

EVALUATION OF THE EFFECT OF COMPOST FROM BY-PRODUCTS OF *JATROPHA CURCAS* L. (EUPHORBIACEAE) ON SOIL FERTILITY AND PRODUCTIVITY OF SORGHUM (*SORGHUM BICOLOUR* (L.) MOENCH) IN BURKINA FASO

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ABSTRACT

Modern agriculture faces to new challenges and problems. Application of organic waste compost represents new possibilities to improve soil organic matter and thus reduce the risk of soil degradation and improve significantly crop yield. This study was conducted to determine the effect of various compost-based *Jatropha* by-products on soil properties and sorghum (*Sorghum bicolor* L.) Moench) growth and production parameters. The treatments of the study corresponded to 13 formulations of *Jatropha curcas* based composts and a control treatment, which did not receive any application. The study showed that *Jatropha* by-products amendment could effectively raise soil fertility by increasing pH and nutrient contents and improved sorghum growth and production parameters. The results also showed positive and significant correlations between panicles yield and seeds yield as well as straws yield. Positive and significant correlations were recorded between seeds yield and straws yield and weight of 100 seeds. These correlations between the different parameters are important of simultaneous improving of growth and crops yield of sorghum. The ACP performed based on measurement parameters permitted to identify the appropriate formulation for any interest parameter. The CAH distinguished four classes of composts among which *Jatropha* biomass-based composts with groups 3 (BM_S and BM+BV) and 4 (BM+CP) are particularly interesting as these treatments are strongly associated with seeds, straw and panicle yields, sorghum spike height

growth and soil fertility improvement. These results supported the best effects of the application of various compost-based by-products of *Jatropha curcas* in sorghum production.

Keywords: *Jatropha curcas*, composts, sorghum, growth, crop yield

1. INTRODUCTION

In developing countries, particularly in sub-Saharan Africa, access to energy is a major constraint for the population. In fact, these countries are characterised by a dependence on fossil fuels, mainly imports, which account for nearly 39% of total energy consumption in sub-Saharan Africa (AfDB, 2006). These energy sources provide more than half of household and industrial electrification. Therefore, energy may become a constraint to the economic development of the region, on the one hand due to limited energy supply, on the other hand due to the high demand in the process of urbanisation. Hence the need to diversify energy sources (Dia et al., 2010). The issue of energy transition should be rethought by giving priority, not to access to modern lighting, but to productive energy services with a view to strengthening the creation of jobs, income and added value (Hanff et al., 2011). In Burkina Faso, many policy options are being implemented to reduce energy dependence and vulnerability, including the introduction of biofuels into agricultural systems. Oils and biodiesel derived from *Jatropha curcas* are considered to be the best alternative to fossil fuels to reduce CO₂ emissions and provide accessible energy to the most vulnerable populations (Janin and Ouédraogo, 2009). Although *Jatropha* does not require high soil fertility, its development requires good management to avoid soil competition between food and energy production (Firdaus and Husni, 2012). Previous studies have reported a good association of this species with food crops without harmful competition (Derra et al., 2013 ; Bazongo et al., 2015). However, this plant has always been known to be phytotoxic to humans and animals (Das and Chandran, 2011); this raised the question of the possible phytotoxicity of its biomass (residual or composted) in relation to adjacent cereal plants.

The reduction of tropical soil fertility and crop productivity is a major concern and indeed a great hindrance to achieving food sufficiency in the tropics (Olowoake et al., 2018). Farmers use mineral fertilizers to improve soil fertility (Powelson et al., 2011). However, the massive use of these fertilizers and some poor farming practices have greatly reduced the organic matter content of soils, directly influencing the physical, chemical and biological properties, and the risk of soil degradation. So, the main consequence of the aforementioned agronomic practices could be the mineralization and desertification of soils (Calderón et al., 2013). Organic fertilisers would be a good method of soil management and are used among others to reduce the adverse effects of synthetic fertilisers on human health and the environment (Diallo, 2011). In addition to being a source of nutrients for crops through its mineral component, organic manure improves the

biological and physical properties of the soil through its organic component (**Ganry et al., 2001; Khan et al., 2019**). Among these organic fertilizers, compost is frequently advocated as a simple and inexpensive solution for a wide variety of agronomic, environmental and socio-economic problems (**Ishola and Ishola, 2019**). In agricultural soils, compost addition increases porosity, structural stability, boost the growth and activity of useful organisms in the soil, ease micronutrient deficiencies, and sustain higher yield due to better soil health (**Tiwari, 2002; Singh et al., 2006**).

