ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 14 (1): 37-42, 2015
ISSN 1812-5379

ansinet
Asian Network for Scientific Information

RESEARCH ARTICLE OPEN ACCESS

DOI: 10.3923/ja.2015.37.42

Bioconversion of Wastes (Khat Leaf Leftovers and *Eucalyptus* Twigs) into Vermicompost and Assessing Its Impact on Potato Yield

Eyasu Mekonnen and Anteneh Argaw
School of Natural Resources Managemen and Environmental Sciences, College of Agriculture and Environmental Sciences, Haramaya University, P.O. Box 337, Dire Dawa, Ethiopia

ARTICLE INFO
Article History:
Received: December 03, 2014
Accepted: February 27, 2015

Corresponding Author:
Eyasu Mekonnen,
School of Natural Resources Management and Environmental Sciences,
College of Agriculture and Environmental Sciences,
Haramaya University, P.O. Box 337,
Dire Dawa, Ethiopia

ABSTRACT

The major rural land use system in Eastern Ethiopia is cultivation of khat (*Catha edulis* Forsk), which is the main perennial cash crop in the region for its stimulant leaf. Due to its financial attractiveness, farmers mostly cultivate the crop on cost of soil nutrient depletion as the marketing practice involves harvesting its fresh leaves throughout the year, wrapping with *Eucalyptus* twigs to retain its freshness during transportation to the local market, where they are dumped as municipal waste. Such routine activity disrupts the nutrient cycle out of its agro ecosystem. This study was conducted to assess fertilizer value of these wasted materials in the form of vermicompost and also to evaluate impacts of the vermicompost when it replenish soil in smallholder agriculture under rainfed condition. The khat and *Eucalyptus* wastes were collected, chopped and filled into 5 cemented pits of 1.5 m^3. Treatments were arranged in a Randomized Complete Block Design with three replications, which was designed as 100% khat leftover; 70% khat leftover mixed with 30% *Eucalyptus* twig and inoculated with red earthworms (*Eisenia fetida*), which feed and ultimately produce the vermicomposts. Its quality analysis showed that both forms of vermicompost are rich with essential plant nutrients. They were bulked and applied into a soil with rate of 0, 15 and 30 t ha^{-1} with or without half dose of recommended nitrogen and phosphorus fertilizer. The rate below 15 t ha^{-1} of vermicompost plus half dose of the recommended fertilizer resulted highest marketable tuber yield. It implies that these forms of vermicomposts can be effective source of organic fertilizer in smallholder agriculture, potato cultivation in particular.

Key words: Ethiopia, bioconversion, municipal waste, vermicompost, potato

INTRODUCTION

Growing Khat (*Catha edulis Forsk*) is the major land use system in Eastern Harerge zone of Oromiya Regional State, Ethiopia. It is an evergreen tree cultivated for the production of fresh leaves that are chewed for their euphoric properties (Dessie, 2013). It shares large proportion of space with staple food crops at the farm level such as maize and *sorghum* (Dessie, 2013; Kandari *et al*., 2014). Farmers in the study area often cultivate crops with a high financial return and become reliant on the cash to access food items. The rise, both in terms of volume and earnings has also continued in 2012/13, reaching 271 million dollars in earnings from the export of 47,000 t of Khat. This was followed by 249 million dollars being earned from 44,000 t over just the past ten months (Addis, 2014). Perhaps, due to the financial attractiveness and market availability, khat cultivation may be continued as the future's major rural land use system in the region. However, it is mostly cultivated with the expense of cereal crops, soil nutrient depletion and environmental pollution (Kandari *et al*., 2014; Dube *et al*., 2014). Expansion of the land use type ultimately leads to disposing large amount of biodegradable wastes, which has become one of the major environmental challenges in most urban areas.

The nature of marketing practices involves collecting fresh twigs of khat, wrapping it with *Eucalyptus* twigs and ultimately disposed as municipal waste materials. Harvesting fresh leaves of khat throughout the year disrupts the nutrient cycle and depletes the soil nutrient budget from its agro ecosystem. Apparently, there is food deficit and low agricultural yield in the region mainly due to poor soil fertility condition in khat cultivating areas (Kandari *et al*., 2014). This phenomenon recalls the need for adaptive soil fertility management practices to replenish the soil.

