International Journal of Waste Resources
ISSN: 2252-5211

Chatterjee et al., Int J Waste Resour 2017, 7:3
DOI: 10.4172/2252-5211.1000296

Review Article

Open Access

Recycling of Organic Wastes for Sustainable Soil Health and Crop Growth

Ranjit Chatterjee*, Somashekar Gajjela and Ravi Kiran Thirumdasu

Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India

Abstract

Enormous amount of organic wastes are generated from plant, animals and industrial activities in day to day life. A considerable part of which remains unutilized and are either burnt or dumped nearby sites that create pollution, harbours pathogen for diseases and causes severe problem of disposal. Instead of disposing, it can be used as source of organic wastes and effectively recycled for the production of compost to meet the nutritional requirement of crops. Considering growing deficiency of plant nutrients in crop field, higher cost of synthetic fertilizers and poor efficiency of chemical fertilizers, the organic wastes recycling for plant nutrient supply is becoming more essential for replenishment of plant nutrients, sustaining soil health, reducing the pollution problem and creating employment opportunities. The study was aimed to explore the possibility of bioconversion of different organic wastes to utilize the embedded nutrients for supplying enriched organic manure for better soil health and crop growth, which will not only improve the yield and quality of the produce but also conserve energy, minimize pollution, save foreign exchange and improve the fertilizer use efficiency subsequently that will helps to revitalize and restore the soil fertility and will revive the microbial activities for sustainable crop production.

Keywords: Organic wastes; Recycling; Green manuring; Composting; Vermicomposting

Introduction

A variety of wastes generated through different agricultural and other activities in our day to day life including crop residues in the form of straw, stover, husk, biomass of uncultivated plant species and weeds, forest biomass; animal wastes and by products like dung, urine, bones, fish processing wastes and human habitation wastes like garbage, sewage and sludge etc. (Table 1). Crop residues are abundantly generated in large quantities during crop cultivation. After harvesting the economic part(s) the plants are considered as wastes and are dumped on field side in mound. These accumulated wastes left on the field side causes major unpleasant odours and create disposal problems. They also create environmental problems like occupying vast area, spreading foul odours and forming breeding home for most of the pathogenic microorganism and mosquito vector. Furthermore they are often source of contamination of ground water. However, most of these potentially nutritious wastes are recyclable organic and good source of organic carbon. These huge inexpensive nutrient source or otherwise unused organic waste can be utilized for recycling as valuable resources. Considering growing deficiency of plant nutrients in crop field, higher cost of synthetic fertilizers and poor efficiency of chemical fertilizer, the organic wastes recycling for plant nutrient supply is becoming more essential for replenishment of plant nutrients, sustaining soil health, reducing the pollution problem and creating employment opportunities, which is now being increasingly recognized as a strategy for sustainable crop production. The organic wastes generally showed no adverse effects on crop yield, soil fertility or biological activity, but rather a stimulation of some properties, by reducing dependence on off-farm inputs and creating more balanced nutrient and energy flows, ecosystem resilience is strengthened, food security is increased and additional income are generated [1]. Tandon [2] stated that a sizeable proportion of nutrient needs of agriculture, horticulture, forest and aquaculture can be met through appropriate recycling of a number of wastes and by-product. With the changing scenario recent years have witnessed a renewed interest for sustainable crop production by revitalizing and restoring the soil fertility and reviving the microbial activity to make the soil lively and healthy (Table 1).

Effect of Recycled Organic Wastes on Soil Properties

The positive impact of organic waste application on the improvement of physical properties of the soils such as soil structure, water holding capacity, soil temperature, bulk density, total porosity, pore size distribution, soil resistance to penetration, aggregation, aggregate stability, hydraulic conductivity, base exchange capacity and resistance to soil erosion have been well documented [3,4].

Gonzalez et al. [5] recorded a positive change of soil physical properties after organic amendment application, as soil organic carbon content, fulvic acid fraction, electrical conductivity and soil respiration were found significantly higher whereas bulk density showed lower values at higher doses of vermicompost–compost amended soil.

Angin and Yaganoglu [6] attributed the increase in water-holding capacity values in plot treated with sewage sludge due to its high organic matter content. Although, crop residue application with or without fertilizer caused a little increase in water-holding capacity, these increases were not statistically significant compared to the control plots. The absence of significant change on soil bulk density and soil water holding capacity indicates that changes in these properties are expected to develop slowly after initiation of organic waste application. Three to four years are required for soil under conservation tillage to develop a more favourable porosity in 0 to 15 cm soil [7]. Incorporation of the crop residue with or without inorganic fertilizer for four seasons significantly increased water-holding capacity over the control and recommended fertilizer treatments. Practice of continuous cereal monoculture cropping and removal of crop residues result in the

***Corresponding author:** Chatterjee R, Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India, Tel: +919434197862; E-mail: ranchat22@gmail.com

Received Augus17, 2017; **Accepted** August 30, 2017; **Published** September 06, 2017

Citation: Chatterjee R, Gajjela S, Thirumdasu RK (2017) Recycling of Organic Wastes for Sustainable Soil Health and Crop Growth. Int J Waste Resour 7: 296. doi: 10.4172/2252-5211.1000296

deterioration of the physical, chemical, and biological properties of the soil [8].

Soil organic carbon (SOC) content decreased rapidly when crop residues from the field were removed regularly coupled with practicing conventional tillage [9,10]. Increase in soil organic carbon was principally due to the continuous addition of carbon through addition of the roots and crop residues at regular interval [11,12]. Increased in soil organic carbon with application of crop residue was also reported by Dhiman et al. [13] and Karanja et al. [14]. Ogbodo [15] found that soil organic matter was significantly higher on the soils treated with rice straw and legume residue than the untreated soils. Yadvinder-Singh et al. [16] found that incorporation of rice residue for 7 years increased soil organic carbon content of the sandy loam soil significantly in comparison with straw burning or residues removal. In another long-term study, Yadvinder-Singh et al. [16] reported that wheat straw incorporation increased organic carbon content from 0.40% in the control treatment to 0.53% in the straw incorporation treatment. On the contrary, Naklang et al. [17] reported no significant effect of rice straw incorporation for 3 years on total and labile carbon content of a sandy soil. In a rice-barley rotation under dry land conditions in northern India, Kushwaha et al. [18] reported that incorporation of crop residues increased soil organic carbon significantly by 28% in comparison with crop residue removal after one annual cycle.

