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RESEARCH ARTICLE

EFFECTS OF DIFFERENT ADDITIVES ON THE QUALITY OF COMPOSTS PRODUCED FROM ORDINARY GARDEN LEAF LITTER

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ABSTRACT

Disposal and proper management of garden waste in urban and semi-urban areas of Sri Lanka have become a problem due to several constraints. Compost production by introducing common additives to garden waste will be an effective solution to overcome this problem. It ensures good quality compost and nutrient supply for the growth of the plants in home gardening. Therefore, the objective of the present study was to determine the effects of different additives on the quality of composts produced from garden leaf litter. By applying a mixing formula, five additives were mixed separately keeping a constant weight of dry leaf litter and the C:N ratio as 25:1 in the compost piles except for the control treatment; (i) dry leaf litter + Gliricidia leaves (*Gliricidia sepium*)-GLL, (ii) dry leaf litter + Siam weed (*Chromolaena odorata*)-SWL, (iii) dry leaf litter + cattle manure-CML, (iv) dry leaf litter + spent poultry layer litter/poultry manure-PLL, and (v) dry leaf litter + urea-UL. As the control treatment, a compost pile was prepared only with leaf litter (LL). After 90 days of composting, the chemical properties of different composts were determined and compared. The characterization included pH, EC, NH_4^+-N, NO_3^--N, available P and available K using standard analytical methods. The pH, EC and C/N ratio values were compared with the indices given by Sri Lanka Standard Institute (SLSI). According to the results, pH and EC were within the standard levels. The different additives have caused differences in NH_4^+-N and NO_3^--N in final compost mixtures. However, the P and K availability has not shown any significant effect with selected additives in leaf litter composting. The C/N ratio of GLL, CML, SWL and LL composts were between 10 and 20, achieving the SLSI standards. In this study, considering the compost characteristics, it could conclude that the additives such as Gliricidia, Siam weed, cattle manure, which have considered in this study could be used with ordinary leaf litter for composting. The ordinary garden leaf litter without any additives has also complied with the compost standards.

Keywords: Animal manure, chemical properties, compost, garden waste, green leaves

INTRODUCTION

Bio-degradable organic waste can be decomposed anaerobically or aerobically to produce compost. This will reduce the problem of organic waste disposal. Compost production is an attractive solution to treat and dispose of organic waste (Gabrielle *et al*. 2005: Zmora-Nahum *et al*. 2007). Further, compost is a valuable organic fertilizer to enhance the fertility of the soil (Obeng and Wright 1987). Garden wastes such as hedge pruning/ clippings, shredded grass and leaf litter contain necessary plant nutrients (Estévez-Schwarz *et al*. 2012). The nutrient value of compost varies widely based on different waste materials used in compost production, and their composition. Compost produced from animal manure is richer in nitrogen, phosphorus and potassium whereas more dried leaves or leaf litter is richer in carbon, which restricts decomposition (Hu *et al*. 2006). They could replace and/or supplement with other organic additives and chemical fertilizers efficiently to reduce the C:N ratio and reach the standard level. Further, most micro-nutrients supplemented by compost are vital for plant growth (Kaboré *et al*. 2010). Hence, the nutrients in compost are very important to provide plant nutrients to the soil.

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Decomposition is a complex process of the biological breakdown of organic material. The remaining humus provides nutrients to the soil, which can hold moisture, enhance soil structure, and supply plant nutrients to the soil. To implement the composting process, appropriate methods and materials should be selected. Further, the factors that affect the process such as pH, moisture, temperature, aeration and C/N ratio etc. should be controlled. Of these factors, the C/N ratio during the production of compost is vital as various raw materials should be properly mixed to adjust the C/N ratio. When producing compost, the C/N ratio should be 25:1 and should maintain aerobic conditions where out of total pores 50% must saturate with water (Rynk *et al*. 1992). Higher carbon, nitrogen ratio (more than 40:1) of compost will immobilize nitrogen and retard the process (Coyne and Thompson 2006).

The C/N ratio of finished compost is used to determine the quality and maturity of composts. (Garcia *et al*. 1992; Wu and Ma 2002). In addition, the final compost pile should resemble a dark colour, giving an earthy smell and crumbly. Other available nutrients such as NH_4^+-N and NO_3^--N, K and P in compost can determine not only the application rate but also their suitability for various end uses (Pierzynski and Logan 1993). Generally, nitrogen will be less available when composting with nitrogen-rich materials while it is highly available with carbonaceous materials. Both ammonium (NH_4^+) and nitrate (NO_3^-) can be absorbed by plants according to their requirements.