Vermicomposting is one of the best-known biotechnological processes in stabilizing biological solid organic wastes (Lung *et al*., 2001; Nair *et al*., 2006) and used as fertilizer in wide range of agronomic practices. Several studies showed that vermicompost is generally rich in macro and micronutrients (Nagavallemma *et al*., 2004; Tognetti *et al*., 2005). Highest uptake of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) by rice (*Oryza sativa*) plant has been observed when fertilizer was applied in combination with vermicompost (Jadhav *et al*., 1997). In contrast, extensive use of chemical fertilizers contributes largely to the deterioration of the environment that leads to loss of soil fertility due to imbalanced use of fertilizers, which adversely impacted agricultural productivity and causes soil degradation (Nagavallemma *et al*., 2004).

This particular study was conducted to demonstrate bioconversion practice of khat and *Eucalyptus* twigs into vermicompost and to evaluate their effects for soil amendment in smallholder potato (*Solanum tuberosum* L. var. *gebissa*) cultivation. Khat leftover and *Eucalyptus* twigs are the 2 most common organic municipal waste materials in many local markets of the region. The study has evidently showed the potential benefits of utilization vermicompost as organic fertilizer when used in combination with half dose of recommended nitrogen (N) and phosphorus (P) fertilizers. In such farming system, applying lower than 15 t of the vermicompost per hectare together with half dose of recommended NP fertilizer can be used as a reference rate of application. The research findings, therefore, would provide pertinent and eco-friendly waste management system for various municipalities in Ethiopia and also enhance agricultural productivity through maintaining the soil fertility.

MATERIALS AND METHODS

Design of the experiments: Two distinctive experiments were conducted consecutively at Haramaya University research site. The first, vermicomposting experiment was conducted by feeding red earthworms (*Eisenia fetida*) with municipal biodegradable wastes (khat leftover and *Eucalyptus* twigs). It involves two treatments (Table 1) 100% khat leftover (Treatment-1); 70% khat leftover and 30% *Eucalyptus* twigs (Treatment-2).

The second experiment was further conducted on research field having specific soil characteristics by applying different rates of composited vermicomposts with/without half dose of the recommended NP fertilizer rate (Table 2). The treatments of this experiment were laid out in randomized completely block design with three replication.

Table 1: Soil physical and chemical characteristics of the field experimental site (0-30 cm)

Parameters	Value
Texture	Sandy clay loam
Bulk density (mg m^{-3})	1.63
Particle density (mg m^{-3})	2.53
Porosity (%)	36
Exch. bases (cmol$^+$ kg^{-1} soil)	
Mg^{++}	8.7
Ca^{++}	31
K^+	0.14
Na^+	0.33
CEC (cmol$^+$ kg^{-1} soil)	25.98
Micro-nutrients (ppm)	
Zn	39.6
Mn	39.6
Fe	28.9
Cu	12.5
pH(H_2O)/pH (KCl)	7.84/7.21
EC mS cm^{-1}	0.14
Total N (%)	0.08
Available P (mg kg^{-1} soil)	9.94
Organic matter (%)	1.29
Organic carbon (%)	0.74
C:N ratio	9:1

Table 2: Design of the field experiment and rate of vermicompost application (VC)

Treatments	Treatment description (tons of dry matter ha^{-1})
VC_0	No vermicompost and recommended NP fertilizer rate
VC_{15}	15 t ha^{-1} vermicompost
VC_{30}	30 t ha^{-1} vermicompost
$VC_0+½_{NP}$	50% of the recommended NP fertilizer rate alone
$VC_{15}+½_{NP}$	50% of the recommended NP fertilizer rate+15 t ha^{-1} vermicompost
$VC_{30}+½_{NP}$	50% of the recommended NP fertilizer rate+30 t ha^{-1} vermicompost

Eisenia fetida (red earthworm) which is readily available in the vermicomposting unit of Haramaya University was used as main decomposer of the waste. Sufficient population of earthworms was raised in a culture (cattle's dung slurry). It is efficient species in bioconversion of the waste. In a day, it can consume an amount of organic matter equivalent to half of its weight (Morin, 2002).