The increase in cation exchange capacity (CEC) may be the result in an increase in available potassium in organic residue. Increase in CEC released more non-exchangeable potassium from the soils, which might have resulted in increased available potassium and potassium utilization by crops in addition to the residues that own potassium supply. The corresponding increase in potassium uptake by plants indicated that solution potassium is removed by plants; more potassium is released from non-exchangeable to exchangeable and soluble pools. The increase in CEC is determined by the proportional increase in soil organic matter content, and any change in soil organic matter directly affected the CEC of soil [7,19,20].

The incorporation of crop residues also increased the crop available phosphorus either directly by the process of decomposition and release of phosphorus from the biomass or indirectly by increase in the amount of soluble organic matter which are mainly organic acids that increase the rate of desorption of phosphate and, thus, improve the available phosphorus content in the soil [21]. However, Sharma et al. [22] and Singh and Sharma [23] found marginal or no increase in available phosphorus in the soils treated with rice or wheat straw. The long term application of maize residues may increase the levels of P and K in the soil [24]. During decomposition process, organic P in crop residues could provide a relatively labile form of P to succeeding crops, thus, providing a larger pool of mineralizable soil organic P to supplement soluble inorganic phosphorus pools [25,26]. The increase in available phosphorus concentration in organic waste treatments with recommended fertilizer could be due to high microbial activity induced by the addition of organic residues and soluble inorganic phosphorus, which speed up phosphorus cycling [27]. Another study by Abbasi et al. [19] showed that white clover residues tested for chemical composition showed 2.9 to 4.4 gkg^{-1} phosphorus as compared to 1.8 gkg^{-1} phosphorus in the grass samples. Therefore, increase in soil phosphorus might be due to the high concentration of phosphorus in guar residues, its mineralization and accumulation in soil, or possibly by increasing the retention of phosphorus in soil.

Biological soil properties are very reactive to small changes occurring in management practices, Application of organic residues to crop field are known to improve soil biological functions, also showing positive effects in the salt-affected soils. Soil derived from alluvial and marine deposits (with 3.3 gkg^{-1} total salts), soil urease and alkaline phosphatase activity and respiration rate were significantly stimulated by incorporation of organic manure [28].

Application of organic matter with a high degree of stability enhances structural properties of soil, which in turn provides a better habitat for microbial development. Increasing availability of nutrients also contributes to improve conditions for microbial activity [29,30]. Again, compost possesses its own microbial population, which may join the edaphic microbiota [31].

Effect of Recycled Organic Wastes on Crop Growth

Benefits of application of compost or vermicompost are mostly obtained from the second and third years onwards. When compost are used to fertilize crops, soil organic matter will increase over time and subsequent rates of application may be reduced because of increased nutrient cycling. Continuous use of manure or compost can lead to high levels of residual plant nutrients in the soil.

Ansari and Sukhraj [32] studied the recycling organic waste through vermicomposting in varied combinations for exploring the effect on productivity of okra. The study revealed that combined use of vermicompost and vermiwash combination resulted in 64.27% yield improvement over the control and chemical fertilizers. The fruits also resulted in greater percentage of fats and protein content by 23.86% and 19.86% respectively compared with those grown with chemical fertilizers.

Ghaly and Alkoaik [33] evaluated the effect of MSW compost on the growth and production of three vegetable crops namely potatoes, corn and squash. The results showed that 50% chemical fertilizers and 50% MSW combination gave the best plant growth, health and yield for potato and corn while NPK gave the best plant growth, heath and yield for squash. Squash did not seem to respond well to MSW compost.

Gonzalez et al. [5] studied the response of garden beet root yield and quality and found that soil amended with mixture of vermicompost and compost resulted in better growth and quality root production.

Mrabet et al. [34] reported that the agricultural recycling of household waste by composting is the most promising sector in comparison to other disposal routes such as incineration. They studied the effect of compost on lettuce and corn and found that yield of lettuce and corn were increased proportionally related to the dose of compost, however incorporation of a dose of 75% of the recommended dose is satisfactory for achieving the best returns.

Naikwade et al. [35] evaluated vegetable waste and agricultural waste for preparation of compost and vermicompost and their effect on fodder maize. They found that vegetable waste had great potential as starting material for composting and vermicomposting than agricultural waste and application of these prepared manures lead to enhancement of growth, quality and yield of fodder maize.

Simeon and Ambah [36] conducted a pot experiment in the green house to determine the effect of municipal solid waste on the growth of maize. They found increase in plant height, leaf area and number of leaves per plant at a range of 16.82 cm to 12.87 cm, 5 to 4 and 64.69 cm to 59.88 cm for the dumpsite and control samples respectively. They concluded that municipal solid waste is beneficial to plant if only proper and careful sorting and separation of hazardous waste is done before application to crop field.

Chatterjee et al. [37] recycled different vegetable wastes for vermicomposting and found that among different vegetable wastes vermicompost prepared from non-legume and legume waste at 2:1 ratio emerged as best growth medium in terms of superior yield and quality attributes with maximum root length (19.26 cm), root volume (73 cm^3) and root weight (68.43 g) as well as beta carotene (3.28 mg 100 g^{-1}) and TSS content of the carrot root (7.96 °Brix). The positive response of vermicompost on plant growth and yield was not only due to the available nutrients but also due to the availability of plant growth influencing materials, such as growth regulators, humic acids produced by the microbial population resulting from earthworm activity.

Giannakis et al. [38] investigated the impact of municipal solid waste compost (MSW-compost) application (0, 50, and 100 t/ha) on the growth of lettuce and tomato plants grown in large, 40 L pots. The findings showed inhibition of plants growth with increasing dose of MSW-compost, compared to plants receiving conventional fertilization. Growth inhibition was associated with a sharp decrease in soil NO –N content. On the other hand, a slower decrease in soil NO –N content occurred in non-planted pots amended with MSW-compost. These findings provide evidence that nitrogen immobilization and/or decreased nitrogen mineralization were responsible for inhibited growth by constraining nitrogen availability.

Manha and Wang [39] prepared vermicompost from rice waste and were mixed with rice hulls ash and coconut husk in different ratio and studied their performance on muskmelon seedling (*Cucumis melo* L.). They found that mixture of vermicompost with rice hulls ash and coconut husk at 1:1:1 resulted highest value of germination rate, plant height, leaf area, plant biomass and the concentration of P, K, Ca and Fe.

