AES BIOFLUX

Advances in Environmental Sciences - International Journal of the Bioflux Society

Performance of single and combined compost enhancers in composting urban wastes at the household level

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Abstract. Household composting is rapidly increasing and many encounter problems on how to make a setup that goes well within their premises. The aim of this paper was to identify organisms or their combinations which improved household composting outcome from selected wastes within Cagayan de Oro City, Philippines. The experiment focused on the application of macro and microorganisms namely, vermi worms (*Eisenia fetida*), *Trichoderma harzianum* and Effective Microorganisms (EM) and their combinations which resulted in the highest percent reduction in weight of waste, biofertilizer produced and macronutrient content after forty five (45) days of composting at the household level. Results showed that *T. harzianum* + *E. fetida* (T4) was most effective in weight reduction of waste and biofertilizer produced while compost produced from the *T. harzianum* (T2) achieved the highest total macronutrient (NPK) among the treatments applied.

Key Words: effective microorganisms, *Eisenia fetida*, household composting, *Trichoderma harzianum*.

Introduction. In many countries of the world, families living in the city are hesitant to perform household composting as part of their solid waste management activity (Sutherland 2013). This could be due to the messy feeling of putting waste within their premises and allowing it to decompose for several days or months. During the composting process, waste can be attacked by vermin, flies, worms and crawling insects. Availability of space, being laborious and time consuming are among the reasons why household composting has not been widely practiced in urban areas. Many find it more convenient and prefer to throw every waste in the garbage for collection and disposal.

However, there are some practices in others countries like in Europe where household composting was performed in composting bins and utilized selected organisms to perform a nuisance-free composting in a fast and easy way (EUC 2000). One of these practices is the use of vermi worms performed by preparing vermi-beds out of shredded papers and feeding worms by way of burying food scraps into it (Dandotiya & Agrawal 2013; Dandotiya et al 2015; Perera & Nanthakumaran 2015). Another example of household composting is by misting Effective Microorganisms (EM) into food waste via sealed containers and left for several days to become useful biofertilizer (Raja Namasivayam & Bharani 2012; Saad et al 2013). These are some of the successful practices done to avoid biodegradable waste to reach dumpsites. However, many households especially in developing countries are not familiar with these practices and therefore leave their waste untreated, thrown in the garbage, collected and dumped into disposal sites.

Cagayan de Oro City is a first class city in Southern Philippines which generates about 71,480 tons day^{-1} (ADB 2012) of solid wastes from 598,803 households (NSO 2013). For this, the city is paying \$133,540 to \$267,080 a month to privately-owned garbage collectors for waste disposal (Ocio 2013). In a study conducted by Lekammudiyanse et al (2009) in the Municipality of Gampaha, Sri Lanka indicated that the wastes disposed to the waste collection services were reduced by 69% from the waste stream after introducing the technology of household composting bins as a waste management technique for household garbage waste among their people. Therefore, if the same will be implemented among the citizens of the city, Cagayan de Oro City can generate savings of $92,142.00-$184,285.00 a month or equivalent to $1.1-$2.1 million annually from waste collection and hauling.

Household composting is an effective way in the management of waste. The wastes are segregated into biodegradable, recyclable and non-biodegradable. The segregated biodegradable component can be turned into a useful product by introduction of selected organisms for several days instead of throwing them into the garbage for hauling to dumpsites. Selected composting organisms will aid in the conversion of waste into biofertilizer in a certain period without causing unfavorable conditions within the household premises. This is accomplished because microorganisms and worms have the ability to disintegrate and consume biodegradable waste while using up potential greenhouse gases in their metabolism (Eureka Recycling 2008).

Without composting, wastes thrown to dumpsite become multiple sources of pollution. In the study of Barlaz et al (1997), the quantity of emitted CH_4 measured from biodegradable components of Municipal Solid Waste that undergo decomposition in landfills such as leaves, grass, branches, food waste, coated paper, news print, old corrugated containers and office paper yields about 144.4, 30.6, 62.6, 300.7, 84.4, 74.3, 152.3 and 217.3 mL CH_4/dry-g of waste, respectively. Aside from gases released from collection and hauling of vehicles and landfill emission, other effects of landfill to the environment include leachate, surface runoff, noise, bad odor and smoke, wind-blows litter and dust, birds, vermin and insects (Ramke 2007). Therefore, household composting is a promising tool in reducing greenhouse gases emission and minimizing environmental degradation.

