QUALITY IMPROVEMENT OF ORGANIC COMPOST USING GREEN BIOMASS

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Abstract

An experimental study following the completely randomized design (CRD) was conducted to address the low nutrient content of compost product from crop residues. Rice straw and corn stalks which were the locally available crop residue were used as the main compost material, while succulent stems plus green leaves of Ipil-ipil (*Leucaena leucocephala*) and wild sunflower (*Tithonia diversifolia)* were used as the green biomass material. Treatments were crop residue and green biomass combinations at 3:0, 3:1, 3:2 and 3:3 ratios subjected to rapid composting method with the aid of *Trichoderma harziamum* as activator. Using the compost products mixed with pure soil at 1:1 ratio, pot experiment was conducted to test the effect of green biomass-enriched compost on the early growth of eggplant (*Solanum melongena*) and green pepper (*Capsicum annuum*).

The results indicated that, gradual enrichment of crop residue compost with green biomass especially those prepared at 3:3 and 3:2 crop residue-green biomass combinations gave significant increase in the Nitrogen, Phosphorous and Potassium contents of the compost. It also showed significant improvement on the percent organic matter, pH level, and weight of the compost product.

The results further revealed that the use of green biomass-enriched crop residue compost significantly stimulated plant growth in terms of plant height, number of leaves, size of leaves, number of buds, and total weight of fresh plant biomass. The overall findings of the study indicated that gradual application of green biomass during composting of crop residue produced better quality of compost that can be used to stimulate plant growth.

Keywords: Compost, compost enrichment, green biomass

Introduction

Rationale

Organic farming and organic products are gaining momentum in the agricultural sector as they are widely promoted by the Department of

Agriculture nationwide. Its main objective is to maintain healthy soil that produces healthy plants and create a balance between the interconnected system of health of people, soil, soil organisms, plants, and animals. One of the requisites of organic farming is the use of organic fertilizers that can be produced by farmers themselves using locally available plant materials. However, due to low NPK nutrient content of organic compost, farmers need to apply large amount of organic fertilizers in their farm increasing their capital and labor inputs. A method of increasing the available nutrient content of compost fertilizer is thus worth pursuing.

An organic fertilizer refers to a soil amendment derived from natural sources that guarantees, at least, the minimum percentages of nitrogen, phosphate, and potash. Examples include compost from plant and animal by-products, rock powders, seaweed, inoculants, and conditioners.

The rising cost of inorganic fertilizers and issues about its impact on the soil environment have led to a significant shift toward the use of organic fertilizers. The increasing popularity of the use of compost organic fertilizer also evolved from the recognition that most of our agricultural lands are nutrient-degraded and soil deterioration keeps on advancing. Soil fertility deterioration is a major constraint for higher crop production in many parts of our country. The increasing land use intensity without adequate and balanced use of chemical fertilizers and with little or no use of organic fertilizer or compost have caused severe soil fertility deterioration resulting in poor harvest of crops grown. Since fertile soil is the fundamental resource for higher crop production, its maintenance is a prerequisite for long-term sustainable crop productivity. Soil organic matter is a key factor for sustainable soil fertility and crop productivity. Organic matter undergoes mineralization with the release of substantial quantities of N, P, K S and smaller amount of micronutrients. Most of the cultivated soils in our country have organic matter far way below a good agricultural soil that should contain at least 2% organic matter. Moreover, this important component of soils is declining with time due to intensive cropping and use of higher doses of nitrogenous fertilizers with little or no addition of organic fertilizer.

An organic fertilizer does more than providing organic nutrients: it improves the water and nutrient holding capacity of coarse-textured sandy soil. On a fine-textured clayey soil, the organic matter over time glues the tiny clay particles into larger chunks or aggregates creating large pore space. This improves water infiltration and drainage, air infiltration, and allows for deeper rooting depths. Buildup of toxicity in the soil is also unlikely. It is important to understand however that only a portion of the nutrients in the product are available to plants in any growing season. Soil microorganisms must process the organic compounds into ions (NO_3^-, NH_4^+, HPO_4^{-2}, H_2PO_4, K^+) before plants can use them.

Organic fertilizers are known to affect soil biological attributes. Soil microorganisms (fungi and bacteria) and other fauna (e.g. earthworms, insects, arthropods) influence the availability of nutrients for crop growth by decomposing soil organic matter and releasing or immobilizing plant nutrients. Biological activity improves soil aggregation through the secretion of soil binding mucilage and hyphal growth. Improved aggregation, in turn, increases water infiltration and the ease of plant root penetration. Soil biological activity is considered an integral attribute of a healthy soil. Soil respiration rate (CO_2 evolution) is an indicator of soil biological activity and indicates the amount of decomposition that is occurring at a given time. Higher CO_2 evolution occurred with amendments that provided greater amounts of easily decomposable (volatile) organic matter.

Organic fertilizers also improve soil physical attributes. Indicators are soil bulk density i.e. mass of soil per unit volume and water infiltration rate. An organic fertilizer plays an important role in reducing bulk density and thus prevents runoff and erosion; it also improves the soil chemical attributes and the soil quality by increasing the concentrations of nutrients and by maintaining adequate level of soil pH.

In general, soil amended with organic fertilizer improves its physical properties (infiltration rate, water-holding capacity, and bulk density) and increases biological activity (respiration rate) more than the inorganic commercial fertilizers. The slow-release nature of organic nutrients probably prevents leaching losses of same magnitude as from the inorganic fertilizers.

The major problem with the use of an organic fertilizer like compost is its low nutrient content and the slow release of such nutrients for the crops being grown. There is therefore a need to use considerable volume of compost to produce healthy crops. It also requires space, time, and labor to produce considerable volume of compost.