Ramezanzadeh et al. [40] studied the impact of municipal solid waste compost, *Azolla*, tea wastes on the growth and yield of the flower English Daisy (*Bellis perennis*) and found that combined medium of municipal wastes compost and *Azolla* compost increased the plant height, shoot dry weight and number of English Daisy flowers.

Ahirwar and Hussain [41] studied the transplant quality and field performance of vegetable transplants namely tomato, eggplant, chilli, potato, sweet corn hybrids, pak choi, spinach and turnip grown in vermicompost. The result showed that the transplant quality was improved in peppers and eggplants while tomato transplant quality was slightly reduced. There were no significant differences in field performance. They concluded that vermicomposting is a sustainable technique for solid waste disposal and to get better yield and quality of diverse crops.

Benefits of recycling of organic wastes in nutrient management:

- Utilization of embedded nutrients of organic wastes
- Conservation of energy
- Complementary source of plant nutrients
- Reduction of import cost of fertilizers
- Maximization of fertilizer use efficiency
- Ecological balancing of soil and land
- Reduce environment pollution
- Sustained agricultural growth

Method of Recycling of Organic Wastes

In situ recycling: raising of green manuring crop

Green manures are forage or leguminous crops that are grown for their leafy materials needed for soil conservation. Application of green leaves and twigs of trees, shrubs and herbs collected from elsewhere is known as green leaf manuring. Cultivation of green manure crops or green leaves manure improves soil structure, increases water holding capacity and decreases soil loss by erosion. It reduces weed proliferation and weed growth. Besides it also helps in reclamation of alkaline soils and minimise the attack of root knot nematodes. Green manures are a valuable potential source of nitrogen and organic matter (Table 2). In rice-based cropping systems diancha (*Sesbania* sp.) is highly suitable as green manure crop for water logging and heavy rain fall areas. Whereas sunhemp (*Crotalaria juncea*) is suitable for rainfed areas. Green gram, black gram, fodder cowpea, horse gram are preferred green manure crops for tropical climate. Niger and cocks comb are selected as potash rich green manure crop. A 45- to 60-day-old green manure crop can generally accumulate about 100 kg N/ha, which corresponds to the amount of mineral fertilizer nitrogen applied to crops. Sometimes green manure crops accumulate more than 200 kg N/ha. Integrated use of green manure and chemical fertilizer can save 50 - 75% of the required nitrogen fertilizers in rice. Green manuring also increases the availability of several other plant nutrients through its favourable effect on chemical, physical and biological properties of soil (Table 2).

Group	Type of wastes	Source of wastes
Plant wastes	Crop residues	Field crop residues and biomass
	Kitchen wastes	Daily kitchen wastes
	Green market wastes	Fruits and vegetable market wastes
	Coconut-arecanut/perennials wastes	By products of these crops
	Forest biomass	Natural forest biomass and by-products.
	Road side vegetation	Weeds and invasive plants biomass
	Aquatic plant biomass	Biomass of aquatic plants
Animal wastes	Animal dung and urine	Faeces and urine of domestic animals and dairies
	Poultry excreta	Poultry droppings of boiler and layering farm.
	Fish meal and fish wastes	Fish wastes arise from fresh water fish and sea fish industries
Other wastes	City garbage	City garbage and municipal solid wastes
	Biogas slurry	By-product of biogas plant
	Sewage and sludge	Industrial/municipal waste water treatment plants
	Sugar industry and distillery wastes	Spent and effluent of sugar industry
	Paper mill industrial wastes	Spent and effluent of the paper mill
	Fly ash	Fly ash generated from thermal power plants.

Table 1: Organic wastes available for recycling.

Green manure crops	Age (days)	Dry matter (t/ha)	N accumulated (kg/ha)
Sesbania aculeata	60	23.2	133
Sesbania rostrata	50	5.0	95
Crotalaria juncea	60	30.6	134
Vigna unguiculata	60	23.2	74
Pillipesara	60	25.0	102
Cyomopsis tetragonoloba	50	3.2	91

Table 2: Biomass production and N accumulation of different green manure crops.

Mulching of organic residues

Covering of root rhizosphere with mulch materials helps in suppressing weed growth, improving water infiltration, increasing soil water retention, maintaining the surface soil structure, drought tolerance and also protecting it from erosion and the leaching of nutrients. Biomulch accelerated the decomposition of crop residue and enhance nutrient cycling. It works by encouraging the natural bio-degradation process. Application of bio-mulches can improve the soil organic matter content, the water and nutrient retention in soils susceptible to leaching and stabilize soil pH. It can be a source of both macro and micro nutrients. However, these benefits can be reduced in hot humid climates, in which the decomposition of organic matter is faster than in temperate climates [42]. For annual crops the bio-mulches should be applied during sowing of the crops and for perennial crops it can be applied during the growing stages of the crop. Sufficient residual moisture should be maintained for proper decomposition and release of nutrients. Organic mulches were an important method of weed control before the development of herbicides in commercial vegetable production. A layer of 10-15 cm of mulch was needed to discourage weed growth. In general, weed seed germination declines as the depth of the covering layer increases, probably due to unfavourable conditions such as high or low temperature, absence of sufficient moisture, O_2, light, and high CO_2 levels [43]. Organic mulches can be as effective as conventional herbicides in controlling weeds [44] (Table 3).

Ex situ recycling: composting

Composting is the natural process of decomposition of organic residues by microorganisms such as bacteria, actinomycetes and fungi under controlled conditions. Besides supplying the essential plant nutrients, it improves the physico-chemical and biological properties of the soil. The goal of composting range from sanitation, reducing volume of waste, inactivating pathogens, parasites, weed seeds, sterilizing the organic constituent and producing a uniform organic material suitable for soil application. Composting is essential to convert the complex biological materials like lignin, cellulose, hemicellulose, polysaccharides, proteins etc. into simple available nutrients. In the process of composing microorganisms break down organic matter and produce CO_2, water and energy in forms of humus and relatively stable organic end product. With the onset of decomposition process the C:N ratio of the substrate reduced due to utilization of nitrogen and release of carbon as CO_2. During composting, microbes utilize the C as a source of energy and the N for building cell structure. The main drawback of traditional composting is the slow rate of decomposition as it takes longer time to convert the entire residues into compost. Again the nutrient composition of compost is highly variable and mostly low levels of nutrients in the final product hurdle its wider acceptability. The degradation of cellulose and lignin has been found to be a limiting step in traditional composting. Above all the potential levels of heavy metals and other possible contaminants in compost, particularly in mixed municipal solid wastes restricted its wider use on food crops. Involvement of earthworm for degradation of organic wastes results quick decomposition, reduce the period of composting and improve the quality of the final product [45] (Table 4).