The benefits of composting are numerous. It benefits the environment by recycling organic resources while conserving landfill spaces (Giesel & Siever 2009). Compost promotes plant growth, fight plant diseases and improved yields of crops. It is a good fertilizer that can increase crop harvest and improve the physicochemical properties of soil (Mrabet et al 2012). Compost contains plant nutrients including N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and B. The uptake of which has positive effects on plant nutrition, photosynthesis, the chlorophyll content of the leaves and improves the nutrient content of the different plant components (roots, shoots and the fruits). The high percentage of humic acids in compost contributes to plant health, as it promotes the synthesis of phenolic compounds such as anthocyanin and flavonoids which may improve plant quality and act as a deterrent to pest and diseases (Theunissen et al 2010). Generally, no more than 1/4 to 1/3 by volume of the potting mix should be compost. Too much compost result in water logging and poor aeration for roots (McLaurin & Wade 2000).

Composting is a tool that allows us to control and accelerate the natural process of decomposition of organic material that returns valuable nutrients to the soil for plant use (De Koff et al 2008). Applications of compost in landscaping projects have resulted in reductions in soil bulk density and soil-borne diseases, improved soil aggregation and slow release of nutrients (Guzman 1999). Furthermore, compost application to soil can be a way of remedying the decline of organic matter content in cultivated soils and to recycle organic wastes as an alternative to their disposal in landfills or incineration (Schneider et al 2009).

Compost is sweet-smelling, dark-brown, humus like material that is rich in organic matter and soil nutrients. Compost is created from the naturally decomposed parts of organic material such as manure, plants (yard waste), and food (kitchen waste). It is a soil conditioner and fertilizer. It is used to replenish the humus, or organic component in the soil. It is made by building a pile made up of wood, paper, kitchen trimmings, garden wastes, weeds, manure, and grass clippings (Maynard 2002). It is produced when worms and microorganisms (mostly fungi and aerobic bacteria) in the soil break down organic matter in the presence of oxygen (Miller & Spoolman 2012). This mixture provides home for microorganisms that aid the decomposition of the plant and manure layers (Golueke 1977). This is accomplished through composting backyard wastes in bins or in indoor containers. It can also be done in collected and composted centralized community facilities (Miller and Spoolman 2012). It has a higher proportion of slow-release nutrients compared to green manure and inorganic fertilizers (Eck & Stewart 1995) that are essential for plant growth.

Composting in bins with worms and microorganisms is a way of accomplishing sound waste management. By composting, waste is reduced; biofertilizer is produced and will end up as soil ameliorant for plant growth to provide healthy food for all.

This study is anchored on the Philippine Ecological Waste Management Act of 2000 (RA 9003 2000). That is to adapt a systematic, comprehensive and ecological solid waste management program which shall protect health and environment, waste avoidance and volume reduction through composting and involvement of the communities in the program and the production of organic fertilizer for plant growth to produce healthy source of food.

This study is in support to the Philippine Organic Agriculture Act of 2010 (RA 10068 2011) or the practice of organic agriculture in the country that will cumulatively condition and enrich the fertility of the soil, increase farm productivity, reduce pollution and destruction of the environment, prevent the depletion of natural resources, further protect the health of farmers, consumers, and the general public, and save on imported farm inputs.

Furthermore, this study supports the program in promoting community-based organic agriculture systems which include, among others, production of purely organic materials such as compost, pesticides and other farm inputs, together with the educational and promotional campaign for their use and processing as well as adoption of organic agriculture system as a viable alternative in waste reduction and crop production.

Undoubtedly, this study will become an essential part of the solution of decreasing the amount of wastes for disposal by the productive use of biodegradable wastes, the urban production of biofertilizer for the agricultural sector to increase crop yield and at the same time harness the essential benefits of environmental protection and conservation.