Biodegradable municipal waste materials: Biodegradable waste materials (khat residues and *Eucalyptus* twigs) were collected from Aweday town, the main market place of khat in the region. Considerable quantity of such municipal waste materials is abundantly available along the roadside, individual homestead and market places. They were collected, sorted and partially crushed to make it palatable to the worms.

Vermicompost process: The wastes mechanically crushed for ease of decomposition and weighed before stacked into cemented pits. Two rows of cemented pits having dimension of 5×1×0.3 m (1.5 m^3) were bedded with 6 kg of dung slurry and uniformly piled with biodegradable wastes. The pits were

Table 3: Vermicompost quality (100% khat leftover and 70% khat leftover and 30% *Eucalyptus* twigs)

Parameters	Treatment-1 100% khat leftover	Treatment-2 70% khat leftover and 30% *Eucalyptus* twigs	Range of nutrient composition (%)*
pH H_2O	7.40	7.30	
pH $BaCl_2$	7.00	6.90	
EC (µS cm^{-1})	0.65	0.68	
Total N (%)	1.10	1.40	0.51-1.61
OM (%)	21.7	28.0	
OC (%)	12.6	16.2	9.8-13.4
Extractable P (%)	0.56	0.57	0.19-1.02
Micronutrient (%)			
Zn	0.0320	0.0312	0.0042-0.110
Mn	0.0833	0.0842	0.0105-0.2038
Fe	0.0931	0.0911	0.2050-1.3313
Cu	0.0031	0.0038	0.0026-0.0048
Basic cations (cmol$^+$ kg^{-1})			
Mg	4.29	4.18	0.093-0.568
Ca	20.2	20.7	1.18-7.61
K	0.89	0.96	0.15-0.73
Na	0.48	0.53	0.058-0.158
CEC (cmol$^+$ kg^{-1})	36.0	36.5	

*Source: Nagavallemma *et al.* (2004)

kept moist throughout the process. Following thermophilic stage of the composting process, the materials/substrates were inoculated with 1200 g of matured earthworms together with some humic materials. During the process, pits were uniformly aerated and moistened (50-65%), covering with gunny cloth when needed to avoid excessive moisture loss. Soon after 15 weeks of the process, the end products were harvested, air-dried and sieved (2 mm sieve) for laboratory analysis. The daily mean air temperature was varied between 15-25°C.

Quality analysis of the vermicomposts: All samples were placed in sealed plastic containers and stored at 5°C until analysis. The samples were analyzed at soil laboratory of Haramaya University for specific parameters, such as pH (H_2O) with ratio of 1:15 vermicompost to water and pH ($BaCl_2$) with 1 M potassium chloride extract EC (µS cm^{-1}), Total OC (%), Total N (%) by Kjeldahl method, Total and available P (%) by Olsen method, micronutrients (Zn, Mn, Fe and Cu) by EDTA method, basic cations (Ca, Mg, K and Na) and CEC (cmol kg^{-1}) by the $BaCl_2$ Compulsive Exchange Method (Gillman and Sumpter, 1986). For each parameter three samples were analyzed to check consistency of data.

Rate of the vermicompost application: Both forms of the end product were composited and kept for field experiment. Potato (*Solanum tuberosum* L. var. *gebissa*) was planted as an indicator crop under rain fed condition. The treatment design includes different rate of vermicompost application (0, 15 and 30 t ha^{-1}) with/without half dose of the recommended NP fertilizers (Table 2).

Statistical analysis: The growth and yield data of potato was tested by one-way analysis of variance and comparison of means was computed based on the Tukey honestly significance difference test (HSD, $p<0.05$, 0.01, 0.001) to determine significant differences among treatments. The analyses were carried out using SAS statistical software.

RESULTS

Vermicompost Analysis: The physical and chemical properties of the vermicomposts (khat alone and khat and *Eucalyptus*) analyzed (Table 3) showed that they can be considered as valuable organic fertilizers. The pH and EC values are within the optimum ranges for most agricultural crops rich in organic matter that is higher in a vermicompost from the mixed waste material. Total nitrogen is very high in both treatments (1.1-1.4%). Micronutrients and basic cations show minimal difference for both treatments except manganese. Extractable phosphorus is optimum (0.57%). There is no marked difference regarding the micronutrients and Cation Exchange Capacity.