Several researches have been conducted for selecting the best compost mixtures using different garden waste and other agriculture wastes (Kaboré *et al*. 2010; Estévez-Schwarz *et al*. 2012). Among these, dry ordinary leaf litter is a valuable potential source of nutrients providing a high quality of organic matter, which provides nutrients back to the soil (Naikwade, 2014). In terrestrial ecosystems, leaf litter decomposition is a major functional process, controlling the cycling of nutrients and thereby governing vegetative productivity (Swift *et al*. 1979). Dry leaf litter is a common garden waste in most areas of Sri Lanka. However, the composting processes solely by leaf litter cannot supply required nutrients appropriately to the soil (Ventura *et al*. 2010). Since the dry leaf litter has comparatively high C content, it should mix with other organic materials with high N content to increase the availability of N. Manios (2004) stated that adding inorganic N to correct the C/N ratio to an optimum value and mixing different feedstock materials are possible in composting. A material high with N could be used as an additive when composting carbonaceous material. In that case, the additives with high percentages of N such as *Gliricidia sepium*, *Chromolaena odorata*, cattle manure, spent poultry layer litter and urea were selected to mix with dry leaf litter which has high C content. The degradation of such carbonaceous materials can be optimized by incorporating other additives.

Gliricidia sepium has been used to prepare compost in much research work (Zaharah and Bah 1999). *Gliricidia sepium* lopping will uniformly increase the N level (Nagavallemma 2000). Expressively low amounts of carbon dioxides (1434 mg g^{-1} soil) removed after incorporating Gliricidia leaves to the soil (Vineela *et al*. 2008). Further, it releases important soil nutrients such as N, P, K, Ca, and Mg (Han *et al*. 2011).

Siam weed (*Chromolaena odorata*) is an aggressive shrub of tropical origin. It causes a threat to the agricultural lands and home gardens that grows invasively and become troublesome to farmers, thus name as “Podisinghomaran” in Sinhalese. It contains high organic C (49.97%) N content (3.79%) and contributed a total P content of 0.29%-0.6% to the soil (Murthy 2013; Setyowati *et al*. 2014; Augustina *et al*. 2019). It has the potential to be used as compost due to the high amount of N and is able to substitute N fertilizer (Jamilah 2010; Setyowati *et al*. 2014).

The use of cattle manure in combination with leaf litter could be considered as an effective way of using cattle manure when compared to fresh cattle manure. The composted manure can be used more evenly and resourcefully through the reduction of mass and bulk (Schoenau *et al*. 2000).

Codling (2002) has compared the usefulness of poultry litter as a fertilizer with an industry -standard fertilizer. Further, the addition of bulking agents to the poultry litter has been practiced to increase the C:N ratio, to expedite the composting process and thereby to increase the quality of the composted product (Rynk *et al*. 1992; Tiquia and Tam 2002). Therefore, poultry litter especially the deep layer litter in composting will reduce disposal problems and provide nutritional value to the plant growth.

Previous studies have found that N fertilizers can be used in composting. The combined application of compost-enriched urea has improved the yield of wheat (Akhtar *et al*. 2011). Further, nitrogen-enriched compost has been used to decrease the sole dependence on chemical fertilizers (Swift and Woomer, 1993). Moreover, urea as a chemical amendment with high N content may increase the decomposition of plant litter. It was reported that compost enriching by urea has increased the net mineralization (Han *et al*. 2004).

Therefore, in this study it was hypothesized that *Gliricidia sepium*, *Chromolaena odorata*, cattle manure, spent poultry layer litter and urea may improve the quality of final compost when incorporated with ordinary dry leaf litter.

Compost based researches were not well targeted the requirements of home gardeners as potential users. The importance of composting in home gardening has increased in public perception in recent years in Sri Lanka, as it is an eco-friendly and safe way to do the cultivation healthier and more productive. Moreover, compost production at the household level is important as this will create pro-environmental behaviour towards waste disposal and home gardening. Thus, it is important to research to find out good quality composts and enhance the nutritional value of compost by adding several additives. In addition, characterization of compost, based on such mixtures is necessary to accomplish the requirements of potential users. Therefore, the objective of the present study was to determine the effect of different additives on the quality of compost produced by ordinary leaf litter.