Based on the benefits derived from using organic compost and on the problem on organic compost as presented above, producing a compost as organic fertilizer with higher nutrient content would be quite promising not only in providing greater stability in production, but also in maintaining better soil fertility. Studies related to this direction is timely and in order. The study thus aimed to investigate the effect of green biomass in improving the quality of compost from agricultural residue. The information obtained from this study is likely to serve as an input in the continuous search for quality improvement of compost as organic fertilizer.

The overall objective of this study is to determine the effect of increasing the volume of green biomass in improving the quality of compost fertilizer from crop residue. Specifically, the study aims to: a) determine the effect of increasing the volume of green biomass on the quality of compost from crop residue in terms of its Nitrogen, Phosphorous, Potassium, organic matter (OM) and pH contents, b) determine the effect of increasing the volume of green biomass on the weight of compost product, and c) determine the effect of green biomass-enriched compost fertilizer on the early growth performance of eggplant (*Solanum melongena*) and green pepper (*Capsicum annuum L.*).

Conceptual Framework

Composting is a proven-technology that can be applied on the spot, but there are many aspects that should be improved in the technology. One of the areas for improvement is on how to improve its nutrient contents. While there are a lot of studies on fortified/enriched compost organic fertilizer (Mian et al. 1990, Torkashvand 2010, Fening 2010, CTA 2007, Ndung'u et al. 2007, Harrison 2005, Naik 2007, Hatem et al. 2008), there is feeble information on improving quality of compost from pure plant material. This study thus aimed to investigate the effect of using green biomass that is nutrient-rich in improving the quality of organic compost from plants.

Compost product also referred to as "organic input" or "soil amendments" is an organic fertilizer that is applied to amend soil physical and chemical properties. Variation in the nutrient content of compost depends upon the nature of the material being composted (Tennakoon & Bandara 2003)**.** Compost materials vary considerably in the concentration of plant nutrients they contain and the rate at which these nutrients are released for plant use. The chemical characteristics of most finished composts vary because of the difference in the initial materials used in composting. For instance, if initial material contains grass clippings, weeds, or manure, it will be richer in nitrogen and other nutrients than if it contains mainly straw, litter, dirt or corn stalks. Agricultural by-products such as rice straw and corn stalks produced in large quantities in rural areas have low nutrient content in general but with high Carbon-Nitrogen ratio (50:1) (Um and Lee 2001). The nutrient concentration of organic compost is generally low (Naik 2007), thus studies on improving our understanding on how to improve the nutrient quality of compost would enable composting more attractive to organic farmers. This study is therefore anchored on the plant nutrient content variation theory which suggests that quality of compost depends on the nutrient content of the composted material.

From the foregoing, this study conceptualized that green biomass that contains high nutrients are good sources of nutrient for organic compost and increasing the amount would correspondingly increase the nutrient quality of compost product. Examples of green biomass include plants with high content of nitrogen indicated by having dark green leaves that make a good organic fertilizer (Anonymous 2007). Since green biomass organic materials for composting contain nutrients, it is logical to expect that portion of these nutrients will be retained in the compost. Green compost materials are much higher in Nitrogen and are important element in amino acids and proteins, serving as vital protein source for the compost microbes, helping to speed up the process of decomposition (IIRR 1993). In fact, Nitrogen-rich leaves from fast growing legume trees such as *Gliricidia* and *Leucaena* were suggested to be promoted as compost material (Teunissen 1995). In fast composting, it also requires the inclusion of a higher proportion of sappy green matter with higher nitrogen content (lower Carbon/Nitrogen ratio) such as grass and other plant cuttings and poultry manure (Misra & Roy 2004).

The conceptual model in this study followed the Input-Process–Output model. The input was the crop residue which is the main material being composted. The process describes the manner on how the same volume of input or crop residue was treated with increasing volume of green biomass aimed at improving the quality of compost product. The output in this study is the final quality of the compost product in terms of its nutrient contents such as nitrogen, phosphorous, potassium contents, organic matter and pH.

Review of Related Literature and Studies

Studies related to improving the quality of compost product are presented in the following paragraphs. Most of the literatures are more on compost enrichment with inorganic substances and the use of microorganisms.

Nitrogen-rich leaves from fast growing nitrogen-fixing-trees *Leucaena*, *Gliricidia* etc. should be promoted as compost material (Teunissen 1995). Fast composting is done by including a higher proportion of sappy green matter with higher nitrogen content (lower Carbon/Nitrogen ratio) e.g. grass cuttings, cabbage leaves, poultry manure, for example.

In an attempt to improve the quality of compost from rice straw, Goyal and Sindhu (2011) used biogas slurry, consortium of fungi with *Trichoderma*, and cattle dung as compost mixture. In the prepared compost, the total Nitrogen (N) content varied from 1.15 in paddy straw alone to 2.17% in paddy straw amended with cattle dung after 90 days of decomposition. Maximum increase in total Phosphorus (P) content was found with fungal culture treatment followed by inoculation of cattle dung and it varied from 0.062 in paddy straw alone to 0.164 by inoculation of fungal consortium. The total potassium (K) content also varied from 0.134 to 0.169% and maximum increase in total K was observed by inoculation of the fungal consortium. Thus, amount of N, P and K contents were found more in compost prepared with consortium of fungi and cattle dung than the compost prepared from biogas slurry.

Kumar et al. 2011 concluded based from their study that better quality compost can be prepared by enriching raw material with some sources of plant nutrients. They further reported that *Trichoderma* can also be used to enrich the compost as can be seen from T9 where phosphorus content was found maximum (1.35%) and it may be because of phosphorus solubilizing action of fungus.

In a study conducted by Znaidi et al., (2002), to assess the quality of compost from different animal manures as organic matters, the researchers found that the pH of all treatments decreased until 7.8 to 7.4 due to the release of organic acids following the decomposition of organic substances. The lowest pH was obtained by the treatment using only cattle manure followed by animal manure mixed with wheat straw. The researchers also stressed that the presence of a carbon source such as wheat straw is very important to ensure a good composting process.

