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AVAILABILITY OF NITROGEN AND ORGANIC MATTER IN SOIL TREATED WITH *CALLIANDRA CALOTHYRSUS* COMPOST IN RWANDA. A CASE OF RUHANDE HILL, HUYE DISTRICT

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ABSTRACT

Food insecurity is becoming an issue both nationally and internationally due to rapid population growth. One way to deal with this problem is to improve soil fertility using organic fertilizers in order to increase soil productivity in a sustainable way, thus rise crop yield and feed the growing population. Compost is one of the proposed suitable organic fertilizers increasing soil nutrients in a regular basis. The compost produced from *Calliandra calothyrsus* biomass can be used as organic fertilizer to provide basically Nitrogen as a primary nutrient and increase soil organic matter as a soil nutrients holder and reservoir. This study assessed the organic matter and the availability of Nitrogen to crops in soil treated with compost from *Calliandra calothyrsus* biomass. To evaluate organic matter and the availability of Nitrogen, plots were designed in Randomized Completely Block Design (RCBD) with four blocks, using *Amaranthus retoflexus*as a reference crop. Each block had two treatments, *Amaranthus retoflexus* + Compost as T_1 and *Amaranthus retoflexus* only as T_2.The results revealed that plots with compost has a higher mineral nitrogen content of 9.33 ppm (3.23 ppm for $NO^-{}_3$ and of 6.11ppm for $NH^+{}_4$) than the control 6.48 (Mineral Nitrogen of 1.23 ppm for $NO^-{}_3$ and of 5.23ppm for $NH^+{}_4$).Moreover, the mean soil organic matter in soil treated with compost was higher (2.48 %) than in the control (1.70%). To sum up, the compost from *Calliandra Calothyrsus* residues is a source of Nitrogen and organic matter to crops.

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INTRODUCTION

In agriculture, one of the basis of low crop yield is due to low level of soil organic matter which lead to nutrients depletion especially Nitrogen; appreciably compost from leguminous plants like *Calliandra calothyrsus* can be the solution as it is considered as a source of organic matter that has the ability to improve sustainably the chemical, physical, and biological characteristics of soils (Golabi, 2014). Therefore, *Calliandra calothyrsus* is widely used as an agroforestry species to rehabilitate the erosion prone areas and improve soil nutrients status by fixing atmospheric Nitrogen thanks to its symbiosis with rhizobium. This makes *Calliandra calothyrsus* to have a high biomass production rich in Nitrogen. Furthermore, composting *Calliandra calothyrsus* residues is considered as a proper way of managing crop residues which may improve soil fertility and environmental conditions and promote urban economic development and generate employment and income as well (Huda, 2002).

The use of compost increases vegetation growth and soil fertility characteristics (Britt, 2006). It may also promote a regular organic recycling and provides soil nutrients particularly Nitrogen and organic matter on a regular basis (Ahmed *et al.*, 1998). Several studies have shown that compost provides the main nutrients useful for the growth of plants: Nitrogen (N), Phosphorous (P) and Potassium (K), often known as NPK with 5-35 Kg N/t, 1-10 Kg P/t and 5-35 kg K/t (Singh *et al.*, 2006). It improves the organic matter in the soil by providing humus; helps the soil hold both water and air for plants; and unlike chemical fertilizer, it also makes trace elements or micronutrients available to plants (Araya, 2008). Moreover, the application of compost supplies Nitrogen and other nutrients like K and P and increase soil organic matter, the efficient N utilization is the key to the solution of problems concerned with high crop production, minimal pollution and energy conservation (Legg and Meisinge, 1982). In addition, the application of compost will increase the amount of soil organic matter and this makes higher the cations exchange capacity and buffering capacities of soils. The increase of soil organic matter serves in nutrients storage and in soil aggregation. Then, where there is not enough organic matter, soil fertility depletion, acidity and erosion problems can result. Nitrogen deficiency as nitrogen overuse can cause many problems and high level of Nitrogen application for example through organic fertilizer can be the main source nitrate accumulation in plants leaves of some vegetables such as *Amaranthus retroflexus* and this may cause stomach cancer or death to humans or cattle who consume those vegetables (Krishona *et al*., 2012). Besides, the excess in Nitrogen through organic fertilizer for instance, can lead to the excessive vegetative growth and this delay plant maturity and cause the plants to be more susceptible to disease and to insect pests and also it makes flower production reduced and favors abundant foliage (Brady and Well, 2002). In soil; Nitrogen enters the plant as NO_3^- or NH_4^+. Comparative uptake and utilization of N under field conditions is strongly influence by environmental conditions throughout the growing season including the position of any available N in the rooting zone in relation to the available water supply and consequent root activity (Olson and Kurtz, 1982). The uptake of N requires movement of ion (NO_3^- or NH_4^+) and as the soil becomes warmer, nitrification proceeds, the root system extends and the amount and uptake of NO_3^- predominates over $NH_4^{+,}$ however NH_4^+ is the available form of N in poor aerated soil like marshland (Olson and Kurtz, 1982), this is because nitrifying organisms are aerobic bacteria. At pH's near neutral (pH 7), the microbial conversion of NH_4^+ to NO_3^- (nitrification) is rapid, and crops generally take up nitrate. In acid soils (pH < 6), nitrification is slow, and plants with the ability to take up NH_4^+ may have an advantage. Compost may be used as a source of nitrogen and organicmatter but with soil and environmental conditions, they may not be available to plant. This study was carried out to assess the availability of nitrogen and organic matter in soil treated with *Calliandra calothyrsus* compost.

