Effect of soybean crop residue compost on the productivity of guinea sorrel (*Hibiscus sabdariffa*)

Abstract

Ivorian soils are facing a loss of fertility that affects the production of market gardeners such as the cultivation of guinea sorrel. In order to propose a method of producing guinea sorrel that takes into account the environment and is accessible at a lower cost to producers, fertilization based on compost from crop residues was undertaken. For this purpose, six (6) doses of compost based on soybean crop residues were tested (0 t. ha-1; 02 t. ha-1; 04 t. ha-1; 06 t. ha-1; 08 t. ha-1 and 10 t. ha-1). The parameters measured concerned the vegetative parameters and the yield components. The vegetative development of the plants was influenced by the different treatments at 45 days after sowing (45 DAS). The 06 t. ha-1 and 10 t. ha-1 treatments generated the best values. As for the yield, it was significantly higher with the doses of 02 t. ha-1; 04 t. ha-1 and 10 t. ha-1 with respectively 18.67; 18.73; 18.33 t. ha-1. According to the results obtained, the dose of 02 t. ha-1 would be the most effective since it is the lowest dose that produced as much as the doses 04 t. ha-1 and 10 t. ha-1.

Keywords: compost, fertilization, vegetative development, guinea sorrel, yield

INTRODUCTION

Guinea sorrel (*Hibiscus sabdariffa L.*) belongs to the Malvaceae family. It is an annual or biennial plant of tropical and subtropical regions that adapts to all climatic conditions (Mehdi, 2012).It is thought to have originated in Central America and was then introduced to various tropical regions, including India, the Antilles and Africa. However, it is probably in West Africa that the greatest diversity of Hibiscus plants is found (Adjé *et al*., 2013).It is a large, sparsely branched and very fibrous plant (Mc Clintok and El-Tahir, 2004). Leaf yield is between 10 and 20 t/ha (Raemaekers, 2001).Sorrel is a plantrich in minerals, protein and vitamins (Cissé *et al*, 2009). It iscultivated for its leaves, seeds and calyxes which constitute a source of income for producers (Kéllou *et al*., 2019). In Ivory Coast, the leaves are used to prepare sauces. The calyx of some species is also used to make a refreshing drink called "bissap". The plant is also used to treat many diseases such as coughs, toothaches and hypertension disorders (Abbas and Ali, 2011).

Its nutritional richness, its multiple culinary uses associated with its industrial uses have encouraged researchers to take an interest in this plant (Ilodibia *et al*., 2019).Despite the benefits of its cultivation, production remains low due to several factors including low soil fertility (FAO, 2005; Housseini, 2013). Indeed, sorrel is generally grown in traditional conditions by small producers without mineral fertilization or pest control (El Naim and Ahmed, 2017). However, some studies have shown the influence of fertilization on the production of Guinea sorrel (Ognalaga *et al*., 2015 ; Boukar *et al*., 2019). Indeed, these authors have shown that the supply of nitrogen and phosphorus has a significant effect on the growth and yield parameters of the plant. It is based on this assertion that producers require large quantities of chemical inputs for sorrel cultivation. However, in commerce, these inputs are mostly inaccessible to farmers due to very high purchasing costs and have a certain impact on the soil environment.

Furthermore, thePrevious work by Ognalaga *et al* (2015) investigated the use of compost based on crop residues (Chromolona odorata and sugarcane scum) on H. sabdarifa.

Based on this work, it would be appropriate to investigate other types of organic matter available in the producer's environment. This would not only reduce producers' needs for synthetic chemical fertilizers, but also improve the quality of production.

The objective of this study is to improve the production and quality of guinea sorrel.