In an attempt to improve the quality of dairy manure compost, Gerngross et al., (2006) used organic amendments such as woodchips, sawdust and peanut hulls applied at 10% and 30% rates. The researchers found that adding10% and 30% of three high carbon materials resulted in significantly higher organic matter of compost products from dairy manures. Of the treatments applied, only the 30% rate of peanut hulls resulted in a significant decrease in pH and in a significant increase in total N of dairy manure compost. The study indicates that adding and increasing the rate or amount of amendments improves the quality of compost product. The study also showed that adding of the organic amendments had no consistent effects on P, Ca, Na, and soluble salts across compost products.

Fening (2010) studied on improving the fertilizer quality of cattle manure by using *Chromolaena odorata, Stylosanthes guyanensis* and corn stover mixture as source of nutrients at 1:1 and 2:1 plant mixture and cattle manure ratio. Results showed that composting cattle manure mixed with plant materials improved the nutrient value of cattle manure and therefore its fertilizer value. The Nitrogen concentration was increased by 53 and 102% respectively for 2:1 and 1:1 which suggests that composting materials are potentially good organic amendments for improving the fertilizer value of cattle manure. The results further showed that 1:1 compost had the highest N,P,K concentration. The pH declined approximately by 27 and 19% respectively for 1:1 and 2:1 compost types. Organic carbon concentration was lowered from 46.5-34.2% and 46.7-32.6% for 1;1 and 2:1 compost, respectively.

Torkashvand (2010) found that molasses as a readily carbon resource is a suitable ammonia suppressant for municipal wastes compost production to increase the total nitrogen of the final compost. Application 8% molasses and 4% office paper respectively at the first and second stages caused to decrease C/N ratio

In the study of Abdelhamid (2004) on composting rice straw, they found total organic carbon concentration decline for mixture during composting. The decrease of volatile solids (VS) may be due to the loss of organic matter through microbial degradation. Compost N concentration increased with increasing volume of oil seed cake and poultry manure. The increase in total nitrogen may have been due to the net loss of dry mass as the loss of organic Carbon as CO_2 during composting (Veil et al. 1987 as cited by Abdelhamid 2008). More over total N can be increased by the activities of nitrogen-fixing bacteria at the end of the composting process. The same authors found that the C/N ratio decrease to 13.3 -8.9 from initial C/N ratio of 19.2.

For degradation of wider C:N ratio substrates, it is better to mix nitrogen rich materials like cakes, green leaves etc, to bring down the C:N ratio to at least 50:1 (Gowda, 1996).

Thakre and Fulzele (1998) opined that the addition of green leafy biomass in the process of composting was indeed genuine as the green leafy biomass was a good source of nitrogen helping degradation of lignocellulosic waste at a faster rate.

Imam and Sharanappa (2002) reported that, composting of poultry manure with different crop residues (wheat and ragi straw) at varying ratios like 0.25:1, 0.5:1, 1.75:1 and 1:1 ratio for 3 months under vat method recorded high nutrient content in 1:1 proportion with the values of 3.5 % N, 4.94% P and 2.1 % K and C:N ratio of 6:1.

Singh et al. (1992) observed reduction in the C:N ratio of pretreated maize leaves with 0.2% N and 0.2% P2O5 from 46.5 to 18.6 and 19.5 respectively after 120 days of incubation. Maize stem showed considerable reduction in C:N ratio from 83 to 26.7 with the addition of 1% N in 120 days of incubation. The decomposition of maize spindle was slow because of wide C:N ratio (108:1), however, enhanced decomposition of spindle with 1% N treatment was observed which resulted in C:N ratio of 34:1 after 120 days.

Ahmad et al. (2007) concluded that organic waste materials can be converted into value-added organic fertilizer by the addition of lower doses of nitrogen as well as biologically active substances. It is possible to get higher yield levels with complimentary use of organic and inorganic (chemical) fertilizers than the application of organic or chemical fertilizers alone. The improvement in soil health and reduction in piling of organic wastes could be extra benefit.

Hunegnaw (2008) found that increasing yard trimming resulted in better quality compost in terms of the nutrient content and salinity level.

Olabode et al. (2007) also reported that better growth and yield of okra resulted from soil treated with freshly crushed and dried ground *Tithonia*.

From the literature, it appears that many studies have been conducted on examining the effect of microorganisms and inorganic substances on compost quality. However, little is known about the effects of green biomass on compost quality. Therefore, there is a need to gather information on how to improve compost quality using green biomass. Hence, the present investigation is aimed at enriching compost using green biomass.

Methodology

The study was conducted in Lamut, Ifugao, Philippines. The municipality is an agriculture-based community where rice and corn farming are the major livelihood activities of the people. Abundant crop residue is a common site after harvest in which some are burned while others are just left to decompose naturally. Within the community, Ipil-ipil (*Leucaena leucocephala*), a legume tree can be seen near residential houses or in farm lots. Wild sunflower (*Tithonia diversifolia*) is also found near farm lots and along creeks.

The study followed the Completely Randomized Design (CRD) research design in three replicates. Completely Randomized Design is the simplest experimental design in which the subjects are randomly assigned to treatments. The design relies on randomization to control for the effects of extraneous variables. The experimenter assumes that, on average, extraneous factors will affect treatment conditions equally, so any significant differences between conditions can fairly be attributed to the independent variable (Stat Trek 2011, Nokoe 2011).