The production of organic fertilisers is limited by the decrease in biomass production which restricts the possibility of compost production; hence the need to explore new sources of fertilisers based on agricultural by-products (**Traore et al., 2015**). Agricultural by-products that cannot be used for other purposes could be a solution to improve soil fertility at low cost in Sudano-Sahelian Africa (**Olowoake, 2019**). In this context, *Jatropha* is of particular interest because more than 85% of its seed biomass is not used to produce biofuel. These are oil cakes and hulls, whose elimination and/or recovery are essential to avoid the problems associated with the management of such solid waste. It is also a loss of income for all actors in the sector. Finding a long-term, inexpensive and environmentally viable solution to recycle and transform these cakes into valuable products is therefore of crucial importance for the sustainability of the sector (**Primandari et al., 2018; Grover et al., 2019**). Significant protein (58%), nitrogen (3.2-4.5%), phosphorus (1.4-2.1%) and potassium (1.2-1.7%) contents in *Jatropha* seed cake were reported by **Kumar and Sharma (2008)**. The presences of these elements were recognized as the organic nutrients sources that are even higher than that of chicken or cow manure. Also, scientific results provide evidence for ways to valorise *Jatropha* pods in compost (**Pandey et al., 2012**). Investigations must be undertaken to confirm the effect of the use of compost from by-products of *Jatropha* on crop production. It is to contribute to this concern that the present study was initiated with the objective of assessing the impact of various compost-based *Jatropha curcas* by-products on soil properties, growth parameters and production yields of *Sorghum bicolor*.

2. MATERIALS ET METHODS

2.1 Presentation of the experimental site

The study was carried out during the crop years 2015, 2016 and 2017 at the experimental site of the agricultural research station of Saria (Figure 1).