I. MATERIALS AND METHODS

1.1. Material

1.1.1. Description of the study site

The study was conducted at the CNRA Food Crop Research Station (SRCV) in Bouaké. The city of Bouaké is located in central Côte d'Ivoire and the food crop research station is located 8 km from the city center, on the road to Sakassou (Figure 1). The geographical coordinates of the station are: 05°52"2 W, 07°40'42.6" N and at an altitude of 430 m. The Bouaké region is located in the Baoulean climate of the Guinean forest climate is characterized by four seasons, including a long dry season (November to February), a long rainy season (March to June), a short dry season (July to August) and a short rainy season (September to October). Each of these periods has become less and less pronounced in recent years, according to Brou *et al*. (2005). The geological formations are located in the crystalline basement with magmatic and metamorphic rocks, on which plinthic dystric and hyper dystric Ferralsols develop (Lauginie, 2007).

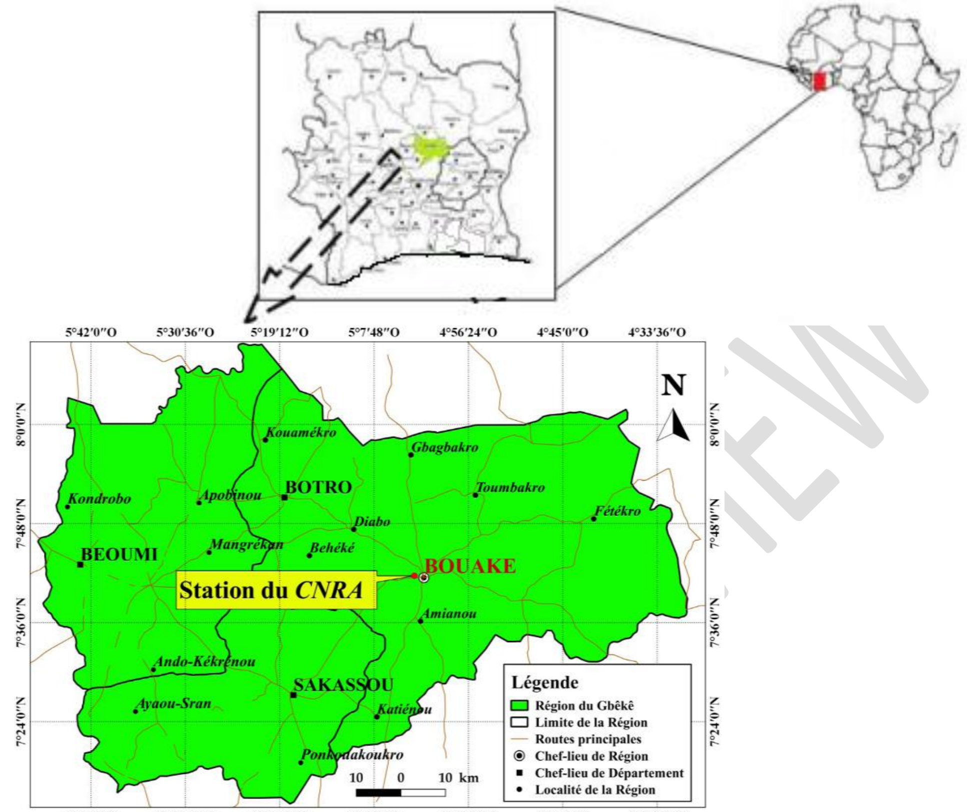


Figure1 : Presentation of the study area (Boa, 2019)

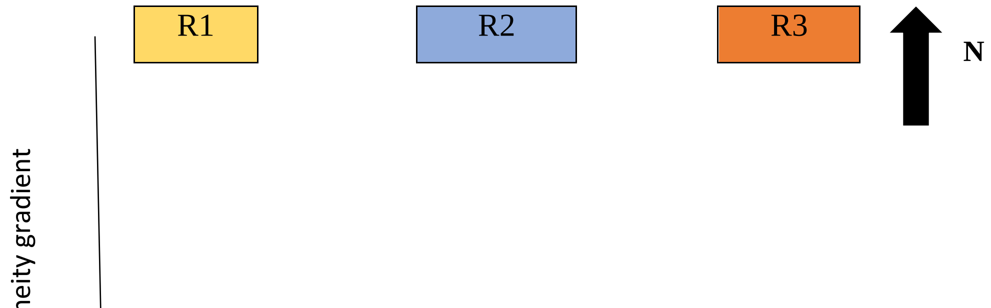
1.1.2. Plant material

The plant material consists of a codified accession of Guinea sorrel OSG1/15T from the CNRA. This accession is widely consumed and appreciated by the population of the north.