In this study, the subjects are the crop residue compost materials and the treatments or independent variables are the increasing volume of green biomass added to the crop residue compost material. The same volume of the subjects (agricultural waste) was randomly assigned to the treatments. The dependent variables were the compost quality parameters in each treatment condition in terms of nutrient contents specifically Nitrogen, Phosphorous and Potassium. It was hypothesized that: if increasing the volume of green biomass is effective in increasing the compost quality, compost treated with greater volume of green biomass should show significantly higher NPK contents than the control treatment. The treatments (T) were as follows:

T_1 Crop residue only or 3:0 ratio - Control treatment

T_2 Crop residue + Green biomass at 3:1 ratio

T_3 Crop residue + Green biomass at 3:2 ratio

T_4 Crop residue + Green biomass at 3:3 ratio

Crop residues (rice straw & corn stalk/leaves) were mixed at a ratio of 3:1 straw - corn stalk ratio while the green biomass (Ipil-ipil, and Wild sunflower) were mixed at a ratio of 1:2.

Composting Procedure

Being the most abundant and locally available crop residues, rice (*Oryza sativa L.*) straw and corn (*Zea mays L.*) stalks were used as the main compost material. Ipil-ipil (*Leucaena leucocephala* (Lam.) de Wit), and Wild sunflower (*Tithonia diversifolia* (Hemsl.) A. Gray) were chosen to be used as green biomass in this study because they are high-biomass- producing plants and can be easily grown locally.

The composting procedure used in this study was patterned from the recommended procedures (*Cuevas 1997*, *PhilRice 1996*) for composting and only varies with the gradual addition of green biomass during composting. The main compost material was 60 kg crop residue and 15 kg green biomass per pile. Compost activator *Trichoderma harzianum* was added to the mixture to speed up the decomposition process. Composting was done using the following steps:

a) Gathering dry rice straw and corn stalks from farm and threshing sites and chopping the corn stalks to almost uniform sizes followed by mixing the materials at 3:1 rice straw-corn stalk ratio.
b) Gathering fresh succulent stems and leaves of Ipil-ipil and wild sunflower, chopping separately, and mixing using 1:2 Ipil-ipil-wild sunflower ratio.
c) Preparing uniform platforms about 1.2 m x 1.2 m made of bamboo elevated about 6 inches above the ground.
d) Soaking the crop residue mixture overnight and allowing excess water to drip.
e) Weighing crop residue mixture at 15 kg per layer and loosely piling in layers on the platform at about 10-15 cm thick (60 kg per compost pile).
f) Broadcasting a handful of activator (*Trichoderma sp*.) on top of each layer.
g) Spreading 5 kg of green biomass on top of each compost layer.
h) Repeating steps e-g until 5 layers were made or a height of about 1 meter is attained.
i) Covering the compost pile with plastic cellophane.
j) Moistening compost pile every 6 days using water sprinkler
k) Harvesting mature compost after 60 days, air drying, pulverizing, screening and packaging and storing in dry place.

For the 3:2 ratio treatment, the same volume of green biomass (15 kg) was mix with the compost pile after 12 days while for the 3:3 ratio, the same volume of green biomass each was applied after 12 and 24 days, respectively.

To prevent loss of Nitrogen due to turning that provide greater opportunity for ammonia volatilization (Harrison 2005), the compost pile was left unturned for a composting period of 36 days in this study. The disturbance occurred only during the addition of green biomass for the 3:2 and 3:3 treatments.

Compost Analysis

The composts in each replicate per treatment were mixed thoroughly (Coker 2007) and two 0.5 kg samples were weighed and brought to the laboratory for analysis at the Department of Agriculture RFU 02 Regional Soils Laboratory, Tuguegarao City.

Parameters measured in this study include indicators of compost quality such as the major plant nutrients as follows: total N (%), total P_2O_5 (%), total K_2O (%), O.M. % and pH.

The weight of the compost and fresh moisture content per replicate per treatment were also measured in this study for comparison. Other compost quality parameters like color, smell, and texture were also evaluated. Color and smell were described based on the physical appearance and odor of the compost. Texture was determined by feel method and were described accordingly either soil-like, gritty, coarse, and the like.

Pot trials: Pot experiments were conducted in an elevated open area to assess the effect of green biomass-enriched compost on the growth of young eggplant (*Solanum melongena*) and green pepper (*Capsicum annuum*) plants. Soil was collected from a corn field and was combined with the enriched composts from the treatments at 1:1 soil-compost ratio. The enriched composts products were from the 3:1, 3:2, 3:3 crop residue-green biomass ratio. The control treatment in the pot experiment was composed of soil mixed with compost with no green biomass at 1:1 ratio. Pre-germinated green pepper and eggplants about 3 inches tall were carefully uprooted and were transplanted to the pots. Nine plants per treatment or a total of thirty-six (36) pepper plants and 36 eggplants were used in the study. The pots were arranged in an elevated platform in a completely randomized design with three replications.

Data on plant height, leaf number, fresh weight, leaf size for eggplant and number of flower buds for pepper were recorded. Plant height means the height in cm of young plants from the soil surface to the shoot tip. Leaf number means the number of leaves of plants at the time of counting. The leaf size of eggplant refers to the width of the leaf measured perpendicular to the leaf length.

Data on compost nutrient content and indicators of plant growth from this study were subjected to one way ANOVA for CRD experiment.

Results And Discussion

Effect of Increasing the Volume of Green Biomass on the Nutrient Quality of Compost

Table 1 shows the quality of the compost in each treatment based on the major plant nutrient (N-P-K) content of the product. The T_1-control treatment represents compost product made of pure crop residue with no enrichment while the T_2-3:1 treatment represents a compost product derived by enriching the crop residue with green biomass at 3:1 mixture ratio. The T_3-3:2 and T_4-3:3 treatments represent the composts derived by enriching crop residue with green biomass at 3:2 and 3:3 mixture ratio, respectively. Green biomass was applied twice and thrice for T_2-3:2 and T_4-3:3 treatments, respectively.

Table 1. Nutrient quality of compost based on the major plant nutrient (N-P-K) content.