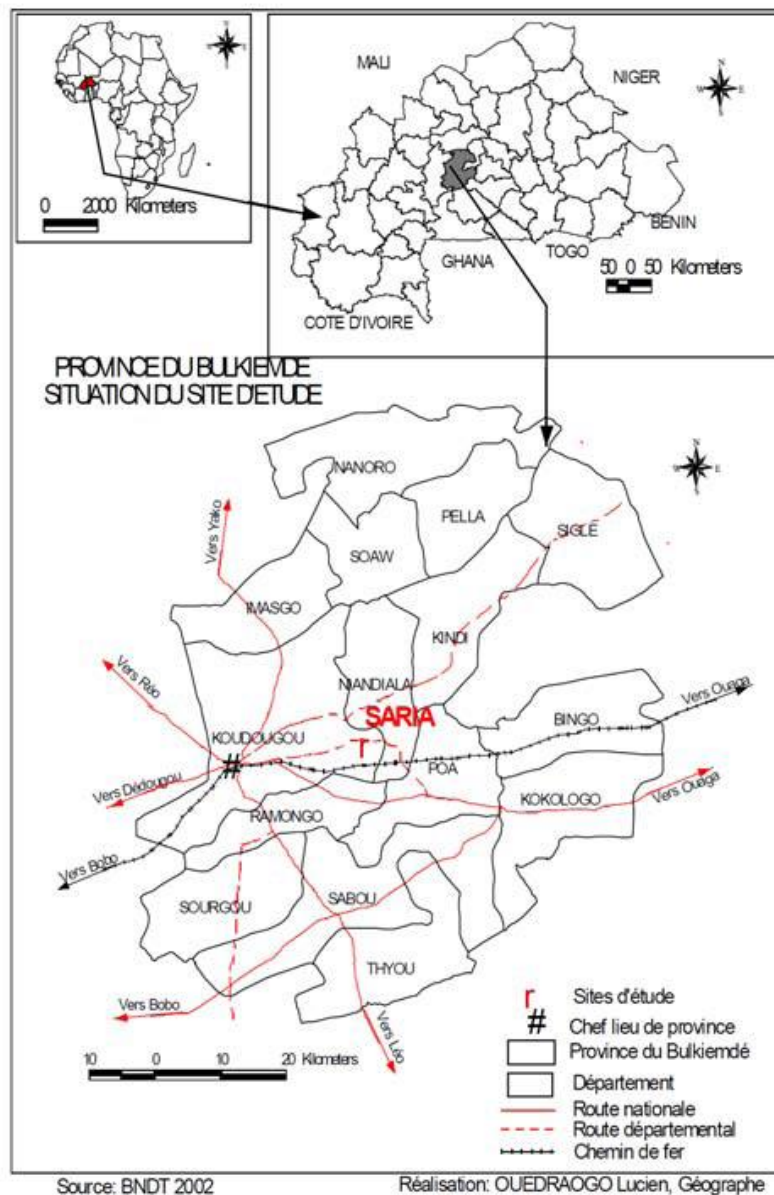


Figure 1: Saria localization map (Yélé mou et al., 2013)

2.2 Pedoclimatic conditions of the experimental site

The experimental site is located in the Sudano-Sahelian zone with an average annual rainfall of 800 mm which extends from May to October with large inter and intra annual fluctuations. The average temperature is about 30°C per year. Relative humidity is less than 20% in the dry season and exceeds 60% in the rainy season (Mando et al., 2005). The Saria agronomy station has a meteorological monitoring station with daily monitoring of rainfall, evapotranspiration and

atmospheric temperature. Rainfall data for the three campaigns and the mean are presented in figures 2.

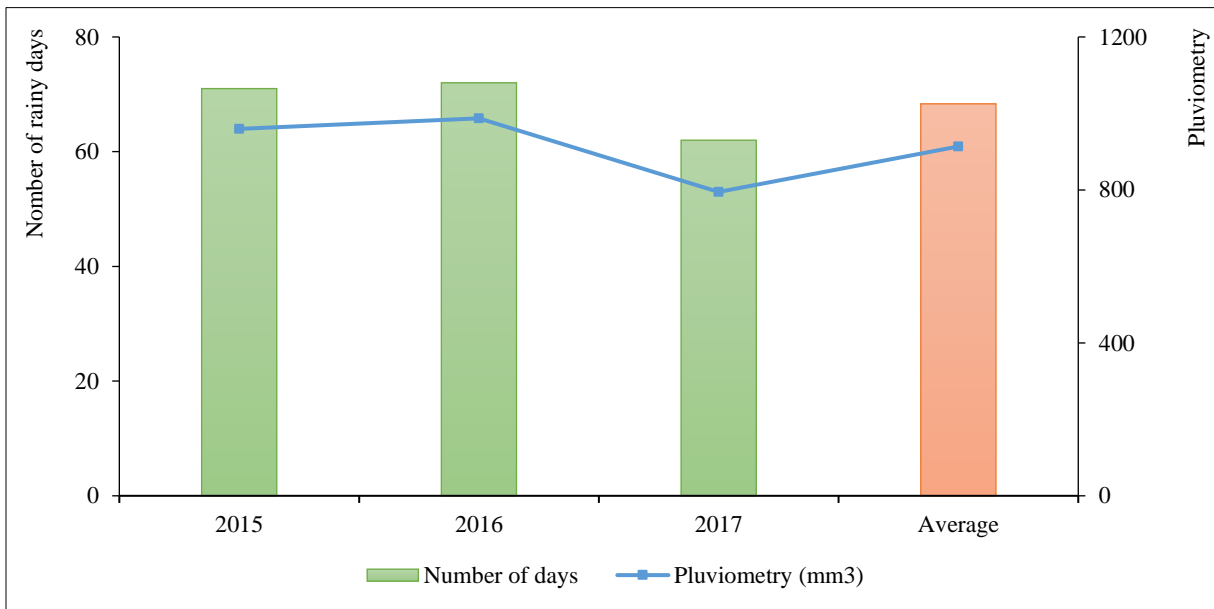


Figure 2: Cumulative rainfall and number of rainy days per season

2.3 Plant material

The culture system set up corresponds to a monoculture of *Sorghum bicolor*, variety ICSV 1049 (Figure 3), which technical data sheet (Agridata, 2013) is given in table 1.