The objectives of this study were to determine which among the applications of Vermi worms *Eisenia fetida*, *Trichoderma harzianum*, Effective Microorganisms (EM), combination of *T. harzianum* + Vermi worms, combination of EM + Vermi worms, and combination of *T. harzianum* + EM + Vermi worms would yield the highest percent weight reduction of wastes and highest weight of biofertilizer produced. Batch comparison in the % weight reduction of waste and % weight of final compost for all treatments were also assessed. Furthermore, the macronutrient contents in the compost after 45 days of composting were likewise determined based on laboratory analysis.

Materials and Methods. Biodegradable wastes like fruits and vegetables and food leftovers were collected from the kitchen of the researcher where the experiment was conducted. Shredded office papers were taken from the office of the Department of Agriculture located within the City. Grass trimmings and brown leaves were collected from Silver Creek Subdivision, Cagayan de Oro City where the experiment was conducted. Guano was gathered from the Department of Agriculture Office. The study was conducted in two trials with the first trial done from November-December 2013 and the second trial was carried-out from June-July 2014. Figure 1 shows the experimental location of the study.

Vermi worms were taken from Claveria Experiment Station at Lanise Claveria Misamis Oriental and the Northern Mindanao Agricultural Research Center at Dalwangan, Malaybalay City at a price of P200.00/kg. *T. harzianum* were acquired from the Regional Soils Laboratory of the Department of Agriculture Region 10 at P10.00/25g-pack and EM was bought from Clarenson Marketing in the City of Cagayan de Oro for P450.00/L.

Washbasins of 46 cm top diameter were prepared as composting bins for the experiment by puncturing 0.32 cm hole of at least 5 cm apart at the sides and bottom. Shredded papers soaked in water for not less than 30 minutes, were squeezed, weighed and wrought out like sponge and were placed into the washbasin. Soaked and shredded yard wastes were weighed and mixed inside the washbasin. Food, vegetable and fruit wastes previously preserved in the refrigerator were weighed and mixed to the substrates in the washbasin. Other ingredients like soil and guano were also weighed prior to mixing.