Treatments	Total N %	Total P_2O_5 %	Total K_2O %
T_1-3:0-Control	0.43^{b}	0.04^{c}	0.09^{c}
T_2-3:1 ratio	0.43^{b}	0.08^{b}	0.42^{b}
T_3-3:2 ratio	0.51^{a}	0.12^{a}	0.43^{b}
T_4-3:3 ratio	0.51^{a}	0.15^{a}	0.52^{a}

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

Table 2 above indicates at a glance that T_4-3:3 treatment showed better quality compost in terms of the nutrient content followed by T_2-3:2, T_2-3:1 and least the T_1-control which was relatively lower in quality.

Total Nitrogen in percentage was observed highest (0.51) at the 3:2 and 3:3 ratio treatments. The control and 3:1 treatments had an equal amount of total Nitrogen (0.43). Total nitrogen (N) includes all forms of nitrogen: organic N, ammonium N (NH_4-N), and nitrate N (NO_3-N). Rice straw/corn stalks contain low 0-0.5, 0-0.5, and 1 % Nitrogen, Phosphate and Potash, respectively Asaolu et al. (2011), thus the increase in the values could be attributed to the effect of green biomass added during composting. According to Anonymous (2007) most finished composts had total Nitrogen content that generally lie between 0.4 and 3.5. The result of this study is within but on the lower portion of the range. Analysis showed that there was a significant difference on the amount of total nitrogen between treatments. Total Nitrogen was significantly higher under the 3:3 and 3:2 treatments compared to the 3:1 and T_1-control treatments. No significant difference however, was observed between 3:3 and 3:2 treatments and between 3:1 and control treatments. This implies that in using green biomass to enrich crop residue compost, higher Nitrogen content can be obtained only by increasing the amount of green biomass at a ratio of at least 3:2. Increasing the ratio to 3:3 does not significantly increase the amount of Nitrogen.

Table 2 also shows the total Phosphorous (P_2O_5) of the finished compost. Highest Phosphorous content (0.15) was recorded when crop residues were enriched with green biomass at the same weight or 3:3 treatment. This was followed by the 3:2 treatment with a Phosphorus content of 0.12. The 3:1 and control treatments had a Phosphorous content of 0.08 and 0.04, respectively. Analysis showed significant differences among treatments. The 3:3 treatment showed significantly higher or superior Phosphorous content over the other treatments except 3:2 treatment in which they are at par. The phosphorous content of treatments 3:2 and 3:1 were also superior over the control treatment. The significantly higher Phosphorous content of compost treated with green biomass could be attributed to the phosphorous content of the green biomass used in the study, in which *Tithonia diversifolia* and *Leucaena leucocephala* had Phosphorous content of 0.24-0.56 and 0.12-0.33, respectively (Jama et al. 2004).

The total Potassium content of the finished compost is also shown in Table 2. The compost in the 3:3 treatment had the highest K content at 0.52%. This was followed by the 3:2 and 3;1 treatments with Potassium content of 0.43% and 0.42%, respectively, while the control treatment had only 0.09 Potassium content. All the composts enriched with green biomass were superior over the control based on the analysis. The Potassium content of the 3:3 treatment was significantly higher over the other treatments. The 3:2 and 3:1 treatments were significantly higher than the control but were not significantly different from each other. The significantly higher Potassium content of crop residue enriched with green biomass was probably due to the high Potassium content of *Tithonia diversifolia* that ranges from 2.7 to 4.8 and *Leucaena leucocephala* that ranges from 1.3 to 3.4% (Jama et al. 2004).

Effect of green biomass on Compost Organic Matter (OM), pH, and Moisture Content

The effect of increasing green biomass on compost organic matter (OM), pH and moisture content is shown in Table 2.

Table 2. Organic matter (OM), pH, and moisture content of compost product

Treatments	OM %	pH	MC %
T_1-3:0-Control	3.3^{c}	4.5^{c}	68.6^{c}
T_2-3:1 ratio	3.4^{bc}	5.8^{b}	69.2^{b}
T_3-3:2 ratio	3.5^{b}	6.3^{ab}	69.6^{b}
T_4-3:3 ratio	3.9^{a}	6.9^{a}	71.4a

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

Table 2 shows an increasing trend on the amount of organic matter starting from the control treatment (3.3%) up to the 3:3 treatment (3.9%). The OM content of 3:3 treatment was the significantly higher than the rest of the treatment. The 3:2 treatment OM (3.5%) was significantly higher than the control but on par with OM of the 3:1 treatment (3.4%). The control treatment was statistically identical with that of the 3:1 treatment. Organic matter is the measure of carbon based materials in the compost. It is an important source of carbon that improves soil and plant efficiency by improving soil physical properties, providing a source of energy to beneficial organisms, and enhancing the reservoir of soil nutrients. High quality compost will usually have a minimum of 50% organic content based on dry weight. Another means of expressing organic content is to list the weight of organic matter per unit volume of compost. High quality composts will have a minimum of 250 pounds of organic material per cubic yard (Darlington 2007).

pH is a symbol indicating the acidity or alkalinity of a substance. Ideally, the pH of any product, particularly compost, should be neutral to slightly acid (6.0 – 7.5) and efforts should be made to control it if it exceeds about 8.5 (Ahmad 2010). A pH in the 6 to 8 pH range indicates a more mature compost. The pH of compost derived in this study was as low as 4.5 to as high as 6.9 (Table 3). Most foreign standards require that pH of compost should not exceed 7.5 which was met by 100% of examined samples. Other national standards suggest pH values between 6 and 8.5 which were met by 50% of compost samples. The control and the 3:1 treatments were low or acidic while the 3:2 and 3:3 treatments were slightly acidic. Analysis revealed that all of the green biomass-enriched composts were significantly different or higher than the control. The pH in the 3:3 and 3:2 treatments were statistically identical. The pH in the 3:2 and 3:1 treatments were also statistically the same but were significantly higher than the control treatment. The low pH in the control treatment could be explained by the fact that some of the rice straws were still recognizable indicating that decomposition was not yet complete, hence it was still acidic. Various authors claim that the pH tend to approach neutral state as compost reaches stability (Tennakoon & Bandara 2003, Fening 2010, Harrison 2005, Gowda 1996). Composts with very low pH (<4.0) should be used with caution since the low pH can be an indication of poor composting practices which result in the formation of potentially toxic organic acids (Gowda 1996).