MATERIALS AND METHODS

Compost production

Six compost mixtures were prepared using different raw materials. The experiment was carried out in the compost production yard and the Soil Science Department, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka. Two types of green manure; (i) Siam weed (*Chromolaena odorata*) (ii) Gliricidia leaves (*Gliricidia sepium*) two types of animal manure (iii) cattle manure (iv) spent poultry layer litter and one chemical fertilizer (v) Urea were considered as raw materials to be mixed with dry leaf litter. The amounts of materials needed were calculated according to equation 1 (Rynk *et al*. 1992). To calculate the required amount of each raw material, the parameters such as moisture content, organic C% and total N% were analysed. Each raw material was separately mixed with a constant weight (20 kg) of dry leaf litter and composted by windrow method and each compost pile having different treatments was replicated three times equal to 18 piles. The compost mixtures were SWL (Siam weed and leaf litter), GL (Gliricidia and leaf litter), CML (cattle manure and leaf litter), PLL (poultry litter and leaf litter), UL (urea and leaf litter) and LL (leaf litter only the control). After mixing the components thoroughly, the mixtures were prepared into heaps appropriately on a concrete floor. They were covered by a black polythene to retain moisture. Water was applied to the heaps by testing the moisture content by field method in the regular intervals (Estévez-Schwarz *et al*. 2012) and turned weekly for aeration to speed the decomposition process. The mixtures were allowed to decompose for 90 days to obtain fully matured compost. Goyal *et al*. 2005 indicated that composts prepared by organic waste were stabilized in 90 days.

$$R = \frac{Q1(C1(100 - M1)) + Q2\,(C2\,(100 - M2)) + \cdots Qn(Cn(100 - Mn))}{Q1(N1(100 - M1)) + Q2(N2(100 - M2)) + \cdots Qn(Nn(100 - Mn))}$$ ...Eqn (1)

where, R is the C:N ratio of compost mixture for optimum decomposition (i.e. assumed 25:1), Qn is the mass of materials n (wet basis), Cn is the organic C % of material n, Nn is the total nitrogen % of material n, Mn is the moisture content percentage of material n. Q1-Qn, C1-Cn, M1-Mn and N1-Nn have represented the raw materials used in the study.

Sample processing techniques

At the initial level, total C percentage, total N, P and K percentages were analyzed for all the raw materials used for the study according to the standard analytical methods (SLSI). The carbon percentage was measured using the Walkley-Black method. The total N was measured using the Kjeldahl method (Velp UDK 139, Italy). The total P and K was measured using the acid digestion method. The obtained data is given in Table 1. At end of the composting process, the final compost mixture was sieved with a 4 mm sieve and brought to the laboratory for analysis. The total C percentage, total Kjeldahl nitrogen percentage, pH (1:2.5 w/v), EC (1:5 w/v), NH_4^+-N and NO_3^--N, available P and K were measured in different compost mixtures. The C:N ratio of each treatments were calculated. All the analyses were done for the samples collected from replicated compost piles.

The total K and P were analyzed (SLS 645, 1983) using hydrochloric acid and nitric acid digestion method using a spectrophotometer (UV 160, Shimadzu). Electrical Conductivity (1:5 w/v compost–water extract) was determined by the electrical conductivity probe (HANNA). The determination of NH_4^+-N and NO_3^--N was analyzed using the colourimetric method (UV 160, Shimadzu) adopting the salicylic acid method at 660 nm and 410 nm wave lengths by using UV visible spectrophotometer, respectively (Markus *et al*. 1985). Samples were extracted from 2M KCl solution. Available P using the Olsen method (Olsen *et al*. 1954) at 882 nm using the spectrophotometer (UV 160, Shimadzu). Available K was analyzed using the flame photometer (Sherwood model 360) by extracting the samples with 1M ammonium acetate solution (Kehres 2003). According to the C and N percentages, the C/N ratio of the raw materials was computed by rationing them.

Statistical analysis

The Duncan's Multiple Range Test (DMRT) in SAS 9 statistical package at P≤0.05 was used to determine the significant differences among mixtures.

Table 1: The chemical composition of the raw materials used for compost production.