Factors	Influenced by
Availability of organic wastes	» Type of crop » Alternate use pattern » Crop agronomic practices » Nature of soil » Collection and storage method » Awareness of growers
Quality of organic wastes	» Nutrient composition of the substrates » C: N ratio of the substrates » Purity/impurity of substrates » Mineralization capacity of wastes » Dry matter content of wastes » Presence of heavy metal/toxic compounds » Presence of disease inoculums or weed seeds
Technical know-how	» Availability of proper technology for composting
	» Preparation of wastes before composting
	» Nature of biodegradable substrate
	» Proper selection of wastes combination
	» Maintenance of moisture level during composting
	» Judging of end point of composting
	» Methods to reduce nutrient leaching
	» Cost involved
Social factors	» Traditional practices of composting
	» Lack of awareness or poor adoption of scientific compost technology
	» Regular demand for alternate use or land filling
	» Easy availability of chemical fertilizers at subsidized rate

Table 3: Factors influencing recycling of organic wastes.

Composting by involving earthworms-an alternative

Vermicompost, an organic cast obtained from the ingested biomass by earthworm. During ingestion, the earthworms fragment the wastes substrate, accelerate the rates of decomposition of the organic matter and alter the chemical and physical and chemical properties of the material. It is rich in in nitrogen, phosphorus and potassium as well as , humic acids, plant growth promoting substances like auxins, gibberellins, and cytokinins, N-fixing and phosphate solubilizing bacteria, vitamins, antibiotics, enzymes etc. Atiyeh et al. [46] stated that involvement of earthworm for degradation of organic wastes will promote faster decomposition with increased rate of mineralization, humification of organic matter and accelerated microbial diversity that improves the quality of the final compost. Vasanthi and Kumarswamy [47] stated that nutrient composition of organic wastes was found to be improved after vermicomposting in comparison to ordinary compost from the same organic materials. Edward [45] analyzed the nutrient content of compost and vermicompost and observed that vermicompost have higher nutrient concentration particularly of nitrogen and it has very low concentration of ammonium nitrogen and very high concentration of nitrate nitrogen whereas opposite in case of many composts. Again vermicompost has lower pH value than compost. Chatterjee et al. [48] in an experiment compared the traditional composting and earthworm mediated vermicomposting and found that highest carbon mineralization rate, lowest easily mineralizable carbon concentration and neutral pH in the final compost makes the vermicompost superior over traditional composting. Bhatnagar and Palta [49] found that earthworm accelerated vermicomposting is

Material	Cellulose	Lignin	Ash	Carbon	C-to-N ratio	PH	Ammonium-N (mg/l)
Fresh green waste	18.0	21.9	38.3	25.1	20:1	7.6	<l
Pre-composted waste (2 weeks)	14.7	21.7	51.6	21.0	15:l	7.9	<5

Source: Frederickson et al. [57] Figures are all % dry solids except for C-to-N ratio, pH and ammonium-N

Table 4: Composition of fresh green waste and pre-composted waste (2 weeks).