MATERIAL AND METHODS

Description of the study area: This study has been conducted in the research station of the project entitled Agroforestry for the Protection of Rainforest Ecosystems(APRECO) located in the central plateau (middle altitudes), Rwanda, Southern Province, Huye District, Ngoma Sector, Ruhande Hill on 1737m of altitude; $2^o36'$S of latitude and $29^o44'$E of longitude with annual average rain of 1.232mm with two rainy seasons, heavy rainy season from March to May and the mild rain from October to December and those two rainy seasons alternate with two dry seasons, one from January to February and the other from June to September (Nsabimana, 2009). The annual average temperature (T^0) is19.60^0 C and according to Köppen Climate Classification System, the climate of this areas is tropical humid (Aw) (Burren, 1995). The soils of this area are representing the characteristics of Oxisols with a deep sombric horizon and they are classified as Ferralisols according to FAO (2008), formed from the parental material of schist and granites mixed with mica schist and quartzite (Verdoodt and Ranst, 2003).

Experimental materials: Ferralisols with sombric horizon and *Amaranthus retroflexus* described as Kingdom: Plantae, Order: Caryophyllales, Family: Amaranthaceae, Genus: *Amaranthus,* Species: A. retroflexus were used as experimental materials.

Experiment design: Single factor experiment using randomized complete block design (RCBD) was used and two treatments T_1: compost +*Amaranthus and* T_2:*Amaranthus* only within four blocks. They were arrayed randomly in eight plots of 2x1m^2 and 30cm of distance between them as follow:

Table 1. Randomized Complete Block Design for this study

Block I	Compost + Amaranthus	Amaranthus only
Block II	Amaranthus only	Compost + Amaranthus
Block III	Compost + Amaranthus	Amaranthus only
Block IV	Amaranthus only	Compost + Amaranthus

Data collection

Soil samples were collected before and two weeks after applying compost using an auger at the depth of 0-25cm. For each plot, the soil was sampled using systematic quadrates method to obtain a composite sample for pH, organic carbon and nitrogen determination. Thus, *Amaranthus* leaves from each plot were sampled at the vegetation stage as recommend by Olsen (1978) for Nitrogen content analysis.

Laboratory analysis

The soil pH is determined with an H^+ ion-selective glass electrode (Okalebo *et al.*, 2002). Soil organic carbon was analyzed using humid oxidation. Total Nitrogen and total plant nitrogen were analyzed using Kjeldahl method following procedures described in Okalebo (2008).

Besides, to know the Nitrogen percentage this formula below was applied:

% N in plant sample= (a-b) 0.2xVx100/1000xWxal (Equation 1)

% N in soil sample= (a-b) x 0.1xVx100/1000xWxal (Equation 2)

Where a: volume of the titre HCl for the blank; b: volume of the titre HCl for the sample, V: final volume of the digestion, W: weigh of the sample taken and al: aliquot of the solution taken for analysis.

Mineral Nitrogen components were determined using Devard's alloys through digestion, distillation and titration as described in Okelebo (2008).

Statistical analysis

All data have been subjected to Analysis of Variance (ANOVA) test which has been generating using Genstat 3rd Edition and Microsoft Excel 2007 tools. Those tools also have been used to generate ANOVA tables and relationship between pH, soil organic carbon and nitrogen content.

RESULTS AND DISCUSSION

Soil and plant physical and chemical parameters*:* The results has shown that the composite sample taken before applying compost and planting had the pH of 4.70, SOC of 0.92 %, SOM of 1.586%, mineral Nitrogen of3.50 ppm for $NH^+{}_4$ and 1.70 ppm for $NO^-{}_3$, while soil total Nitrogen was 0.3 % and the analysis of variance showed that all those parameters were significantly increased ($p<0.05$) compared to the control as shown below in Table 2.

