academicJournals

Vol. 10(51), pp. 4668-4674, 17 December, 2015
DOI: 10.5897/AJAR2015.9013
Article Number: 6EB490A56396
ISSN 1991-637X
Copyright ©2015
Author(s) retain the copyright of this article
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

# Valorization of *Jatropha curcas* seed cake into different kinds of compost and effect of these composts on cabbage yield in Togo

**Komi Sogbedji[1,3]*, Gbénonchi Mawussi[2], Amen Yawo Nenonene[2], Koffi Tozo[3], Geng Mingjian[1] and Wu Lishu[1]**

[1]College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, Hubei, China.
[2]Unité de Recherche sur les Agroressources et la Santé Environnementale (URASE), Ecole Supérieure d'Agronoomie, Université de Lomé, B.P. 1515 Lomé, Togo.
[3]Laboratoire de Gestion, Traitement et Valorisation des Déchets (GTVD), Faculté des Sciences Université de lomé, B.P. 1515 Lome, Togo.

Received 12 September, 2015; Accepted 20 October, 2015

***Jatropha curcas* L. is a plant species from the family of Euphorbiaceae. The extraction of oil from its seeds produces a cake for which its accumulation causes different environmental problems related to solid waste management. The valorization of this cake into compost could be a contribution to solving this problem. Therefore different types of compost were made with *J. curcas* seed cake associated with animal feces incorporated at 0, 10 and 20% rate. To achieve their combination, 5 composting test and 2 replicates each have been set up. These composts were tested on cabbage yield in a completely randomized design with 6 treatments and 3 replicates. The different composts have improved significantly the chemical characteristics of the soil and the cabbage biomass yield. Mixing *J. curcas* seed cake with 10% sheep's droppings ($C_{10}$) gave chemical characteristics compost with a high N and K content (Total-N 18.32 g.kg$^{-1}$; Total-K 17.60 g.kg$^{-1}$). The compost made with *J. curcas* seed cake and 20% sheep's droppings ($C_{20}$) had the best cabbage total biomass and shoots of cabbage biomass yields respectively 43.11±3.15×10$^{3}$ and 21.56±1.58×10$^{3}$kg.ha$^{-1}$. That compost $C_{20}$ could be recommended to farmers for the improvement of crop yield field after trials followed by validation.**

**Key words:** *Jatropha curcas,* seed cake, compost, cabbage shoot yield.

## INTRODUCTION

*Jatropha curcas* L. is a drought-resistant shrub belonging to the family of Euphorbiaceae. It can live up to 50 years and grow on poor soils (Henning, 2008). This plant is widespread in all arid and semi-arid tropical areas of the world. It becomes an important industrial crop due to its seed which contains 30 to 40% oil with properties similar

*Corresponding author. E-mail: sogbedjikomi@webmail.hzau.edu.cn.

Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

to those of fossil diesel (Sanou, 2010). *J. curcas* can easily be propagated by cuttings. It is widely planted as a hedge to protect fields because of the fact that it is not browsed by cattle or other animals. It is often used to protect soil from erosion (Martinez-Herrera et al., 2006; Samake, 2007). The seeds of *J. curcas* are used in medicines, soap and cosmetics manufacture in various tropical countries (Domergue and Pirot, 2008). To obtain biodiesel from *J. curcas* it is necessary to extract the oil from its seeds. After this extraction, the obtained byproduct is the seed cake. This seed cake can be used for biogas production and composts production (Domergue and Pirot, 2008; Raheman and Mondal, 2012). Although the seed cake is rich in protein (Staubmann et al., 1997), it is toxic to rats, mice and ruminants and therefore cannot be used as an animal forage nor can it be used directly as fertilizer in agricultural farming due to the potential presence in the seed cake of toxic elements that are saponin, curcin and phorbol esters (Akintayo, 2004; Gübitz et al., 1999).

In Togo, more than 80600 ha would be reserved for the production of *J. curcas* (Demba, 2011) to produce great quantity of biofuel. Some companies began already to exploit *J. curcas* in Togo. Approximately 15150 tons of *J. curcas* seed cake is produced each year (Demba, 2011). These seed cakes accumulation causes different environmental problems related to solid waste management. Previous research indicated that a huge volume of *J. curcas* seed cake can be eliminated through composting or by biogas production (Das et al., 2011).

However, the decrease of soil fertility is of a particular concern for both farmers and researchers in Togo. Famers face high cost of mineral fertilizers and scarcity of manure. Researchers are looking for new technologies to maintain or restore fertility of degraded soils. Extensive operating system of land based on shifting cultivation and long-term fallow had the advantage of being balanced and allowed to maintain a relatively stable agricultural production (Zoumana and César, 1994).

