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Compost biomass, pH value and C, N, K contents of some local wild plant species: Case of *Panicum maximum* L., *Trypsacum laxum* L. and *Pueraria javanica* (Benth.) Benth, in the Region of Kisangani, Democratic Republic of Congo

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Soil fertility transience and weed management are often among decried impediments undermining agricultural productivity in many tropical countries. A study aiming at transforming baffling problems of abundant weed biomasses especially that of *Panicum maximum (T1)*, *Trypsacum laxum (T2)* and *Pueraria javanica (T3)*, often cause of crop yield loss into advantage to enhance soil fertility, increase crop productivity as well as help tackle weed issue was initiated in the region of Kisangani. To do this, a 90-day composting experiment involving a mono factorial randomized complete block design including three replications and three treatments of above mentioned weed biomasses was conducted from 23rd March to 23rd June 2013. The results of analysis of variance showed significant differences among treatments for pH H_2O ($p \leq 0.013$) and potassium content ($p \leq 0.001$). The three composts demonstrated high nutrient content level in total organic carbon, nitrogen and potassium able to restore soil fertility. Moreover, the study revealed that the pH values of all the composts were closer to neutral on average and can be used to fix the recurrent issue of soil acidity in the region. Finally, the results showed that the species were able to produce sufficient compost mass with 41.5, 36.3 and 30.9% of initial mass loss respectively for T1, T2 and T3 in a relatively short time.

Key words: Soil fertility transience, compost, weed management, agricultural productivity, DR Congo.

INTRODUCTION

In many tropical countries with extreme climatic conditions, highly weathered soils coupled with practiced

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cropping systems lead to intense perturbations of soil physicochemical properties. In this context, the resulting transient fertility is always one of the impediments to an agricultural productivity to meet small farmers' socioeconomic needs (Steiner et al., 2007, 2009; Solia, 2016). However, a massive chemical fertilizer use even rational cannot be envisaged as sustainable solution, because of their long run damaging effects connected to the eventual land pollution and their biodiversity as well as public health issues (He et al., 2005; Dhaliwal et al.,2010; Han et al.,2016; Chandini et al., 2019). In contrast, tropical regions are characterized by rapid plant growth due to prevailing high temperature (KCMG, 2014), which contributes to plant species proliferation including weeds, making the sustainable management of this latter difficult. Labor shortage and financial resources added to this, further complicate farm running for small farmers. Yet, this less favorable situation linked to weed proliferation can be reversed to an advantageous benefit to small farmers, by the use of this plentiful plant biomass for soil amendment in order to increase agricultural productivity. The composting process may turn out to be the most suitable and sustainable approach of the utilization of invading weeds to increase farm productivity to smallholders (Indrayani and Surendra, 2014).

In the Congo Basin, especially in the region of Kisangani, several invasive species such as *Panicum maximum* L., *Pueraria javanica* (Benth.) Benth and *Tripscum laxum* L. are some species always considered as tremendous weeds hardening crop weeding task to poor small farmers and sometimes contributing to large production loss (Tomita et al., 2003; Maombi, 2006; Mirshekari et al., 2013; Soltaniet al., 2016). Yet, the abundant and available biomass of these weed species fueled by favorable ecological conditions can be transformed in compost to amend soils and alleviate the pressure of their infestation on crops and so, increase the productivity. Though the production per hectare has been declining markedly over decades in the region, prospects for a quick and sustainable accretion of agricultural production volume are still good (Tanzito and Ibanda, 2010).

Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. Raw organic materials such as crop residues, animal wastes, food garbage, some municipal wastes and suitable industrial wastes, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting (FAO, 2003). Compost is a rich source of organic matter (FAO, 2003; Mahimairaja, 2008; Chatterjee et al., 2013). Soil organic matter plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrient, it improves the physico-chemical and biological properties of the soil. As a result of these improvements, the soil becomes more resistant to stresses such as drought, diseases and toxicity; helps the crop in improving uptake of plant nutrients; and possesses an active nutrient cycling capacity because of vigorous microbial activity (Craswell and Lefroy, 2001; Bot and Benites, 2005). These advantages manifest themselves in reduced cropping risks, higher yields and lower outlays on inorganic fertilizers for farmers (FAO, 2003).

Food and Agriculture Organization of the United Nations and other scholars roughly divides composting into two types: anaerobic (occurring where oxygen is absent or is in limited supply) and aerobic (taking place in the presence of ample oxygen) composting (FAO, 2003; Naikwade et al., 2011; Mehta and Sirari,2018). However of the two types, the aerobic composting process, although producing intermediate compounds such as organic acids, the resultant compost has little risk of phytotoxicity and is the most advised to the small scale farmers. In fact, several small scale aerobic composting methods have been developed across the world including, Indian Bangalore method, Indian Coimbatore method, Indian Indorepit method, Indian Indore heap method, Chinese rural composting pit method, Chinese rural composting high temperature method, Ecuador on-farm composting, Berkley rapid composting method with shredding and frequent turning, North Dakota State University hot composting using mineral nitrogen activator, composting organic materials with high lignin content and lime treatment, Effective micro-organisms (EM)-based quick composting, Institute of Biological Sciences (IBS) rapid composting and weed composting method (FAO, 2003).