The moisture content of the finished compost right after it was gathered is shown in Table 3. The compost indicated by the 3:3 treatment had the highest moisture content upon harvest at 71.4% followed by the 3:2

treatment at 69.6%. The 3:1 treatment had a moisture content of 69.2%, while the control treatment had 68.6%. Statistical analysis showed that the 3:3 treatment was significantly different from the rest of the treatment. The moisture content of the 3:2, 3:1 and control were statistically the same. Moisture content of compost based on "as-received" or upon delivery weight should be between 35% and 60% (Darlington 2007) for optimal product handling and transport. The moisture content of the composts in this study were higher since it was air-dried for 2 days only instead of 4 days due to time constraints for analysis.

Effect of Increasing the Volume of Green Biomass on the Weight of Compost Product

Table 3 shows the weight of harvested compost per replicate and the mean weight from the four treatments.

Table 3. Weight of harvested compost in the four treatments

Treatments	Weight of Compost (Kg.)			
Crop residue-Green biomass ratio	Replicate I	Replicate II	Replicate III	Mean Weight (Kg)
T_1-3:0-Control	42.1	35.5	37.5	**38.37^c**
T_2-3:1 ratio	43.6	38.5	39.5	**40.53^c**
T_3-3:2 ratio	46.5	46.5	43.5	**45.50^b**
T_4-3:3 ratio	48.5	49.5	46.9	**48.30^a**

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

Treatment 3:3 showed the highest weight of harvested compost at 48.30 kilograms. The average weight of compost at the 3:2 treatment was 45.50 kg while the compost derived at the 3:1 treatment weighs 40.53 kilograms. The control treatment on the other hand showed an average weight of 38.37 kg.

Data analysis showed significant differences on the weight of finished compost. The 3:3 treatment was significantly higher than rest of the treatments according to Scheffe's test. The 3:2 treatment was also significantly higher than the 3:1 and control treatments. This implies that adding green biomass on crop residue during composting following the ratio significantly increases the weight of finished compost. The 3:1 and 3:0 treatments were statistically identical with each other.

Physical Characteristics of Harvested Compost

The composts derived in this study were generally dark-brown to black with the exception of the control treatment which appeared brown in color. The compost smells soil-like and did not emit any unpleasant odor. In all the treatments, the compost were relatively soft, soil-like, and only those woody twigs of Ipil-ipil and the hard covering of the corn stalks were recognizable or not yet completely decomposed. There was no recognizable rice straw nor leaves of Ipil-ipil and sunflower in all the biomass-enriched compost. Only the control treatment showed some recognizable rice straw which indicated that it was not yet fully decomposed or matured. According to Darlington (2007) physical characteristics that are suggestive of a mature compost include a dark brown to black color and a soil-like or musty odor. There should be little or no recognizable grass or leaves. Compost that has a sour or putrid smell is not yet matured. Based from the physical characteristics of the harvested compost, it could be said that they are almost matured except for the control treatment which was not yet matured. The absence of green biomass in the control treatment as a source of nutrient for compost organisms might have slowed down the activities of the composting organisms.

Effect of Green Biomass-Enriched Compost on the Growth of Young Pepper Plants

Each of the green biomass-enriched composts derived from composting crop residue at the 3:0, 3:1, 3:2, and 3:3 treatments were mixed with cornfield brown soil at 1:1 ratio and their effects on growth parameters of pepper plants were assessed up to 40 days in pot culture. The effect of the harvested composts on the growth performance in terms of plant height of young pepper plants is presented in Table 4.

Table 4. Height of young pepper plants in the four treatments

Treatments	Height of Pepper (cm.)			Mean Height (cm)
	Replicate I	Replicate II	Replicate III	
T_1-3:0-Control	39.00	36.33	35.67	**37.00**^{c}
T_2-3:1 ratio	48.33	53.67	47.67	**49.89**^{b}
T_3-3:2 ratio	50.33	54.33	52.67	**52.67**^{ab}
T_4-3:3 ratio	62.00	61.33	57.00	**60.11**^{a}

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

Treatment levels were found to have significant effect on height of young pepper plants (Table 5). Among the treatments, pepper plants grown in T_4 treatment (1:1 mixture of soil and green biomass-enriched compost from the 3:3 treatment), showed maximum height (60.11 cm) which was significantly superior over control (37 cm) and over T_2-3:1 treatment (49.89 cm) except T_3-3:2 treatment (52.57 cm) with which they statistically on par. No significant difference was observed between 3:2 and 3:1 treatments based Scheffe's test.

The green biomass-enriched compost with good amount of plant nutrients has promoted plant growth. The data in Table 5 indicate that, the composted crop residue enriched with green biomass had an influence on the plant height when compared to the control. The significantly higher nutrient content in compost must have influenced the plant height to a maximum average of 57 cm on 40 days after planting where as in the control treatment, the height was as low as 37 cm on the average.

In general, there was an increase in the number of leaves per plant with the increase in the amount of green biomass-enriched compost (Table 5). The application of green biomass-enriched compost at all levels significantly increased the number of leaves of pepper plants compared to control. Plants grown in T_4-3:3 treatment (1:1 mixture of soil with compost from the 3:3 treatment) showed maximum number of leaves per plant (143.56) followed by T_3-3:2 treatment (115.11), which was statistically at par with each other but were significantly superior over control (28.00). The number of leaves in the T_3-3:2 and T_2-3:1 treatments were superior over control, but they were not significantly different with each other.

