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Bioconversion of Non Edible Vegetables from Market into Biofertilizer for Crop Improvement

Geetha Karuppasamy[1,†], Michael Antony D'Couto[1,†] & Anant Achary[1]

[1] Department of Biotechnology, Centre for Research, Kamaraj College of Engineering & Technology, Virudhunagar, Tamil Nadu, India

Correspondence: Anant Achary, Department of Biotechnology, Centre for Research, Kamaraj College of Engineering & Technology, S.P.G.C. Nagar, Virudhunagar-626001, Tamil Nadu, India. Tel: 91-4549-278-171. E-mail: achyanant@yahoo.com

[†] *These authors contributed equally to this paper.*

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Abstract

The fruits and vegetables lost due to spoilage in the market can be converted to nutrient rich organic biofertilizer, vermicompost and worm tea. In this study, non-edible vegetables from market [French beans (S1), Lady's fingers (S2) and Brinjal (S3)] were used for production of vermicompost and worm tea using *Eisenia fetida* for environmental friendly management and recycling, as value added product for crop production. Vermicomposting was carried out in four bins. Three bins (S1, S2 & S3) consisted of individual pre-digested vegetables and the fourth bin (S4) was set up with a mixture of all three pre-digested vegetables in equal proportions. Physico-chemical properties and essential nutrients like pH, temperature, moisture content, total organic carbon (C), total nitrogen (N), available phosphorus (P) and exchangeable potassium (K) of the pre-digested vegetables and/or compost were analysed at regular time intervals. There was around 6-10 fold increase in earthworm count at the end of vermicomposting. During vermicomposting, the N and P content of the compost showed 2 to 4 fold increase whereas 10 to 15 fold increase in K content was noticed. Low C:N ratio (4 to 9) was obtained for vermicompost VS4. The worm tea (vermi wash) and vermicompost collected were used for plant growth studies on *Vigna radiata* (Green gram). Growth parameters like germination percentage, vigour index, germination index (GI), shoot length (cm), root length (cm) and leaf length (cm) were studied. There was noticeable improvement in germination % (1.7 fold), vigour index (2.7 fold) and germination index. A 20 fold increase in shoot length was also seen in test plants when compared to control (2 fold). Statistical analysis of various growth parameters like root length and plant height indicated that vermicompost made with waste brinjal has a significant response with $p \leq 0.05$. Based on the results obtained, waste brinjal, which is abundantly available locally can be economically converted to organic biofertilizers and used for soil and crop improvement. Through this study, a cost effective and environment friendly method for efficient utilization of market waste vegetables has been proposed for promoting plant growth and development.

Keywords: vermicomposting, *Eisenia fetida*, vermi wash, *Vigna radiata*, vegetable waste, Madurai

1. Introduction

All the cities and towns have vegetable markets producing significant amount of non-edible vegetable wastes. Management of solid waste in the form of spoilt vegetables has become one of the biggest problems faced today by all the cities. The collection, transportation and disposal of this waste is a big problem. These wastes are usually dumped in the market itself and allowed to rot. However, this discarding system is reported to produce perilous ecological impacts and new policies are initiated to protect the environment from such impacts by discouraging the practice of unhygienic disposal of non-edible vegetable wastes (Kumari, 2013). Alternative disposal techniques that are eco-friendly need to be explored. At the same time, environmental degradation is one of the major threats confronting the world and the extensive use of chemical fertilizers contributes chiefly to the worsening of the environment through exhaustion of fossil fuels, generation of carbon dioxide (CO_2) and contamination of water resources. Excessive use of fertilizers has unfavourably affected agricultural productivity causing soil degradation. Owing to its high organic and moisture content, the vegetable wastes can be considered as a very useful and promising feedstock for bioconversion into nutrient rich organic biofertilizer that can be an excellent alternative to chemical fertilizers.

Vermicomposting refers to the production of nutrient-rich excreta of worms. After earthworms digest organic matter, they excrete a high-nutrient product known as castings. Earthworms have the efficiency to consume all types of organic rich wastes including vegetable waste and other organic waste. The food passes through the digestive tract and the worms secrete chemicals that break down organic matter into sustainable nutrition. Vermicompost is a peat like material consisting of excellent porosity, structure, aeration and moisture holding capacity that makes it good organic manure for growing plants. Another important property of vermicompost is its vast surface area that provides strong absorbability and nutrient retention ability (Dominguez et al., 1997). As a soil conditioner, vermicompost is healthier to traditional compost for its capability to improve and enhance soil configuration and its water-holding capacity (Kalra et al., 2010).