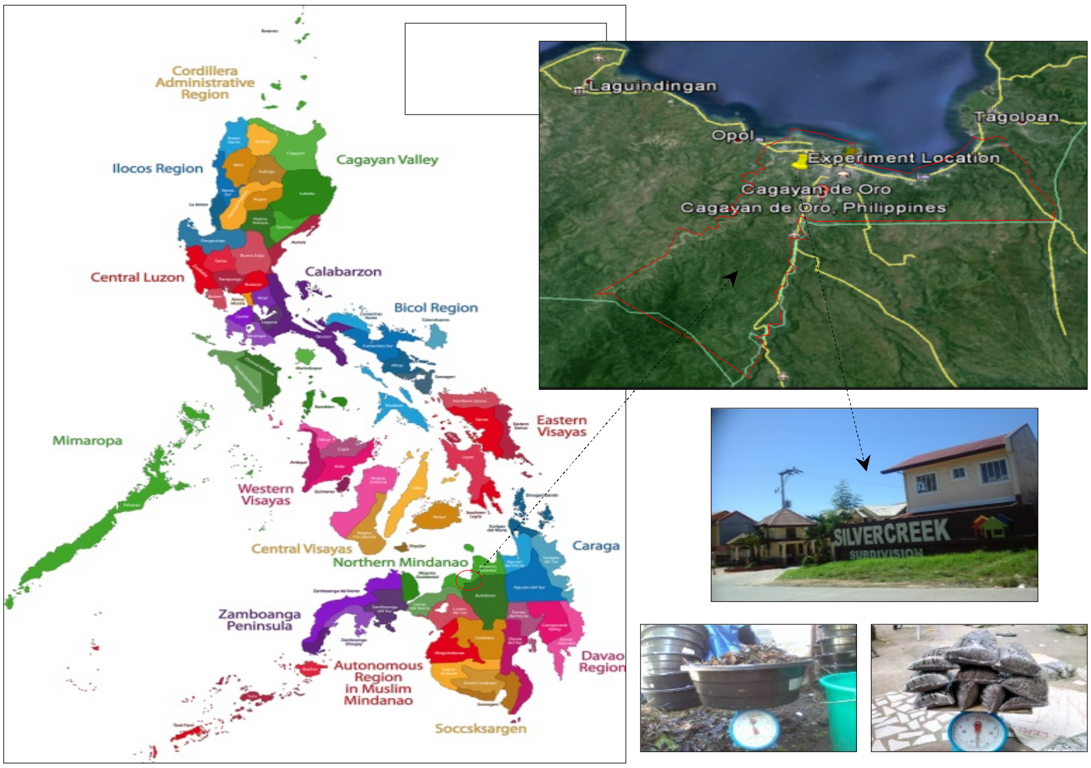

Figure 1. Map of Cagayan de Oro City, Philippines showing the experimental location (Source: http://thaiembassyuk.org.uk/activities/Philippines-map and Google Earth. Taken: August 24, 2014).

Composting was done using a 25:1 Carbon to Nitrogen (C:N) ratio where 25 parts brown wastes were mixed with 1 part of green wastes (Golueke 1977; Ndegwa & Thompson 2000; Anay et al 1996). Brown wastes included shredded paper, dry plant leaves, yard wastes and soil while green wastes included vegetable, fruit and, kitchen wastes and guano (US EPA 2009). The total weight of mixed substrates was 9 kgs/bin and was composed of the following:

Brown wastes = 8.65 kg:
- shredded papers = 7.0 kg;
- dry plant leaves and yard wastes= 1.55 g;
- Soil = 0.1 kg.

Green wastes = 0.35 kg:
- fruits and vegetables = 0.2 kg;
- kitchen wastes = 0.05 kg;
- guano = 0.1 kg.

Organisms used in this study were vermi worms, *T. harzianum*, EM and their combinations of *T. harzianum* + vermi worms, EM + vermi worms and *T. harzianum* + EM + vermi worms. The composting period lasted for 45 days (PCAMRD-DOST 2004). All treatments were replicated three times and done in two trials. The composting treatments were the following:

Treatment 1 (T1) – Vermicomposting (*E. fetida*);
Treatment 2 (T2) – *T. harzianum* composting (TH);
Treatment 3 (T3) – Effective Microorganisms composting (EM);
Treatment 4 (T4) – Combination of *T. harzianum* and Vermicomposting (TH + Vermi);
Treatment 5 (T5) – Combination of EM and composting (EM + Vermi);
Treatment 6 (T6) – Combination of *T. harzianum* and EM and composting (TH + EM + Vermi).

Composting organisms were introduced into the substrates as required for each organism. The required moisture content was maintained for each organism by misting the substrate with water if moisture drops and by air-drying if moisture was too wet. Air-drying was done by removal of the cover and frequent turning until the required moisture content was attained (De Koff et al 2008). Temperature, pH and moisture content of the substrates were checked every three days and were done by random measurement in the substrates using soil thermometer (PT-1 Food and Soil Thermometer) and pH & moisture meter (DM15 – on the spot Soil pH and Moisture Tester). Treatments were covered with sacks to minimize evaporation. Composting was terminated at the end of 45 days (PCAMRD-DOST 2004). Composts produced in all treatments were sieved (2 mm sieve) and weighed to determine the weight of the final compost.

T1. Vermicomposting*.* Vermicomposting was performed by introducing ninety (90) pieces of earthworms at the start of the experiment into each composting bin (Mupondi et al 2010) equivalent to the recommended stocking density of 10 pieces of matured worms (approximately 1 g/pc) for every 1 kilogram of substrate (PCAMRD-DOST 2004). Moisture content of the substrate was maintained at an average of 80% (Mupondi et al 2010).

T2. T. harzianum composting*.* In this composting method, *T. harzianum* solution was prepared by mixing one pack of *T. harzianum* (25 grams) to 500 mL non-chlorinated water and shaken vigorously to homogenize the solution (DA-RFO 10) . After thorough mixing, 45 mL solution was poured into the mister and applied completely to the substrates. Moisture content of the substrate was maintained at an average of 60% (Mupondi et al 2010).