Besides, similar works including *Panicum maximum* and some species of *Pueraria* have been undertaken across the tropics. For example, Quansah et al. (2001) conducted studies on the potential of *Chromolaena odorata*, *Panicum maximum* and *Pueraria phaseoloides* as nutrient sources and organic matter amendments for soil fertility maintenance in Ghana and found that compost prepared from these plants were not significantly different in terms of their N, P, K, Ca and Na contents. They also found that pH of all composts were near neutral making them suitable for application to any soil type. The same report suggested that plant residues or compost prepared from them could therefore be used as sources of nutrients and soil organic matter amendment for increased crop production in Ghana. It is in this goal that this study was initiated aiming at: 1) Assessing the post composting biomass of some local wild species namely *Pueraria javanica* (Benth.) Benth, *Panicum maximum* L. and *Trypsacum laxum* L in the region of Kisangani in DR Congo and 2) searching the high proportions of major nutrients (N, K and C) subsequent to composting process in these species in order to compare related composts in terms of their nutrient content.

The ultimate objective of the research was to provide to local small farmers, pretty simple and accurate specific

Figure 1. Geographical location of the city of Kisangani in the central east region of the D R of Congo.
Source: USAID (2015)

technical skills about composting process and its relevance, to reduce potential chemical fertilizer use and related consequences in a region where organic matter such as poultry manure and cow dung are scarce and the access to inorganic fertilizers is limited due to high cost. Finally, the study was a sort of innovation which would enable local smallholders to produce by themselves local resource-based composts aiming at correcting soil properties to enhance their production.

MATERIALS AND METHODS

Geographical location of the study area

This study was conducted in the city of Kisangani. Kisangani is the main city of the former Eastern province (today province of Tshopo) in the northeastern part of the Democratic Republic of the Congo (Figure 1). The average geographic coordinates of the area are 0°36' latitude north, 25°13' longitude east, with an altitude varying between 376 to 470 m. The region of Kisangani is located in the bioclimatic zone of evergreen tropical rainforest. The zone is characterized by a Af_1-like climate according to the classification of kôppen- Geiger (Upoki, 2001; Thienpondt, 2016; MFAN, 2018). The temperature of the coldest month is above 18°C and the rainfall average of the driest month is above 60 mm. Generally, the temperature revolves around 25.3°C in March and 23.5°C in August with a yearly average of 24.4°C. The relative air humidity varies between 79.1 % in February and 87.3% in July with an annual average of 84.0%. Precipitations are in abundance throughout the year with an annual average of 1782.7 mm with two equatorial maxima around October and April and two solstitial minima around January and July. The annual average number of rainy days is around 155. However, with climatic perturbations observed currently at the global level, the region experiences the occurrence of a small dry season around January (Upoki, 2001; MFAN, 2018). The insolation is quite high in the region (Makondambuta, 1997). The yearly average turns around 5.4 h per day, with high intensity between 10 and 14 H especially during the driest months (January). It reaches 1945 h per year which correspond to 45% of total radiation. In contrast, there are months during which it declines up to 36%. Figure 2 depicts the average trend of rainfall and heat prevailing in the region over the trial period in 2013.

Soils in the region of Kisangani like all those in equatorial climates are relatively poor (Kombele, 2002; Thienpondt, 2016). They are mostly oxisols (ferralsols according to FAO classification), with low humus content (average rate of carbon and organic nitrogen 1.5 and 0.1%), predominately sandy (sand average rate: 70.1%, silt: 6.5%, clay: 23.4%) and controlled by kaolinite in the clayey fraction. They are acid soils (average water pH and KCL (1N) respectively 4.9 and 3.7) with low cation exchange capacity (CEC: < 7 meq/100g) (Kombele, 2002; Thienpondt, 2016). The vegetation in the area is consisted of primary, secondary forest and fallow lands, with species like *Gilbertiodendron dewevrei, Polyanlthia mavelolens, Strombosia glaucescens*, *Pycnanthus angolensis, Zanthoxelon gilletii, Cynometra hankey, Petersianthus macrocarpum, Funtumia elastica, Uapaca guineensis, Lannea welwitschii, Ricinodendron heudelotii, Sterculia bequertii, Musanga cecropioides, Afromomum laurentii* and so many other shrubby. Grass species include especially *Panicum maximum, Pueraria javanica* and so many others (Mikwa, 2012).

Trial timing and materials

This study lasted for three months, from March 23rd to June 23rd, 2013. The composting pile was constructed using the standard methodology as described by FAO (2003). The plant biomasses used to fill the composting heap included two types; fresh and dehydrated biomasses.