Raw material	Total C %	Total N %	C:N ratio	P %	K %
Siam weed	18.32	1.65	11.10	0.25	1.4
Gliricidia	18.30	2.80	6.54	1.8	2.5
poultry litter	24.98	3.53	7.07	1.5	2.6
urea	20.00	46.0	0.43	-	-
cattle manure	15.44	2.98	5.18	0.75	2.9
dry leaf litter	41.50	1.49	27.85	1.7	4.6

RESULTS AND DISCUSSION

The chemical characteristics of the raw materials are given in Table 1. N content of raw materials varied as leaf litter<siam weed<glyricidia<cattle manure<poultry litter<urea. Accordingly, the C:N ratio of amendments varied as urea<cattle manure<glyricidia< poultry litter<siam weed<dry leaf litter. The nitrogen content in the raw materials can affect the C:N ratio of the final compost mixtures.

pH values of different composts

The pH values of different composts are shown in Figure 1 (a). The pH of compost mixtures was between 8.2-8.5 showing slight alkalinity. Thus, all composts are within the standard level of pH recommended by SLS (SLS 1635:2019) between 6.5-8.5. To minimize ammonia volatilization, pH should not rise above 8.5. The highest pH value was observed in urea added litter compost (UL) which was 8.5 while the lowest value was in Siam weed added litter compost (SWL). The pH will decrease in the composting process due to the release of CO_2 and organic acids, however, neutralized by NH_3 generation (Esteves 2011).

Electrical conductivity of different composts

The electrical conductivity (EC) values of different composts are shown in Figure 1 (b). For the field application of compost, there is no definite guideline for electrical conductivity (EC). However, for a growing medium, electrical conductivity (EC) is a measure of dissolved salts present in the compost. Glyricidia added litter compost (GLL) had the highest value of 0.613 dSm^{-1} and poultry litter added litter compost (PLL) had the lowest value of 0.273 dSm^{-1}. Compost soluble salt levels are typically ranged up to 10 dSm^{-1} and the maximum acceptable level was given as 4 dSm^{-1} (Bhamidimarri and Pandey 1996, SLS 1635:2019). However, acceptable levels are determined based on the intended use of the compost (Amarasinghe 2021). The EC may vary according to the ability of added raw materials to retain water and salts and less infiltration. The compost produced by green leaves will accelerate the decrease in redox potential (Eh) and accumulate CO2, and as a result, in the release of a large amount of ions the EC may be increased (Singh 1992). GLL, UL and CML had significantly higher ($p<0.05$) EC values than the leaf litter compost (LL).

NO_3^--N and NH_4^+-N content of different composts

The NO_3^--N values of different composts are shown in Figure 1 (c) and varies as PLL<LL<GLL<SWL<CML<UL. According to the analysis of different composts, urea amended litter compost (UL) had the highest value of 7.52 mg kg^{-1} and poultry litter compost had the lowest value of 5.88 mg kg^{-1} of NO_3^-—N. UL and CML had significantly higher ($p<0.05$) NO_3^--N values than the LL. In all the composts pH was higher and above 8. Khalil *et al.* (2005) showed that nitrification was faster in high pH conditions. Accordingly, higher NO_3^--N amounts were observed in some final composts with respect to higher pH. However, NO_3^--N were comparatively less than NH_4^+-N which may be reduced due to leaching, volatilization and consumption by the compost producing organisms. Tiquia and Tam (2002) stated that the reason for the low content of NO3—N may be due to a certain amount of the NH_4^+ ions in compost that have not converted into NO_3^- but were lost through NH_3 volatilization. Further, the C/N ratio of organic materials may directly regulate the accumulation or removal of NO_3^--N (Khalil *et al.* 2010) and according to Kobore *et al.* (2010), the high C/N ratio may be accountable for N immobilization. When mixed with urea, having the lowest C/N ratio showed a higher amount of NO_3^--N in the final compost.

