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Effect of sugarcane scum and ashes of *Chromolena odorata* L. on the aptitude of *Hibiscus sabdariffa* L. production

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ABSTRACT

The main objective of this study was to develop an intensive cropping system for the *Hibiscus sabdariffa* L, reachable to all farmers in rural and peri-urban areas in Gabon. The ashes of *Chromolaena odorata* used alone or in combination with the sugarcane scums amended to ferralitic soil from *Imperata cylindrica* rich savannahs to evaluate their effects on *H. Sabdariffa* growth performance and leaf yields. Soils were mixed with different amounts of ash of *Chromolaena odorata* (30, 40 and 50 g/m²) and sugarcane scum (1.5; 2.0 and 2.5 kg/m²) and transferred to polythene pots. Our results showed that the fertilization significantly influences the growth in diameter and height of the stem and the leaf yields of *H. sabdariffa*. The best growth were obtained with the of 50 kg/m² of ash of *Chromolaena odorata* and 2.5 kg/m² of sugar cane scum, where the average stem diameter and average stem height were respectively 6.50 ± 0.40 mm and 42.07 ± 3.12 cm. The optimum leaf yield (9.87 ± 0.41 t/ha) was also obtained with this combination. Use of these fertilizers could improve the yields of Hibiscus sabdariffa, to obtain surplus production for salet o obtain surplus production for sale

Keywords: *Hibiscus sabdariffa* L., ash *Chromolaeana odorata*, sugarcane scum, ferralitic soil.

INTRODUCTION

Food requirements have increased strongly in Central Africa, while the productivity of food crops has declined (Dwivedi et al., 2017). The Central African countries have not yet performed their green revolution and have been supplementing their food deficit by imports of cereals, especially from Asia. The proportion of rural population has been declining steadily for the last 40 years (Zaccheo et al., 2017). This rural exodus has led to a drastic reduction of the working population, which results in a weakening of the work capacity in the rural areas (Mbetid-Bessane et al., 2003). In addition, the use of inadequate agricultural practices with slash-and-burn, poor soil quality and lack of mineral fertilizers decrease agricultural productivity thereby exacerbating the food deficit. To achieve food self-sufficiency in the Central African region. At present, there are no innovative cropping systems available for this

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crop. It is essential to introduce innovative and accessible cropping systems to the rural and peri-urban areas facing land pressure in order to increase yields of the local main crops productivity highly preferred by the populations (Monaco et al., 2017). Several studies had already been achieved in this direction, among which some have specifically focused on the effect of the green manure (*C. odorata*, sugarcane scum, etc.) on *H. sabdarifa* (Ognalaga et al., 2015; Ognalaga and Itsoma, 2014 a, b). In southeast Gabon, *Hibiscus sabdariffa* L. is one of the most consumed vegetables (Ondo et al., 2012). It is grown in rural and peri-urban areas (reference). In the southeast Gabon, ferrallitic soils are desaturated and the individualization of oxyhyroxides of iron and aluminium leads the organic matter to evolve by insolubilization (Ognalaga et al., 2016). These alterations, which are often very thorough, are at the origin of the almost-total loss of the production (reference). This leached and degraded land results in poor and insufficient crop yields for the farmers who don’t use intensive agricultural practices with the mineral fertilizers and other inputs (Tchawa et al., 2001). Hence, an increase of the production involves the improvement of these cropping systems.