Vermicompost can be applied either directly by incorporating as a component for potted plants or as liquid fertilizer, called worm tea (vermiwash), collected from the composting bin. This worm tea has soluble plant nutrients, some organic acids along with microbes and enzymes which encourage the growth and yield of crops and even develop resistance against diseases in crops (Hatti et al., 2010). It also promotes growth rate and improves crop production by increasing the soil organic matter. When various organic wastes are inoculated with earthworms, the nutrient content of the waste is found to improve drastically with a concomitant decrease of the C:N ratio to a desirable level.

Sustainable development can be achieved by providing adequate food for which agricultural water management is an important aspect. Water resources being very limited in nature, Valipour (2015b, 2015c) has studied the cropping intensity in irrigated area and crop production for food security and stressed on the undeniable role of macroeconomic policies in agricultural water management. Interactions among various factors like soil, water and environment together, for crop improvement, will determine future food security and poverty reduction. The irrigation systems that when used effectively can also improve the crop productity and to achieve sustainable agriculture in future, identification of effective distinctions on land use for cropping intensity should be a priority (Valipour, 2012, 2015a).

The most important element of agriculture is water and it is mostly consumed during irrigation (Valipour, 2013). According to Valipour (2014, 2015d), irrigation efficiency can be enhanced by soil improvement. Vermicompost application to nutrient deficient soil has been found to improve the quality of soil and growth of the crops. Likewise, recycling of water used during vermicomposting process in the form of vermi wash is yet another way to enhance the seed germination and rate of plant growth (Tiwari & Singh, 2015; Valipour, 2015b). There is marked reduction of water resources in most areas of southern Tamilnadu (Angappapillai & Muthukumaran, 2012). Application of vermicompost in agriculture will help in the conditioning of soil and thus prevent crop loss due to scarcity of water.

The most common earthworm species used for vermicomposting are *Eisenia fetida*, *Eisenia andrei*, *Eudrilus eugeniae* and *Perionyx excavatus*. Among the four, *E. fetida* has been confirmed as the best for organic waste vermicomposting (Edwards & Bater, 1992). Vermicompost has been prepared from different organic materials including sugarcane trash, neem leaves and banana peduncle to increase the yield of various plants and the fertility of soil. In this study, non-edible vegetable from market was converted to a value added product, organic biofertilizer, using *E. fetida,* in an ecofriendly and cost-effective manner. The effect of the biofertilizer on the growth of *V. radiata* was evaluated and statistically analyzed.

2. Method

2.1 Collection of Sample

Three different non-edible vegetables [*Phaseolus vulgaris* (French beans), *Abelmoschus esculentus* (Lady's finger) and *Solanum melongena* (Brinjal)] were collected from local vegetable market at Madurai, Tamil Nadu (9°58′N, 78°10′E).

2.2 Earthworm Species

In the temperate climate, the most common vermicomposting worms are *E. fetida* and *E. eugeniae*. For this study, *E. fetida* was selected for vermicomposting of the market vegetable waste as it is pertinent for the climatic condition of Virudhunagar. The earthworms were collected from J.P. Farm, Virudhunagar, Tamil Nadu, India.

2.3 Pre-Digestion

Shade dried cow dung was broken to small pieces. The substrates (cow dung and diced non-edible vegetables) were mixed in the ratio of 1:1. Required amount of water was added to the mixture to maintain a 70-80% moisture level. Different vegetables (PS1: French beans; PS2: Lady's finger; PS3: Brinjal and PS4: Mix of all the three in equal proportions) with cow dung, as shown in Table 1, were allowed to decompose for 15 days in cement tanks with proper drainage facilities.

Table 1. Experimental setup for pre-digestion of market vegetable wastes

S.No	Experimental setup	Composition	Quantity
1.	PS1	French beans + Cow Dung	10 Kg each
2.	PS2	Lady's Finger + Cow Dung	10 Kg each
3.	PS3	Brinjal + Cow Dung	10 Kg each
4.	PS4	[French Beans + Lady's Finger + Brinjal] + Cow Dung	3.3 Kg of each vegetable waste + 10 Kg cow dung

2.4 Vermicomposting

Vermicomposting bins containing pre-digested French beans (VS1), Lady's finger (VS2), Brinjal (VS3) and mix of all the three vegetables (VS4) (Figure 1) were set up using Vermitech pattern. Four plastic bins, each of 75 litres capacity, were labelled and placed in a shaded elevated area on a pedestal of bricks for effective water drainage. The basal layer of the vermibed comprised of broken bricks and stones above which a layer of sand upto the height of 10 cm was set up to ensure proper filtration and drainage. This was followed by first a 10 cm high layer of cow dung (3 kg) and 5 cm high layer of pre-digested vegetable waste [PS1(3 kg), PS2 (3 kg), PS3 (3 kg) and PS4 (1 kg of all three)]. A 6~8 cm layer of straw was added to cover the bedding material that helped retain moisture (Ismail, 1997). Approximately 60-75 earthworms (*E. fetida*) were inoculated in each bin. The vermicomposting units were kept in shade and covered with a mesh for 45 days. Water was sprinkled to maintain sufficient moisture. For operative collection of worm tea, a small hole was drilled near the base of each bin and a tube was attached. Turning of the vermicomposting pile was carried out periodically.