Table 2. Soil and plant physical and chemical parameters

Treatments	pH_{H2O}	pH_{KCl}	SOC (%)	SOM (%)	NH^+_4(ppm)	NO^-_3 (ppm)	Soil TN (%)	Leave TN (%)
Compost + Amaranthus	4.87	3.56	1.44	2.48	6.11	3.23	0.62	2.83
Amaranthus only(Control)	4.80	3.51	0.99	1.70	5.23	1.23	0.5	2.05

SOC: Soil Organic Carbon, SOM: Soil Organic Matter, TN: Total Nitrogen, %: Percentage, ppm: Particle per matter.

Table 3. Correlation between parameters

Leave TN	1							
Soil TN	0.6142	1						
NO^-_3	0.6946	0.2797	1					
NH^+_4	0.7843	0.5501	0.6307	1				
SOC	0.7932	0.9011	0.53	0.7624	1			
SOM	0.7932	0.9012	0.5299	0.7623	1	1		
pH_{KCl}	0.6576	0.6138	0.403	0.4536	0.5179	0.5178	1	
pH_{H2O}	0.5219	0.0108	0.5543	0.572	0.1045	0.1043	0.6309	1
	LeaveTN	**Soil TN**	**NO^-_3**	**NH^+_4**	**SOC**	**SOM**	**pH_{KCl}**	**pH_{H2O}**

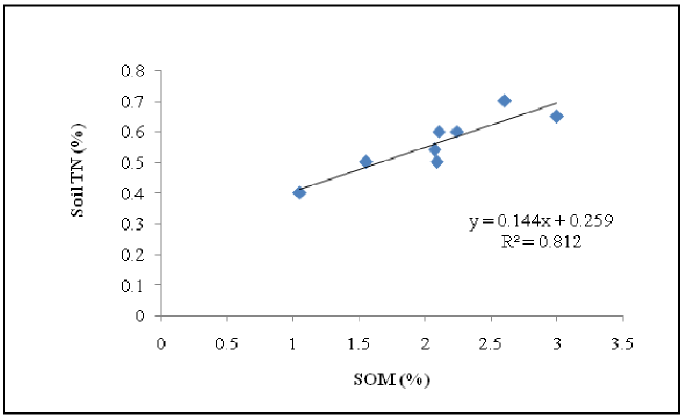

Figure 1. Relationship between SOM and Soil TN

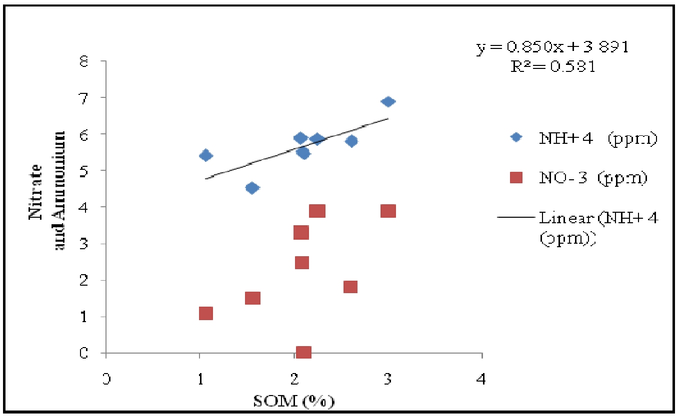

Figure 2. Relationship between SOM, nitrate and Ammonium Ions

Soil pH_{H2O} varied from 4.76 to 4.91 and pH_{KCl} from 3.5 to 3.8. The mean of soil pH treated with compost is higher (4.87) than the control (4.80) for $pH_{H2O}$and pH is equal to 3.56 for pH_{KCl} in soil treated with compost while in the control is 3.51 (Table 2). The application of compost has significantly increased pH ($p<0.05$). At pH ranged between about 5.5 to 7.0, the availability and the supply of nitrogen are high (Brady and Well, 2002). SOC varied from 0.61 to 1.74%. The mean soil organic carbon in soil treated with compost was higher (1.44 %) than in the control (0.99%). Moreover, SOM varied from 1.051 to 2.99%. The mean SOM in soil treated with compost was higher (2.48 %) than in the control (1.70%). Those results show that compost application has increased SOM. The increase in soil organic carbon and soil organic matter were significantly ($p<0.05$) enhanced by the application of compost. Plants roots take up N from soil solution as NO^-_3 and NH^+_4 ions and certain plants grow best when provided mainly one or other of these forms, but a relatively equal mixture of the two ions gives the best results with most plants (Brady and Well, 2002). However, plots with compost has a higher mineral nitrogen content of 9.33 ppm (3.23 ppm for NO^-_3 and of 6.11ppm for NH^+_4) than the control 6.48 (mineral Nitrogen of 1.23 ppm for NO^-_3 and of 5.23ppm for NH^+_4), The application of compost has significantly increase soil mineral nitrogen ($p<0.05$) mainly nitrate because nitrate availability is highly significant ($p<0.01$) while ammonium is significant ($0.001\leq p<0.05$). Results in table 3 showed that soil TN in plots treated with compost is higher (0.62%) than in the control (0.5%) and the application of compost significantly ($p<0.05$) increased soil TN. Healthy plant foliage generally contains 2.5 to 4.0 % Nitrogen depending on age of leaves and weather the plant is a legume high (Brady and Well, 2002). However, for this study Nitrogen content in leaves is high 2.83% in plots with compost compared to 2.05% in the control. This shows that Nitrogen uptake in soil treated with compost was higher and the foliage is healthier as compared to the control. Statistical analysis indicated that observed differences were significant at $p< 0.05$.