1.2. METHODS

1.2.1. Experimental device

The device used in this study is in complete randomized blocks comprising six (06) treatments and three (3) repetitions. Each repetition comprised six (06) elementary plots of 10 m² (5 mx 2 m) each, i.e. a total of 18 elementary plots with a total useful surface area of 180 m2 without the borders. LThe quantities of compost applied and the application times are summarized in Table 1.



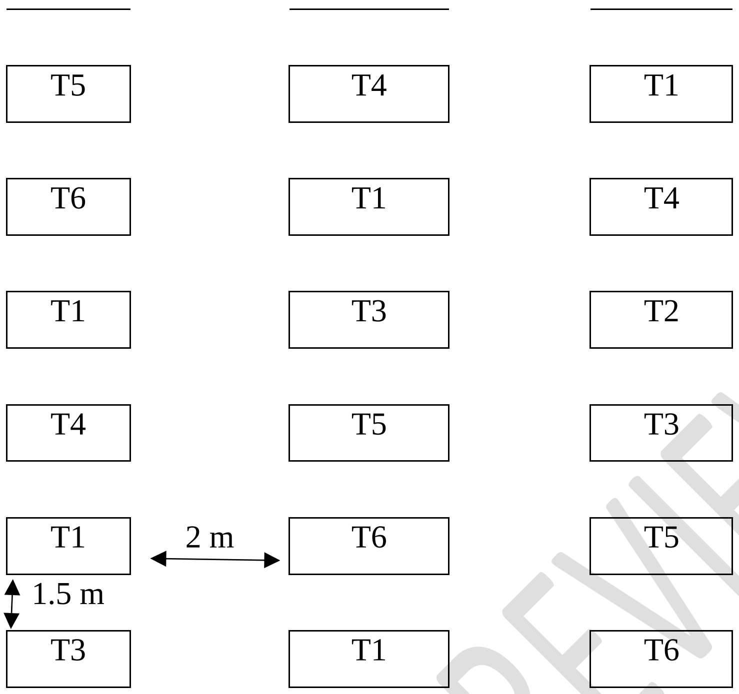


Figure 2: Experimental design in randomized complete blocks

Table 1: The different doses of compost based on crop residues applied

Treatments	Quantities applied	Processing times
To	$0\ kg.ha^{-1}$	No fertilizer application
T1	$02\ t.ha^{-1}(0{,}2kg/m^2)$	Apply organic matter 15 days before sowing
T2	$04\ t.ha^{-1}(0{,}4kg/m^2)$	
T3	$06\ t.ha^{-1}(0{,}6kg/m^2)$	
T4	$08\ t.ha^{-1}(0{,}8kg/m^2)$	
T5	$10\ t.ha^{-1}(1kg/m^2)$	

1.2.2. Cultural practices

1.2.2.1. Compost preparation

The fertilizer used in this study is a compost based on soybean harvest residues. Obtaining the compost requires several steps that can last up to six (6) months. The debris obtained after the soybean harvest is first chopped using a machete and a shovel. Then they are gathered in piles, watering them gradually. Finally, the pile formed is covered with black plastic. Every two weeks the organic matter is turned over using shovels until it matures.

1.2.2.2. Implementation and monitoring of the test

Direct seeding was carried out on September 2, 2019. To do this, a 5 m long and 2 m wide board was made after plowing the soil. The board was disinfected with a nematicide-insecticide at a rate of 50g/m². Then, the doses of compost were added as a base fertilizer 15 days before sowing.

1.2.2.3. Insecticide treatments

During cultivation, a biological insecticide treatment based on neem oil was carried out. Weeding was carried out to eliminate weeds.