extremely efficient in breaking the complex decomposable organic matter and it was 2-5 times faster than conventional methods of composting. In traditional composting full conversion was approximately done in six months. However, 10 kg earthworms (10,000 numbers of worms) would convert 1 ton organic wastes per month within 5 m^2 composting pit. One million earthworm housed inorganic wastes spread just in an enclosure of 22.6 m × 22.6 m have potentialities of composting the wastes of 250 tonnes every month. The chemical compositions of vermicompost differ from substrate to substrate. Organic wastes rich in plant nutrients produced better quality vermicompost. Vasanthi and Kumaraswamy [47] evaluate the nutrient content of vermicompost prepared from different crop residues. Nitrogen content in vermicompost was 2.99% (Ipomea weeds), 2.83% (banana wastes), 2.99% (*Parthenium* weeds), 2.67% (sugarcane trash) and 2.61% (neem leaves). Similarly phosphorus content in vermicompost was 1.37% (*Ipomoea* weeds), 1.18% (banana wastes), 1.20% (*Parthenium* weeds), 1.06% (sugarcane trash) and 1.17% (neem leaves). The potassium content of vermicompost was 1.46% (*Ipomoea* weeds), 1.32% (banana wastes) and 1.19% (*Parthenium* weeds). Bansal and Kapoor [50] studied the composting and vermicomposting of crop residues using mustard residue and sugarcane trash as substrates. The substrates were mixed with cattle dung and allowed for vermicomposting for a period of 90 days. Similar experiment of composting was conducted without using earthworm. The results showed significant reduction of C:N ratio (26.3) and increased in mineral nitrogen content (191 mg/kg) in vermicompost over normal composting (29.5 and 182 mg/kg, respectively). Total P, K, Cu content did not differ in compost and vermicompost. They further observed that during vermicomposting the microbial activity as measured by the dehydogenase assay increased up to 60 days and declined on subsequent incubation. Biradar and Patil [51] studied the suitability of some weed species for vermicomposting by employing the earthworm *Eudrillus euginiae*. The weed species utilized were *Cassia seracea, Parthenium hysterophorus, Achyranthus aspera, Pennisetum* Sp. and *Euphorbia geniculata*. The results showed that higher vermicompost yield (683 kg/bed) was recorded with the weed *Cassia seracea* having 9531 number of clitellate and 14729 non clitellate worms, whereas higher biomass of clitellate worm (9354 g/bed) and 14729 non clitellate worms (4685 g/bed) were recorded with cow dung. The biomass of non clitellate worms with *Cassia seracea* and Parthenium hysterophorus were on par with each other and were significantly than other weed treatments. They finally concluded that *Cassia seracea* can be used as a source of organic biomass for vermicomposting. Ndegwa and Thompson [52] studied the effect of integrating composting and vermicomposting for decomposition of biosolids. They adopted two approaches of pre-composting followed by vermicomposting and pre-vermicomposting followed by composting. *Eisinea foetida* was the species of earthworm used for vermicomposting. The results indicated that a system that combines the two processes not only shortens stabilization time, but also improves the product quality. Among these combining compost- vermicomposting system resulted in product that was more stable and consistent (homogenous) and had less potential impact on environment. Nirmalnath et al. [53] conducted an experiment on recycling of agricultural crop residues on vermicompost yield and microbial population in vermicompost. They recorded the highest vermicompost yield (759.80 kg/bed) when cow dung alone was used as the substrate against 675.70 kg/bed from pigeon pea residues. Maximum microbial population such as bacteria (73×10^5), actinomycetes (100×10^4) and phosphate soluble microorganism (29×10^4) were recorded with the cow dung vermicompost. Among the crop residues sunflower residue harboured more number of bacteria (48×10^5), actinomycetes (98.60×10^4) and phosphate soluble microorganism (25×10^4). Raghavendra and Bano studied the manurial value of vermicompost prepared from different green leaves. Four types of green leaves namely honge (*Pongamia pinnata*), subabol (*Leucaena leucocephala*) neem (*Azadiracta indica*) and cashew leaves were mixed with cow dung slurry at 4:1 proportion each and were composted using a mixed culture of the earthworms *Eudrilus eugeniae* and *Eisinea foetida*. The results showed a decreased C:N ratio from 10 to 15% indicated of rapid humification during vermicomposting. The percent organic carbon was low in all the composts and the other macronutrients were also increased compared to control. They finally concluded that green leaves of perennials are highly effective for vermicomposting. Talukdar et al. [54] conducted an experiment on vermicomposting by using seven different biowastes namely kitchen wastes, crop residues, cattle shed wastes, waste papers, city garbage, water hyacinth and sugarcane bagasse with the help of locally available earthworm Amynthas diffringens. The results showed that maximum decomposition percentage and earthworm population were found when cattle shed wastes was used as substrate which was followed by kitchen wastes and crop residues. Again highest total nitrogen and total phosphorus contents were also recorded in cattle shed wastes vermicompost while potassium was highest in water hyacinth vermicompost. Barik et al. [55] conducted an experiment on vermicomposting to evaluate the suitability of paddy chaff powder with respect to the growth of earthworm *Eisinea foetida* and production of vermicompost after mixing with different proportion of legume straw powder and kitchen wastes. 1 kg mixture of paddy chaff powder, legume straw powder and kitchen wastes in the proportion of 8:1:1 mixed with equal quantity of cow dung on dry weight basis results increased biomass (fresh weight) production of *Eisinea foetida* from 7 to 53.4 g in 180 days. This was significantly superior over the mixture of above substrate in 8:2:0, 8:0:2 or 10:0:0 ratio. Again increased composting period beyond 180 days to 210 days results in declined biomass production and followed a reverse trend. It was 40% in 8:1:1 mixture and 18.9% in that of 10:0:0 mixtures. Shweta and Sharma [56] studied the biomass and vermicompost production by using the indigenous earthworm *Lampito mauritii* in different locally available organic wastes. The substrates used were kitchen wastes, cow dung, buffalo dung, leaf litters, oil cakes and agricultural wastes individually or in combination. The results revealed that the vermicompost of leaf litters had the highest number of earthworm with minimum earthworm weight, whereas cow dung had least number of earthworms with maximum body weight. The optimum increase in both number and weight was observed in mixed substrate with cow dung. Singh and Sharma [23] tried to integrate composting and vermicomposting for decomposition of organic residues. The results revealed that combination of composting followed by vermicomposting reduced the overall time required for composting and accelerate the composting of lignocellulosite wastes besides producing a nutrient enrich compost product. Chatterjee et al. [37] recycled different vegetable wastes for vermicomposting and found that among different vegetable wastes, substrate combining mixture of non-legume and legume wastes at 2:1 emerged best substrate considering the nutrient contents, C/N ratio, earthworm biomass and vermicompost recovery (Tables 5-8) [57-61].

Future research needs in recycling of organic wastes

1. Documentary evidence on ill effect of chemical farming and benefits of organic recycling on soil health, human health and environment should be propagated for better public awareness.

2. The emerging issues on organic recycling like availability of organic wastes, economic viability and profitability of the production system, financial support for the operation need to be addressed.

3. Transfer of recent scientific finding on modern composting methods, utilization of different microbes for decomposition, enrichment of compost and vermicompost through addition of

Treatments	Organic carbon (%)	Total N (%)	C: N ratio	Total P (%)	Total K (%)
T_1- Cow Dung (CD)	29.94	1.11	26.97	0.70	1.23
T_2- Cow Dung (CD)+Earthworm(EW)	28.21	1.20	23.51	0.71	1.28
T_3- Wheat straw + CD	35.33	0.92	38.40	0.60	1.11
T_4- Wheat straw + CD+EW	32.55	1.04	31.30	0.62	1.31
T_5- Mustard straw + CD	33.59	1.04	32.30	0.54	1.35
T_6- Mustard straw + CD+EW	32.25	1.16	27.80	0.56	1.62
T_7- Mixture of vegetable residues + CD	27.06	1.52	17.80	0.57	1.67
T_8- Mixture of vegetable residues +CD+EW	24.57	1.73	14.20	0.61	1.71
C.D.(0.05)	0.16	0.08	1.80	0.05	0.27

Source: Chatterjee and Bandyopadhyay [58].

Table 5: Nutrient content of compost at the end of decomposition (pooled of 2 years).