Today, the above mentioned balance is broken due to the population growth that is leading to more changes in land use at the expense of fallow and forests. Therefore, to improve soil fertility using *J. curcas* seed cake, this study was conducted aiming to: (1) assess the compost made with *J. curcas* seed cake alone or *J. curcas* seed cake associated with animal feces (sheep's droppings or chicken dejection) and (2) assess the effectiveness of these composts in improving soil chemical properties and cabbage shoot yield.

## MATERIALS AND METHODS

The study was conducted at the University of Lomé Research Station in Lomé, Togo (6°10'N, 1°10'E; altitude = 19-60 m). The soil type was a rhodic ferralsol locally called "Terres de Barre" that developed from a continental deposit (Saragoni et al., 1991). This soil is red, deep and suitable for almost all crops. The chemical characteristics of the soil of the site before trial were: Organic-C= 7.60 $g.kg^{-1}$, Total-N = 0.90 $g.kg^{-1}$, Total-P= 0.024 $g.kg^{-1}$, Total-K= 0.115 $g.kg^{-1}$. These characteristics show that the levels of N, P and K are relatively low rendering this soil as a suitable experimental site. The experiment was done at ambient temperature. The experiment site's climate is sub-equatorial type with 2 rainy seasons and 2 dry seasons where the average annual rainfall is less than 1100 mm and the average annual temperature is 27°C. The following materials were used to develop different types of compost submitted to agronomic test: *J. curcas* seed cake which is the main source of organic material used was procured by PISA IMPEX TOGO (Agro-Industry in Togo: Production of palm kernel oil, soya oil, Neem oil and biofuel with *J. curcas* seed); the animal feces used as fermentative bacteria sources were sheep's droppings and chicken dejection from the School of Agronomy Research Station of Lomé. They were incorporated at the rate of 10 and 20% in the heap.

The effect of different types of compost was evaluated on Oxylus variety of cabbage (*Brassica oleracea* L.) whose heads could weigh about 2.5 or 3 kg. The cabbage was chosen because of its easy handling and rapid growth that allow to set a controlled cropping area and to speed up data collection as well as its demanding for N, P, and K nutrients. The experiment was conducted in 2 phases: production of different composts and agronomic test

Composting was carried out in compost bins with cemented bottoms to prevent effluents from the compost pile to seep into the soil. The piles were covered with plastic sheeting which protects the compost from the air and reduces the release of heat generated inside the pile. This method of composting is an aerobic method that combines Indore and Bangalore methods with modifications (Toundou et al., 2014). It differs from the Indore method by the lack of brush at the base of the heap (compost bin bottom was cemented). However, it is closed to the Bangalore method because the compost bin is completely covered by plastic sheeting (instead of mud or soil's clods use in Bangalore method) protecting ambient air and preventing the release of heat generated inside the pile.

For the preparation of compost, 2 factors were involved: the nature of the incorporated animal manure (sheep's droppings or chicken dejection) and the rate of incorporation of animal manure (0, 10 and 20% of the heap mass) deriving in the following combinations: $C_0$, $C_{10}$, $C_{20}$, $F_0$, $F_{10}$ and $F_{20}$. Animal feces are adjuvant to the heap and their rates are randomly selected. To achieve their combination, 5 composting test were replicated 2 times each in a total of 10 experimental units that have been designed instead of 6 composting test. *J. curcas* seed cake compost objects without the addition of animal feces $C_0$ and $F_0$ are identical to $T_m$ which is the control (Table 1).

During the agronomic test, the effect of compost on cabbage yield and soil characteristics was tested. Each compost was buried at the dose of $3\times10^4$ $kg.ha^{-1}$ of dry matter on elementary plots of 6 $m^2$ (Figure 1). Six treatments combinations were laid out under completely randomized block design with 3 replications. The treatments carried out are: $\mathbf{T_0}$: without compost (control); $\mathbf{T_m}$: *J. curcas* seed cake compost; $\mathbf{C_{10}}$: *J. curcas* seed cake+ sheep's droppings (10%) compost; $\mathbf{C_{20}}$: *J. curcas* seed cake+ sheep's droppings (20%) compost; $\mathbf{F_{10}}$: *J. curcas* seed cake + chicken dejection (10%) compost and $\mathbf{F_{20}}$: *J. curcas* seed cake + chicken dejection (20%) compost.