1.2.3. Observations and measurements

The observations and measurements concerned the vegetative parameters and those of the. The sampling involved five (05) plants chosen at random on each elementary plot for the measurements and observations.

a. Vegetative parameters

The measurements carried out for the determination of the vegetative parameters concerned:

- Plant height (HP):It was measured using a tape measure from the collar to the top of the plant.
- The collar diameter (DC):It was measured at the collar level.
- The length and width of the sheet; they were measured using a graduated ruler.
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- Leaf area (LA)according to the method of Cornelissen *et al*. (2003). The leaf area of a leaf (SF) is calculated when the number of leaves (NF) is equal to 1.

$$\mathbf{SFT = 2.23 \times NF \times L \times l \times \pi 4}$$

NF:number of leaves per plant, L: average length of leaflets, l: average width of leaflets, SFT: total leaf surface expressed in cm.

- Vegetative vigor indexwas determined using the following formula:

$$\boxed{\mathrm{IV} = \log\left(\frac{C^2\ X\ H}{4\pi}\right)\ ;\ C = \ \pi\ X\ D}$$

With: IVV: Vegetative vigor index, C: Circumference at the collar of the plants (cm), D: Diameter at the collar of the plants (cm), H: Height of the plants (cm).

b. Performance parameters

The determined production parameters are:

- The number of leaves (Nbr F): Shewas done by counting the number of leaves of the five (5) plants chosen at random.
- The yield (biom yield):dIn each square, the harvested leaves were weighed to determine the total biomass yield of Guinea sorrel.

1.2.4. Data processing

The data obtained were analyzed using STATISTICA version 7.1 and Excel 2016 software. The Fisher LSD test was chosen for the comparison of means when the analysis of variances revealed significant differences between treatments at the 5% probability threshold.

II. Results

2.1. Effect of compost doses applied on vegetative parameters

2.1.1.Plant height (HP)

Analysis of Table 2 showed that plant height measurement showed no significant difference between treatments except for height at 45 and 66days after sowing (DAS). Indeed, at these stages, the lowest values were produced by the T0 treatments without fertilizer. The highest values were obtained by the T4 treatment (08 t/ha) at 45 DAS, and by T5 (10 t/ha) at 66 DAS (Table 2): Plant height at 30 and 45 days after sowing (DAS) and at the different harvests.

Table 2. Plant height measurement for vegetative parameters

Treatment Codes	Plant Heights (30 JAS cm)	Plant Heights (45 JAS cm)	Plant Heights1ST REC (66 JAS; cm)	Plant Heights2nd REC (75 JAS; cm)
T0	7.84 ± 1.43a	11.37 ± 1.88c	13.27 ± 2.64c	19.93 ± 0.76a
T1	7.35 ± 1.17a	12.01 ± 2.9ab	15.6 ± 3.14b	20.4 ± 2.31a
T2	8.09 ± 1.36a	12.76 ± 1.15ab	16.53 ± 2.5ab	23.13 ± 0.81a
T3	7.46 ± 2.7a	11.8 ± 3.15 ab	16.6 ± 2.46ab	23.47 ± 2.48a
T4	10.33 ± 2.5a	15.76 ± 3.36a	14.33 ± 0.81b	21.73 ± 1.22a
T5	7.36 ± 2.65a	13.9 ± 2.29b	16.93 ± 3.21a	21.67 ± 2.14a
Averages	8.07 ± 1.97	12.93 ± 2.45	15.54 ± 2.46	21.72 ± 1.62
Probabilities	0.702759	0.000014	0.000946	0.169393

In the same column, values followed by the same letters are not significantly different at the 5% threshold (Fisher test).

2.1.2.Neck diameter (DC)

Table 3 shows the collar diameters of the different treatments. They varied significantly at 45 days after sowing (45 DAS), the first harvest (66 DAS) and the second harvest (75 DAS). At the first harvest, the largest diameters were those of the T2 (04 t/ha), T3 (06 t/ha), and T5 (10 t/ha) treatments, with 0.48, 0.49 and 0.52 cm respectively. The average collar diameters of the T5 treatment(10 t. ha-1) at 45 DAS (0.26 cm) and 2nd REC (0.63 cm) were significantly higher than those of T0 at 45 DAS (0.17 cm) and T4 at the 2nd REC (0.48 cm) which were lower.