Fresh green biomasses of *Panicum maximum, Tripsacum laxum* and *Pueraria javanica* were collected from premises and adjoining areas of the campus of the Faculty Institute of the Agronomic Sciences of Yangambi, located in the south west of the city of

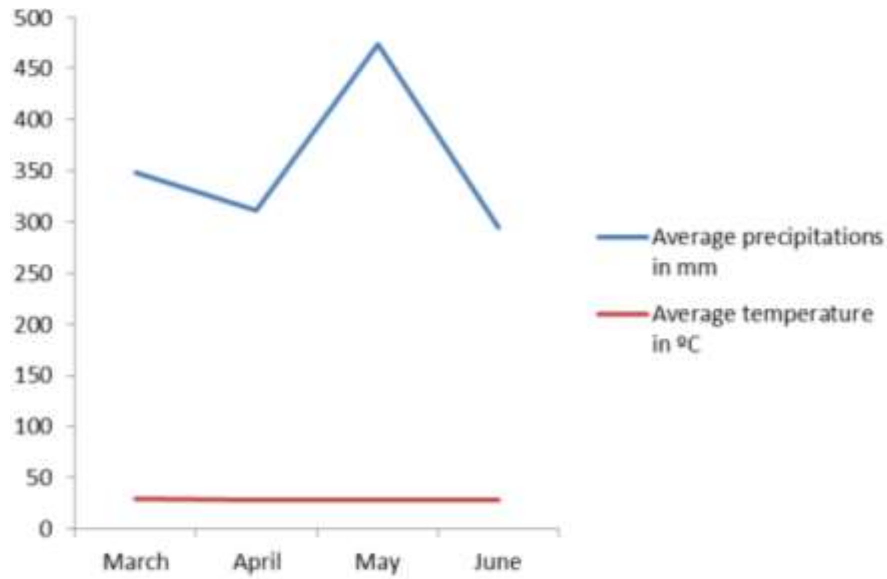

Figure 2. Average precipitations (mm) and temperature (^{0}C) during the trial period (source: meteorological service of crop sciences and production Department of the Faculty Institute of the Agronomic Sciences of Yangambi in Kisangani).

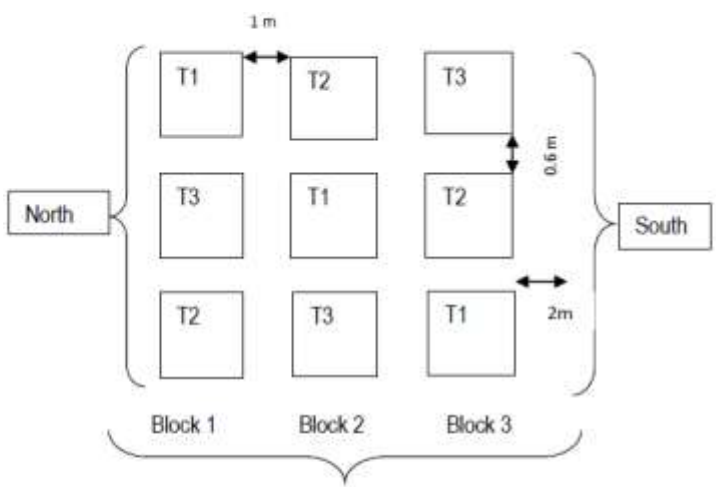

Figure 3. Experimental design of the study.

Kisangani, in DR Congo. The fresh plant material was chopped into pieces (10-15 cm) using a usual machete. The chopped fresh biomasses were wilted in the sun for one week for dehydration. Other feedstock used included the fresh biomass of the same plant species, mixture of pig dejections and rice husk, as well as ash, derived from rice husk.

Experimental design

The experimental layout was a mono factorial randomized complete block design (RCBD) including three replications with three treatments each. The testing plots had an expanse of 1.20 sq. metres each (1 × 1.20 m) and were separated in between by pathways of 0.6 m, whereas the distance in between blocks was 1 m wide. On each experimental unit, 110kg of raw materials was piled (Figure 3). A cleared empty distance of 2 m wide was left around the perimeter of the experimental area in order to demarcate it from the surrounding vegetation. The whole experimental design was sheltered with a shed made of palm leaves to protect it from heavy rains. The studied factor was the biomass of local weed plants with three treatments namely, T1: 110 kg of *P. maximum* biomass, T2**:** 110 kg *T. laxum and* T3: 110 kg *P. javanica* biomass.

Heap filling and handling

The composting heap filling was implemented gradually: to begin with, three woodcuttings were placed vertically from the bottom in

Table 1. Analysis of variance of different measured parameters.

Source of variation	d.f.	Weight	pH_H_2O	pH_KCl	% TOC	% Nitrogen	% Potassium
Block	2	313.44	0.028	0.00023	7.89	0.012	15.73
Treatment	2	102.11	0.11*	0.00023	26.27	0.0012	555.2***
Residual	4	66.44	0.007	0.00027	7.60	0.0023	7.55
CV (%)		11.6	1.3	0.3	19.6	4.1	10.6

***, *Significant at P<0.001, 0.05, pH_ H2O= pH in water, pH_ KCl= pH in potassium chloride, TOC= Total organic carbon.

order to facilitate the ventilation within the heaps being formed. Then, one first layer of 15 kg of wilted biomass (rich in carbon) of the species intended to the experimental unit (treatment) was primarily laid down. This was thereafter followed respectively by 25 kg of fresh biomass of the same species (with high nitrogen content), followed by 10 kg of the mixture pig dejections and rice husk, plus 5 kg of rice husk ash. After a good watering, the above piling steps were repeated in the same way up to reach 110 kg of composting feedstock, followed by a further heavy watering. The whole heap was finally covered with a layer of *Panicum maximum* straw (± 3 cm) to keep up the heat. To be closer to the real world of small farmers, the first punched biomass turning was given one month after piling the heap and the second two months later and by three months, the compost was ready to be used (FAO, 2003).