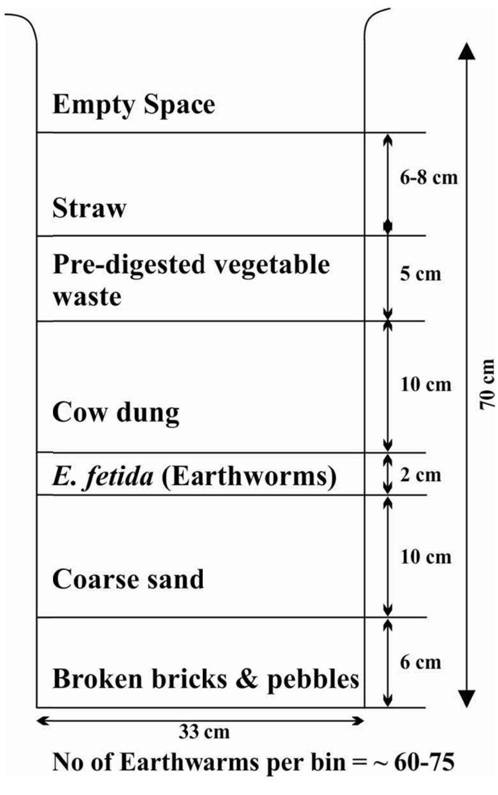

Figure 1. Experimental setup of vermicomposting bins

2.5 Collection and Preparation of Worm Tea

Water poured on top of the unit slowly percolate through the compost, carrying with it nutrients, through the filter unit and this is referred to as worm tea (vermiwash). Plastic bottles were used to collect and store the worm tea.

2.6 Physico-Chemical Analysis of Pre-Digested Vegetable Waste and Vermicompost

During the process of vermicomposting, microbes break down organic matter to produce carbon dioxide, water, heat, and humus as relatively stable organic end products. Under optimal conditions, composting proceeds through three phases: 1) the mesophilic, or moderate-temperature phase; 2) the thermophilic, or high-temperature phase; and finally 3) the cooling and maturation phase (Ansari and Ismail, 2012). Hence, with the aim of understanding the dynamics of the composting process, three representative days (days 1, 15 and 45) corresponding with the three phases of the composting process were selected for analysis of various physico-chemical parameters.

2.6.1 Temperature

The temperature of the vermibed/pile was recorded at regular time intervals throughout the composting period using a thermometer.

2.6.2 Moisture

Weighed quantity of samples were kept on watch glasses and placed in a hot air oven at 80 °C for 48 h. The weight of samples before and after drying was determined. The procedure was repeated thrice for each sample till the weight of the sample became constant. The moisture content for each sample was calculated as presented in detail in the Official Methods of Analysis (1990).

$$y = \frac{x_1 - x_2}{x_1} \times 100 \quad (1)$$

Where,

y =g % Moisture content (on wet basis); x_1 = weight of wet sample (g); x_2 = weight of dry sample (g).

2.6.3 pH

The pH of the sample was recorded according to the method described by Jackson (1973). 20 g of sample was taken and 40 ml of distilled water was added and mixed well. pH of the samples was determined using standard digital pH meter.

2.6.4 Total Organic Carbon

Total organic carbon was estimated as per the method described by Walkey and Black (1934). 100 mg of sample was weighed in 500 ml conical flask. 10 ml of 0.1667 M $K_2Cr_2O_7$ and 20 ml of concentrated H_2SO_4 was added and swirled gently. The reaction mixture was allowed to cool for 30 minutes. After cooling, the reaction mixture was diluted with 200 ml distilled water and 10 ml of H_3PO_4 was added to it. 0.1 ml of diphenylamine indicator was added and the solution was titrated against 0.5M $FeSO_4$ solution. The end point was the appearance of brilliant green color. A blank without the sample was titrated simultaneously. The percent organic carbon was calculated using the Equation (2).

$$\%\,Organic\ carbon\ (x) = \frac{[10(S-T)\times 0.003\times 100]}{[S\times Weight\ of\ sample]} \quad (2)$$

Where,

S: ml $FeSO_4$ solution required for blank; T: ml $FeSO_4$ solution required for sample; Actual amount of organic carbon (Y) = X × (100/77); Percent organic matter = Y × 1.724.