Table 3: Diameter at the collar of the plants at 30 and 45 days after sowing (DAS) at the different harvests

Treatment Codes	Collar Diameters 30 JAS (cm)	Collar Diameters 45 JAS (cm)	Collar Diameters 66 JASREC (cm)	Collar Diameters75 JAS (cm)
T0	0.11 ± 0.03a	0.17 ± 0.04c	0.4 ± 0.05a	0.5 ± 0.07ab
T1	0.10 ± 0.05a	0.2 ± 0.07b	0.48 ± 0.02ab	0.52 ± 0.03abc
T2	0.12 ± 0.02a	0.23 ± 0.02ab	0.49 ± 0.07ab	0.55 ± 0.14ab
T3	0.11 ± 0.01a	0.21 ± 0.01ab	0.46 ± 0.08ab	0.59 ± 0.06b
T4	0.13 ± 0.03a	0.25 ± 0.05a	0.44 ± 0.1b	0.48 ± 0.04c
T5	0.13 ± 0.01a	0.26 ± 0.02a	0.52 ± 0.08a	0.63 ± 0.1a
Averages	0.12 ± 0.03	0.22 ± 0.02	0.46 ± 0.05	0.54 ± 0.07
Probabilities	0.411303	-------------	0.012667	0.036370

In the same column, values followed by the same letters are not significantly different at the 5% threshold (Fisher test).

2.1.3.Vegetative developments and leaf surface

Vegetative development at 30 and 45 DAS, leaf area and total leaf area are presented in Table 4. The results did not show any difference between treatments with regard to vegetative development (VD) at 30 DAS and total leaf area. However, a significant difference was observed between treatments for vegetative development and leaf area at 45 DAS. Indeed, at 45 DAS, the VDs of treatments T3 (6 t. ha^{-1}) and T5 (10 t. ha^{-1}; 3.33 cm) were statistically identical and significantly higher than that of the control which obtained the lowest value (2.33 cm).

The leaf area of the T4 treatment (8 t. ha^{-1}; 323.2 cm2) is higher than that of the control (without OM; 178.77 cm2) which is significantly lower. The total leaf area (TLA) did not vary with the treatments.

Table 4: Vegetative development and leaf surfaceplants subjected to different doses of fertilization

Treatment codes	Vegetative Development 30 JAS	Vegetative Development 45 JAS	Leaf Area (cm2)	Total Leaf Area (cm2)
T0	2.67 ± 0.58a	2.33 ± 0.58c	178.77 ± 81.74a	5237.76 ± 2861.85a
T1	2.67 ± 0.58a	2.67 ± 0.58bc	215.26 ± 26.36bc	6274.29 ± 824.23a
T2	3.33 ± 0.58a	3 ± 0b	216.68 ± 66.9bc	6900.86 ± 4245.8a
T3	3 ± 0a	3.33 ± 0.58a	180.89 ± 53.2ab	5107.27 ± 3071.12 a
T4	3.33 ± 0.58a	3 ± 0abc	323.2 ± 65.96a	13380.25 ± 4976.54a
T5	3 ± 0a	3.33 ± 0.58a	274.52 ± 95.48b	8793.46 ± 5159.87a
Average	3 ± 0.38	2.94 ± 0.38	231.55 ± 64.94	7615.64 ± 3523.23
Probability	0.136525	0.007490	0.001349	0.090432

In the same column, values followed by the same letters are not significantly different at the 5% threshold (Fisher test).

- **2.1.4. Vegetative vigor indices (VVI)**

Vegetative vigor indices (VVI) of plants showed no variability between treatments compared to vigor indices at 30 and 45 DAS (Table 5). On the other hand, variability was observed between treatments regarding vigor indices at the 1st and 2nd harvest. Indeed, the VVI at the first harvest (66 DAS) of treatment T5 (10 t. ha^{-1}; 54) was significantly higher than that of the control T0 (without OM, 0.21). Similarly, the VVI at the 2nd REC of treatment T5 (10 t. ha^{-1}; 0.82) was significantly higher than that of the control and treatment T4 (0.59).