Compost biomass weighing and chemical analysis

After three months of composting, the first operation consisted of collecting from the resulting compost, composite samples (9 in total) for the upcoming chemical analyses. Subsequently, compost masses derived from different species were weighed and compared, at first to their initial mass (110 kg) depending on treatment and blocks, as well as among themselves in order to determine which species has provided the highest amount of compost mass. However, it should be noticed that heat measures having prevailed within the different treatments throughout the composting period were not tracked out, given the study considered that all the treatments were subject to the same range of temperature viewing the general typical tropical weather conditions prevailing during the research period. The 9 composite samples were dried in open air (away from the sun) for two weeks in the laboratory of soil sciences of the Faculty Institute of Agronomic Sciences of Yangambi in Kisangani and sifted with a 2-mm sieve squared mesh and put in small bags.

The water and KCl pH were determined using a PH-220s brand pH-meter with a reference electrode, on a soil/water and soil/KCl suspension in 1:2 proportions (w/v). The total organic carbon (TOC) was indirectly determined subsequent to the determination of total organic matter (TOM) from which the content was deducted using a simple ratio between the TOM and the conversion factor (1.724), that is, the percentage of TOC = % TOM / 1,724 (Schumacher, 2002). The total organic matter of samples was determined through weight loosing method (Alongo, 2007). This latter involves oven calcination of 10 g of soil sample at 375 ^{0}C during 16 h. The amount of total organic matter was determined by the ratio between the current and the initial weight (% TOM = Wa - Wb/Wa x 100). Besides, the total Kjeldahl nitrogen (TKN) was determined by the standard method (digestion-distillation-titration) using a Kjeldhal digestion flask (Mohammad and Flowers, 2004; Indrayani and Surendra, 2014); whose total nitrogen percentage was deducted as follows:

$$\% \text{ N} = \frac{\text{meq N} \times N_1 V_1 \times V_2}{\text{Sample W} \times V_3} \times 100$$

Where: meq N = 14.10^{-3}; N_1 = actual Normality of acid (0.01N); V_1 = total volume of diluted digest; V_2 = titre value (volume) of HCl used (100 ml); SampleW = weight of the aliquot (5 g) and V_3 = volume of H_3BO_3 (2%), meq = Milliequivalen.

Finally, the quick perchloric acid ($HClO_4$ 1N) method (with ethylic alcohol) was used (Rao et al., 1998) to determine the total potassium (K) amount (K_2O % = 100 (0.33996 weight) 25/5).

Statistical analysis

The one-way analysis of variance (ANOVA) was conducted using Genstat 12th edition to estimate the amount of variability among different samples of compost. Means were separated using Fisher's LSD test at 5% probability level (Ibanda et al., 2018). Boxplots were plotted with the mean of the three replicates for all parameters measured using R statistical package (Version 3.6.1, 2019-07-05).

RESULTS AND DISCUSSION

Analysis of variance for chemical composition of composts

The results of the mass loss of different biomasses indicated no significant difference by the completion of study, which implies that the mineralization rates were almost similar as shown by the analysis of variance (Table 1). There was significant difference ($p \leq 0.013$) in the composts regarding their pH H_2O and a high significant ($p \leq 0.001$) difference of composts in their potassium (K) content. In contrast, the weight, pH KCl, total organic carbon (TOC) nitrogen in percentage and the percentage of potassium showed non-significant differences among them (Table 1).

Mean performance for different compost treatments

The averages of final compost mass produced by the completion of composting process at the 90th day were almost in contradiction with the supposed initial nitrogen content of species; nitrogen being the main agent for a substantial mineralization of organic matter. In general, the narrow the C/N ratio, the fast and substantial is the mineralization, resulting in low organic matter (compost mass) contribution (Quansah et al., 2001; Musinguzi et al., 2013). In fact, *P. javanica* (T3) produced the highest mass of compost (76 kg /110kg, that is 30.9% of initial