Days	Kitchen wastes				Agricultural wastes			
	EC (ms/cm)	TKN (%)	P (%)	TK (%)	EC(ms/cm)	TKN (%)	P (%)	TK (%)
0	0.4 ± 0.05 (0.4 ± 0.05)	0.25 ± 0.005 (0.25 ± 0.008)	0.13 ± 0 (0.13 ± 0.005)	0.087 ± 0.001 (0.087 ± 0.005)	0.3 ± 0.05 (0.3 ± 0)	0.18 ± 0 (0.18 ± 0.012)	0.070 ± 0.003 (0.070 ± 0.005)	0.062 ± 0.001 (0.062 ± 0.001)
20	0.5 ± 0.05 (0.4 ± 0.02)	0.31± 0.011 (0.27 ± 0.005)	0.13 ± 0.005 (0.13 ± 0)	0.133 ± 0.003 (0.107 ± 0.005)	0.5 ± 0.11 (0.5 ± 0.16)	0.20 ± 0.017 (0.18 ± 0.015)	0.076 ± 0.0005 (0.070 ± 0.0003)	0.090 ± 0.001 (0.073 ± 0.001)
40	1.4 ± 0.05 (1.4 ± 0.05)	0.38 ± 0.01 (0.28 ± 0.012)	0.15 ± 0.005 (0.13 ± 0.005)	0.195 ± 0.003 (0.155 ± 0.001)	0.5 ± 0.11 (0.3 ± 0.15)	0.30 ± 0.036 (0.3 ± 0.025)	0.080 ± 0.0005 (0.071± 0.0005)	0.141 ± 0.004 (0.088 ± 0.006)
60	1.7 ± 0.05 (1.5 ± 0)	0.56 ± 0.01 (0.30 ± 0.02)	0.16 ± 0.011 (0.16 ± 0.016)	0.332 ± 0.003 (0.214 ± 0.015)	0.6 ± 0.08 (0.4 ± 0.08)	0.45 ± 0.034 (0.27 ± 0.036)	0.090 ± 0.0005 (0.074 ± 0.0008)	0.181 ± 0.012 (0.095 ± 0.015)
80	1.9 ± 0 (1.5 ± 0.01)	0.78 ± 0.034 (0.41± 0.04)	0.17 ± 0 (0.14 ± 0.08)	0.387 ± 0.006 (0.268 ± 0.002)	1.4 ± 0.05 (0.8 ± 0.02)	0.66 ± 0.096 (0.40 ± 0.05)	0.10 ± 0.0005 (0.076 ± 0)	0.223 ± 0.003 (0.137 ± 0.005)
100	2.3 ± 0.05 (1.6 ± 0.06)	1.10 ± 0.023 (0.57 ± 0.02)	0.18 ± 0 (0.14 ± 0.05)	0.436 ± 0.006 (0.310 ± 0.006)	1.5 ± 0.05 (0.9 ± 0.06)	0.88 ± 0.051 (0.55 ± 0.05)	0.10 ± 0.001 (0.078 ± 0.001)	0.263 ± 0.006 (0.155 ± 0.002)

Source: Garg et al. [59]. EC- Electrical conductivity; TKN- Total kjeldahl nitrogen; P- Phosphorus; TK-Total potassium. All values are the mean and standard deviation of three replicates; all values are given in the percentage except EC (ms/cm). The values given in parentheses are the control values.

Table 6: Characteristics of the vermicompost prepared from kitchen and agricultural wastes at different time period.

Treatments	Organic carbon (%)	Total N (%)	C:N ratio	Total P (%)	Total K (%)
T_1 -Solanaceous veg. crop residues	27.67	1.68	16.47	0.49	0.78
T_2 -Leguminous veg. crop residues	25.86	2.04	12.68	0.51	0.68
T_3 -Cruciferous veg. crop residues	29.40	1.57	18.73	0.54	0.75
T_4 -Cucurbitaceous veg. crop residues	27.20	1.62	16.79	0.49	0.87
T_5-Mixture of T_1,T_2,T_3 and T_4 at 1:1:1:1 ratio	29.93	1.75	17.10	0.61	0.93
T_6- Non Legume : Legume veg. crop residues at 1:1 ratio	26.67	1.94	13.75	0.63	0.71
T_7 -Non Legume : Legume veg. crop residues at 2:1 ratio	28.20	1.91	14.76	0.68	0.98
T_8- Kitchen residues	26.87	1.78	15.10	0.58	0.83
T_9- Veg. market residues	26.32	1.32	19.94	0.41	0.61
T_{10}-Cow dung (control)	36.10	1.23	29.40	0.76	0.82
S.Em (±)	2.04	0.02	2.23	0.02	0.04
CD (P=0.05)	6.02	0.05	2.41	0.05	0.10

Source: Chatterjee et al. [60]

Table 7: Nutrient content of vermicompost at the end of decomposition (pooled of 2 years).

	N (%)	P(%)	K (%)	B (µg/g)	Ca (µg/g)	Fe (µg/g)	Mg (µg/g)	Mn (µg/g)	Na (µg/g)	S (µg/g)	Zn (µg/g)
Food waste vermicompost	1.3	2.7	9.2	23	18614	23264	4364	610	842	2587	279
Cow manure vermicompost	1.9	4.7	1.4	58	23245	3454	5802	160	3360	5524	516
Paper waste vermicompost	1.0	1.4	6.2	31	9214	17811	7661	447	613	1929	127
Biosolids compost	1.7	1.8	6.4	33	27965	7714	7185	364	930	6291	1281
Yard waste compost	0.5	1.8	6.6	50	89207	9031	21229	324	212	2860	120

Source: Arancon et al. [61].

Table 8: Composition of nutrient elements of vermicomposts and leaf composts**.**

micronutrients or bioinoculants etc. should be promoted.

4. The nutrient values of the different wastes/residues and their processed compost need to be standardized.

5. More research should be focused on easy decomposition of cellulose, hemicellulose, polysaccharides and lignin containing organic wastes.

6. Identification and exploitation of indigenous microbial strains for decomposition and their commercial formulation should be promoted.

7. Microbial consortium containing a mixture of different decomposing soil organisms instead of a single strain need to be promoted for better decomposition of complex wastes.

8. Adoption of proper guidelines for municipal soil waste management and application to crop field should be encouraged.

9. More research should be focused on utilization of agro-industrial wastes for crop cultivation.

10. Studies on the potential risks associated with recycling of contaminated urban wastes with heavy metal, plasticizers and surfactants accumulation on soil health and uptake by plants should be encouraged.

11. Health hazards associated with consumption of fruits and vegetable grown with city wastes and sewage sludge containing harmful pathogen need in depth study [62,63].

Conclusion

In the present agricultural system energy crisis, food shortage and environmental pollution are the main hurdles facing by the mankind. Over dependence on chemical fertilisers and pesticides and non-judicious use of synthetic agrochemicals is posing serious threat to ecological balance. Maintenance of healthy soil is now become a challenge for crop cultivation. The relatively high success of organic recycling in some countries are due to the high awareness and growing concern on the ill effects of chemical farming on environment. The enormous amount of organic wastes available for recycling of the world should be explore for possible bioconversion to utilize the embedded nutrients of the wastes for sustainable soil health and crop growth. It will not helps to meet the deficit of fertilizer nutrients but also to conserve energy, minimize pollution, save foreign exchange and improve the fertilizer use efficiency. Recent scientific advancement need to be exploited for more effective, economical and sustainable recycling of diverse organic wastes.