Before planting and at harvesting, experimental soils samples were collected from of 0 to 15 cm soil depth to test pH-$H_2O$, pH-KCl, Total N, Total P, Total K and organic carbon. These analyses were done in the Laboratory of Soil and Plants Analyses of the Superior School of Agronomy and in the Water Chemistry Laboratory, Faculty of Science, University of Lomé. Total N was determined by Kjeldahl method, digestion in a mixture of $H_2SO_4$-selenium followed by distillation and titration (Bremner and Mulvaney, 1982); total P by (Murphy and Riley, 1962) method, K by (Gueguen and Rombauts, 1961) method; organic carbon (Walkley and Black, 1934), wet oxidation with $K_2Cr_2O_7$ procedure; pH-$H_2O$ and pH-KCl using glass

**Table 1.** Composting test objects.

| Composting test objects | Combinations |
|---|---|
| $T_m$ ($C_0$ or $F_0$) | *J. curcas* seed cake (90%) + Soil (10%) |
| $C_{10}$ | *J. curcas* seed cake (80%) + Sheep's droppings (10%) + Soil (10%) |
| $C_{20}$ | *J. curcas* seed cake (70%) + Sheep's droppings (20%) + Soil (10%) |
| $F_{10}$ | *J. curcas* seed cake (80%) + Chicken dejection (10%) + Soil (10%) |
| $F_{20}$ | *J. curcas* seed cake (70%) + Chicken dejection (20%) + Soil (10%) |

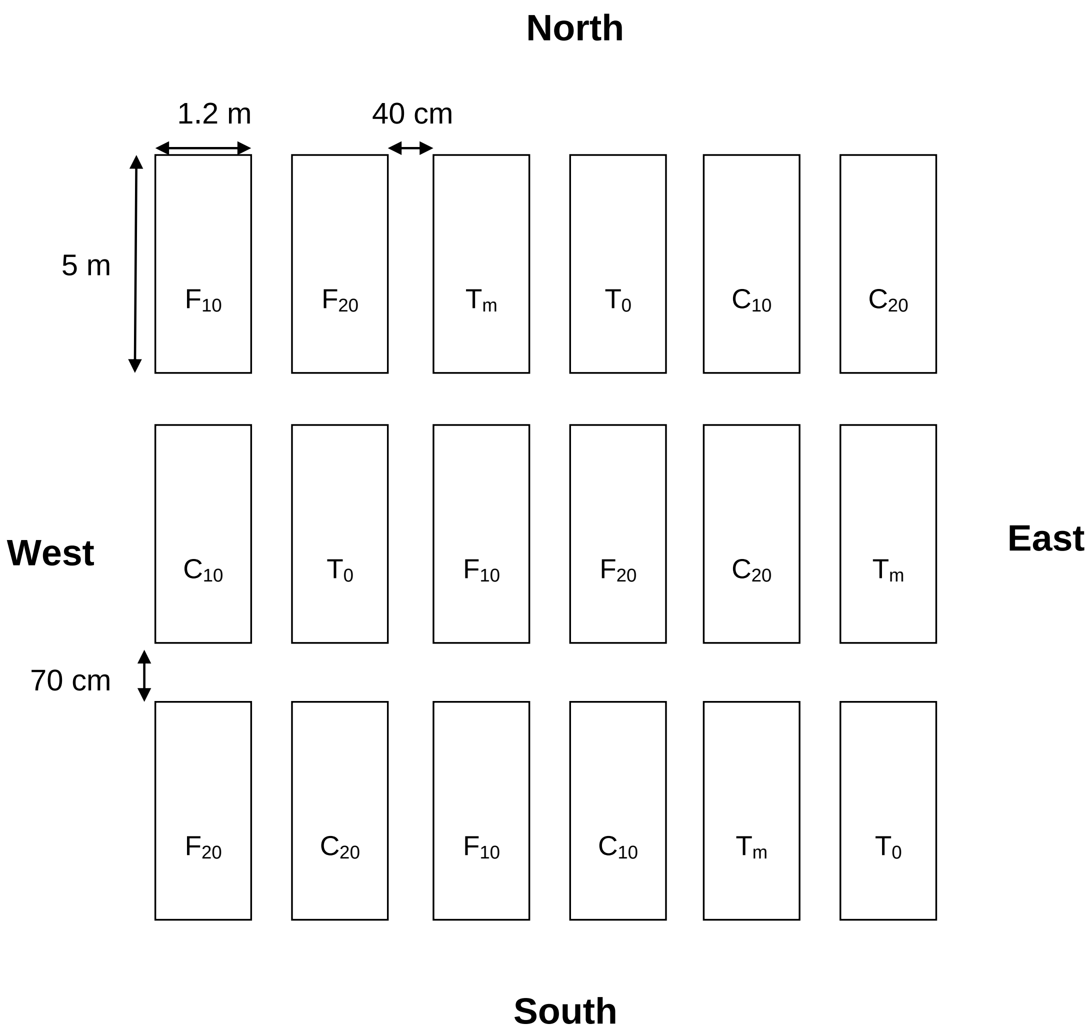


**Figure 1.** Trial design.

electrode in 1:2.5 v/v soil solution.