Figure 3: *Sorghum bicolor*, variety ICSV 1049

Table 1: Technical data sheet of the test plant

Name	ICSV 1049
Cycle	105 - 110 days
Station yield	4 t/ha
Yield in peasant environment	1 – 1.5 t/ha
Rainfall of growing areas	700 - 1000 mm

2.4 Treatments used

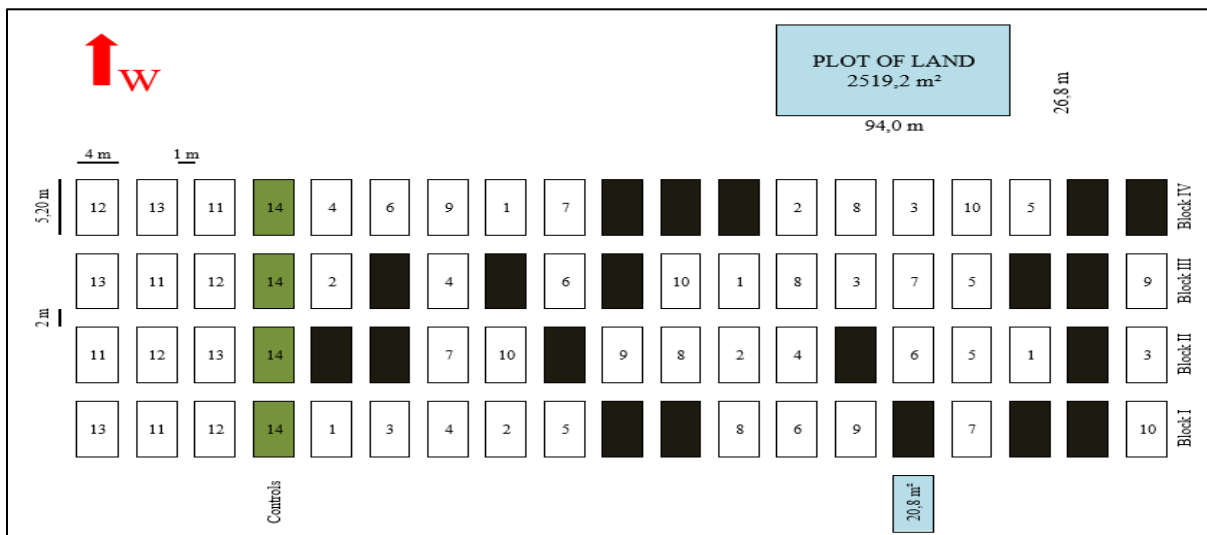
The treatments correspond to 13 composts formulations of *Jatropha curcas* based composts. The table 2 shows the compositions of the different compost formulations.

Table 2: List of applied composts

Codes	Treatments
G_S	<i>Jatropha</i> pod alone
G+CP	<i>Jatropha</i> pod + Compost plus
G+BV	<i>Jatropha</i> pod + Cow dung
T_S	<i>Jatropha</i> cake alone
T+CP	<i>Jatropha</i> cake + Compost plus
T+BV	<i>Jatropha</i> cake + Cow dung
P+CP	Straw of sorghum + Compost plus
P_S	Straw of sorghum alone
G+DA	<i>Jatropha</i> pod + Slaughterhouse waste
T+DA	<i>Jatropha</i> Cake + Slaughterhouse waste
BM_S	Biomass of <i>Jatropha</i> alone
BM+CP	Biomass of <i>Jatropha</i> + Compost plus
BM+BV	Biomass of <i>Jatropha</i> + Cow dung

2.5 Experimental layout

The experimental layout is a complete randomised block (Figure 4), with elementary plots of 5.20 x 4 m with 1 m separated and 4 blocks with 2 m separated. For each treatment, a dose of 5 t/ha or 10.4 kg of compost was applied to each unit plot at the beginning of the campaign, except in the control plot. A control plot was considered in each block. After spreading the various substrates (composts), plowing is done to the cattle at 15-20 cm deep. An extended dose of NPK is given 15 days after sowing and urea 30 days after weeding.



