	66.29±0.39*	92.32±0.52*	90.19±1.37*
Dung + Wheat	66.38±0.59*	92.71±1.45*	95.26±1.30*
Dung + Straw	65.46±0.09*	93.68±1.02*	93.90±1.68*
Dung + Vegetable Wastes	64.54±1.16*	89.91±0.13*	91.98±0.70*
Dung + Barley Bran	64.84±1.58*	90.19±0.29*	92.38±1.17*
Dung + Gram Bran	64.46±2.00*	91.58±0.58*	95.25±0.47*
Buffalo Dung	70.14±1.68*	105.35±0.92*	106.84±2.02*
Dung + Rice Bran	65.19±1.80*	97.33±1.83*	99.18±1.96*
Dung + Wheat	65.15±0.95*	96.52±1.43*	95.26±1.71*
Dung + Straw	65.35±1.26*	96.83±1.40*	96.16±0.26*
Dung + Vegetable Wastes	64.51±0.44*	92.92±0.26*	95.35±0.72*
Dung + Barley Bran	65.58±1.01*	93.89±0.11*	93.84±0.09*
Dung + Gram Bran	62.76±2.09*	93.23±0.19*	96.37±0.06*
Sheep Dung	72.18±1.45*	103.58±0.65*	102.20±2.16*
Dung + Rice Bran	69.28±0.47*	97.29±1.60*	96.25±1.54*
Dung + Wheat	66.24±0.77*	95.66±1.17*	95.82±0.97*
Dung + Straw	66.58±0.05*	95.15±0.94*	95.76±0.22*
Dung + Vegetable Wastes	64.18±1.15*	93.39±1.18*	92.80±0.38*
Dung + Barley Bran	67.92±1.36*	94.14±0.85*	93.96±0.72*
Dung + Gram Bran	65.18±1.47*	94.85±1.00*	94.24±1.17*
Goat Dung	72.15±0.39*	104.35±1.06*	106.54±0.92*
Dung + Rice Bran	70.37±1.31*	96.67±0.25*	95.55±1.12*
Dung + Wheat	69.84±1.58*	94.14±1.15*	93.29±0.49*
Dung + Straw	68.10±0.28*	95.35±1.55*	92.12±0.36*
Dung + Vegetable Wastes	67.25±1.59*	90.49±2.09*	89.64±1.16*
Dung + Barley Bran	65.86±1.85*	91.39±2.15*	90.83±1.54*
Dung + Gram Bran	66.12±0.96*	91.85±0.15*	91.96±1.68*
Horse Dung	70.15±0.22*	104.64±0.26*	103.16±1.58*
Dung + Rice Bran	67.50±0.83*	85.00±0.09*	84.20±1.45*
Dung + Wheat	68.55±1.75*	86.26±0.59*	85.17±0.55*
Dung + Straw	69.17±1.20*	87.45±1.36*	86.39±0.46*
Dung + Vegetable Wastes	65.15±0.21*	82.14±1.65*	80.18±0.12*
Dung + Barley Bran	65.78±0.16*	83.36±1.54*	84.54±1.68*
Dung + Gram Bran	65.55±0.73*	83.80±0.92*	83.77±1.68*

Each value is the mean ± SE of six replicates.

*Significant (P‹ 0.05) 't' test was applied in between treated and control group

Table 6 Effect of vermicomposts of different animal dung's with combination of agro/kitchen wastes (1:1 ratio) on the productivity (kg/m^2) of different crops.

	Paddy	Maize	Millet
Control	.480±.30	.360±.20	.600±.30
Cow Dung	.712±.10*	.742±.33*	.710±.90*
Dung + Rice Bran	.798±.89*	.812±.35*	1.20±.92*
Dung + Wheat	.810±.26*	.792±.70*	1.50±1.4*
Dung + Straw	.800±.46*	.800±.50*	.900±.61
Dung + Vegetable Wastes	.845±.56*	.896±.60*	1.70±2.1*
Dung + Barley Bran	.752±.26*	.750±.56*	1.30±.80*
Dung + Gram Bran	.880±.52*	.790±.80*	1.10±.20*
Buffalo Dung	.692±.39*	.385±.60	.620±.40
Dung + Rice Bran	.720±.58*	.770±.64*	.689±.30
Dung + Wheat	.755±.14*	.823±.65*	1.10±.49*
Dung + Straw	.832±1.4*	.780±.80*	1.60±1.2*
Dung + Vegetable Wastes	.863±.90*	.835±.90*	1.92±.28*
Dung + Barley Bran	.695±.30*	.734±.50*	1.00±.90*
Dung + Gram Bran	.770±.91*	.804±.20*	1.40±.70*
Sheep Dung	.663±.16*	.420±.80	.650±1.4
Dung + Rice Bran	.693±.41*	.596±.30*	.760±.60
Dung + Wheat	.712±1.6*	.563±.64*	.900±.10
Dung + Straw	.596±.03*	.590±.21*	1.20±.98*
Dung + Vegetable Wastes	.645±.67*	.722±.50*	1.30±.30*
Dung + Barley Bran	.710±1.5*	.693±.60*	.905±.60
Dung + Gram Bran	.750±.10*	.588±.23*	1.40±.70*
Goat Dung	.610±.13	.420±.40	.620±1.1
Dung + Rice Bran	.689±.90*	.550±.60*	.710±.30
Dung + Wheat	.700±.60*	.622±.30*	.912±.62
Dung + Straw	.620±.10*	.523±.67*	1.00±.30*
Dung + Vegetable Wastes	.795±.59*	.752±.40*	1.50±.80*
Dung + Barley Bran	.755±.89*	.702±.90*	1.10±.36*
Dung + Gram Bran	.640±.30*	.852±.32*	1.30±.50*
Horse Dung	.653±.11*	.690±.70*	.810±.30
Dung + Rice Bran	.766±.50*	.750±.80*	.900±.50
Dung + Wheat	.810±1.6*	.730±.90*	1.20±.95*
Dung + Straw	.796±.90*	.706±.86*	1.10±.39*
Dung + Vegetable Wastes	.863±.70*	.865±.20*	1.60±.32*
Dung + Barley Bran	.800±.50*	.802±.62*	1.30±.50*
Dung + Gram Bran	.690±.10*	.810±.68*	1.50±.40*