The harvest took place on the 76th day after transplanting. Using a knife, the plants were cut just below the basal leaves. The cabbages were harvested and weighed using scales CAMRY to determine fresh biomass yield.

Statistical analyses were performed using STATISTICA. The parameters were subjected to a one way analysis of variance. Duncan's multiple range test (DMRT) was performed to compare differences in means among treatments. All significance levels were set at P<0.05.

## RESULTS

### Characteristics of the composts

The different composts had the same brown color and the same friable texture. Table 2 shows the chemical characteristics (mean values of pH-$H_2O$, Total N, Total P, Total K and organic carbon) of different composts produced. The incorporation of sheep's droppings or

**Table 2.** Chemical characteristics (mean values) of different composts prepared.

| Types of compost | $pH-H_2O$ | Organic-C | Total-N | C:N | Total-P | Total-K |
|---|---|---|---|---|---|---|
| | ½ | (g.kg$^{-1}$) | | | (g.kg$^{-1}$) | |
| $T_m$ | 7.89$^c$ | 148.72$^c$ | 17.06$^{ab}$ | 8.72 | 22.80$^b$ | 11.65$^{bc}$ |
| $C_{10}$ | 8.27$^a$ | 193.76$^a$ | 18.32$^a$ | 10.57 | 19.58$^c$ | 17.60$^a$ |
| $C_{20}$ | 7.36$^d$ | 166.56$^{bc}$ | 17.50$^{ab}$ | 9.52 | 16.75$^d$ | 8.85$^c$ |
| $F_{10}$ | 8.24$^a$ | 192.40$^{ab}$ | 15.58$^b$ | 12.35 | 19.60$^c$ | 15.40$^{ab}$ |
| $F_{20}$ | 8.10$^b$ | 178.37$^{ab}$ | 15.31$^b$ | 11.65 | 26.26$^a$ | 18.20$^a$ |

$T_m$ ($C_0$ or $F_0$) = *J. curcas* seed cake (90%) +Soil (10%) ; $C_{10}$ = *J. curcas* seed cake (80%) + sheep's droppings (10%) +Soil (10%); $C_{20}$ = *J. curcas* seed cake (70%) + sheep's droppings (20%) +Soil (10%) ; $F_{10}$ = *J. curcas* seed cake (80%) +chicken dejection (10%) +Soil (10%); $F_{20}$ : *J. curcas* seed cake (70%) + chicken dejection (20%) + Soil (10%). The values assigned to the same column of the same index letters are statistically identical to the 5% level.