(The plots in black have not been considered in the experiment)

Figure 4: The experimental field

2.6 Evaluation of soil fertility parameters of the different treatments

- The pH-H₂O and pH-KCl were measured by the electrometric glass electrode method using a pH meter in a mass to volume ratio (1 g / 2.5 mL). The soil/water suspension (or KCl solution) was stirred for one hour before reading.
- Total organic carbon was determined using the method described by **Walkley and Black (2003)** with modifications. The organic carbon is oxidised in a concentrated sulphuric medium by excess potassium dichromate; as this oxidation is incomplete (on average 75%), the results were corrected by multiplying by the ratio 100/75. The rate of organic matter is then obtained by the formula: Rate of Organic Matter = Rate of carbon x 1.724.
- Total nitrogen was determined using the Kjeldahl method based on French standards (**Norme NF, 1994**). The determination is made by attacking the organic matter with concentrated sulphuric acid in the presence of selenium as a catalyst. The organic nitrogen is mineralised and converted to the ammoniacal state as ammonium sulphate (NH₄)₂SO₄. Nitrates and nitrites are not converted. The ammoniacal nitrogen thus obtained is determined by colorimetry.
- Total phosphorus and total potassium were determined by the Bray 1 method cited by (**Michaelson et al., 1987**). This determination is carried out using a mixed solution of ammonium fluoride and hydrochloric acid. This solution allows the extraction of acid-soluble phosphorus. Ammonium fluoride dissolves iron and aluminium phosphates by

forming complexes with these metals in an acid medium. Total phosphorus is determined by automatic colorimetry and total potassium is determined by flame photometry.

2.7 Evaluation of sorghum agronomic parameters

The agronomic parameters evaluated are plant height, weight of 100 seeds and evaluation of seed, panicles and straws yields. Plant height measurements were made successively at three stages of sorghum development (lifted, flowering and maturation). Yield parameters (panicles, seeds, straw) and weight of 100 seeds were evaluated at harvest.

2.8 Statistical analyses

All experiments were repeated three times with four replicates per treatment for sorghum seeds production. Data were treated with MS Excel and then subjected to analysis of variance (ANOVA) using XL-Stat 2016 software. Newman-Keuls multiple rank test at the 5% threshold was used to separate the means.

3. RESULTS

3.1 Effect of *Jatropha* composts on soil fertility

The acidity of the soils after application of the different treatments are presented in the table 3. The results showed a significant variation between the different treatments for the parameters pH-H₂O and pH-KCl. In general, all treatments significantly improved pH-H₂O and pH-KCl compared to the control. In addition, treatment G+BV gave the best values of pH-H₂O and pH-KCl respectively 5.7 and 5.3.

Table 3: Acidity of soils

Treatments	pH-H ₂ O	pH-KCl
G_S	5.4 ± 0.8 ^{ab}	5.0 ± 0.8 ^{abc}
G+CP	5.2 ± 0.1 ^{abc}	4.8 ± 0.2 ^{abc}
G+BV	5.7 ± 0.8 ^a	5.3 ± 0.9 ^a
T_S	5.1 ± 0.3 ^{abc}	4.8 ± 0.7 ^{abc}
T+CP	5.1 ± 0.4 ^{abc}	4.7 ± 0.4 ^{abc}
T+BV	5.2 ± 0.5 ^{abc}	4.8 ± 0.6 ^{abc}
P+CP	5.1 ± 0.3 ^{abc}	4.8 ± 0.3 ^{abc}
P_S	5.2 ± 0.3 ^{abc}	4.8 ± 0.3 ^{abc}
G+DA	5.0 ± 0.3 ^{bc}	4.6 ± 0.3 ^{abc}
T+DA	5.2 ± 0.4 ^{abc}	4.9 ± 0.4 ^{abc}
BM_S	5.0 ± 0.2 ^{bc}	4.6 ± 0.1 ^{bc}
BM+CP	5.4 ± 0.8 ^{ab}	5.3 ± 1.0 ^{ab}

BM+BV	4.9 ± 0.1 ^{bc}	4.5 ± 0.2 ^c
Control	4.7 ± 0.3 ^c	4.4 ± 0.2 ^c
Pr > F	0.001	0.001
Significant	Yes	Yes

For each variable, values that have the same subscript are not significantly different according to Newman-Keuls test at 5% level.