2.6.5 Total Nitrogen

Nitrogen in the sample was estimated by following the micro Kjeldahl method as outlined by Jackson (1973). Dried samples (0.5 g) were digested using 10 ml of concentrated sulphuric acid in presence of 0.3 g of catalytic mixture containing potassium sulphate, copper sulphate and selenium powder in the ratio 50:10:1 in the micro Kjeldahl digestion unit. The digested samples were diluted with distilled water and distilled after the addition of sufficient quantities of 40 per cent NaOH to make the sample alkaline in the micro Kjeldahl distillation unit. The ammonia evolved was trapped in 2% boric acid mixed indicator solution and titrated against 0.05 N sulphuric acids. The nitrogen content was calculated from the volume of acid consumed.

$$\% N = \frac{Titer\, value \times N\, of\, H_2SO_4 \times 0.014 \times Dilution\, factor}{Weight\, of\, the\, Sample(g)} \times 100 \tag{3}$$

2.6.6 Phosphorus

Phosphorus was estimated using the method as described by Jackson (1973). 0.5 g of dried sample was pre-digested with 5 ml of concentrated nitric acid and it was further digested with 10 ml of acid mixture (concentrated nitric acid, perchloric acid and sulphuric acid at 10:4:1 proportion). The digested material was then made upto 50 ml with distilled water. From this, 2 ml of aliquot was taken in a 100 ml volumetric flask along with 10 ml vanadomolybdic acid reagent and the volume was made up to 100 ml with distilled water. Yellow colour, developed within three minutes, was read at 490 nm against a reagent blank. The concentration of P in the sample was obtained by comparing phosphorus standard curve. Then using the following formula, percent of P (P_2O_5) was calculated.

$$P_2O_5(\%) = \frac{Graph\, ppm \times Volume\, made \times Volume\, of\, extract \times 100 \times 2.2}{10^6 \times Weight\, of\, the\, Sample \times aliquot\, taken} \tag{4}$$

2.6.7 Potassium

The concentration of potassium in the extract was determined by Flame photometric method (Jackson, 1973). 1 ml of an aliquot of tri-acid digest of the samples was transferred to 50 ml volumetric flask and volume was made up with distilled water. Flame photometer was calibrated to zero with zero ppm standards and to 100 with 5-ppm standard solution. Diluted solutions of the samples were fed to flame photometer and FPR was recorded. Standard curve of potassium was drawn by plotting FPR along Y – axis and potassium concentration along x – axis. The concentration of K (ppm) in the sample was obtained by referring to the standard curve. Then, the concentration of potassium was determined using the formula as given below.

$$\% K = \frac{Graph\, ppm \times Dilution\, factor \times Volume\, of\, the\, digest \times 100}{10^6 \times Weight\, of\, the\, Sample} \tag{5}$$

2.7 Plant Growth Experiment

Worm tea and vermicompost from the four bins were collected and used to determine the growth of Green gram (*V. radiata*) seeds. Growth parameters viz. germination percentage, vigour index, germination index (GI), shoot length (cm), root length (cm) and leaf length (cm) were studied. A pot experiment was conducted in red clay pots having 11 cm height with 12 cm top diameter and 6 cm bottom diameter under natural environment. Each pot could accommodate 800 g of horticultural media. Total number of five seeds was sown at a depth of 3 cm and 3 cm distance in each pot. The pot experiment was carried out in a Randomized complete Block Design (RCBD) with five treatments and three replications. The different treatments are tabulated and presented in Table 2. The total tamount of vermicompost incorporated into the soil was twenty five percent. Vermiwash was diluted five fold in deionized water which was used as a foliar spray at regular intervals. Germination % was calculated after 48 h and the shoot and root lengths were measured during 2^{nd}, 4^{th}, 6^{th}, 8^{th}, 10^{th}, 12^{th} and 15^{th} day. On the final day, the plant length and vigour index were calculated.