However Organic Matter (OM) was higher in vermicompost that resulted from khat residue mixed with *Eucalyptus* twigs. Field experiment was further conducted to evaluate impact of vermicompost on potato yield based on yield response such as average number of tuber per plant, mean tuber weight, marketable/non-marketable yield and total yield performance (Table 4).

On the other hand, It was found that percentage of diseased tuber was significantly higher ($p<0.05$) when rate of the vermicompost is excessive and when ½ NP fertilizer is added (Fig. 1). The tuber yield was reduced by 47% when the rate of the vermicompost is increased to 30 t ha^{-1}. This may be due to the enhanced moisture retention capacity in the upper soil layer, which triggers pest infestation (Haverkort, 1982). Because regulating the soil moisture was unlikely as the experiment was conducted under rain-fed condition, especially during tuber initiation.

The marketable tuber yield includes the sum yield of larger and medium tubers based on item quality in the local market. In our study we observed that proportion of marketable yields decreased at $VC_{30+½}$NP. This might be due to excessive moisture retention in the upper soil surface layer in response to higher rate of amendment. The optimum rate of vermicompost amendment falls between 0-15 t h^{-1}a while

Table 4: Effects of the vermicomposting amendment on growth and yield of potato

Treatments	Av. number of tuber/plant	Max. number of tuber/plant	Tuber wt. ($kg\ plot^{-1}$) Large	Medium	Small	Marketable yield ($t\ ha^{-1}$)	Non Marketable yield ($t\ ha^{-1}$)[1]	Total Yield ($t\ ha^{-1}$)	Marketable Yield (%)
VC_0	12^a	15^b	1.17^b	1.05^{bc}	0.83^b	9.87^b	4.58^b	14.40^c	73.0^a
VC_{15}	10^a	20^{ab}	1.17^b	1.39^{ab}	1.20^{ab}	11.38^b	7.16^{ab}	18.53^b	61.5^{ab}
VC_{30}	11^a	19^b	1.32^b	1.23^{bc}	1.27^{ab}	11.29^b	5.64^{ab}	16.93^{cb}	67.3^{ab}
$VC_{0+½ NP}$	10^a	16^b	0.96^b	1.29^{bc}	1.12^b	10.00^b	4.49^b	14.49^c	69.2^{ab}
$VC_{15+½ NP}$	11^a	27^{ab}	1.83^a	1.96^a	2.10^a	16.84^a	9.33^a	26.18^a	64.3^{ab}
$VC_{30+½ NP}$	9^a	32^a	0.89^b	0.73^c	1.24^{ab}	7.20^c	6.67^{ab}	13.87^c	52.4^b
Mean	11	21	1.22	1.27	1.29	11.10	6.31	17.40	-
F-value	0.66*	5.03**	11.49****	11.26****	4.27*	48.65****	4.81*	33.94****	-
LSD	-	12.35	0.4708	0.5755	0.9777	0.4885	0.8959	0.8536	17.4
CV	19.38	22.4	14.04	16.46	27.56	7.13	23.04	7.95	-

[1]Value include small size tubers (which may be use as seed stock) and diseased tubers, [abc]Means with the same letter are not significantly different at p>0.05 (Tukey HSD test, $\alpha = 0.05$), *Significantly different at p<0.05, **Significantly different at p<0.01 and ***Significantly different at p<0.001

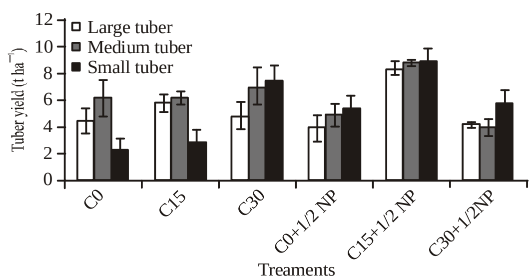

Fig. 1: Increased potato yields in response of different rate of Khat residue-made vermicompost amendment with/without half dose of recommended NP fertilizers

keeping the same rate of NP application. Higher proportion of tuber weight from each class was recorded from a treatment of VC_{15}+½ NP which is significantly higher as compared with VC_0 and VC_0+½ NP (no vermicompost amendments). Similarly, the weight of larger sized tubers was significantly higher than all other treatments.