T3. Effective Microorganisms (EM) composting*.* For the EM composting method, application was done by misting EM at the dilution rate of 1:200 into non-chlorinated water to constitute 1.75 mL of EM for every 9 kg substrates following the recommended application rate of 10 ounce/cu.ft substrates (Teraganix 2013). Moisture content level was maintained at an average of 60% for the entire duration of composting (Mupondi et al 2010).

T4. Combination of T. harzianum and Vermicomposting*.* In the treatment involving the combination of *T. harzianum* and vermi worms, *T. harzianum* was applied first at the rate similar to T2 and allowed to decompose for 14 days (PCAMRD–DOST 2004) maintaining an average MC of 60% in the substrates (Mupondi et al 2010). At the end of 14 days, 90 pieces of vermi worms/bin at 10 pc-worms/kg waste were released to continue the composting process for the remaining 31 days. Moisture content was maintained at an average of 80% (Mupondi et al 2010).

T5. EM and Vermicomposting*.* In the combination of EM and vermicomposting, EM was applied at the same rate with T3 and allowed to decompose the substrate for 14 days (PCAMRD–DOST 2004) at an average MC of 60% (Mupondi et al 2010). At the end of 14 days, 90 pieces of vermi worms or 10 pc-worms/kg wastes were released to continue composting for the remaining 31 days. Moisture content was maintained at an average of 80% (Mupondi et al 2010).

T6. T. harzianum, EM and Vermicomposting. In the treatment combination of *T. harzianum*, EM and vermiworms, the procedure was similar to Treatments 4 and 5 except that in this treatment, both *T. harzianum* and EM were applied together at the rate of one-half (½) of the said treatments. Both microorganisms were allowed to decompose the waste for 14 days (PCAMRD–DOST 2004) at an average of 60% MC (Mupondi et al 2010). At the end of the 14 days, 90 vermi worms were introduced into each bin to continue composting for the remaining 31 days. Moisture content was maintained at an average of 80% (Mupondi et al 2010).

The experiment was laid out in a Randomized Completely Block Design (RCBD) involving six-treatment combinations replicated three times.

After 45 days of composting, all treatments (raw compost) were sieved using 2 mm sieve (Lopez et al 2002) to separate large particles and worms from small particles. Weighing was done after sieving to determine the weight of the sieved particles. The sieved particles were the final compost produced. The final composts were subjected to laboratory analysis to determine the macronutrient contents per treatment. Kjeldal, Vanadomolybdate and Flame Atomic Emission Spectroscopy are the methods used in determining NPK contents respectively. The following categories of data were collected:

1. <u>Percent weight reduction of waste after composting</u> was determined by dividing the difference between the initial weight and the weight of raw compost (unsieved) by the initial weight (9 kg) multiplied by 100;
2. <u>Percent weight of biofertilizer produced</u> was determined as quotient of the sieved weight (final compost) and the initial weight (9 kg) multiplied by 100;
3. <u>Level of macronutrients (NPK)</u> in the final compost for each treatment based on laboratory analysis.

For each category of data collected above, Analysis of Variance (ANOVA) was done to determine differences among treatment means at the 5% level of significance. Mean separation was done using the Duncan's Multiple Range Test (DMRT).

Results and Discussion. Selected wastes within Cagayan de Oro City were subjected to household level composting using different macro and microorganism of *E. fetida*, *T. harzianum*, EM, combination of *T. harzianum* and vermi worms (TH + vermi), combination of EM and vermiworms (EM + vermi), and combination of *T. harzianum*, EM and vermi (TH + EM + vermi) to find out which among the treatments would yield the highest percent weight reduction of wastes, highest weight of compost produced. Further, batch comparison in the % weight reduction of waste and % weight of final compost for all treatments was also assessed. Furthermore, the macronutrient contents in the compost after 45 days of composting were likewise determined based on laboratory analysis.