Table 2. Experimental setup for plant growth study

Sl. No.	Sample	Treatment group	Symbol
1	P1	Vermicompost from VS1	VC
		Vermicompost and worm tea from VS1	VC+WT
2	P2	Vermicompost from VS2	VC
		Vermicompost and worm tea from VS2	VC+WT
3	P3	Vermicompost from VS3	VC
		Vermicompost and worm tea from VS3	VC+WT
4	P4	Vermicompost from VS4	VC
		Vermicompost and worm tea from VS4	VC+WT
5	P5 (control)	Soil	C

2.7.1 Germination Percentage

On the 2^{nd} day, the germinated seeds were counted and the % germination was computed using the given formula (Naik & Sreenivasa, 2009).

$$Germination\,\% = \frac{No.of\ seeds\ germinated}{No.of\ seeds\ sown} \times 100 \tag{6}$$

2.7.2 Vigour Index

The seedling's vigour index was calculated adopting the method suggested by Abdul-Baki and Anderson (1973) and expressed as whole number.

$$Vigour\ index = Germination\ \% \times Seedling\ length \tag{7}$$

2.7.3 Germination Index (GI)

The germination index (GI) was calculated as described in the Official Methods of Analysis (1990) by using the formula:

$$GI = \frac{No.of\ germinated\ seeds}{Days\ of\ first\ count} + \ldots + \frac{No.of\ germinated\ seeds}{Days\ of\ final\ count} \tag{8}$$

2.8 Statistical Analysis

The experimental data was expressed as mean values. One way analysis of variance (ANOVA) was carried out using SIGMASTAT 3.5 to determine the difference between treated and control groups.

3. Results

3.1 Vermicomposting

In the present study, each unit started with ~ 60-75 earthworms (*E. fetida*). The vermicompost was harvested after a 45 day period. The earthworms were enumerated in each bin and the results are presented in Table 3. There was a 10 fold increase in the population of earthworms in the bin containing pre-digested brinjal (VS3) [~753 earthworms] and 8.6 fold in the bin containing the mix (VS4) [~645 earthworms]. The vermicomposting bins containing pre-digested French beans (VS1) and lady's finger (VS2) had low number of earthworms [~576 and ~425], comparatively.

Table 3. Enumeration of earthworms after vermicomposting

S.No	Sample	Earthworm count	
		Day 1	Day 45
1.	VS1	~ 60-75	~ 576
2.	VS2	~ 60-75	~ 425
3.	VS3	~ 60-75	~ 753
4.	VS4	~ 60-75	~ 645

Table 4 represents the moisture content, pH and temperature of the vermicompost after 45 days of vermicomposting. The moisture content of the compost bed was found to decrease in all the bins with the progression of vermicomposting. The pH and temperature of vermicompost showed an increase that might be because of exothermic decomposition of organic matters. Though the increase was only marginal, still, all the four experimental setup showed a similar increasing trend.

Table 4. Moisture content, pH and temperature of vermicompost

S.No	Sample	Vermicompost					
		Moisture Content (%)		pH		Temperature (^{o}C)	
		Initial	Final	Initial	Final	Initial	Final
1.	VS1	83.67	53.44	7.00	7.26	25	30
2.	VS2	84.35	58.67	7.20	7.29	26	32
3.	VS3	88.76	56.34	7.13	7.24	27	30
4.	VS4	89.48	60.76	7.25	7.28	25	30

3.2 Physico-Chemical Analysis

The samples from each experimental vermicomposting bins (VS1, VS2, VS3 and VS4) were collected on the 1st, 15th& 45th days. The samples were air dried to monitor the changes in physico-chemical characteristics. All the samples were analyzed in triplicates and results were averaged. The data pertaining to total carbon (%), total Kjeldahl nitrogen (%), total phosphorus (%) and total potassium (%) content of vermicompost obtained from VS1, VS2, VS3 and VS4 at different time intervals are presented in Table 5a. All the vermicomposting bins showed a steady decrease in total organic carbon (1.5-1.2 fold). The bins, VS1 and VS2, showed only a marginal increase in nitrogen content (1.67 and 1.98 folds) whereas VS3 followed by VS4 showed significant increase in the nitrogen content (2.38 and 2.14 folds). The C:N ratio of the vermicompost during the initial stages were in the range of 12.68 to 23.37 whereas the final C:N ratio of the vermicompost were in the range of 4.87 to 14.94 as shown in Table 5b.

The amount of total phosphorus increased moderately during the process of vermicomposting in all the four bins while in bin VS4, a steep increase of 3.92 folds was observed. The decrease in phosphorous content in bin VS1 was recorded on 15th day of vermicomposting from initial 0.40% to 0.23%. However, on 45th day it was found to be 1.62 folds higher than initial amount. There was a significant increment in total potassium in all wastes during vermicomposting. The increased potassium content in bins VS1 and VS2 was 15.42 and 14.23 folds respectively whereas in bins S3 and S4, there was 9.44 and 13.06 fold increase in potassium content. Although N, P and K content increased in all the vermicomposts but based on the overall results, it can be concluded that a mixture of all the three pre-digested vegetables is a rich organic biofertilizer (C-1.2 fold decrease; increase in N-2.14 fold; P-3.92 fold and K-13.06 fold) when compared to others tested.