The current approach for innovation and improvement of the monoculture of *H. sabdariffa* is results on certain vegetable crops with high added value such as cucumber, tomato and cabbage, because it brings a lot of income to households, especially in peri-urban areas (Ouedraogo, 2004). However, the valorisation of the industrial crops residues, such as sugarcane scum as a source of organic matter, can improve the quality of ferralitic soils-based substrates (Ognalaga et al., 2016) The use of *C. odorata* ashes as biofertilizers is of particular interest due to the fact that it could provide mineral elements readily to plants in the soil (Majeau et al., 2013). Also, these organic fertilizers would constitute a supplementation to improve the quality of substrates by increasing the soil pH and the crop yields (Pare et al., 2012). The *C. odorata* ashes used singly or in combination with the sugarcane scums could optimize leaves yield of *H. sabdariffa* and also consolidate the vigour and resistance of this plant against biotic and abiotic attacks (reference). The development of this cropping system would be a complement to the work of Ognalaga et al. (2017), it’s therefore necessary to use optimal doses of these fertilizers that could help to generate more production for the market and provide additional income to the households.

MATERIALS AND METHODS

Study site and plant material

The experiments were carried out in September 2015 at the experimental platform of the National Higher Institute of Agronomy and Biotechnology, Masuku University of Science and Technology. The site is located at 371 meters above sea level in southeast Gabon at 13º33'3 " of East longitude and 1º37'14"s of South latitude.

The planting material used consists of seeds of *H. sabdariffa* L, Bissap koor variety.

Thirty kilograms of ferralitic soil collected from savannah dominated by *Imperata cylindrica* (L.) P. Beauv (grass), *Annona senegalensis* Pers. (Annonaceae) and *Bridelia Ferruginea* Benth. (Euphorbiaceae) were put in polythene bags 10 liters capacity. This base substrate was sampled at the horizons surface within the first 20 centimetres. The cultivable area of each bag is 0.5 m².

Fertilizer (organic manure)

The sugarcane scum was collected from a sugarcane factory located in the southeast Gabon. The scum were put into a heap and stabilized naturally in the open air for 6 months. The amounts of 1.5; 2.0 or 2.5 kg were incorporated into the base substrate/m². This organic manure was applied singly or in mixture with *C. odorata* ashes as shown in Table 1.

A direct seeding was carried out in each pot with 2 seeds spaced of 30 cm. A thinning is done after two weeks, to leave the most vigorous *H. sabdariffa* per pot. The bags were laid out on a platform and watered twice daily. From the forty-third day three successive harvests of leaves, spaced a fortnight, were carried out on each plant.

Measured parameters and experimental protocol

Growth parameters such as diameter at the collar and height of the stem were measured thirty-five days after sowing. The measurements were made with digital caliper Reading 0-100 mm/Accuracy 0.1 mm LCD display. The exposed leaf area was measured by the Mesurim Pro software via a photograph of fifth leaf from terminal bud. Leaf yields were estimated using three harvests at 43, 56 and 70 days after planting, and weighing was carried out on a Sartorius scale of 0.2 milligrams of precision.

The experiments were carried out in a complete randomized block design. Each treatment was carried out three times with 40 plants per replication.

The statistical analyses were carried out with the software Xlstat 2007. The comparison of the significantly different means was performed with the Newman and Keuls test ($\alpha = 0.05$).

Table 1 : The various treatments and combinations provided in base substrate

Treatments	Scum (kg/m²)	Ash of *C. odorata* (g/m²)	ScumXAhs (kg/m² X g/m²)
T0	-	-	-
A1	30	-	-
A2	40	-	-
A3	50	-	-
S1	-	1,5	-
S2	-	2,0	-
S3	-	2,5	-
A1 X S1		-	30 x 1,5
A1 X S2	-	-	30 x 2,0
A1 X S3	-	-	30 x 2,5
A2 X S1	-	-	40x 1,5
A2 X S2	-	-	40x 2,0
A2 X S3	-	-	40 x 2,5
A3 X S1	-	-	50 x 1,5
A3 X S2	-	-	50 x 2,0
A3 X S3	-	-	50 x 2,5

T0: Control; An: Ash; Sn: Scum; An X Sn: Ash X Scums

RESULTS

Differences in diameter growth performances

Table 2 shows the variation in diameter growth performance diameter and other growth parameters between treatments measured 35 days after sowing and table 3 presents analysis of the variance main growth parameters. The stems diameter of plants varies from 2.1 to 6.2mm between treatments 35 days after sowing. The highest average diameter, 6.57 ± 0.24 mm, was obtained on plants from A2S3 combination, ie 40 g / m² × 2.5 kg / m². In fact, the lowest average diameter, 2.1 ± 0.40 mm, was recorded only on plants from control treatment made by ferralic soils. It is obtained with three combinations: A2S3; A3S1; A3S3. These performances are not significantly different from those obtained with the other treatments, except for the control treatment. However, this seems to increase with the amounts of amendments.