Table 5. Number of leaves of young pepper plants in the four treatments

Treatments	Leaf Number of Pepper Plants			Mean Leaf Number
	Replicate I	Replicate II	Replicate III	
T_1-3:0-Control	31.33	32.00	20.67	**28.00**^{c}
T_2-3:1 ratio	83.33	95.00	66.00	**81.44**^{b}
T_3-3:2 ratio	125.00	116.00	104.33	**115.11**^{ab}
T_4-3:3 ratio	164.67	130.67	135.33	**143.56**^{a}

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

The data in Table 5 indicate that, the green biomass-enriched compost had an influence on the number of leaves when compared to control. The compost influenced number of leaves to a maximum average of 144 on 40 days after planting where as in pure soil or control, the number of leaves remained as low as 28 on the average. The higher nutrient content of compost enriched with green manure must have been helpful in increasing number of leaves.

The data presented in Table 6 indicated that, treatment levels were found to have significant effect on number of flower buds of young pepper. Among all the treatments, plants from T_4-3:3 treatment showed the highest number of buds (18.22) which was significantly superior over control (3) and over T_2-3:1 treatment (7), except 3:2 treatment (10.44) with which they were at par.

Table 6. Number of buds of young pepper plants in the four treatments

Treatments	Bud Number of Pepper Plants			Mean Bud Number
	Replicate I	Replicate II	Replicate III	
T_1-3:0-Control	5.00	1.67	2.33	**3.00^c**
T_2-3:1 ratio	8.67	7.67	4.67	**7.00^{bc}**
T_3-3:2 ratio	13.00	10	8.33	**10.44^{ab}**
T_4-3:3 ratio	20.67	18.67	15.33	**18.22^a**

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

The data in table 6 indicate that, the green biomass-enriched compost had an influence on the formation of flower buds when compared to control. The compost influenced bud formation to a maximum on the average of 18.22 on 40 days after planting where as in pure soil or control the number of buds remained as low as 3.0 on the average. The findings in this study were similar to the findings of Berova (2009) where in the number and mass of flower buds were significantly higher after application of organic fertilizer. The significantly higher amount of phosphorous and potassium substances present in the compost must have beneficial effect on flower bud formation.

Table 7 shows the fresh weight of young pepper plants. The data show that the highest weight was from the plants in the 3:3 treatment with mean weight of 49.67 grams followed by the 3:2 treatment with mean weight of 45 grams. The weight of plants from the $T_2$3:1 and control treatments were 38.6 and 15.67, respectively.

Table 7. Fresh weight in grams of young pepper plants in the four treatments

Treatments	Weight of Pepper Plants (g)			Mean Weight (g)
	Replicate I	Replicate II	Replicate III	
3:0 - Control	**14**	**16**	**17**	**15.67^c**
3:1 ratio	**38**	**41**	**37**	**38.67b**
3:2 ratio	**46**	**44**	**45**	**45.00^a**
3:3 ratio	**49**	**52**	**48**	**49.67^a**

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

The fresh biomass weight of the plants grown with green biomass-enriched compost was higher than the control (by 147% in 3:1, 187% in T_3 and 217% in T_4 treatments). The increase of fresh biomass weight was mainly on the account of the increased mass of the above the ground organs (Berova 2009). This tendency was more pronounced in plants from the 3:3 treatments.

Analysis showed significant differences in fresh weight of plants from the four treatments. All of the plants grown with compost treated with green biomass were significantly higher than control by Scheffe's test. The

T_4-3:3 treatment was found statistically identical with T_3-3:2 treatment but were significantly higher than the T_1-3.1 and control treatments. The significant differences in weight could be attributed to the effect of green biomass-enriched compost added to the soil which may contain more nutrient than the control.

Effect of Green Biomass-Enriched Compost Fertilizer on the Growth of Young Eggplants

The compost products from compost treatments 3:0, 3:1, 3:2, 3:3 were mixed with cornfield brown soil each at 1:1 ratio and their effects on growth parameters on young eggplant plants were assessed up to 45 days in pot culture. Table 8 shows the height of young eggplants subjected to the different treatments. Treatment levels were found to have significant effect on the height of young eggplant plants. Among the treatments, plants grown in the T_4-3:3 treatment (1:1 mixture of soil and green biomass-enriched compost from the 3:3 treatment) showed maximum height (24.17 cm) which was significantly superior over control (14.14 cm) but were not statistically different over T_2-3:1 treatment (19.42 cm) and T_3-3:2 treatment (21.76 cm). The T_3-3:2 treatments was also significantly higher over the control treatment. No significant differences were observed between control and T_2-3:1 treatments and between T_2-3:1 and T_3-3:2 treatments.

Table 8. Height of young eggplants

Treatments	Height of Eggplants (cm.)			Mean Height (cm)
	Replicate I	Replicate II	Replicate III	
T_1-3:0 - control	18.03	11.47	12.93	**14.14^{c}**
T_2-3:1 ratio	18.23	20.57	19.47	**19.42^{abc}**
T_3-3:2 ratio	21.97	22.23	21.07	**21.76^{ab}**
T_4-3:3 ratio	23.93	24.63	23.93	**24.17^{a}**

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

The green biomass-enriched compost with good amount of plant nutrients has promoted the growth of eggplants. The data in Table 8 indicate that, the composted crop residue enriched with green biomass had a significant influence on the plant height when compared to control. The significantly higher nutrient content in compost at the 3:3 ratio must have influenced the plant height to a maximum average of 24.17 cm on 45 days after planting where as in the control, the height was as low as 14.14 cm on the average.