DISCUSSION

Concerning the steadily increasing demand and financial attractiveness of the cash crop, which is the major rural land use practice of the region, it is evident that khat-made vermicompost can be sustainable agricultural input for smallholder farming system. The composting materials as well as red worm culture is readily available throughout the year. In addition, the technology may be a win-win solution by leveraging efforts of the local municipal waste management system. The results of Shimelis (2011) indicates the high organic content of the waste spotlight the necessity for frequent collection as well as an opportunity to give top priority to the recycling of the organic waste materials through composting as waste management approach in Aweday.

The results (Table 2) coincide with several earlier studies of vermicomposting. They have evidently shown that vermicompost provides all nutrients in readily available form and also enhances uptake of nutrients by plants. It has been reported that no generalization can be made regarding the higher quality of vermicomposts and composts as it depends on the original materials and the processing technology used (Tognetti *et al*., 2005). However, the growth and yield response indirectly shows the beneficial impacts of vermicompost application on the soil quality. and have also reported that vermicomposting increases the nutrient value of weed plants like Parthenium and they can be used as organic fertilizer (Vijayakumari *et al*., 2011; Yadav *et al*., 2012; Yadav and Anteneh, 2014).

The first phase, thermophilic stage helps to reduce pathogenic activity through degradation of organic matter. It is an active phase where the earthworms modify the waste physical state and microbial composition (Lores *et al*., 2006). It is the microorganisms that biochemically degrade the organic matter where as the earthworms act as mechanical blenders, modifying its physical and chemical status of organic matter by gradually reducing the ratio of C/N and increasing the surface area exposed to microorganisms. The C/N ratio showed maturity of the vermicompost within three months, 11.3-12.5.

In this particular experiment, red earthworm (*Eisenia foetida*) was chosen as waste decomposer for its efficiency in the conversion process of wastes into vermicompost (Nagavallemma *et al*., 2004; Morin, 2002). The duration of active phase depends on the species and density of earthworms and their ability to ingest the waste (Nagavallemma *et al*., 2004; Dominguez *et al*., 1997). Within a day, it ingest half of its weight and produces cast equivalent to about 50% of the waste it consumes (Morin, 2002).

Nitrogen and phosphorus are two of the most crucial limiting soil nutrient to favor plant growth. Crude recommendations of 100 kg Di-ammonium phosphate (DAP) and 50 kg of Urea were formulated across Ethiopia for all crops and soil types, which are sufficient for most crops. However, farmers often follow practices they can only afford than the recommended practices (Dejene, 2003). Utilizing such kinds of vermicompost would help to achieve effective soil fertility management and attain the maximum benefit from our limited land resources.

Using the vermicompost as organic fertilizer would reduce the burden of farmers who are dependent on inorganic fertilizers. Highest N uptake and soil available N was found to be increased significantly with increasing levels of vermicompost at 50% of the recommended fertilizer rate plus 10 $t\ ha^{-1}$ vermicompost (Jadhav *et al*., 1997;

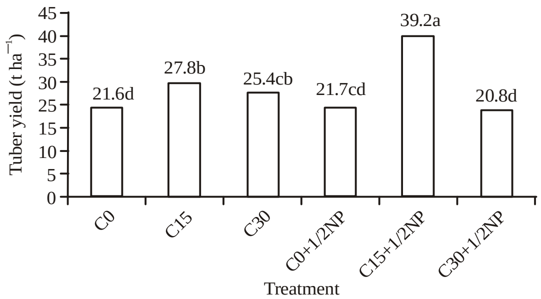

Fig. 2: Yield response of different tuber size (small, medium and large tubers) to vermicomposting amendment (Values are Means±Standard Error)

Sreenivas *et al*., 2000). Vermicompost also plays a major role in improving germination, growth and yield of different field crops, vegetables, flowers and fruit crops (Arancon *et al*., 2003; Nagavallemma *et al*., 2004; Karmegam *et al*., 1999; Karmegam and Daniel, 2000). Similarly, our field experiment has shown positive interaction between inorganic NP fertilizer and the vermicompost. As shown in Fig. 2, the yield responses are generally promising at the rate of 15 t ha^{-1} in combination half dose of recommended NP fertilizer (C_{15}+½ NP).