Table 5a. Carbon (C), Nitrogen (N), Phosphorous (P) and Potassium (K) content of vermicompost

S.No	Sample	Carbon (%)			Nitrogen (%)			Phosphorous (%)			Potassium (%)		
		Day1	Day15	Day45	Day1	Day15	Day45	Day1	Day15	Day45	Day1	Day15	Day45
1.	VS1	12.30	10.37	7.89	0.97	1.37	1.62	0.40	0.23	0.65	0.14	0.48	2.16
2.	VS2	34.52	30.52	26.76	0.90	0.98	1.79	0.25	0.35	0.67	0.17	0.70	2.42
3.	VS3	29.87	26.75	23.92	0.81	1.37	1.93	0.15	0.27	0.41	0.18	0.48	1.70
4.	VS4	18.93	17.68	15.74	0.81	1.50	1.74	0.14	0.24	0.55	0.15	0.72	1.96

Table 5b. C:N Ratio of vermicompost

S.No	Sample	C:N Ratio of vermicompost		
		Day1	Day15	Day45
1.	VS1	12.68	7.56	4.87
2.	VS2	38.35	31.14	14.94
3.	VS3	36.87	19.52	12.39
4.	VS4	23.37	11.78	9.04

3.3 Application of Vermicompost and Worm Tea on Seed Germination and Plant Growth

The germination and growth of *Vigna radiata* (Green Gram) was monitored in soil treated with 25% (w/w) vermicompost (VC) and worm tea (WT). The results of the study are presented in Tables 6-8. The growth parameters studied were germination percentage, vigour index and germination index (GI) (Table 6), number of leaves, shoot length (cm) and leaf length (cm) (Table 7), root length (cm) and plant height (cm) (Table 8). Both vermicompost and worm tea have shown a significant difference ($P \leq 0.05$) in the growth parameters like root length and plant height. All the treated groups showed an ability to enhance germination when compared to control (Table 6) where as control group showed much lower germination percentage (41.66±8.35). VC alone and VC+WT treatments helped in improving vigour index when compared to control. In both the cases, plants from all treatment groups showed a significant growth ($P \leq 0.05$). However, among the two treatment groups and control, VC+WT treatment helped to improve the vigour index to a greater extent (3.31 fold) when compared to VC alone (2.4 fold). Earlier germination of seeds was recorded in seeds treated with VC+WT as indicated by higher GI value (Table 6).

VC alone and VC+WT treated groups also had a significant effect ($P \leq 0.05$) on the number of leaves, shoot length (cm) and leaf length (Table 7). A noteworthy increase in the shoot length (20 fold) was observed in all the treated groups (P1, P2, P3 and P4) except control (P5) (2 fold). There was marginal increase in root length (1.8-2.67 fold) and plant height (1.63-1.89 fold) in VC+WT treated groups when compared to VC alone and control groups (Table 8). Although VC+WT treated plants of P4 showed 1.89 fold increase in plant height, P3 group plants also showed an increase of 1.79 fold in plant height indicating that crop improvement on application of vermicompost and worm tea made with brinjal alone gave results in equivalence to that achieved with the application of vermicompost made with a mix of all the three vegetables. Since, brinjal is abundantly available in the local area, SV3 vermicompost will be a better candidate vermicompost for future field experiments.

Table 6. Germination %, Vigour Index and Germination index (GI) of *V. radiata* seeds grown with Vermicompost (VC) and Worm tea (WT)

Parameters	Treatment Groups	P1	P2	P3	P4	P5
Germination %	VC	53.01±4.71	60.27±2.09	60.36±13.89	67.14±6.22	41.66±8.35
	VC+WT	**79.97±11.55**	**70.36±6.41**	**63.96±8.58**	**73.01±10.99**	
Vigour Index	VC	1908	1727	1692	2284	919
	VC+WT	**2362**	**2580**	**2622**	**3050**	
Germination Index (GI)	VC	16.01	17.43	16.28	19.74	12.83
	VC+WT	**25.57**	**22.68**	**21.73**	**24.89**	