Variation of leaf area between treatments

The best leaves development was obtained by the plants grown on the fertilized substrate than those grown on the control soil, without amendment (Table 2). The largest exposed surfaces were obtained by three treatments A1S1, A2S3 and A3S1, respectively 28,02 ± 4,12 cm^2. 25,71 ± 3,10 cm² and 25,22 ± 2,13cm^2. Sugarcane scum or C. *odorata* ash applied alone did not produce better results, the control treatment showed a mean leaf area of 9.02 ± 3.7 cm². The optimal combination was A1S1, which increased the foliar area of *H. sabdarifa* by 67% compared to the control substrate.

Variation of leaf yield between treatments

These leaf yields decreased from the first to the third harvest in all the treatment of the fertilized media from 0.9 kg / m² to 0.4 kg / m² for the best combination (Figure 1). At the same time, they increased proportionally as a function of the amount of input applied into the substrate.

The harvested leaves varied from 0.67 to 0.987 ± 0.042 kg / m^2 for first harvest and from 0.2 to 0.41 kg / m² for the third harvest in soil which have received an amendment alone or in combination. The highest leaf yields are obtained with the combination A3S3 for which the plant gave a yield varying between 0.987 ± 0.042 kg / m². However, on the control soil, there was an increase in yields from the first to the third harvest. On the other hand, the average yields increased from 0.013 to 0.053 kg / m² between the first and third harvest. The use of both two amendments in combination gives the best results.

Table 2: Growth parameters *H. sabdariffa* L. 35 days after culture.

Treatment	Diameter (mm)	Leaf area (cm²)	Height (cm)
T0	2,1^{c}	9,02^{d}	10,96^{d}
A1	4,53^{abc}	20,55^{abc}	25,42^{bcd}
A2	4,32^{abc}	15,17^{cd}	20,28^{cd}
A3	3,78^{bc}	16,81^{bcd}	19,78^{cd}
S1	4,93^{abc}	20,31^{abc}	28,39^{bc}
S2	5,82^{ab}	23,28^{ab}	34,44^{ab}
S3	5,40^{abc}	21,19^{abc}	31,5^{abc}
A1 X S1	5,61^{ab}	28,02^{a}	34,05^{ab}
A1 X S2	5,95^{ab}	21,37^{abc}	30,11^{abc}
A1 X S3	6,15^{ab}	24,68^{ab}	34,85^{ab}
A2 X S1	5,42^{abc}	24,68^{ab}	29,33^{abc}
A2 X S2	5,73^{ab}	24,34^{ab}	34,85^{ab}
A2 X S3	6,57^{a}	25,71^{a}	38,39^{ab}
A3 X S1	6,15^{a}	25,22^{a}	30,50^{abc}
A3 X S2	5,94^{ab}	23,63^{ab}	34,0^{ab}
A3 X S3	6,50^{a}	24,49^{ab}	42,07^{a}

Digits followed by same superscript letter are not significantly different.
T0: Control; An: Ash; Sn: Scum; An X Sn: Ash X Scums.

Table 3: analysis of the variance of the main growth parameters.