Legend: G_S (Jatropha pod alone), G+CP (Jatropha pod + Compost+), G+BV (Jatropha pod + Cow dung), T_S (Jatropha cake alone), T+CP (Jatropha cake + Compost+), T+BV (Jatropha cake + Cow dung), P+CP (Straw of sorghum + Compost+), P_S (Straw of sorghum alone), G+DA (Jatropha pod + Slaughterhouse waste), T+DA (Jatropha cake + Slaughterhouse waste), BM_S (Biomass of Jatropha alone), BM+CP (Biomass of Jatropha + Compost+), BM+BV (Biomass of Jatropha + Cow dung)

The table 4 shows the physicochemical properties of the different soils after application of *Jatropha curcas* composts. Apart from potassium, all other parameters evaluated varied significantly between treatments. Thus, treatment BM+CP presented the best values of OM (0.61 ± 0.04 %), carbon (3.54 ± 0.23 g/kg of soil), nitrogen (0.29 ± 0.04 g/kg of soil) and treatment T+CP presented the best value of phosphorus (0.07 ± 0.02 g/kg of soil).

Table 4: Physicochemical parameters of soil

Treatments	OM (%)	Carbon (g/kg soil)	Nitrogen (g/kg soil)	Phosphorus (g/kg soil)	Potassium (g/kg soil)	C/N
G_S	0.51 ± 0.04 ^{bcd}	2.95 ± 0.21 ^{bcd}	0.22 ± 0.03 ^{bc}	0.04 ± 0.00 ^{bc}	1.05 ± 0.09 ^a	14 ± 2 ^a
G+CP	0.43 ± 0.07 ^d	2.49 ± 0.41 ^d	0.25 ± 0.03 ^{abc}	0.05 ± 0.01 ^{bc}	1.06 ± 0.08 ^a	10 ± 1 ^b
G+BV	0.46 ± 0.07 ^{cd}	2.64 ± 0.39 ^{cd}	0.21 ± 0.03 ^c	0.05 ± 0.01 ^{bc}	1.00 ± 0.04 ^a	13 ± 1 ^{ab}
T_S	0.57 ± 0.07 ^{ab}	3.32 ± 0.38 ^{ab}	0.26 ± 0.05 ^{abc}	0.05 ± 0.01 ^{bc}	1.00 ± 0.09 ^a	13 ± 2 ^{ab}
T+CP	0.56 ± 0.01 ^{ab}	3.27 ± 0.07 ^{ab}	0.27 ± 0.05 ^{abc}	0.07 ± 0.02 ^a	1.00 ± 0.09 ^a	12 ± 1 ^{ab}
T+BV	0.50 ± 0.06 ^{bcd}	2.88 ± 0.37 ^{bcd}	0.26 ± 0.05 ^{abc}	0.06 ± 0.02 ^{ab}	0.87 ± 0.05 ^a	11 ± 2 ^{ab}
P+CP	0.47 ± 0.08 ^{bcd}	2.71 ± 0.48 ^{bcd}	0.23 ± 0.03 ^{abc}	0.06 ± 0.01 ^{ab}	0.94 ± 0.12 ^a	12 ± 1 ^{ab}
P_S	0.48 ± 0.01 ^{bcd}	2.80 ± 0.03 ^{bcd}	0.21 ± 0.02 ^c	0.03 ± 0.01 ^c	0.96 ± 0.13 ^a	14 ± 1 ^a
G+DA	0.53 ± 0.03 ^{abcd}	3.08 ± 0.20 ^{abcd}	0.22 ± 0.03 ^{abc}	0.05 ± 0.01 ^{bc}	1.07 ± 0.09 ^a	14 ± 1 ^a
T+DA	0.53 ± 0.03 ^{abcd}	3.08 ± 0.16 ^{abcd}	0.24 ± 0.04 ^{abc}	0.04 ± 0.01 ^{bc}	1.01 ± 0.12 ^a	13 ± 1 ^{ab}
BM_S	0.51 ± 0.03 ^{bcd}	2.98 ± 0.20 ^{bcd}	0.28 ± 0.03 ^{ab}	0.04 ± 0.00 ^{bc}	0.94 ± 0.12 ^a	11 ± 1 ^{ab}
BM+CP	0.61 ± 0.04 ^a	3.54 ± 0.23 ^a	0.29 ± 0.04 ^a	0.06 ± 0.01 ^{bc}	1.01 ± 0.17 ^a	13 ± 1 ^{ab}
BM+BV	0.54 ± 0.04 ^{abc}	3.13 ± 0.25 ^{abc}	0.28 ± 0.02 ^{ab}	0.05 ± 0.01 ^{bc}	0.96 ± 0.06 ^a	11 ± 1 ^{ab}
Control	0.47 ± 0.05 ^{bcd}	2.73 ± 0.31 ^{bcd}	0.22 ± 0.03 ^{abc}	0.04 ± 0.00 ^{bc}	1.04 ± 0.07 ^a	13 ± 1 ^{ab}
Pr > F	0.000	0.000	0.000	0.000	0.530	0.007
Significant	Yes	Yes	Yes	Yes	No	Yes