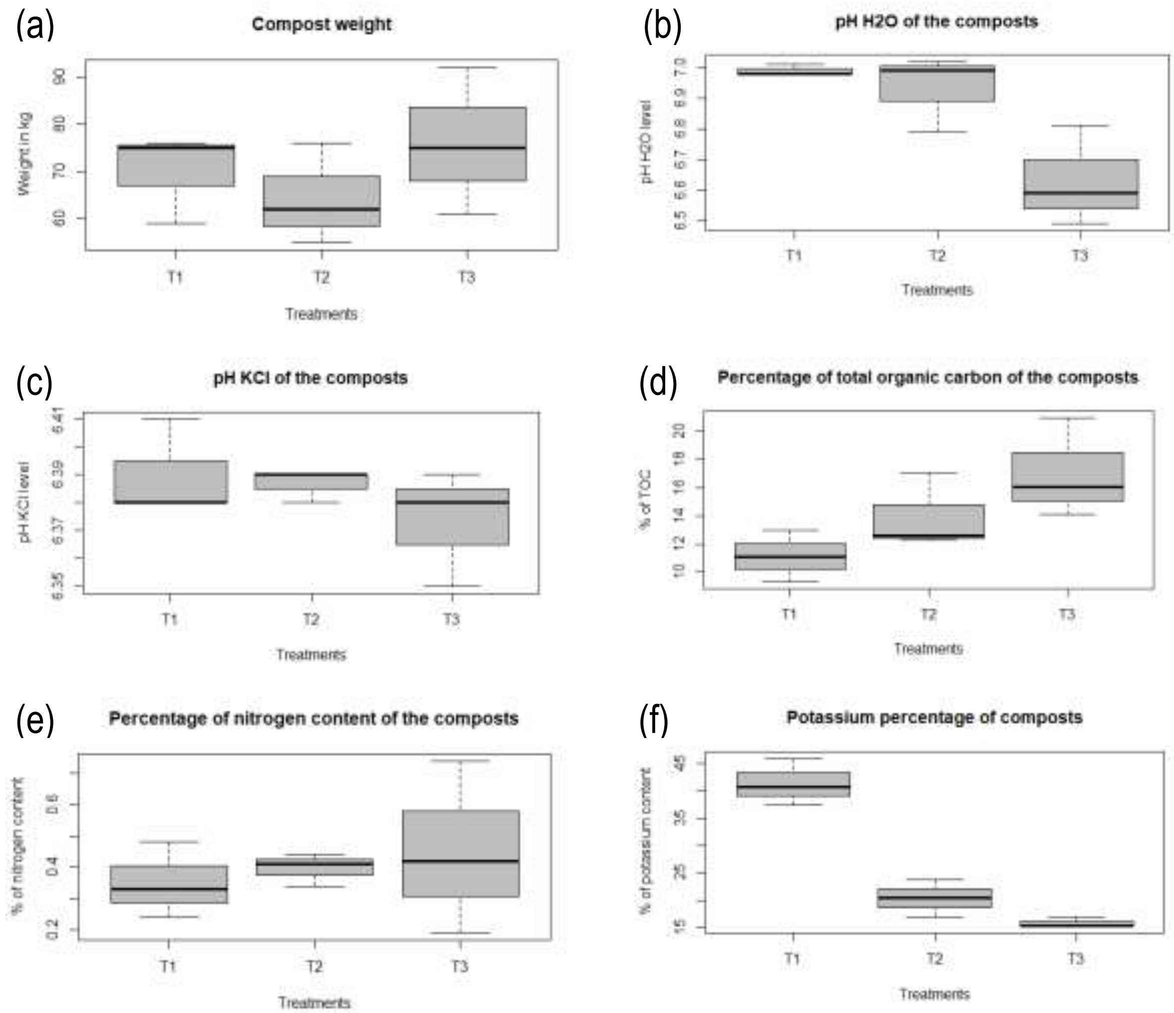

Figure 4. (a) Weight in kg of compost at the 90th days; (b) pH H_20; (c) pH KCl; (d) % of total organic carbon; e. Percentage of nitrogen and f. percentage of potassium in treatments.

mass loss), which is a little bit inconsistent with its supposed initial nitrogen content as a legume (Figure 4a). It was followed by *T. laxum* (T2, 70 kg/110 kg that is 36.3% of mass loss) and *P. maximum* (T1) with 64.3 kg/110kg that is 41.5% of mass loss. These results contradicted those of other studies by Douglas et al. (1980), who found greater initial mass loss from crop residues with the highest N content. In contrast, the results confirm research conducted by Quansah et al.(2001) in Ghana, who observed the highest initial mass loss in *Chromolaena odorata,* which contained the lowest amount of N. Nevertheless, this relative incompatible situation of organic matter production may be due to the immaturity of the two other species (*P. maximum* and *T .laxum*) during their collection time (Parr and Papendick, 1978). Thus, if only considering the produced averages of compost mass (Figure 4a), it may be concluded that, of the three weed biomasses composted, *P. javanica* (T3) performed better and may constitute the best compost candidate despite of its initial lowest C: N ratio as a legume.

The results showed that compost prepared from *P. javanica* (T3), despite its supposed lower initial C/N ratio, demonstrated a high carbon percentage (17.05 %) against 13.97% for *T. laxum* (T2) and 11.13% for *P. maximum* (T1) (Figure 4d). This result once again contradicted the hypothesis supported in earlier studies according to which, high nitrogen content results in faster and substantial mineralization producing lower organic matter, which is the carbon matrix (Quansah et al., 2001; Musinguzi et al., 2013). The same assumption of the biomass immaturity collected for the composting process mentioned above may also apply to justify this. In contrast, all the three biomasses proved increased values of compost carbon content. In fact, several studies suggested a soil critical level in carbon content at 2% in temperate climate, which is about 3.4% of soil total organic matter (Howard and Howard, 1990; Huber et al., 2008). In tropical soils, carbon thresholds of less than 10 g kg^{-1} (less than 0.1 %) without adding organic matter can be too low and can result into disequilibrium in nitrogen supply to plants. However, Musinguzi et al. (2013) suggested that, this critical level is closely related to local physical and climatic conditions undergone by the soil as well as the crop itself. They stated that soil organic carbon (capacity) = f (climate, topography, texture, disturbance, inputs). Moreover, Baize (1993) on his side, categorized soil organic carbon contents of < 0.60% as very low, 0.60 - 1.25% as low and 1.26 - 2.50% as medium.