Table 5: Vegetative vigor index of plants at 30 and 45 days after sowing (DAS) and at different harvests

Treatment codes	IVV at 30 JAS	IVV at 45	IVV at the 1st REC (66 JAS)	IVV at the 2nd REC (75 JAS)
T0	-1.13 ± 0.26a	-0.59 ± 0.24a	0.21 ± 0.21c	0.59 ± 0.13c
T1	-1.36 ± 0.63a	-0.48 ± 0.44a	0.44 ± 0.12ab	0.63 ± 0.09bc
T2	-1.05 ± 0.22a	-0.29 ± 0.1a	0.49 ± 0.19b	0.73 ± 0.22b
T3	-1.2 ± 0.25a	-0.41 ± 0.11a	0.43 ± 0.21ab	0.8 ± 0.14b
T4	-0.91 ± 0.27a	-0.12 ± 0.27a	0.32 ± 0.22ab	0.59 ± 0.07c
T5	-1.01 ± 0.2a	-0.14 ± 0.02a	0.54 ± 0.22a	0.82 ± 0.18a
Average	----------	-----------	0.40 ± 0.195	0.69 ± 0.14
Probabilities	----------	-------------	0.000392	0.035976

In the same column, values followed by the same letters are not significantly different at the 5% threshold (Fisher test).

2.2. Effect of compost doses applied on yield parameters

- **2.2.1.Production parameters**

The analysis of the number of leaves, fresh and dry biomass, water content and total yield are presented in Table 6. The analysis of the table shows that only the total biomass yield (TBR) showed a highly significant difference ($P < 0.01$). Indeed, the total biomass yield of the treatments (T1 to T5) that received the compost are significantly higher than that of the control (13.7 t. ha^{-1}). The TBR of T1, T2 and T5 is significantly higher with respectively 18.67 t. ha^{-1}, 18.73 t. ha^{-1}, 18.33 t. ha^{-1}.

Table 6: Yield parameters of plants subjected to different fertilization doses

Treatments codes	Number of leaves	Fresh Biomass (g)	Dry biomass (g)	Water content (%)	Total Biomass Yield (t/ha)
T0	28 ± 5.19^{has}	564.67 ± 211.38^{has}	78.83 ± 21.12^{has}	85.64 ± 1.61^{has}	13.07 ± 5.18c
T1	29.13 ± 0.81^{has}	490.33 ± 36.47^{has}	72.52 ± 11.19^{has}	85.27 ± 1.21^{has}	18.67 ± 5.64a
T2	30 ± 9.99^{has}	644.33 ± 389.52^{has}	105.18 ± 77.12^{has}	84.44 ± 1.92^{has}	18.73 ± 2.12a
T3	26.8 ± 8.13^{has}	712.67 ± 229.01^{has}	113.74 ± 32.11^{has}	83.87 ± 0.98^{has}	17.07 ± 2.72ab
T4	40.47 ± 7.49^{has}	514 ± 75.62^{has}	78.84 ± 18.32^{has}	84.76 ± 1.93^{has}	17.8 ± 1.93ab
T5	30.4 ± 7.7^{has}	546.33 ± 127.03^{has}	78.88 ± 15.85^{has}	85.5 ± 0.45^{has}	18.33 ± 0.7a
Averages	30.80 ± 6.55	578.72 ± 178.17	87.99 ± 29.28	84.91 ± 1.35	17.27 ± 3.04
Probabilities	0.699408	0.334459	0.738556	0.627633	0.000029

In the same column, values followed by the same letters are not significantly different at the 5% threshold (Fisher test).