Each value is the mean ± SE of six replicates.

*Significant (P‹ 0.05) 't' test was applied in between treated and control group

in TOC, pH, C:N ratio and EC. Earthworm *Eisenia foetida* improved the quality of different VC of organic wastes. These vermicomposts have sufficient potential to grow plants, starting early flowering as well as productivity of the crops. Among the treatment combinations, CD +vegetable wastes, buffalo dung+ vegetable wastes and buffalo dung+ gram bran performed better. Thus, preparation of particular type of VC from different combinations of organic wastes can be used for better growth and productivity of crops. These VC will be easily biodegradable, less expensive and more natural than synthetic fertilizers. The small industry of vermicomposting will also improve the socio-economic condition of the farmers. It can be concluded that vermicomposting is a biotechnological tool which is ecologically sound and most acceptable among farmers.

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REFERENCES

Ansari AA (2008) Effect of vermicompost and vermiwash on the productivity of spinach (*Spinacia oleracea*), onion (*Allium cepa*) and potato (*Solanum tuberosum*). *World Journal of Agriculture Science* **4**, 554-557

Atiyeh MR, Domínguez J, Subler S, Edwards CA (2000) Changes in biochemical properties of cow manure during processing by earthworm and the effects on the seedling growth. *Pedobiologia* **44**, 709-724

Atiyeh RM, Arnacon NQ, Edwards CA, Metzger JD (2002) The influence of earthworms processed organic wastes on plant growth. *Bioresource Technology* **81**, 103-108

Bansal S, Kapoor KK (2000) Vermicomposting of the crop residues and cattle dung with *Esenia foetida. Bioresource Technology* **67**, 155-161

Bhattacharya SS, Chattopadhyay GN (2004) Transformation of nitrogen during vermicomposting of fly ash. *Waste Management Resource* **22**, 488-491

Bremner JM, Mulvaney RG (1982) Total nitrogen. In: Page AL, Miller RH, Keeney DR (Eds) *Method of Soil Analysis*, American Society of Agronomy, Madison, WI, pp 575-624

Bulluck LR, Restain JB (2002) Effect of synthetic and organic soil fertility amendments on shouthern blight, soil microbial communities, and yield of processing tomatoes. *Phytopathology* **92**, 181-189

Canellas LP, Olivares FL, Okorokova AL, Facanda AR (2002) Humic acids isolated from earthworm compost enhance root elongation, areal root emergence, and plasma membrane H^+-ATPase activity in maize root. *Plant Physiology* **130**, 1951-1957

Davis JG, Lverson KV, Vigi MF (2002) Nutrient variability in manure: Implications for sampling and regional database creation. *Journal of Soil and Water Conservation* **57 (6)**, 473-478

Dhawan K, Malhotra S, Dahiya BS, Singh D (1991) Seed protein fractions and amino acid composition in gram (*Cicer arientum*). *Plant Foods for Human Nutrition* **41**, 225-232

Domínguez J (2004) State of the art and new perspectives on vermicomposting research. In: Edwards CA (Ed) *Earthworm Ecology*, CRC Press, Boca Raton, FL, USA, pp 401-424

Edwards CA, Domínguez J, Arancon NQ (2004) The influence of vermicomposts on plant growth and pest incidence. In: Shakir SH, Mikhail WZA (Eds) *Soil Zoology for Sustainable Development in the 21st Century*, self-published, Cairo, Egypt, pp 397-420

Egball B, Gilley JE (1999) Phosphorus and nitrogen in runoff following beef cattle manure or compost application. *Journal of Environmental Quality* **28**, 1201-1210

Elvira C, Sampendro L, Benitez E, Nogales R (1998) Vermicomposting of sludges from paper mill and dairy industries with *Eisenia andrei. Bioresource Technology* **63**, 205-211

Erich MS, Fitzgerald CB, Porter GA (2002) The effect of organic amendments on phosphorus chemistry in a potato cropping system. *Agriculture Ecosystem and Environment* **88**, 79-88