It is now widely recognized among experts and policymakers regarding the need of Ethiopian soil for micronutrients. The increasing application of fertilizer at the current price will not be affordable to many farmers. Thus, extension and research should accord a high priority to find an economically viable option that uses fertilizer in combination with other local available organic sources (FAO., 2003). This study revealed that combined use of inorganic fertilizer and vermicompost may potentially help smallholder farming through minimizing cost of production.

Adding vermicompost into wide range of soil types enhance soil aggregation and structure, water holding capacity, raised microbial biomass, increased enzyme activity and associated nitrogen and carbon mineralization and also the development of resistance in plants to pests and diseases. Similar study by Getnet and Raja (2013) reported that vermicompost have significant impact on cabbage growth promotion and reduce the aphid infestation. Vermicomposting practice is also regarded as a promising and sustainable practice to manage biodegradable wastes such as coffee husk, enset waste, Khat waste and vegetable waste (Degefe *et al*., 2012).

CONCLUSION

In the present investigation two forms of organic residues were fed to red earthworms. Khat residue is the main composting materials which are found abundantly in East Harerge suburbs areas as solid waste materials. It is basically considered as a challenge of municipal solid waste management. This study therefore, conducted to evaluate the potential fertilizer value of the end product, vermicompost from these municipal organic wastes. Therefore, this study would convey the possibility of utilizing such biodegradable waste materials as agricultural input. The feedstock, of course, is sustainably available in the study area as khat cultivation is nearly irreversible practice in the region.

A survey study showed that Aweday city, which is the largest market place of Khat in the region, generate about 57 t of khat residue in a day , mainly from khat preparation room (94%) followed by commercial street shops (average 120 kg per shop). It is further a win-win solution to get free ride of municipal waste management efforts.

The study showed that khat residuals can be used as alternative means of recycling municipal organic wastes in the region. When the residual biomass is returned into the soil in the form of agricultural input would be promising for smallholder farming system. It further allows the municipal solid waste management effort to get free ride on its goal such as providing clean environment.

In general, the study revealed that khat residue made vermicompost is rich with essential plant nutrients, which makes the end product as highly suitable for various fruits and vegetables crops. Therefore, application of khat residue made vermicompost can be an effective soil fertility management practice in smallholder farming while maintaining a healthy agro-ecosystem.

ACKNOWLEDGMENTS

The authors are grateful to the office of the vice president for research affairs, Haramaya University, for facilitating the research and Ethiopian Agricultural Research Institute (EIAR) for funding the experiment.

REFERENCES

Addis, 2014. To ban or not to ban. Foreign Ban Challenges Khat Export, While Gov't Remains Indifferent.

Arancon, N.Q., C.A. Edwards, P. Bierman, J.D. Metzger, S. Lee and C. Welch, 2003. Effects of vermicomposts on growth and marketable fruits of field-grown tomatoes, peppers and strawberries: The 7th international symposium on earthworm ecology. Cardiff. Wales. 2002. Pedobiologia, 47: 731-735.

Degefe, G., S. Mengistu and J. Dominguez, 2012. Vermicomposting as a sustainable practice to manage coffee husk, Enset waste (Enset ventricosum), Khat waste (Catha edulis) and vegetable waste amended with cow dung using an epigeic earthworm Eisenia Andrei (Bouch'1972). Int. J. PharmTech. Res., 4: 15-24.

Dejene, A., 2003. Integrated natural resources management to enhance food security: The case for community-based approaches in Ethiopia. Environment and Natural Resources Working Paper No. 16, Food and Agriculture Organization of the United Nations, Rome, Italy, July 2003.

Dessie, G., 2013. Favouring a demonized plant: Khat and Ethioian smallholder enterprise. Current African Issues No. 51, Nordiska Afrikainstitutet, Uppsala, Sweden, pp: 1-30.

Dominguez, J., C.A. Edwards and S. Subler, 1997. A comparison of vermicomposting and composting. Biocycle, 4: 57-59.

Dube, D.K., R.H. Yadav and S.K. Dube, 2014. Why a shift from coffee to chat? A study of the Kersa woreda in Jimma zone of South Western Ethiopia. Res. Hum. Social Sci., 4: 176-182.

FAO., 2003. Arable and permanent cropland, tractor usage, irrigated land, fertilizer use and pesticide use. Food and Agriculture Organization of the United Nations, Rome, Italy.