The finding of this study showed that the resulting composts from the three studied species, given the high level of carbon percentage demonstrated can constitute excellent source of soil amendment in the region. In contrast, Musinguzi et al. (2013) confirmed their difficulty to establish the highest soil critical level of carbon content beyond which crops cannot positively respond given that, both the lowest soil carbon content as well as its highest content may negatively impact crops and environment (Figure 4d).

The pH values were all near neutral (7) as well for pH H_2O (Figure 4b) and for pH KCl (Figure 4c), ranging from 6.63 to 6.99 for pH H_2O and 6.37 to 6.39 for pH KCl; but compost from *P. maximum* (T1) and *T. laxum* (T2) which were shown to be significantly ($p \leq 0.013$) different with high pH than *P. javanica* would be preferred when focusing on improving soil related acidity.

Landon (1991) categorized pH values as follows: > 8.5 = very high, 7.0 - 8.5 = high, 5.5 - 7.0 = medium and < 5.5 = low. Therefore, in view of these results, all biomasses in the study had demonstrated a medium pH. Therefore, the moderate pH value near the neutral demonstrated throughout all the three biomasses clearly supported the appropriateness of the three species for compost production in order to amend soils of the region whose pH are mainly acidic with an average water pH and KCl (1N) 4.9 and 3.7 respectively (Kombele, 2002).

Despite the non-significant variation found in nitrogen content among treatments, the mean performance for nitrogen content showed that *P. javanica* compost (T3) had the highest N rate with an average of 0.44%. It was followed by the compost made of *P. maximum* (T1) (0.39 %) and finally that of *T. laxum* (0.35%) (T2) (Figure 4e). The high nitrogen content in *P. javanica* (which is a legume) compost was not surprising given the supposed high initial nitrogen rate in legumes in general. However, as it is known, nitrogen is a key nutrient for crop growth and is always qualified as limiting factor. Furthermore, soil nitrogen concentration has impacts on other nutrient content such as C. The critical threshold of N concentrations in tropical soil is suggested to range between 20 to 25 mg g^{-1} (0.2 to 0.25%) below which net N immobilization from soil would be expected (Janssen, 1993; Quansah et al., 2001). Considering Janssen's baseline, all composts from the three species which demonstrated high nitrogen content may be qualified of good quality in terms of nitrogen content. Consequently the three species could help in increasing nitrogen levels of most soils in the region of Kisangani for enhancing crop production.

The mean performance of percentage of potassium showed that the highest rate of potassium was found in compost from *P. maximum* (T1) (41.36%). *T. laxum* (T2) and *P. javanica* (T3) produced 20.39 and 15.86% of potassium respectively (Figure 4f), confirming the high significant ($p \leq 0.001$) differences found among them in Table 1. Result of potassium content related to *P. maximum* compost was relatively different from those found by Quansah et al. (2001) in Ghana. They found a quite low percentage 0.71 mg g^{-1} of potassium in compost made from *P. maximam* which is equivalent to about 0.071% of K. According to Kaddar et al. (1984), the critical concentrations of exchangeable soil K in the tropics at which deficiencies occur range up to 0.45 meq K/100 g of soil. However, this level may differ depending on soils and crop type. Thus, although the three different composts obtained from the biomasses studied differed significantly in terms of their characteristics in potassium content; still, the level of the nutrient they demonstrated was quite satisfactory compared to the lowest threshold required for potassium in tropical soils. Therefore, the three species can constitute good source for compost to control potassium related issues in tropical soils but with preference for *P. maximum.*

CONCLUSION AND RECOMENDATION

This study, which is one of the pilot researches aimed at transforming the baffling problems related to the abundant weed biomasses especially that of *P. maximum*, *T. laxum* and *P. javanica*, often cause of crop yield loss. The goal was to transform them into advantage to enhance soil fertility and increase crop productivity. The study demonstrated that these common weeds in the region of Kisangani contain underutilized resources in the form of nutrients for soil fertility management. The total organic carbon, nitrogen and potassium were quite at high level to restore soil fertility for a good agricultural productivity for small farmers in a region where organic matter such as poultry manure and cow dung are scarce and the access to inorganic fertilizers is limited due to high cost. The study revealed also that, the pH values of all the composts produced from the three weed species were closer to neutral on average, able to fix the recurrent issue related to soil acidity in the region, which constitutes one of the leading roots to the low soil productivity and transient fertility. Finally, the research showed that the species used were able to produce fairly good compost mass and in a relatively short time, despite prevailing climatic conditions supposed to be responsible of substantial mineralization of organic matter and which could lead to the loss of most key elements for crops through natural pathway. However, there might be limitations as to the quantities of weed biomass a farmer may obtain from his field. So, the suggestion is that farmers keep on their fields, for instance on a small portion of field, in situ weed biomass intended to compost production instead of destroying them using fire as it is the common practice in the region. Moreover, it is recommended that the pH H_2O and pH KCl, the total organic carbon, nitrogen and potassium contentsof weed species be measured prior to the experiment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Alongo L (2007). Etude de l'effet de lisières sur l'humidité équivalente et la température du sol d'un écosystème forestière de la cuvette centrale congolaise. « Cas de la réserve forestière, jardin systématique INERA-Yangambi ». Master's dissertation, Faculty of Sciences, University of Kisangani, DR Congo.