Correlation between Soil and Plant Total Nitrogen, NO^-_3,NH^+_4, Soil Organic Carbon, Soil Organic Matter

Table 3 shows the correlations between measured parameters. For instance, SOM has a strong positive correlation with soil total nitrogen (correlation coefficient = 0.9012), with TN in leaves (correlation coefficient: 0.7932) and with NH^+_4 (correlation coefficient = 0.7623) while $NO^-_3$is moderate with correlation coefficient: 0.0.5299 with SOM and evenNH^+_4(0.6307).

Relationship between SOM and Soil TN: There is a strong relationship with $R^2 = 0.8121$ between soil organic matter and soiltotal nitrogen as shown in figure 4. This is because organic matter is considered as a store of nitrogen and other nutrients from which they are slowly released by mineralization.

Relationship between soil organic matter, nitrate and ammonium ions: There is a moderate relationship between soil organic carbon and ammonium ions withR^2=0.5811 because those ions are positively charged so organic matter may tie them up rather than nitrates ions which are negatively charged with R^2= 0.2808 which is low as it is illustrated in Figure 2.

Relationship between pH, Nitrate and Ammonium ions: The results (Figure 3) showed that there are a low relationship with $R^2 = 0.3272$ between pH and NH_4^+-N and $R^2 = 0.3072$ between pH and NO_3^--N. These two ions differ in their effect on the pH of the rhizosphere, NO_3^- anions move easily to the root with the flow of soil water and exchange at root surface with $HCOO_3^-$ or OH^- ions that in turns stimulate an increase in the pH of the soil solution immediately around the root. In contrast NH_4^+ exchange root surface with hydrogen ion thereby lowering pH of rhizosphere (Brady and Well, 2002). In addition, the oxidation of organic nitrogen sources, nitrification, significantly increase soil acidity by producing H^+ ions.

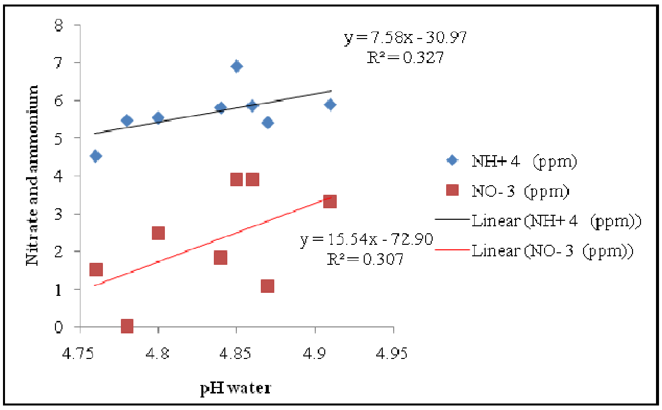

Figure 3. Relationship between pH and mineral Nitrogen

Conclusion

This study aimed at assessing the availability of Nitrogen and organic matter content in soil treated with compost from Calliandra residues. The results showed that among principal available forms of Nitrogen, nitrate was highly significant with $p<0.01$ with the content of 3.23 ppm in plots treated with compost and 1.26 ppm in the control. As, a consequence, plots treated with compost were higher in Nitrogen (0.62% of TN, mineral Nitrogen of 3.23 ppm for NO^-_3 and of 6.11ppm for NH^+_4) than the control (0.5% of TN, mineral Nitrogen of 1.23 ppm for NO^-_3 and of 5.23 ppm for NH^+_4) similarly, the Nitrogen content in Amaranthus leaves was higher (2.83%) in plots with compost than in the control (2.05%). In addition, soil organic matter as the supply of nitrogen, its relationship with total nitrogen was strong with $R^2 = 0.8121$. Therefore, the compost from Calliandra residues is a source of nitrogen and organic matter to crops. But in acidic soil, the application of compost should go with the lime application to equilibrate the pH because the application of compost increases ammonium ions which may lower the soil pH.

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