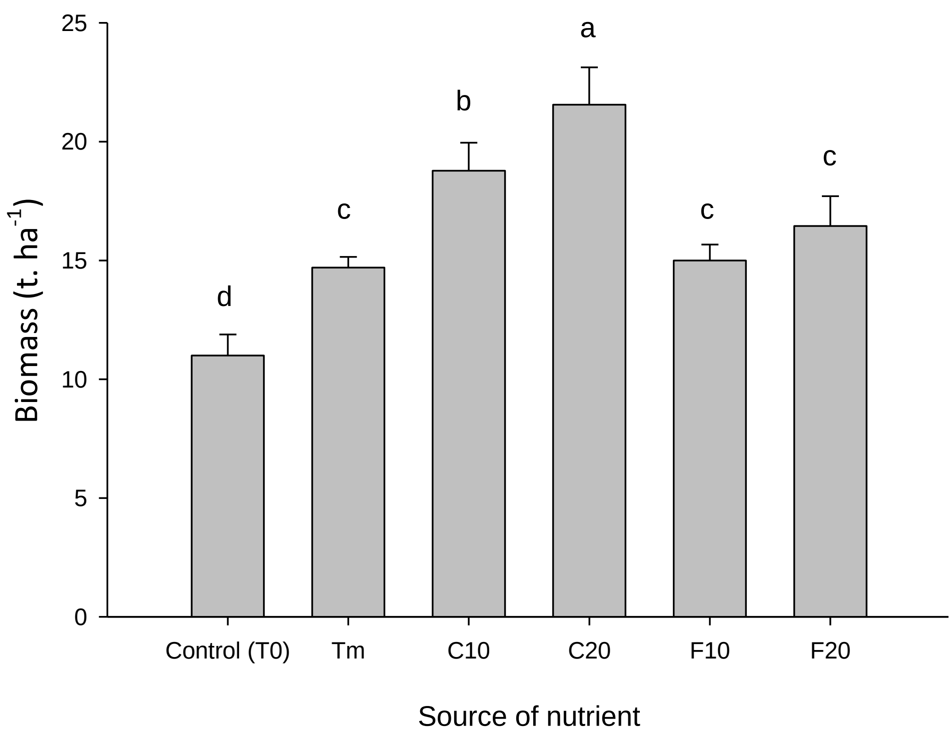


**Figure 2.** Evolution of biomass yields of cabbage for the different composts used. Vertical bars denote standard errors. Bars of the same types labeled with the same letter are statistically identical to the 5% level. $T_0$ = Control ; $T_m$ ($C_0$ or $F_0$) = *J. curcas* seed cake (90%) + Soil (10%) ; $C_{10}$ = *J. curcas* seed cake (80%) + sheep's droppings (10%) + Soil (10%); $C_{20}$ = *J. curcas* seed cake (70%) + sheep's droppings (20%) + Soil (10%) ; $F_{10}$ = *J. curcas* seed cake (80%) + Chicken dejection (10%) + Soil (10%) ; $F_{20}$ : *J. curcas* seed cake (70%) + Chicken dejection (20%) + Soil (10%).

chicken dejection in *J. curcas* seed cake before composting seems to increase the pH of the compost. On the other hand, the pH of the compost $C_{20}$ or $F_{20}$ is less than the ones containing 10%. The later had the highest alkalinity (pH = 8.27). The mixture of *J. curcas* seed cake with 10% of sheep's droppings produced good quality compost with the highest levels of N (18.32 g.kg$^{-1}$) and K (17.60 g.kg$^{-1}$).

### Effect of different composts on cabbage shoots biomass

Figure 2 shows the effect of different types of compost used on biomass of cabbage shoots. All tested composts produced a cabbage shoot biomass which was significantly higher than the control. The $C_{20}$ had the highest biomass significantly higher than the rest. This

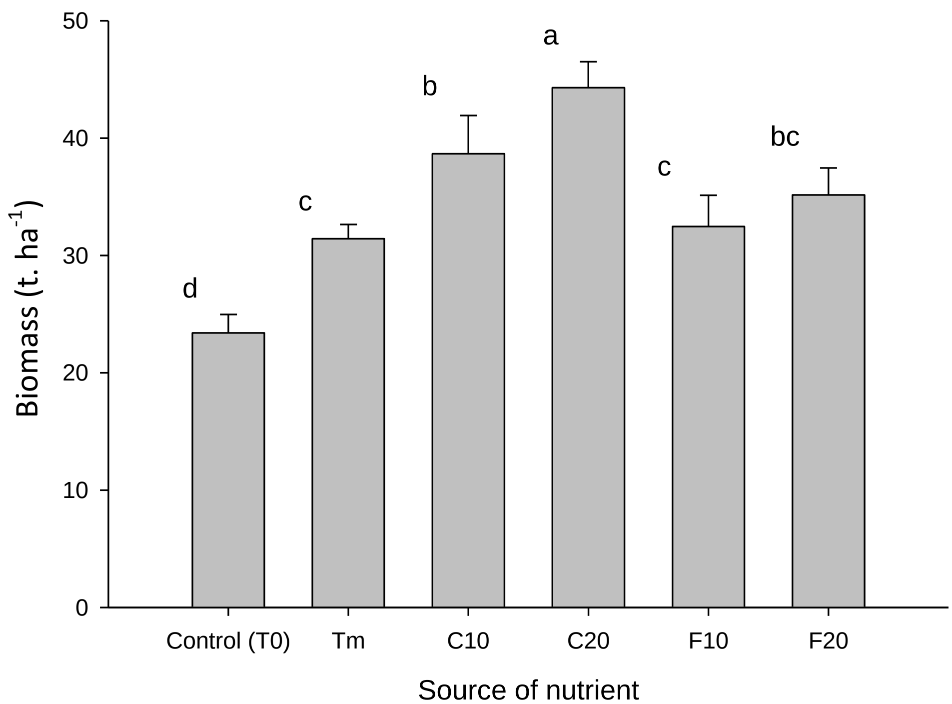


**Figure 3.** Evolution of total biomass yields of cabbage for different composts used. Vertical bars denote standard errors. Bars of the same types labeled with the same letter are statistically identical to the 5% level. T0 = Control ; Tm (C0 or F0) = *J. curcas* seed cake (90%) + Soil (10%) ; C10 = *J. curcas* seed cake (80%) + sheep's droppings (10%) +Soil(10%); C20 = *J. curcas* seed cake (70%) + sheep's droppings (20%) + Soil (10%) ; F10 = *J. curcas* seed cake (80%) + Chicken dejection (10%) + Soil (10%) ; F20 : *J. curcas* seed cake (70%) + chicken dejection (20%) + Soil (10%).