Getnet, M. and N. Raja, 2013. Impact of vermicompost on growth and development of cabbage, Brassica oleracea Linn. and their sucking pest, Brevicoryne brassicae Linn. (Homoptera: Aphididae). Res. J. Environ. Earth Sci., 5: 104-112.

Gillman, G.P. and E.A. Sumpter, 1986. Modification to the compulsive exchange method for measuring exchange characteristics of soils. Soil Res., 24: 61-66.

Haverkort, A.J., 1982. Water management in potato production. Technical Information Bulletin No. 15, International Potato Center (IPC), Lima, Peru, pp: 1-22.

Jadhav, A.D., S.C. Talashilkar and A.G. Powar, 1997. Influence of the conjunctive use of FYM, vermicompost and urea on growth and nutrient uptake in rice. J. Maharashtra Agric. Univ., 22: 249-250.

Kandari, L.S., R.H. Yadav, A.K. Thakur and T. Kandari, 2014. Chat (Catha edulis): A socio economic crop in Harar region, Eastern Ethiopia. SpringerPlus, Vol. 3. 10.1186/2193-1801-3-579

Karmegam, N. and T. Daniel, 2000. Effect of biodigested slurry and vermicompost on the growth and yield of cowpea, Vigna unguiculata (L.) Walp. variety Cl. Environ. Ecol., 18: 367-370.

Karmegam, N., K. Alagermalai and T. Daniel, 1999. Effect of vermicompost on the growth and yield of greengram (Phaseolus aureus Rob.). Trop. Agric., 76: 143-146.

Lores, M., M. Gomez-Brandon, D. Perez-Diaz and J. Dominguez, 2006. Using FAME profiles for the characterization of animal wastes and vermicomposts. Soil Biol. Biochem., 38: 2993-2996.

Lung, A.J., C.M. Lin, J.M. Kim, M.R. Marshall, R. Nordstedt, N.P. Thompson and C.I. Wei, 2001. Destruction of Escherichia coli O157:H7 and Salmonella enteritidis in cow manure composting. J. Food Prot., 64: 1309-1314.

Morin, E., 2002. Vermicomposting: An ecological way of dealing with organic waste. http://www.eco-quartiers.org/documents/vermicomposting%20eng.pdf.

Nagavallemma, K.P., S.P. Wani, S. Lacroix, V.V. Padmaja, C. Vineela, M.B. Rao and K.L. Sahrawat, 2004. Vermicomposting: Recycling wastes into valuable organic fertilizer. Global Theme on Agrecosystems Report No. 8, International Crops Research Institute for the Semi-Arid Tropics, Andhra Pradesh, India, pp: 1-20.

Nair, J., V. Sekiozoic and M. Anda, 2006. Effect of pre-composting on vermicomposting of kitchen waste. Bioresour. Technol., 97: 2091-2095.

Shimelis, B., 2011. Generation, composition and characteristics of urban solid waste in a major khat producing and marketing area in Eastern Ethiopia. Int. J. Environ. Protect., 5: 9-16.

Sreenivas, C., S. Muralidhar and M.S. Rao, 2000. Vermicompost: A viable component of IPNSS in nitrogen nutrition of ridge gourd. Ann. Agric. Res., 21: 108-113.

Tognetti, C., F. Laos, M.J. Mazzarino and M.T. Hernandez, 2005. Composting vs. vermicomposting: A comparison of end product quality. Compost Sci. Utiliz., 13: 6-13.

Vijayakumari, B., J.A.T. Silva and H.Y. Rameshwar, 2011. Influence of fresh and decomposed parthenium and poultry droppings on sesame yield. Asian Aust. J. Plant Sci. Biotechnol., 5: 54-61.

Yadav, R.H., M. Eyasu and B. Vijayakumari, 2012. Bioconversion of Parthenium hysterophorus into valuable organic manure. Proceedings of the National Conference on Science, Technology and Innovations for Prosperity of Ethiopia, May 16-18, 2012, Bahir Dar, Ethiopia, pp: 54-58.

Yadav, R.H. and A. Anteneh, 2014. Bioconversion of Parthenium hysterophorus into organic manure and its value addition using different animal manures. Proceedings of the National Symposium on Science, Technology and Innovations for National Development, March 21-22, 2014, Wollega University, Ethiopia, pp: 40-46.