Effects of different treatments on the % weight reduction of compost. Table 1 shows that among the six treatments applied for household level composting of urban waste, the combination of *T. harzianum* and *E. fetida* (T4) had consistently produced the highest percentage in waste reduction in the two trials conducted from November to December 2013 and June to July 2014, respectively. It was significantly different from the following treatments: *T. harzianum* (T2) in both trials and vermicomposting (T1) in trial 2 ($p \leq 0.05$) but not in all other treatments ($p \geq 0.05$). This means that the combination of *T. harzianum* and vermi worms in composting has the potential for increasing weight reduction of waste.

This result is in agreement with Tara Crescent (2003) who explained that vermicomposting utilizes microorganisms (fungi and bacteria) and earthworms to hasten decomposition. Miller & Spoolman (2012) further affirmed that compost is produced when worms and microorganism – mostly fungi and aerobic bacteria breakdown organic matter in the presence of oxygen. Similarly, PCARD-DOST (2004) described that fungus and bacteria decompose waste and allow the worms to finish the work, thus enhance decomposition.

Table 1

Percent weight reduction of urban wastes after 45 days of composting in the different treatments

Treatment	Initial wt. of waste (kg)	Trial 1		Trial 2	
		Average wt. after composting (kg)	% Wt. [1]Reduced*	Average wt. after composting (kg)	% Wt. [1]Reduced*
T1	9	6.92	23.08[ab]	6.30	29.94[b]
T2	9	7.47	16.96[b]	6.39	29.06[b]
T3	9	7.06	21.5[ab]	6.02	33.05[ab]
T4	9	6.45	28.38[a]	5.75	36.08[a]
T5	9	6.78	24.66[ab]	6.13	31.88[ab]
T6	9	6.77	24.81[ab]	5.98	33.52[ab]

[1] - means followed with similar letter are not significantly different from each other; * - means significant at 5% level of significance.

Effects of different treatments on the % weight of final compost. Table 2 shows that from among the six treatments from batch 1 and batch 2 experiments, T4 (*T. harzianum* + vermicomposting) produced the highest average sieved weight of final compost and is comparable to T1 (vermicomposting), T5 (EM + vermicomposting) and T6 (*T. harzianum* + EM + vermicomposting), respectively ($p > 0.05$). It follows that vermi worms in composting, or coupled with microorganisms yielded highest percentage weight of the final compost from among the treatments which is significantly different from T2 (*T. harzianum*) and T3 (EM) ($p < 0.05$). This means that vermicomposting has the potential in increasing compost finish products. Tara Crescent (2003) confirmed this result that vermicomposting is faster than natural composting (microorganisms alone). Yasir et al (2009) affirmed that the combination of fungi to vermi worms works well in composting because changes in bacterial community play a major role during vermicomposting. In addition to bacteria, fungi especially cellulolytic fungi play an important role during vermicomposting. Population of cellulolytic fungi was found to increase during vermicomposting of different organic wastes. Conversely, the presence of earthworms was related with increased in overall microbial biomass and activity, which decreased when earthworms left the substrate; the same pattern was observed for fungi (Aira et al 2007).

Table 2

Average sieved weight of final compost and the percent weight of final compost from urban wastes in the different treatments after 45 days of composting

Treatment	Initial wt. of waste (kg)	Trial 1		Trial 2	
		Ave sieved weight of final compost (kg)	% Wt[1] of final compost*	Ave sieved weight of final compost (kg)	% Wt[1] of final compost*
T1	9	1.22	13.56[a]	1.48	16.45[a]
T2	9	0.40	4.42[b]	0.999	11.10[b]
T3	9	0.38	4.21[b]	1.00	11.11[b]
T4	9	1.24	13.83[a]	1.76	19.54[a]
T5	9	1.23	13.64[a]	1.64	18.23[a]
T6	9	1.18	13.11[a]	1.76	19.52[a]

[1] – means with similar letter are not significantly different from each other; * - significant at 5% level of significance.

Results of the effects treatment and batch on the % weight reduction of waste. Based on the analysis of variance (Table 3), it shows that irrespective of batch, there are significant differences ($p < 0.05$) among the treatment means as to their effects on the percent weight reduction of compost. It also shows that irrespective of treatment, there is a significant difference in %weight reduction between batches ($p < 0.05$).