Baize D (1993).Soil Science and analysis. A guide to current use, John Wiley and sons Ltd, West Sussex. 201pp.

Bot A, Benites J (2005).The importance of soil organic matter.Key to drought-resistant soil and sustained food and production.FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy

Chandini, Randeep K, Ravendra K, Om P (2019). The Impact of Chemical Fertilizers on our Environment and Ecosystem. Research trends in environmental sciences, 2nd edition, and chapter 5, pp. 69-86.

Chatterjee N, Flury M, Hinman C, Cogger CG (2013). Chemical and Physical Characteristics of Compost Leachates. Washington State University, 2606 W Pioneer, Puyallup, WA, 98371, Washington, USA

Craswell ET, Lefroy RDB (2001). The role and function of organic matter in tropical soils. Managing Organic Matter in Tropical Soils: Scope and Limitations, pp. 7-18. https://doi.org/10.1007/978-94-017-2172-1_2

Dhaliwal GS, Jindal V, Dhawan AK (2010).Insect Pest Problems and Crop Losses: Changing Trends. Indian Journal of Ecology 7(1):1-7.

Douglas CL, Allmaras RR, Rasmussen PE, Ramig RE, Roager NC (1980). Wheat straw composition and placement effects on decomposition in dryland agriculture of the Pacific Northwest.Soil Science Society of America Journal 44(4):833-837. https://doi.org/10.2136/sssaj1980.03615995004400040035x

FAO (2003).On-farm composting methods. Viale delle Terme di Caracalla, 00100 Rome, Italy

Han SH, An JY, Hwang J, Kim SB, Park BB (2016). The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera Lin.) in a nursery system. Forest Science and Technology, pp. 1-7 http://dx.doi.org/10.1080/21580103.2015.1135827

He ZL, Yang XE, Stoffella PJ (2005). Trace elements in agroecosystems and impacts on the environment. Journal of Trace Elements in Medicine and Biology 19(2-3):125-140. https://doi.org/10.1016/j.jtemb.2005.02.010

Howard PJA, Howard DM (1990). Use of organic carbon and loss-on-ignition to estimate soil organic matter in different soil types and horizons. Biology and Fertility of Soils 9:306-310. http://dx.doi.org/10.1007/BF00634106

Huber S, Prokop G, Arrouays D, Banko G, Bispo A, Jones RJA (2008). Environmental assessment of soil for monitoring: Volume I indicators and criteria. Office for the Official Publication of the European Communities, Luxembourg, pp. 1-339. DOI:10.2788/93515

Ibanda AP, Karungi J, Malinga GM, Tanzito GA, Ocan D, Badji A, Mwila N, OdongT L, Tukamuhabwa P, Rubaihayo P R (2018). Influence of environment on soybean [Glycine max (L .) Merr .]resistance to groundnut leaf miner , *Aproaeremamodicella* (Deventer) in Uganda. Journal of Plant Breeding and Crop Science 10(12):336-346. https://doi.org/10.5897/JPBCS2018.0764

Indrayani R, Surendra S (2014). Composting of tropical toxic weed Lantana camera L. biomass and its suitability for agronomic applications. Compost Science and Utilization 22:105-115. DOI:10.1080/1065657X.2014.895455

Janssen BH (1993). Integrated nutrient management: the use of organic and mineral fertilizers. In: Van Rueler H, Prins WH (eds.). The Role of Plant Nutrients for Sustainable Food Crop Production in Sub Saharan Africa, Ponsen&Looijen; Wageningen, The Netherlands, pp. 85-105.

Kaddar T, Russel DA, Cooke GW (1984). The vital role of potassium fertilizers in tropical agriculture.The present position, future potential and constraint to progress.In Frederick ED, and Roth EN (Eds).International Fertilizer Development Center Alabama 35662, USA.

Knox County Master Gardeners (KCMG) (2014). How weather affects plants. University of Illinois Extension, Illinois, USA.

Kombele BM (2002). Caractéristiques pédologiques comparées de termitières sous forêts primaires du plateau de Yangambi en cuvette centrale congolaise. Tropicultura 20(2):76-82

Landon JR (1991). Booker tropical soil manual, Hand Book for soil survey and Agricultural land evaluation in Tropics and sub-tropics.Longman. New York. 74p.

Mahimairaja S, Dooraisamy P, Lakshmanan A, Rajannan G, Udayasoorian C, Natarajan S (2008). Composting technology and organic waste utilization in Agriculture. A.E. Publications, P.N. Pudur, Coimbatore.

Makondambuta E (1997). Les types de climat.Congonline.Afriqu'Infoasbl, Bruxelles, Belgique.