Table 7. Effect of application of vermicompost and worm tea on plant growth

Sample	Treatment Groups	No. of leaves		Shoot length (cm)		Leaf length (cm)	
		Day 4	Day 15	Day 4	Day 15	Day 4	Day 15
P1	VC	1.2±0.44	1.90±0.43	8.12±3.39	24.20±6.09	0.35±0.18	2.39±1.06
	VC+WT	2	2	10.5±2.27	28.80±6.75	0.63±0.13	2.96±0.63
P2	VC	1.25±0.5	2.1±0.30	9.5±1.17	21.50±6.43	0.53±0.29	2.96±0.97
	VC+WT	1.44±0.52	2	4.8±3.86	29.58±6.80	0.60±0.47	2.76±1.30
P3	VC	1	1.93±0.37	7.85±0.33	20.50±6.53	0.47±0.24	2.91±1.00
	VC+WT	2	1.94±0.52	10.66±2.18	32.57±6.82	0.61±0.32	2.58±1.10
P4	VC	2	2	7.58±3.20	28.50±4.83	1.51±0.15	3.19±0.85
	VC+WT	1.83±0.38	2.78±0.59	9.56±3.75	32.69±8.96	1.73±0.89	3.33±1.35
P5	CON	Nil	2	Nil	16.20±5.3	Nil	3.31±0.78

Table 8. Effect of vermicompost and worm tea on root length (cm) and plant height (cm)

Sample	Treatment Groups	Day 15	
		Root Length (cm)	**Plant Height (cm)**
P1	VC	5.96±1.84	29.54±1.74
	VC+WT	11.06±1.80	36.00±1.83
P2	VC	5.98±1.05	28.66±1.73
	VC+WT	10.6±2.17	36.68±2.15
P3	VC	6.16±1.11	28.04±2.16
	VC+WT	15.40±1.51	41.00±2.35
P4	VC	10.60±1.30	34.02±1.96
	VC+WT	15.02±1.65	41.78±1.75
P5	CON	5.62±1.25	22.06±1.20

The results of the effect of vermicompost and worm tea on *Vigna radiata* were expressed as mean values and One-way Analysis of Variance (ANOVA) was carried out to find the significant differences among the treatments. The results of ANOVA for various growth parameters like root length and plant height indicated a significant response with $p \leq 0.05$.

4. Discussion

Pre-digestion is essential for better vermicomposting of the feed. Ndegwa et al. (1999) has shown that the initial pre-digestion results in better quality of vermicompost. In the present study, non-edible vegetable wastes from the market [*P. vulgaris* (French beans), *A. esculentus* (Lady's finger) and *S. melongena* (Brinjal)] were collected for vermicomposting. There was a considerable increase in the population of *E. fetida* in bins VS3 and VS4 during vermicomposting that may have attributed to the quality and the yield of vermicompost in them. The increase in the population of worms indicates that the brinjal waste with cow dung may be the preferred nutrient for growth and multiplication of *E. fetida* than the other vegetables. This might be due to the fact that among the three vegetables used, brinjal has soft tissue that can be digested at a much faster rate when compared to the other two. Ansari and Jaikishun (2010) and Indrajeet et al. (2010) have also used materials like leaf litter, kitchen & feed waste, farm waste like paddy straw in combination with cow dung as substrate for vermicomposting. In their study, the multiplication rate of the earthworms was found faster in wastes which were easier to digest than others.

Vermicomposting requires the action of other microorganisms which help the earthworms to break down the waste. The decrease in moisture content during vermicomposting may be attributed to the increase in temperature as is evident from the results of this study. Dominguez et al. (1997) have reported 57-60% moisture content in vermicompost and further revealed that moisture content above 60% tends to become anaerobic which corresponds with the results obtained in this study using vegetable waste. During vermicomposting, the pH dropped to 6.5 within first 15 days of composting and this decrease in the initial stage may be due to nitrogen volatilization and release of H^+ ions caused by nitrification process of nitrifying bacteria (Eklind and Kirchmann, 2000). Microorganisms are known to generate heat as they decompose organic material. Initial temperature (25 °C) of the vermibed was found to increase to 30 °C because of exothermic decomposition process of organic matters. Garg and Gupta (2011) observed similar changes in temperature during vermicomposting.