was followed by the $C_{10}$ treatment. The highest yield is obtained with compost $C_{20}$, $C_{10}$ and $F_{20}$ composts have acted in the same way on performance. The lowest yields were obtained from the $T_m$ compost even though this was not statistically different from the $F_{10}$ and $F_{20}$ treatments.

## Effect of different composts used on the total biomass of cabbage heads

The effect of different types of used compost in the total biomass of cabbage is presented in Figure 3. All tested composts had a significant increase in the total biomass of cabbage heads when compared with the control. Compost $C_{20}$ had the best performance in total biomass whereas composts $T_m$, $F_{10}$ and $F_{20}$ had lower cabbage head biomass.

## Soil chemical properties after harvesting cabbage as influenced by different nutrient sources

The soil chemical characteristics (mean values of pH-$H_2O$, pH-KCl, Total N, Total P, Total K and organic carbon) after harvesting were presented in Table 3. Compost $C_{10}$ and $C_{20}$ had a slight increase in soil alkalinity. The contents of carbon and N decreased on the soil before trial compared to the soil on the plot without compost ($T_0$). All composts made increased the soil P content as compared with that before trial.

## DISCUSSION

The alkalinity of composts can be related to the prevalence of ammonia coupled with basic cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$) present in these substrates from *J. curas* seed cake and sheep's droppings or chicken dejection. Generally, the pH of a good compost at maturity is between 7 and 8.5 (Koledzi, 2011; Weber et al., 2007). The compost $C_{10}$ has the highest carbon content. Poor decomposition (microbial utilization of organic matter) might be the reason for this high carbon content (Das et al., 2011). The pellet like structure of sheep's droppings may not allow thorough homogenization with the rest of the compost pile which ultimately affects the decomposition.

N, P and K are the nutrients which are the most used by plants. N content of compost $C_{10}$, $C_{20}$ and $T_m$ are

**Table 3.** Chemical characteristics (mean values) of soil during harvesting.

| Nutrient sources | pH | | Organic-C | Total-N | C:N | Total-P | Total-K |
|---|---|---|---|---|---|---|---|
| | $H_2O$ | KCl | (g.kg$^{-1}$) | | | (g.kg$^{-1}$) | |
| **Soil before trial** | 7.20 | 6.18 | 7.60 | 0.90 | 8.44 | 0.024 | 0.115 |
| **$T_0$** | $7.34^c$ | $6.47^c$ | $5.27^d$ | $0.39^c$ | $13.69^a$ | $0.033^c$ | $0.096^c$ |
| **$T_m$** | $7.27^d$ | $6.34^d$ | $9.14^{ab}$ | $0.91^a$ | $10.04^{bc}$ | $0.057^{ab}$ | $0.126^b$ |
| **$C_{10}$** | $7.79^a$ | $7.05^a$ | $9.37^{ab}$ | $0.82^b$ | $11.45^b$ | $0.059^a$ | $0.127^b$ |
| **$C_{20}$** | $7.50^b$ | $6.63^b$ | $8.43^{bc}$ | $0.76^b$ | $11.15^{bc}$ | $0.053^b$ | $0.139^a$ |
| **$F_{10}$** | $7.11^e$ | $6.25^e$ | $9.61^a$ | $0.89^a$ | $10.82^{bc}$ | $0.054^{ab}$ | $0.140^a$ |
| **$F_{20}$** | $7.24^d$ | $6.61^b$ | $7.54^c$ | $0.78^b$ | $9.62^c$ | $0.053^b$ | $0.126^b$ |

$T_0$ = absolute reference ; $T_m$ ($C_0$ or $_{F0)}$ = *J. curcas* seed cake (90%) +Soil (10%) ; $C_{10}$ = *J. curcas* seed cake (80%) + sheep's droppings (10%) +Soil(10%); $C_{20}$ = *J. curcas* seed cake (70%) + sheep's droppings (20%) +Soil (10%) ; $F_{10}$ = *J. curcas* seed cake (80%) +chicken dejection (10%) +Soil (10%) ; $F_{20}$ : *J. curcas* seed cake (70%) + chicken dejection (20%) +Soil (10%). The values assigned to the same column of the same index letters are statistically identical to the 5% level.

statistically identical. Therefore, adding sheep's droppings had no effect on N content. Unlike the incorporation of chicken dejection reduced the total N content. The high levels of $_K$ and P contents in $F_{20}$ compost could be attributed to the chicken dejection. Adding animal feces might be improve *J. curcas* seed cake compost in K and P contents.