Mineralization is the process, which the organic matter is decomposed and released as soluble inorganic forms in the plant-available form. However, most of the organic N is resistant to decompose. Moreover, the NH_4^+ is converted to NO_3^- by nitrification and the losses of volatilization may occur in the early stages of the composting process. The NH_4^+-N values of different composts are shown in Figure 1 (d). According to the NH_4^+-N results the poultry litter compost (PLL) had the highest value and the leaf litter compost (LL) had the lowest value of 101.07 mg kg^{-1} and 61.63 mg kg^{-1}, respectively. The NH_4^+-N concentration of final composts varies as LL<SWL <CML<GLL<UL<PLL. As the uric acid content in poultry litter contains uric acid it is converted to urea using a limited number of microorganisms (Schefferle, 1965). Therefore, urea is hydrolyzed to NH_4^+-N using urease, with the process consuming H^+ ions and raising pH by another category of bacteria. Also, the N amount in urea may produce a higher amount of NH_4^+-N. These may be the reasons for having higher NH_4^+-N in UL and PLL. All the composts except Siam weed amended leaf litter compost showed significantly higher ($p<0.05$) NH_4^+-N values compared to the leaf litter compost.

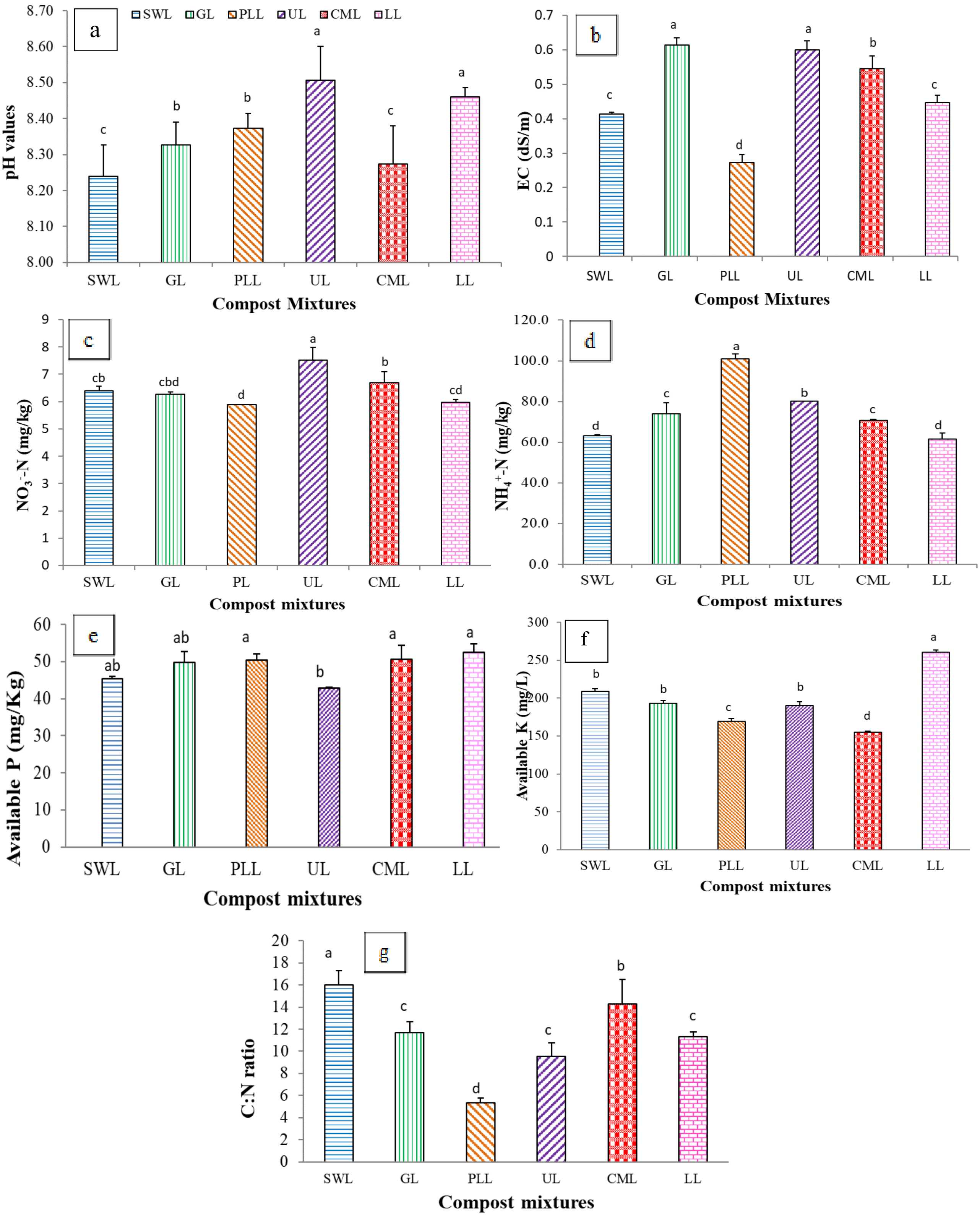

Figure 1. (a) pH (b) EC (c) NO_3^--N (d) NH-$_4^+$-N (e) available P (f) available K and (g) C/N ratio of different compost mixtures at the end of the composting process. Vertical bars represent standard error (mean ± SE) and mean values designated by the same letter are not significantly different at *p*<0.05 as determined by DMRT.