This result could probably be due to the variations in the substrate between batches for texture, moisture, temperature, pH level (H-ion concentration), nutrient concentration and availability and oxygen concentration during composting (Golueke

1977). It further shows no interaction between the mean values of treatments and batches in the percent weight reduction of waste ($p > 0.05$). This means that the effects of treatments on the percent reduction of waste were not altered or influenced due to batch differences.

Table 3

Analysis of variance of the main effects and the 2 way interaction of treatment and batch and their effects on the % weight of waste reduced

Source of variation	*Df*	*SS*	*MS*	*F*	*p-value*
Treatment	5	279.66	55.93	2.69	0.046*
Batch	1	730.91	730.91	35.14	4.07E-06**
Interaction (treatment x batch)	5	37.78	7.56	0.36	0.869
Within	24	499.25	20.80		
Total	35	1547.60			

* - significant at 5% level of significance; ** - highly significant at 1% level of significance.

Result of the effects of treatments and batch on the % weight of the final compost*.* Table 4 shows that irrespective of the batch, there are highly significant differences ($p < 0.01$) among the treatment means in the percent weight of final compost. It also shows that irrespective of treatments, there is highly significant difference in % weight of final compost between batches ($p < 0.01$). The reasons can be attributed to the factors mentioned above.

On the other hand, it shows no interaction between the mean values of treatments and batches in the percent weight of the final compost ($p > 0.05$). This means that the effects of treatments on the percent weight of the final compost are not necessarily altered due to batch differences.

Table 4

Analysis of variance of the main effects and the 2 way interaction of treatment and batch and their effects on the % weight of final compost

Source of variation	*Df*	*SS*	*MS*	*F*	*p-value*
Treatment	5	529.30	105.86	39.54	8.01E-11**
Batch	1	261.21	261.21	97.58	6.24E-10**
Interaction (treatment x batch)	5	9.46	1.89	0.71	0.6240
Within	24	64.25	2.68		
Total	35	864.22			

** - highly significant at 1% level of significance.

Results of the laboratory analysis on the macronutrient contents in the compost

Nitrogen content of compost. For the nitrogen present in the compost, laboratory results showed no significant difference among treatments ($p > 0.05$) where T3 (EM) compost had the highest value among the treatments. This proves the superior performance of the presence of fungus and photosynthetic bacteria found in EM that increases the number of other bacteria acting as nitrogen binders (Higa & Parr 1994). Further, results showed that all treatments exceeded the nitrogen range of vermicompost in the study of Nagavallemma et al (2004) of 0.51-1.61% DM, while they fall within the range of *T. harzianum* compost from Anay et al (1996) of 0.19-2.18% DM and EM compost of Jusoh et al (2013) 1.25-2.30% DM. The increase in N values in compost according to Jusoh et al (2013) may be due to the dry mass net loss as the loss of organic C as CO_2 during composting. He mentioned that N values might also increase due to the nitrogen-fixing bacteria activity that commonly occurs at the end of composting. Although a decrease of N can occur due to leaching of NO_3-N and ammonia volatilization, covering with plastic sacks purposely to retain the moisture have also a positive effect on the mineralization of N.

Nitrogen plays a significant role in photosynthesis, cell division and differentiation, growth and somatic embryogenesis, chlorophyll content, ribulose-1,5-bisphosphate carboxylase/oxygenase (rubisco) activity, electro transport rate, photosynthetic rate, anthocyanin production and is an important component of proteins required for the metabolic process that take place during plant growth (Theunissen et al 2010). Nitrogen present in the compost is in an organic form and not water-soluble and that N release is often much less than inorganic nitrogen but it can contribute substantial nitrogen for crops (Prasad 2009). However, according to Mikkelsen & Hartz (2008), it is challenging to synchronize N release from these materials which the plant demands.

Phosphorus content of compost. Laboratory results show that no significant difference ($p > 0.05$) among treatments in the phosphorus content of compost where EM had the highest value among the treatments (Table 5). Results show that all treatments fall within the range provided by Nagavallemma et al (2004) in vermicompost (0.19-1.02% DM) and the range of *T. harzianum* compost from Anay et al (1996) (0.19-0.71% DM) but have exceeded the range provided by Jusoh et al (2013) (0.17-0.22% DM) on EM compost. He said that compost applied with EM has more N, P and K content compared to compost without EM.