In general, there was an increase in the number of leaves per plant with the increase in the amount of green biomass-enriched compost (Table 9). The application of green biomass-enriched compost prepared at 3:3 and 3:2 ratios significantly increased the number of leaves of young eggplant plants compared to control. Plants grown in soil-compost mixture at 1:1 where compost was from the 3:3 treatment (T_4-3:3 treatment), showed maximum number of leaves per plant (10.89) followed by T_3-3:2 (9.78), and T_2-3:1 (9.44) treatments which were statistically at par with each other but were significantly superior over control 7.33. The number of leaves in the T_3-3:2 ratio and T_2-3:1 treatments were superior over control (T_1-3:0), but were not significantly different from each other.

Table 9. Number of leaves of young eggplants

Treatments	Leaf Number of Eggplants			Mean Leaf Number
	Replicate I	Replicate II	Replicate III	
T_1-3:0 - control	7.67	7.33	7.00	**7.33**^{c}
T_2-3:1 ratio	9.00	10.33	9	**9.44**^{ab}
T_3-3:2 ratio	9.67	9.33	10.33	**9.78**^{ab}
T_4-3:3 ratio	10.00	11.33	11.33	**10.89**^{a}

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

The data in Table 9 indicate that, the green biomass-enriched compost had an influence on number of leaves when compared to control. The compost influenced number of leaves to a maximum average of 11 leaves on 45 days after planting where as in pure soil or control, the number of leaves remained as low as 7 leaves on the average. The higher nitrogen content of compost must have been helpful in increasing number of leaves.

Table 10 shows the fresh weight of young eggplant plants. The highest weight was observed from the plants grown in the T_4-3:3 treatment with mean weight of 60.33 grams and was significantly higher than the rest of the treatments. The second highest weight was recorded from the T_3-3:2 treatment (47.33 grams) followed by the T_2-3:1 treatment with mean weight of 38 grams. The least weight was from the plants in the control treatment (14.67 grams).

Table 10. Fresh weight of young eggplants

Treatments	Weight of Eggplants (g)			Mean Weight (g)
	Replicate I	Replicate II	Replicate III	
T_1-3:0 - control	**12**	**14**	**18**	**14.67**^{d}
T_2-3:1 ratio	**39**	**35**	**40**	**38.00**^{c}
T_3-3:2 ratio	**47**	**49**	**46**	**47.33**^{b}
T_4-3:3 ratio	**60**	**63**	**58**	**60.33**^{a}

Values sharing similar letters in a column do not differ significantly at p<0.05, according to Scheffe's test

All the plants grown with compost had higher fresh biomass weight than the control (by 159% in T_2-3:1, 223% in T_3-3:2 and 311% in T_4-3:3 treatments). Analysis showed significant differences in fresh weight of plants from the four treatments. All of the plants grown with enriched compost were significantly higher than the control by Scheffe’s test and were also significantly different from each other.

There was an increase in the size of leaves per plant with the increase in the amount of green biomass-enriched compost (Table 11). The application of green biomass-enriched compost at all levels significantly increased the size of leaves of young eggplant plants compared to control. The application of the same weight of compost from the 3:3 compost treatment with that of the soil growing media (T_4-3:3 treatment) showed maximum sizes of leaves per plant (12.89) followed by T_3-3:2 ratio (11.07), which were statistically at par with each other but were significantly superior over control (8.13). The average leaf size of plants in the T_2-3:1 treatment was at par with those of the control treatment.

Table 11. Leaf size of young eggplants

Treatments	Leaf Size of Eggplants (cm)			Mean size (cm)
	Replicate I	Replicate II	Replicate III	
T_1-3:0 - control	8.30	8.67	6.77	7.91^{c}
T_2-3:1 ratio	9.07	10.00	9.43	9.50^{bc}
T_3-3:2 ratio	10.73	11.57	10.90	11.07^{ab}
T_4-3:3 ratio	11.47	13.17	14.03	12.89^{a}

Values sharing similar letters in a column do not differ significantly at $p<0.05$, according to Scheffe’s test

The data in Table 11 indicate that, the green biomass-enriched compost had an influence on the size of leaves when compared to control. The compost influenced size of leaves to a maximum average of 12.89 on 45 days after planting where as in pure soil or control, the size of leaves remained as low as 7 on the average. The higher nitrogen content of compost must have been helpful in increasing the size of leaves.

Summary, Conclusions And Recommendations

Conclusions

1. Increasing the volume of green biomass increases the nutrient quality of crop residue compost in terms of its Nitrogen, Phosphorous and Potassium contents. The higher the green biomass added, the higher is the compost nutrient quality.
2. Increasing the amount of green biomass increases the organic matter content of crop residue compost, improves the pH value to almost neutral state, and produce compost with relatively high moisture content at harvest.
3. Increasing the volume of green biomass increases the weight of harvestable crop residue compost. The higher the green biomass added, the higher is the weight of compost.

4. Green biomass-enriched crop residue compost with good amount of plant nutrients was found to stimulate plant growth in terms of total height of plants, number of leaves, size of leaves, number of buds, and total weight of fresh plant biomass.

5. The study has shown that green biomass can be used to improve the quality of crop residue compost by adding green biomass gradually during the composting process.

Recommendations

1. Green biomass (tender stems plus green leaves) of plants like *Leucaena leucocephala and Tithonia diversifolia* known to contain high level of nutrients is recommended as an alternative method of improving the nutrient quality (N, P, K) of crop residue compost.

2. The use of green biomass for enrichment of compost is also recommended to improve organic matter content and pH level of compost. Enrichment should be gradual preferably three times within the composting period.

3. The gradual addition of green biomass is recommended not only to improve compost quality but to increase the volume of harvestable compost which is important in commercial compost production.

4. Green biomass enriched compost with good amount of plant nutrients is recommended to be used to stimulate growth of eggplant and pepper plants and probably other agricultural crops.

5. In support to a healthier food and environment, composting should be practiced and promoted by everybody.

6. Further researches in improving the quality of compost using green biomass in combination with nitrogen-fixing microorganisms and animal waste are also recommended.

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