Nitrogen content of the soil is important as it helps the plants to access other nutrients like phosphorous and potassium. Phosphorous also plays an important role in various metabolic processes in plants along with energy transformation. On the other hand, potassium is required in development of resistance against fungal and bacterial disease to plants. Potassium increases resistance of plants towards diseases & drought and reduces water logging (Mulongoy & Bedoret, 1989). The amount of total N, P and K increased during the process of composting. The increase in the nitrogen content of the compost could be due to the nitrogen fixation by the microorganisms under aerobic condition and by the breakdown of proteins (Roger, 2000). Metabolic products of earthworms such as muco-proteins, casts and urine may also increase total nitrogen content (Uma & Vijayalakshmi, 2003). During the process of vermicomposting, the degree of mineralization and stabilization rate of the substrate is evident from the C:N ratio of the vermicompost (Yadav & Garg, 2011). The decline in the C:N ratio is mostly caused due to accumulation of nitrogen in the form of mucous and excreta and loss of carbon as carbondioxide through microbial respiration (Singh et al., 2010). A C:N ratio less than 20 represents a reasonable degree of maturity of vermicompost (Yadav & Garg, 2011), whereas a C:N ratio lower than 12 is further appropriate to guarantee an excellent measure of maturity for agricultural applications (Jimenez & Garcia, 1992). Vermicompost prepared from the mix of all waste vegetables (VS4) showed a C:N ratio of 9.04 which is well within the range. The increase in phosphorus can be attributed to gradual mineralization of organic matter. Increase in the phosphorus content was found to be similar to that reported by Suthar (2009). Zularisam et al. (2010), and Ananthakrishnasamy et al. (2009) who have also reported increase in phosphorus content in the vermicompost. The ingested organic matter may get degraded at an increased rate due to the symbiotic microflora present in the gut and the cast of earthworm along with secreted mucus and water leading to release of available metabolites which enriches the vermicompost with exchangeable potassium. Parthasarathi and Ranganathan (2000), Ansari and Ismail (2012), Ansari and Ismail (2008), and Jaikumar et al. (2011) have also reported increase in potassium content in the vermicompost. However, Ananthakrishnasamy et al. (2009) has reported lower levels of potassium in vermicompost than in the initial substrate.

V. radiata grown on soil amended with a combination of vermicompost and worm tea developed nodes and new leaves at a significantly higher rate when compared to control. This could be due to increased bioavailability of macro and micronutrients from vermicompost and worm tea (Erich et al., 2002). Organic manure like vermicompost and worm tea, when added to soil, augments crop growth and yield (Lalitha et al., 2000). Atiyeh et al. (2001), and Suthar (2009) have also shown that the addition of vermicompost in bedding media, improved seed germination, enhanced the seedling growth and increased overall plant productivity. The author has further shown that the greatest response from the plants could be observed only when the vermicompost was used at 10-40% of the volume of plant growth medium. A germination index of ≥ 60% has been suggested as an indicator of the removal of phytotoxicity in composts (Zucconi et al., 1985). On the other hand, a germination index of 40% or less would represent phytotoxic potential of vermicompost (Garcia-Prendes, 2001). Thus from our experimental results (16-25%), it can be noted that the phytotoxicity of the soil was reduced by the addition of vermicompost and worm tea. The results of Chadha et al. (2012) showed that the application of worm tea on plants gave significantly higher yield than control and also worm tea exhibited 72.2% post-emergence disease control. According to Devi and Wani (2007), diluted samples of worm tea was found to be effective in stimulating the growth of tomato plants and the germination efficiency of seeds of chickpea and pearl millet. Large amount of humic acid is produced during vermicomposting and this has been reported to have positive effect on plant growth. Vermicomposts have been shown to influence the growth and productivity of a variety of plants, cereals and legumes (Suthar, 2009). Gutiérrez-Miceli et al. (2007) highlighted in their study that greater plant height promotes the development of a greater number of leaves and chlorophyll. This increase in the number of leaves will increase total photosynthesis and thus favor fruit's weight and yield. The positive effect of worm tea on crop growth and yield in the present study is in conformity with the studies of Meghvansi et al., (2012) on increase in growth and yield of paddy with the application of worm tea and vermicompost.

5. Conclusion

Non-edible vegetables from market [French beans (S1), Lady's fingers (S2), Brinjal (S3) and Mix of all the three (S4)] were used for production of vermicompost and worm tea using *E. fetida*. Vermicomposting resulted in 6-10 fold increase in earthworm count along with increase in concentrations of N (2-4 fold), P (2-4 fold) and K (15-23 fold) during vermicomposting. The pH and temperature were found to be in the range ~7.2 and ~30 °C at the end of vermicomposting. Application of vermicompost and worm tea on growth of *V. radiata* showed an improvement in germination % (1.7 fold) and vigour index (2.7 fold). Higher germination index indicated earlier germination in VC+WT treated seeds. By the same token, 20 folds increase in shoot length was also observed when compared to control (2 fold). Overall, the effect of VC+WT, obtained from waste brinjal, on the growth of *V. radiata* was significant ($P \leq 0.05$) when compared to control. Thus, based on the results obtained in this study, vermicomposting of non-edible waste vegetables from market can be utilized as an environmental friendly and cost effective waste management method to produce value added product for soil and crop improvement.

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