References

1. Peterson SO, Henriksen K, Mortensen GK, Krogh PH, Brandt KK, et al. (2003) Recycling of sewage sludge and household compost to arable land: fate and effects of organic contaminants, and impact on soil fertility. Soil & Tillage Research 72: 139-152.
2. Tandon HLS (1995) Recycling of crop, animal, human and industrial wastes in agriculture .Technical Bulletin. Fertilizer Development and Consultation Organization, New Delhi, India. p. 55.
3. Aggelides SM, Londra PA (2000) Effect of compost produced from town wastes and sewage sludge on the physical properties of a loamy and a clay soil. Bioresour Tech 71: 253–259.
4. Elsgaard L, Petersen SO, Debosz K (2001) Effects and risk assessment of linear alkylibenzene sulfonates in agricultural soil. 1. Short-term effects on soil microbiology. Environ Toxicol Chem 20: 1656–1663.
5. Gonzalez P, Ronald P, Neilson, James M, Lenihan Raymond J, et al. (2010) Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. Glob Ecol Biogeogr 19: 755–768.
6. Angin I, Yaganoglu AV (2011) Effects of sewage sludge application on some physical and chemical properties of a soil affected by wind erosion. J Agr Sci Tech 13: 757–768.
7. Mubarak AR, Rosenani AB, Zauyah SD, Anuar AR (2003b) Effect of incorporation N accumulation of white clover (Trifolium repens L.) in the hill farming system of Azad Jammu and Kashmir. Commun Soil Sci Plant Anal 40: 1546–1565.
8. Giller KE, Cadisch G, Ehaliotis C, Adams E, Sakala WD, et al. (1997) Building soil nitrogen capital in Africa. In: Buresh RJ, Sanchez PA (eds). Replenishing soil fertility in Africa.
9. Yang XM, Wander MM (1999) Tillage effects on soil organic carbon distribution and storage in silt loam soil in Illinois. Soil Tillage Res 52: 1-9.
10. Mann L, Tolbert V, Cushmann J (2002) Potential environmental effects of corn (Zea mays L.) stover removal with emphasis on soil organic matter and erosion. Agric Ecosyst Environ 89: 149–166.
11. Blanco-Canqui H, Lal R (2007) Soil structure and organic carbon relationships following 10 years of wheat straw management in no-till. Soil Tillage Res 95: 240–254.
12. Bhattacharyya R, Kundu S, Prakash V, Gupta HS (2008) Sustainability under combined application of mineral and organic fertilizers in a rain fed soybean–wheat system of the Indian Himalayas. Eur J Agron 28: 33-46.
13. Dhiman SD, Nandal DP, Om H (2000) Productivity of rice (Oryza sativa)-wheat (Triticum aestivum) cropping system as affected by its residue management and fertility levels. Indian J Agron 45: 1–5.
14. Karanja NK, Ajuke FO, Swift MJ (2006) Organic resources quality and soil fauna:their role on the microbial biomass, decomposition and nutrient release patterns in Kenyan soils. Tropical Subtropical Agroecosyst 6: 73–86.
15. Ogbodo EN (2009) Effect of crop residue on soil chemical properties and rice yields on an Ultisol at Abakaliki, Southeastern Nigeria. Am Eurasian J Sustain Agric 3: 442-447.
16. Yadvinder-Singh BS, Ladha JK, Khind CS, Khera TS, Bueno CS (2004) Effects of Residue Decomposition on Productivity and Soil Fertility in Rice–Wheat Rotation. Soil Sci Soc Am J 68: 854–864.
17. Naklang K, Whitbread A, Lefroy R, Blair G, Wonprasaid S, et al. (1999) Nitrogen rates on productivity and nutrient uptake of rice (Oryza sativa) of green manure crops. Soil Sci Soc Am J 67: 1186–1194.
18. Kushwaha CP, Tripath SK, Singh KP (2000) Variation in soil microbial biomass and N availability due to residue and tillage management in a dry land rice agroecosystem. Soil Till Res 56: 153-166.
19. Abbasi MK, Khizar A, Tahir MM (2008) Forage production, nitrogen fixation

and soil N accumulation of white clover (Trifolium repens L.) in the hill farming system of Azad Jammu and Kashmir. Commun Soil Sci Plant Anal 40: 1546–1565.