The incorporation rate seems to have no effect on the C:N ratio. The C:N ratios obtained ranging from 8.72 to 12.35 are favorable for microbiological processes in the soil (Busby et al., 2007). However C:N ratio cannot be used as an absolute indicator of compost quality because of the large variability in raw materials and often gives a misleading indication of maturity (Das et al., 2011). A wide range of C:N is mentioned in the literature for composts, example for compost in fermentation phase, the C:N ratio ranges from 10 to 80 (Bernal et al., 1998; Koledzi, 2011). This ratio decreases during composting to reach values ranges from 8 to 25, which is explained by the fact that microorganisms consume more C than N (Bernal et al., 1998; Koledzi, 2011).

The positive effect of different composts on the production of shoots of cabbage was observed in Benin with composts of municipal organic waste improved with chicken dejection and maize stover residues (Amadji, 2006; Amadji et al., 2009). These results show that various composts produced by *J. curcas* seed cake ($T_m$, $C_{10}$, $C_{20}$, $F_{10}$ and $F_{20}$) have increased significant effect on the cabbage shoot yield. Compost made with *J. curcas* seed cake can be used as fertilizer to improve culture yield.

Different composts increased the pH of the soil. That could be due to cations present in the various composts ($T_m$, $C_{10}$, $C_{20}$, $F_{10}$ and $F_{20}$) at the maturity (Weber et al., 2007). This increase of the pH value after using various composts was observed on hydromorphic soil under cabbage (Fassinou, 1996), on ferralitique soil under radish and amaranth (Cédric, 1997) and on a sandy soil under cabbage (Amadji, 2006).

The soil content of C and N decreased in the soil control compost ($T_0$). These increased in the soils with different kinds of compost namely $T_m$, $C_{10}$, $C_{20}$, $F_{10}$ and $F_{20}$. This clearly shows that the addition of different composts has raised C and N contents in soil. The control ($T_m$) and the $F_{20}$ compost were the most improved soil in C and N content.

Generally, different composts made by *J. curcas* seed cake have improved the chemical characteristics of the soil. It is still to know the effects of phytotoxicity spreading at high doses and for long time use of different composts made with *J. curcas* seed cake on crops and soil. Future research will take into account this aspect. It will be good to extend this test to determine the equivalent of mineral fertilizers from composts prepared.

## Conclusion

The $C_{10}$ compost produced good chemical characteristics compost with a high N and K content (Total-N 18.32 g.kg$^{-1}$; Total-K 17.60 g.kg$^{-1}$). The $C_{20}$ compost produced the highest head and shoot biomass respectively 43.11±3.15 $10^3$ kg.ha$^{-1}$ and 21.56±1.58 $10^3$ kg.ha$^{-1}$. The different composts made with *J. curcas* seed cake improved significantly the chemical characteristics of the soil. The incorporation of sheep's droppings has improved the chemical characteristics of the *J. curcas* seed cake compost, even though adding chicken dejection would not improve *J. curcas* seed cake compost maybe due to their composition. Sheep's droppings richer than chicken dejection would be due to sheep's alimentation. However, the applicability and potential use of such compost as a soil amendment should be assessed effectively through field trials followed by validation prior to recommendation.

## Conflict of Interests

The authors have not declared any conflict of interests.

## ACKNOWLEDGMENTS

We are grateful to all the anonymous reviewers who improved the quality of the first draft of this paper.

**REFERENCES**

Akintayo E (2004). Characteristics and composition of *Parkia biglobbossa* and *Jatropha curcas* oils and cakes. Bioresour. Technol. 92(3):307-310.

Amadji G (2006). Valorisation des ordures ménagères par la production du chou pommé sur sol sableux du littoral. Actes de l'Atelier «Agricultures et Développement Urbain en Afrique de l'Ouest et du Centre» sous presse.

Amadji G, Saidou A, Chitou L (2009). Recycling of organic residues in compost to improve coastal sandy soil properties and cabbage shoot yield in Benin. Int. J. Biol. Chem. Sci. 3(2).

Bernal M, Navarro A, Sánchez-Monedero M, Roig A, Cegarra J (1998). Influence of sewage sludge compost stability and maturity on carbon and nitrogen mineralization in soil. Soil Biol. Biochem. 30(3):305-313.