Phosphorous plays a role in increasing water-use efficiency of plants (Theunissen et al 2010). It is vital for plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next (Armstrong et al 1999).

Table 5

Average of Nitrogen, Phosphorus and Potassium (NPK) analyses of the composts

Organism(s)	*N ^{NS} (%DM)*	*P ^{NS} (%DM)*	*K ^{NS} (%DM)*	*Total NPK^{NS}*	*Reference*
T1 - Vermi	1.65	0.43	0.61	2.68	Average of Trial 1 and Trial 2 of this study
T2 - TH	1.87	0.48	0.55	2.89	
T3 - EM	2.01	0.50	0.36	2.69	
T4 - TH + Vermi	1.84	0.36	0.61	2.81	
T5 - EM + Vermi	1.85	0.42	0.61	2.87	
T6 - TH + EM + Vermicompost	1.96	0.37	0.36	2.69	
Vermicompost	0.51-1.61	0.19-1.02	0.15-0.73	0.85–3.36	Nagavallemma et al (2004)
T. harzianum compost	0.19-2.18	0.19-0.71	0.37-1.73	0.75–4.62	Anay et al (1996)
EM compost	1.25-2.30	0.17-0.22	0.6-1.91	2.02–4.43	Josuh et al (2013)

^{NS} – means no significant difference with F-test.

Potassium content of compost. The laboratory results for potassium content in compost show that no significant difference ($p > 0.05$) among treatments where T1, T4 and T5 having similar values and are on top of other treatments. These treatments involved vermicomposting and their values fall within the studies of Nagavallemma et al (2004) on vermicompost (0.15-0.7% DM), Anay et al (1996) on T. harzianum compost (0.37-1.73% DM) and Jusoh et al (2013) on EM compost (0.6-1.91% DM), respectively. Theunissen et al (2010) support this result saying that vermicomposting contains plant nutrients N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B.

Potassium is a nutrient that plays a role in many physiological processes essential for plant growth, including the maintenance for plant water balance and protein synthesis (Theunissen et al 2010).

Total NPK content of compost. T2 (*T. harzianum*) topped the average total NPK of 2.89% DM from laboratory analysis but is not significantly different from all other treatments ($p > 0.05$). T1 (Vermicomposting) has the least value of 2.68% DM. The total NPK content of all compost falls within the range of 2.5 - < 5% that has a description of compost or soil conditioner (BAFPS 2013).

Conclusions. This study was conducted to determine which among the organisms and their combinations yielded the highest waste reduction, most biofertilizer produced and having the highest macronutrient content in compost after 45 days composting. The six treatments applied were: Vermicomposting (T1), *T. harzianum* composting (T2), Effective Microorganism composting (T3), *T. harzianum* + vermicomposting (T4), EM + vermicomposting (T5), and *T. harzianum* + EM + vermicomposting (T6).

The study has shown that T4 was most effective in reducing the weight of the waste. Likewise, it produced the highest percentage weight of final compost/soil conditioner among other treatments tested. Among the treatments applied, T2 produced compost with the highest macronutrient contents based on the laboratory analysis. For economic reason, vermicomposting alone may also be a good alternative treatment for compost production.

Acknowledgements. The senior author would like to thank the Department of Agriculture (DA) through its Expanded Human Resource Development Program of the Agricultural Technical Institute – Regional Training Center 10 (ATI-RTC 10) for the scholarship and financial support for the conduct of the study and the Department of Agriculture - Regional Field Office 10 (DA-RFO 10) Regional Soil Testing Laboratory for the soil analysis.

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Received: 03 August 2015. Accepted: 15 September 2015. Published online: 18 October 2015.
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How to cite this article:
Bercero D. II M., Aranico E. C., Tabaranza A. C. E., Amparado Jr. R. F., 2016 Performance of single and combined compost enhancers in composting urban wastes at the household level. AES Bioflux 8(1):83-95.