20. Abbasi MK, Mushtaq A, Tahir MM (2009) Cumulative effects of white clover residues on the changes in soil properties, nutrient uptake, growth and yield of maize crop in the sub-humid hilly region of Azad Jammu and Kashmir, Pakistan. Afr J Biotechnol 8: 2184–2194.
21. Nziguheba G, Palm CA, Buresh RJ, Smithson PC (1998) Soil phosphorus fractions of crop residues on a maize- groundnut sequence in the humid tropics. I: Yield and nutrient uptake. J Plant Nutr 26: 1841–1858.
22. Sharma SN, Singh S, Prasad R (2001) The effect of seeding and tillage methods on productivity of rice-wheat cropping system. Soil Tillage Res 65: 125-131.
23. Singh A, Sharma S (2002) Composting of a crop residues through treatment with microorganisms and subsequent vermicomposting. Biores Tech 85: 107-111.
24. Dam RF, Mehdi BB, Burgess MSE, Madramootoo CA, Mehuys GR, et al. (2005) Soil bulk density and crop yield under eleven consecutive years of corn with different tillage and residue practices in a sandy loam soil in central Canada. Soil Tillage Res 84: 41–53.
25. Cavigelli MA, Thien SJ (2003) Phosphorus bioavailability following incorporation of green manure crops. Soil Sci Soc Am J 67: 1186–1194.
26. Fuentes B, Bolan N, Naidu R, Mora ML (2006) Phosphorus in organic waste soil systems. J Soil Sci Plant Nutrition 6: 64–83.
27. Melero S, Madejon E, Ruiz JC, Herencia JF (2007) Chemical and biochemical properties of a clay soil under dryland agriculture system as affected by organic fertilization. Eur J Agron 26: 327–334.
28. Mariangela D, Francesco M (2015) Effectiveness of organic wastes as fertilizers and amendments in salt-affected soils. Agriculture 5: 221-230.
29. Carrera LM, Buyer JS, Vinyard B, Abdul-Baki AA, Sikora LJ, et al. (2007) Effects of cover crops, compost, and manure amendments on soil microbial community structure in tomato production systems. Appl Soil Ecol 37: 247-255.
30. Kowaljow E, Mazzarino MJ (2007) Soil restoration in semiarid Patagonia: chemical and biological response to different compost quality. Soil Bio Biochem 39: 1580-1588.
31. Selivanovskaya SY, Latypova VZ (2006) Effects of composted sewage sludge on microbial biomass, activity and pine seedlings in nursery forest. Waste Manage 26: 1253-1258.
32. Ansari AA, Kumar Sukhraj (2010) Effect of vermiwash and vermicompost on soil parameters and productivity of okra (Abelmoschus esculentus) in Guyana. Afr J Agric Res 5: 1794-1798.
33. Ghaly AE, Alkoaik FN (2010) Effect of municipal solid waste compost on the growth and production of vegetable crops. Am J Agric Biol Sci 5: 274-281.
34. Mrabet L, Belghyti D, Loukili A, Attarassi B (2012) Effect of household waste compost on the productivity of maize and lettuce. Agricultural Science Research Journals 2: 462-469.
35. Naikwade PV, Sankpal ST, Jadhav BB (2012) Management of waste by composting, vermicomposting and it's use for improvement of growth, yield and quality of fodder maize. ARPN Journal of Science and Technology 2: 184-194.
36. Simeon PO, Ambah B (2013) Effect of municipal solid waste on the growth of maize (Zea mays L.). International Letters of Natural Sciences 2: 1-10.
37. Chatterjee R, Bandyopadhyay S, Jana JC (2014) Evaluation of vegetable wastes recycled for vermicomposting and its response on yield and quality of carrot (Daucus carota L.). Int J Recycl Org Waste Agri 3: 60-64.
38. Giannakis GV, Kourgialas NN, Paranychianakis NV, Nikolaidis NP, Kalogerakis N (2014) Effects of Municipal Solid Waste Compost on Soil Properties and Vegetables Growth. Compost Science & Utilization 22: 116-131.
39. Manh Vo H, Wang C Ho (2014) Vermicompost as an important component in substrate: Effects on seedling quality and growth of muskmelon (Cucumis melo L.). APCBEE Procedia 8: 32- 40.
40. Ramezanzadeh F, Mohammadi Torkashvand A, Khakipour N (2014) The use of municipal wastes, azolla and tea wastes composts as the growth medium of English daisy. Eur J Exp Biol 4: 510-513.
41. Ahirwar CS, Hussain A (2015) Effect of vermicompost on growth, yield and quality of vegetable crops. International Journal of Applied and Pure Science and Agriculture 1: 49-56.
42. Dick WA, McCoy EL (1993) Enhancing soil fertility by addition of compost.
43. Baskin JM, Baskin CC (1987) Temperature requirements for after-ripening in buried seeds of four summer annual weeds. Weed Res 27: 385-389.
44. Singh Aparbal, Man Singh, Singh DV, Singh A, Singh M (1985) Relative efficacy of organic mulch and herbicides for weed control in cymbopogon species.
45. Edward CA (1998) The use of earthworms in the breakdown and management of organic wastes.
46. Atiyeh RM, Lee S, Edwards CA, Arancon NQ, Metzger JD (2002) The influence of humic acids derived from earthworms-processed organic wastes on plant growth. Biores Tech 84: 7-14.
47. Vasanthi D, Kumaraswamy K (1999) Efficacy of vermicompost to improve soil fertility and rice yield. Journal of Indian Society of Soil Science 47: 268-272.
48. Chatterjee P, Metiya G, Saha N, Halder M, Muhkerjee D (2005) Effect of substrates and composting methods on the quality of compost. Journal of Interacademicia 9: 66-75.
49. Bhatnagar RK, Palta RK (1996) Earthworm: Vermiculture and vermicomposting. Kalyani Publishers, Ludhiana. Pp: 6-49.
50. Bansal S, Kapur KK (2000) Vermicomposting of crop residues and cattle dung with Eisenia foetida. Biores Tech 73: 95-98.
51. Biradar AP, Patil MB (2001) Studies on utilization of prominent weeds for vermiculturing. Indian Journal of Weed Science 33: 229-230.
52. Ndegwa PM, Thompson SA (2001) Integrating composting and vermicomposting in the treatment and bioconversion of biosolids. Biores Tech 76: 107-112.
53. Nirmalnath PJ, Biradar AP, Patil AB, Patil MB (2001) Vermicompost microflora as influenced by different crop residues. Karnataka Journal of Agricultural Science 14: 168-169.
54. Talukdar MC, Das J, Goswami B (2001) Biowastes as source of vermicompost. Journal of the Agricultural Science Society of NE India 14: 171-175.
55. Barik T, Samal KC, Panda RK, Nanda S, Mohapatra SC (2002) Study on vermicomposting of farm and kitchen wastes. Journal of Applied Zoological Researches 13: 236-237.
56. Shweta, Sharma M (2003) Biomass and vermicompost production by the earthworm, Limpito mauritii in different organic wastes. Journal of Applied Zoological Researches 14: 98-100.
57. Frederickson J, Butt KR, Morris RM, Daniel C (1997) Combining vermiculture with traditional green waste composting systems. Soil Bio Biochem 29: 725-730.
58. Chatterjee R, Bandyopadhyay S (2010) Studies on composting of different crop residues as influenced by earthworm activity. J Soil Bio Eco 30: 169-177.
59. Garg P, Gupta A, Satya S (2006) Vermicomposting of different types of waste using Eisenia foetida: A comparative study. Biores Tech 97: 391-395.
60. Chatterjee R, Jana JC, Bandyopadhyay S (2010) Growth and multiplication of Eisinea fetida during vermicomposting of different vegetable crop residues. J Soil Bio Eco 30: 178-187.
61. Arancon NQ, Edwards CA, Bierman P, Metzger JD, Chad L (2005) Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. Pedobiologia 49 : 297-306.
62. Lacatusu R, Rauta C, Carstea S, Ghelase I (1996) Soil-plant-man relationships in heavy metal polluted areas in Romania. Appl Geochem 11: 105–107.
63. Raghavendra MA, Bano K (2001) Studies on the manorial value of vermicompost from different green leaves. Current Research(UAS, Bangalore) 30: 35-37.