Bremner JM, Mulvaney C (1982). Nitrogen-total. Methods of soil analysis. Part 2. Chemical and microbiological properties (methodsofsoilan2), pp. 595-624.

Busby RR, Torbert HA, Gebhart DL (2007). Carbon and nitrogen mineralization of non-composted and composted municipal solid waste in sandy soils. Soil Biol. Biochem. 39(6):1277-1283.

Cédric D (1997). Etude de la réponse de cultures d'amarante et de radis cultivées sur sol ferrallitique suite à l'apport de trois engrais organiques. (Diplôme d'ingénieur EPLF en Génie rural ; mention Environnement), UNB, Cotonou, Benin.

Das M, Uppal H, Singh R, Beri S, Mohan K, Gupta VC, Adholeya A (2011). Co-composting of physic nut (*Jatropha curcas*) deoiled cake with rice straw and different animal dung. Bioresour. Tech. 102(11):6541-6546.

Demba D (2011). Rapport final de l'évaluation du potentiel de développement des bioénergies au Togo: Ministère des Mines et de l'Energie (Togo).

Domergue M, Pirot R (2008). *Jatropha curcas* L. Rapport de synthèse bibliographique.

Fassinou DS (1996). Etude comparative de valeurs fertilisantes de deux types d'engrais biologiques sur les cultures du gingembre (*Zingiber officinal*) et de chou pommé (*Brassica oleracea* L.) sur un sol hydromorphe à pseudogley. (These d'ingénieur agronome), UNB, Cotonou, Benin.

Gübitz GM, Mittelbach M, Trabi M (1999). Exploitation of the tropical oil seed plant *Jatropha curcas L*. Bioresour. Technol. 67(1):73-82.

Gueguen L, Rombauts P (1961). Dosage du sodium, du potassium, du calcium et du magnésium par spectrophotométrie de flamme dans les aliments, le lait et les excréta. Paper presented at the Annales de Biologie Animale Biochimie Biophysique.

Henning RK (2008). Identification, selection and multiplication of high yielding *Jatropha curcas* L. plants and economic key points for viable Jatropha oil production costs. Int. Consultation Pro-poor Jatropha Dev. pp. 10-11.

Koledzi KE (2011). Valorisation des déchets solides urbains dans les quartiers de Lomé (Togo): approche méthodologique pour une production durable de compost.

Martinez-Herrera J, Siddhuraju P, Francis G, Davila-Ortiz G, Becker K (2006). Chemical composition, toxic/antimetabolic constituents, and effects of different treatments on their levels, in four provenances of *Jatropha curcas L*. from Mexico. Food Chem. 96(1):80-89.

Murphy J, Riley JP (1962). A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta 27:31-36.

Raheman H, Mondal S (2012). Biogas production potential of jatropha seed cake. Biomass Bioenergy 37:25-30.

Samake F (2007). Les acquis de la recherche agronomique en matière de pourghère. Paper presented at the Forum national sur le biocarburant dans le cadre du projet de développement de la filière pourghère au Mali, Bamako 6 et 7 septembre 2007.

Sanou F (2010). Production de *Jatropha curcas* et impact de la plante sur les propriétés chimiques du sol: Cas de Bagré (Centre Est du Burkina Faso). Master dissertation, Université Polytechnique de Bobo Dioulasso, Bobo Dioulasso. French.

Saragoni H, Olivier R, Poss R (1991). Dynamique et lixiviation des éléments minéraux. Agron. Trop. 45(4):259-273.

Staubmann R, Foidl G, Foidl N, Gübitz GM, Lafferty RM, Arbizu VMV, Steiner W (1997). Biogas production from *Jatropha curcas* press-cake Biotechnology for Fuels and Chemicals Springer, pp. 457-467

Toundou O, Tozo K, Amouzouvi KA, Kolani L, Tchangbedji G, Kili K, Gnon B (2014). Effets de la biomasse et du compost de *Cassia occidentalis* L. Sur la croissance en hauteur, le rendement du maïs (*Zea mays L*.) et la teneur en npk d'un sol dégradé en station expérimentale. Eur. Sci. J. 10(3).

Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 37(1):29-38.

Weber J, Karczewska A, Drozd J, Licznar M, Licznar S, Jamroz E, Kocowicz A (2007). Agricultural and ecological aspects of a sandy soil as affected by the application of municipal solid waste composts. Soil Biol. Biochem. 39(6):1294-1302.

Zoumana C, César J (1994). Production et utilisation du fumier dans la zone dense de Korhogo en Côte d'Ivoire. Agric. Syst. Afr. 4(2):20-27.