Source	DDL	Somme des carrés	Moyenne des carrés	F	Pr > F	Significatif
Diam. (mm)	15	115,254	7,684	12,678	< 0,0001	Oui
Surface (cm^2)	15	1883,584	125,572	14,945	< 0,0001	Oui
Hauteur (cm)	15	4629,002	308,600	16,747	< 0,0001	Oui
Rendement 1	15	404,034	26,936	9,414	< 0,0001	Oui
Rendement 2	15	99,515	6,634	7,155	< 0,0001	Oui
Rendement 3	15	43,134	2,876	3,509	0,001	Oui

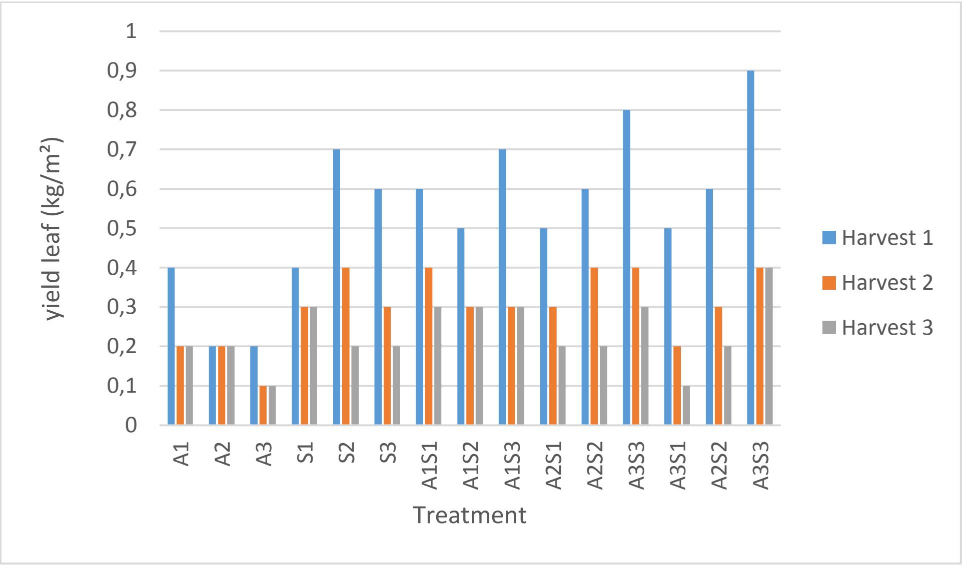

Figure 1: yield in leaves according to crops. T0: Control; An: Ash; Sn: Scum; An X Sn: Ash X Scums; R1: Harvest 1; R2: Harvest 2; R3: Harvest 3.

DISCUSSION

Our results indicated that all growth parameters, in particular the stem diameter, the leaf area and height of the stems, were considerably improved with the addition of ash, sugarcane scum alone or the combination of the two types of fertilizer. Leaf yields, which are the edible part, increased from double to triple with the combination of both types of fertilizer at high doses. Although differences are not significantly between the combinations, the both use of two amendments in combination, at high doses, improve the growth performance and foliar productivity of *H. sabdarifa*. The inorganic fertilizer supply from *Chromolena odorata* ash and sugarcane scum enriches the substrate with ferrallitic savanna soil, in which the mineralization is low, due to the complexity and toxicity of iron on microorganisms (Chabalier et al., 2005), as well as Dugué and Gigou (2002), have shown that acidity of these soils combined with their abundant geochemical background lead to an inhibition of microbial activity, which is a major factor in the mineralization process. This process remains low on the control soil, which would justify the low performance obtained by *H. sabdarifa* L. in the base substrate, compared to the substrates improved by ash, sugarcane scum alone or in combination. It would be interesting to use both fertilizers simultaneously, to improve leaf yields.