DISCUSSION

The treatments applied did not present any variability with regard to the collar diameter and height of the in the first stage of crop development. It would seem that these parameters were not influenced by fertilizer inputs. These parameters would therefore be subject to the control of internal plant factors. Also, vegetative development at 30 days after sowing also did not present any significant variability. In fact, on all the treated plots, the plants had moderately good development overall. These results seem to indicate that during this phase of development, guinea sorrel is not too demanding in nutrients. Thus, the nutrient requirements for nitrogen and potassium which are essential mineral elements for growth and development are little used from sowing to fruit set as stated by Kouadio (2017).

Furthermore, vegetative development, plant height and collar diameter at 45 days after sowing varied significantly depending on the treatments. This indicates that the mineral elements contained in the different compost treatments had an impact on the plant. In the second stage of development (from 45 DAS), the elements essential for good plant development are a priori available in different quantities depending on the treatment applied by the plant. Indeed, these growth and development parameters were greater with the highest doses of compost (8 and 10 t.

ha-1). This could mean that the higher the dose of compost, the greater quantities of mineral elements essential for plant development are released and available for plant growth and development. At low doses of organic fertilizers and particularly soybean residue compost, the nutrients released ensure good growth, but they are not sufficient in the soil; or the supply of nutrients to the soil seems to be greater in high-dose treatments (10 t. ha-1) as opposed to low doses and unfertilized plants (Ognalaga *et al*., 2015). These results confirm the work of Choudhary and Suresh (2013) on maize cultivation as well as Ognalaga and Itsoma (2014) on H. sabdariffa L. according to their studies, the higher the dose of compost provided, the greater the positive reaction of the plants. But this depends on the type of residues. Indeed, the work of Ognalaga and Itsoma (2014) Indeed, the work of Ognalaga and Itsoma (2014) shows that high doses of *Chromolaena. odorata*-based compost result in good vegetative development and yield of sugarcane, unlike that of *Leucaena leucocephalae*.

During the harvests, the variations observed in the height of the plants and the diameter at the collar did not allow to discriminate the doses of organic matter applied. It would seem that at the harvest, there is no longer any great variation in these parameters, because the growth and vegetative development phase of the plants is complete. Indeed, at this stage, the plant mobilizes the elements available for reproduction which contributes to yields.

Regarding leaf area, variability was also observed between treatments. The dose of 10 t. ha-1 of compost generated the highest leaf area. This was the source of the increase in aerial biomass. This would mean that the treatment allowed the leaf surfaces to be enlarged in order to increase the photosynthetic activity of the sorrel plants. This could be explained by the high photosynthetic activity governed by the effect of nitrogen contained in chlorophyll. This could be explained by the fact that nitrogen (N) promotes cell multiplication and vegetative growth (Koné *et al*., 2009; Masome and Kazemi, 2014).

Concerning the number of leaves, the weight of dry biomass, fresh biomass and water content, the values obtained were statistically the same. In other words, these parameters were not influenced by the different fertilizer applications. This finding indicates that these parameters are not influenced by external factors, but rather linked to the genetic heritage of guinea sorrel. These results are in line with those of Shiva *et al*. (2015) who showed that the development of the parameters, the number of leaves and flowers and then the leaf biomass is not significantly influenced by fertilizer applications.

The results obtained also showed a significant difference between the treatments in terms of yield and total biomass. Indeed, the compost doses at doses of 10 t. ha-1, and 4 t. ha-1 gave the highest yields, while the control without organic matter obtained (13.07 t/ha) the lowest yield of all treatments. This would be attributable to the fact that the level of organic matter in the soil remains the important factor for maintaining fertility in the soil (Jama *et al*., 2000).

Conclusion

This study was conducted to evaluate the effects of increasing doses of composts based on soybean crop residues on the development and yield parameters of Guinea sorrel. Generally, the compost doses improved the parameters evaluated. Indeed, growth and yield were considerably improved following the contributions of the different doses of composts. Compost The compost doses of 2 t. ha-1 4 t. ha-1 and 10 t. ha-1 gave the best yields with respectively 18.67; 18.73; 18.33 t. ha-1. That is a yield gain of 30% compared to the control. The dose of 2 t. ha-1 can be recommended to farmers but, it would be wise to carry out a comparative study with different doses of chemical fertilizers in order to convince users.

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