Maombi KM (2006). Contribution à l'analyse chimique de *Puerariajavanica* se trouvant dans l'ecosysteme de kisangani. Mémoire Présenté en vue de l'obtention du titre de licence en sciences. Université de Kisangani. Centre d'Echange d'Informations de la RD Congo. http://cd.chm-cbd.net/biodiversity/biblio/publications-biotechnologiques/agronomie/contribution-l-analyse-chimique-de-pueraria-javanica-se-trouvant-dans-l Acceded on 8th/2/2020

Mehta CM, Sirari K (2018).Comparative study of aerobic and anaerobic composting for better understanding of organic waste management: A mini review. Plant Archives 18(1):44-48

MFAN (Ministry of Foreign Affairs of the Netherlands) (2018).Climate Change Profile Democratic Republic of the Congo (East).https://www.government.nl/ministries/ministry-of-foreign-affairs/documents/publications/2019/02/05/climate-change-profiles Acceded on 11th/2/2019

Mikwa J-F (2012). Evaluation par télédétection des effets de la déforestation et de la dégradation des forêts Kisangani : cas de la réserve forestière de Masako. TFE, DES, Facultéd'agronomie, Université de Kisangani, DRC, 54p.

Mirshekari B, Baser S, Allahyari S, Hamedanlu N (2013). Yield loss by weeds interference can be predicted by empirical models: Case study: Marigold-lambsquarters interspecific competition. Life Science Journal 10(1s):182-184.

Mohammad A, Flowers TH (2004). Evaluation of kjeldahl digestion method.Journal of Research (Science).BahauddinZakariya University, Multan, Pakistan 15(2):159-179.

Musinguzi P, Tenywa JS, Ebanyat P, Tenywa MM, Mubiru DN, Twaha BA, Leip A (2013). Soil organic carbon thresholds and nitrogen management in tropical agroecosystems: Concepts and prospects. Journal of Sustainable Development, Canadian Center of Science and Education 6(12). DOI:10.5539/jsd.v6n12p31

Naikwade P, Mogle U, Jadhav B (2011).Comparative study of aerobic and anaerobic composts prepared from autumn leaves on *Zea mays* L. Science Research Reporter 1(2):77-82.

Parr JF, Papendick RI (1978).Factors affecting decomposition of crop residues by microorganisms. Crop Residue Management Systems

101-127. https://doi.org/10.2134/asaspecpub31.c6

Quansah C, Fening JO, Ampontuah EO, Afreh D, Amin A (2001). Potential of Chromolaenaodorata, Panicum maximum and Pueraria phaseoloides as Nutrient Sources and Organic Matter Amendments for Soil Fertility Maintenance in Ghana. Biological Agriculture & Horticulture 19(2):101-113. http://dx.doi.org/10.1080/01448765.2001.9754915

Rao CS, Rao AS, Takkar PN (1998).Evaluation of several methods for determining the potassium content in diverse plant materials. Communications in Soil Science and Plant Analysis 29(17-18):2785-2792. DOI:10.1080/00103629809370153

Schumacher BA (2002). Methods for the determination of total organic carbon (TOC) in soils and sediments.US Environmental protection agency, National Exposure Research Laboratory NCEA-C-1282, Washington, DC.

Solia ES (2016). Etude de conditions écologiques d'AfzeliahipindensisHarms (Fabaceae) dans la région de Kisangani, RD Congo. Thèse de doctorat, Faculté de Gestion des Ressources Naturelles Renouvelables, Université de Kisangani, RD Congo.

Soltani N, Dille JA, Burke IC, Everman WJ, VanGessel MJ, Davis V M, Sikkema PH (2016). Potential Corn Yield Losses from Weeds in North America. Weed Technology 30(4):979-984. https://doi.org/10.1614/WT-D-16-00046.1

Steiner C, Teixeira W, Zech W (2009). The effect of charcoal in banana (Musa Sp.)Planting holes – An on-farm study in central Amazonia, Brazil. In: Woods WI, Teixeira WG, Lehmann J, Steiner C, WinklerPrins A, Rebellato L (eds). Amazonian Dark Earths: WimSombroek's Vision. Springer, Dordrecht https://doi.org/10.1007/978-1-4020-9031-8_24

Steiner C, Teixeira WG, Lehmann J, Nehls T, MacêdoJLVd, Blum WEH, Zech W (2007). Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. Plant and Soil 291(1-2): 275-290. https://doi.org/10.1007/s11104-007-9193-9

Tanzito G, Ibanda A (2010). Effect of increasing frequencies and doses of the liquid organic manure (made from the fresh biomass of *PuerariaJavanica* L.) on a local variety of amaranth (*Amaranthushybridus* L.). Les cahiers du CRIDE-UNIKIS, DRC 10(1):23-45.

Thienpondt B (2016). Increasing soil fertility and crop yield in the Democratic Republic of Congo through implementation of an integrated soil fertility management approach. Master of Science in de biowetenschappen: land- en tuinbouwkunde, University of Gent, Belgium.

Tomita S, Miyagawa S, Kono Y, Noichana C, Inamura T, Nagata Y, Sributta A, Nawata E (2003).Rice yield losses by competition with weeds in rainfed paddy fields in northeastThailand. Weed Biology and Management 3(3):162-171. https://doi.org/10.1046/j.1445-6664.2003.00101.x

Upoki A (2001). Etude du peuplement en « bulbuls » (*Pycnonotidae, Passeriformes*) dans la réserve forestière de Masako à Kisangani (R.D Congo). Thèse de doctorat, Faculté des Sciences, UNIKIS, 160p.

USAID (United States Agency for International Development) (2015). Democratic Republic of the Congo. Staple food market fundamentals. In Chemonics International Inc (Ed).Famine Early Warning Systems Network, USA.