The ash of *C. odorarata* is obtained by incineration at 250 °C. The concentration of mineral elements in the ash therefore remains important because the temperature of combustion is below 538 °C, which does not significantly affect the chemical composition of ash (Saıdou et al., 2003). These ashes contains about 4% phosphorus, which plays an major role in roots development, implantation of young plants, general growth of plant and optimizes the various growth parameters studied. Also ash contains 10% potassium which confers rigidity to the plant. Moreover, the ash increases pH of the base substrate and consequently improves crop and life in the soil. The ash's pH is basic, it promotes root absorption mineral elements, in particular nitrogen. Its incorporation into the substrate improves soil structure with the addition of calcium and magnesium ions (Adekayode and Ogunkoya, 2011; Olatunji et al., 2015). This fact leads to a better absorption of nutrients by the crop (Chamayou and Legros, 1989). Yields increase of certain crops such as *Brassica napus* L., *Trifolium subterraneum* L. and *Cynodon dactylon* L.) Pers., have been observed by Mele et al. (2003) in soils fertilized by wood ash. The use of bagasse ash in wheat crops has proved to be particularly interesting and effective, as reported by Jamil et al. (2004), they have resulted in a significant yield increase due to their favorable effect on plant height, tillering and the number of seeds obtained in wheat. Mineralized elements supplied by the ash are in soluble or readily soluble form and are therefore readily available for plants and microorganisms (Obernberger and Supancic, 2009), which justifies the improvement of all growth parameters and yields of *H. sabdariffa* in fertilized substrates.

Sugarcane scum represents a source of valuable organic matter that enriches the base substrate. They are rich in calcium and phosphorus (Soobadar, 2009). These residues of sugar industry have a double interest due to the contribution of microorganisms but also the enrichment of substrate in minerals required for plant development. Chabalier et al. (2005) have shown that a supply of 30 tonnes per hectare of sugarcane scum represents the equivalent of 210 kg of nitrogen, 270 kg of phosphorus, 36 kg of potash, 255 kg of calcium and 600 kg of silica. Stabilized sugarcane scum has other beneficial effects, maintaining high soil organic matter, improving the soil structure in the acidic soil, increasing pH and above all preventing iron toxicity by complexing the ions ferric in solution. These sugarcane scum are therefore both an amendment, which improves the physico-chemical conditions of the soil, and a fertilizer which provides mineral elements for the plant growth.

The good growth and the high yield observed in the fertilized bags compared to the control soil reflect the richness of the substrate as a mineral element fertilizer throughout the vegetative cycle of the plant. These chemical elements present in the ashes and those resulting from the mineralization of the foams have enriched the soil with phosphorus, potassium, calcium and magnesium, consequently causing the high development of the sorrel. Oyewole and Mera (2010) and (Ognalaga and Itsoma, 2014) obtained similar results on *H. sabdarifa*, using organic amendments, with characteristics close to those of this study, the base medium was mixed with cow dung and green manure made up with *C. odorata* and *Leucaena leucocephala* L. de Wit. (Breton and Hébert, 2008) and Majeau et al. (2013) have also improved the yields of different crops such as maize, wheat, common beans and soybeans by improving the quality of different substrates with wood ash. The variations observed in leaf area of the plant could be explained by the fact that mineral requirements of *H. sabdarifa* would be small compared to those required for other growth parameters such as collar diameter and height. The supply of fertilizer units in large quantities by the combined addition of *C. odorata* ash and stabilized sugarcane scum in the ferralitic savanna soil base substrate would therefore be saturating and inhibit the increase leaf area.

Conclusion

In this study, the best results on both growth parameters and leaf yields were obtained with combination 0.5 kg / m² of ash and 2.5 kg / m² of sugarcane scum (S3A3). This optimal combination represents highest nutrient intake in the base substrate. Both fertilizers have physicochemical properties that differ highly in nutrient composition, physical characteristics, or biodegradability. Their combination therefore constitutes a complementarity that optimizes the set of growth parameter and yields. This method of growing sorrel, could be considered as an innovative method that can substitute the traditional metshod. It's a more intensive and speculative cultivation technique especially in peri-urban areas where pressure on land makes it difficult to cultivate extensive crops.

COMPETING INTERESTS

The authors declare that they have no competing interests

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