Farahbakhsh H, Pakgohar N, Karimi A (2006) Effect of nitrogen and sulphur fertilizers on yield, yield components and oil contents of oil seed rape (*Brassica napus* L.). *Asian Journal of Plant Sciences* **5**, 112-115

Garg VK, Chand S, Chhillar A, Yadav YK (2005) Growth and reproduction of *Eisenia foetida* in various animal wastes during vermicomposting. *Applied Ecology and Environment Research* **3**, 51-59

Garg VK, Yadav YK, Sheoran A, Chand S, Kaushik P (2006) Live stocks excreta management through vermicomposting using an epigeic earthworm *Eisenia foetida*. *Environmentalist* **26**, 269-276

Gunadi B, Blount C, Edwards CA (2002) The growth and fecundity of *Eisenia foetida* (Savigny) in cattle solids pre-composted for different periods. *Pedobiologia* **46**, 15-23

Gupta PK (2005) *Vermicomposting for Sustainable Agriculture*, Bharat Printing Press, Jodhpur, India, pp 11-14

Hartenstein R, Hartenstein F (1981) Physico-chemical changes affected in activated sludge by the earthworm *Eisenia foetida*. *Journal of Environmental Quality* **10**, 377-382

Hu G, Huang S, Cao S, Ma Z (2009) Effect of enrichment with hemicellulose from rice bran on chemical and functional properties of bread. *Food Chemistry* **115**, 839-842

Kaviraj S (2003) Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. *Bioresource Technology* **90**, 169-173

Krosese R (2002) Industrial agricultures war against nature. In: Kimbrell A (Ed) *Fatal Harvest: The Tragedy of Industrial Agriculture*, Island Press, Washington, pp 21-27

Nelson DW, Sommers LE (1982) Total organic carbon and organic matter. In: Page AL, Miller RH, Keeney DR (Eds) *Method of Soil Analysis*, American Society of Agronomy, Madison, WI, pp 539-579

Parthasarthi K, Ranganathan LS (2002) Supplementation of press mud vermicasts with NPK enhances growth and yield in leguminous crops (*Vigna mungo and Arachis hypogaea*). *Journal of Current Science* **2**, 35-41

Pathak RK, Ram RA (2004) *Manual on Jaivik Krishi*, Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow, pp 31-32

Peyvest G, Olfaati JA, Maadeni S, Foghani A, Samizadeh H (2008) Vermicomposting as a soil supplement to improve growth and yield of parsley. *International Journal of Vegetable Science* **14 (1)**, 82-92

Ramamoorthy P (2004) Stabilization and nutrient analysis of vermicomposting of sugar cane wastes, press mud-trash-bagasse by *E. eugeniae* (Kinberg) and *E. foetida* (Savigny) and the effect of vermicompost on soil fertility and crop productivity. PhD thesis, Annamalai University, India

Senapati BK, Dash MC, Rane AK, Panda BK (1980) Observation on the effect of earthworms in the decomposition process in soil under laboratory conditions. *Composting Physiology and Ecology* **5**, 140-142

Sokal R, Rohlf J (1973) *Introduction to Biostatistics*, W.H. Freeman and Co., San Francisco

Stone AG (2002) Organic matter mediated suppression of *Pythium, Phytophthera* and *Aphonomyces* root rots in field soils. Columbus, Ohio: CD Rom. In: *Proceedings of an International Composting and Compost Science Symposium*. Available online: https://www.agronomy.org/publications/sssaj/articles/65/3/761

Suthar S (2006) Potential utilization of gour gum industrial wastes in vermicomposts production. *Bioresource Technology* **97**, 2474-2477

Suthar S (2007) Nutrient changes and biodynamics of epigeic earthworm *Perionyx excavatus* (Perrier) during recycling of some agriculture wastes. *Bioresource Technology* **98**, 1608-1614

Suthar S (2008) Feasibility of vermicomposting in bio-stabilization of sludge from a distillery industry. *Science of the Total Environme*nt **394**, 237-243

Suthar S (2009) Vermicomposting of vegetable-market solid waste using *Eisenia foetida*: Impact of bulking material on earthworm growth and decomposition rate. *Ecological Engineering* **35**, 914-920

Tripathi G, Bharatdwaj P (2004) Comparative studies on biomass production, life cycles and composting efficiency of *Eisenia foetida* (Savigny) and *Lampito mauritii* (Kinberg). *Bioresource Technology* **95**, 77-83

Vasanthi D, Kumaraswamy K (1999) Efficacy of vermicompost to improve soil fertility and rice yield. *Journal of Indian Soil Science* **47**, 268-272

Venkatesh RM, Eevera T (2008) Mass reduction and recovery of nutrients through vermicomposting of fly ash. *Applied Ecology and Environmental Research* **6 (1)**, 77-84

You IS, Jones RA, Bortha R (1982) Evaluation of chemically defined for attachment of 3, 4 dichloroaniline to humans. *Bulletin of Environmental Contamination and Toxicology* **29**, 476-482

Zaller JG (2006) Vermicompost as a substitute for peat in organic potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. *Biological Agriculture and Horticulture* **24**, 165-180