Available Phosphorus of different composts

The available P values of different composts are shown in Figure 1 (e). The highest amount of P was found in the leaf litter compost (LL) while the lowest was in urea added compost (UL). The additives which were used to prepare compost had almost equal percentages of P except for the urea (Table 1). There was no significant difference ($p<0.05$) of P in composts compared to the leaf litter compost. Much of the organic P is easily decomposable by soil microorganisms and the P mineralization variation in different composts may also be due to some factors such as temperature, moisture content, and pH (Hue *et al*. 1994).

Available Potassium of different composts

The available K values of different composts are shown in Figure 1 (f). The highest amount of K was obtained in LL compost, which was not amended by any other additives. The reason may be the higher amount of K in the leaf litter (Table 1). The leaf litter decomposition and nutrient mineralization depend on climatic factors and the characteristics of the leaf litter (Whitmore and Handayanto 1997). In leaf litter, the K release is faster and greater than that of either N or P (Ventura *et al*. 2010) and this may be the reason for having a high amount of K in the leaf litter composts. Further, the K concentration of each compost mixture may be influenced by its origin and additives.

C/N ratios of different composts

The C:N ratio of different compost mixtures are shown in Figure 1 (g). All the compost mixtures except PLL and UL composts had C:N ratio above 10. The C:N ratio varies as PLL<UL<LL<GLL<CML<SWL. The end use of compost in case of quality, stability and maturity has been measured mostly by C:N ratio (Goyal *et al*. 2005; Kaboré *et al*. 2010). Chanyasak and Kubota (1981) explained that the C:N ratio can be used as a gauge of compost maturity as C and N concentrations are related to the metabolism rates of microorganisms during composting activity. Further, the amount of C and N of final compost depends on the raw materials used for composting (Charert *et al*. 2004). Nitrogen which is mostly organic and closely associated with C, is generally released as NH_4^+ and NO_3^- and C as CO_2 (Zaharah and Bah 1999). Therefore, the C:N ratio of organic materials decrease in the process of composting due to losses of C as CO_2 which may ultimately stabilize in the range of 15-20 (Golueke 1977).

The final composts by incorporating materials high with N such as poultry litter and urea end up with less C:N ratios than other mixtures. Reddy *et al*. (1979) and Sanchez-Monedero *et al*. (2001) showed that composting with a low C:N ratio losses more N than in materials with a high C:N ratio. This is because at lower C/N ratios, the nitrogen content is in excess amounts and will be volatilized as ammonia gas. However, in higher C/N ratios, the adequate amount of N will not available to the microbial populations, then the decomposition rate might be low.

Different C/N ratios have been identified in several research studies and different standards have been implemented. According to the standards by SLSI, the C:N ratio should be 10:1- 20:1 (SLS 1635:2019). In that sense, only the poultry litter and urea compost mixtures were below the standard level for compost (Figure 1). However, according to the FAO indices (Misra 2003), in the final product the C/N should range between 10:1 and 15:1 and Bernal *et al*. (1998) has reported an ideal value for C/N is 12 for the end-use.

CONCLUSIONS

The chemical properties such as pH, EC, NO_3^--N, NH_4^+-N, available P and K of final composts were varied with the type of raw materials used. However, all the composts prepared in this study had pH and EC complied with SLSI. Further, urea amended dry leaf litter compost mixture reported the highest NO_3^--N level whereas poultry litter amended dry leaf litter compost reported the highest NH_4^+-N level after 90 days of composting. However, in this study, the P and K availability has not shown any significant effect with selected common additives in leaf litter composting. The C/N ratio of GLL, CML, SWL and LL composts complied with SLSI standards. Therefore, in this study, it could conclude that the additives such as Gliricidia, Siam weed, and cattle manure could be mixed with dry leaf litter for composting. Moreover, the dry leaf litter without any additives has also complied with SLSI compost standards.

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