For each variable, values that have the same subscript are not significantly different according to Newman-Keuls test at 5% level.

Legend: G_S (Jatropha pod alone), G+CP (Jatropha pod + Compost+), G+BV (Jatropha pod + Cow dung), T_S (Jatropha cake alone), T+CP (Jatropha cake + Compost+), T+BV (Jatropha cake + Cow dung), P+CP (Straw of sorghum + Compost+), P_S (Straw of sorghum alone), G+DA (Jatropha pod + Slaughterhouse waste), T+DA (Jatropha cake + Slaughterhouse waste)

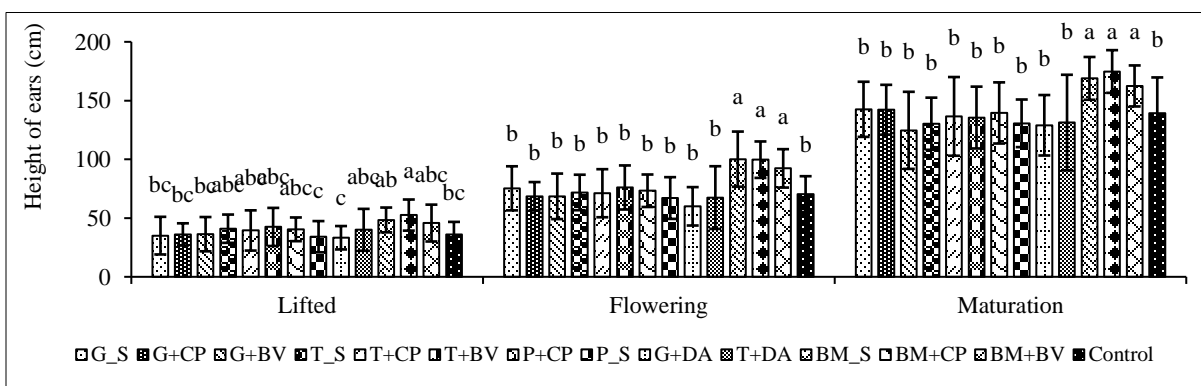
Slaughterhouse waste), BM_S (Biomass of *Jatropha* alone), BM+CP (Biomass of *Jatropha* + Compost+), BM+BV (Biomass of *Jatropha* + Cow dung)

3.2 Effect of *Jatropha* composts on the growth of *Sorghum bicolor*

The following figures (5, 6 and 7) represent the height growth of *Sorghum* cobs in the 2015, 2016 and 2017 crop years. The results (n = 20) are expressed in cm as an average ± standard deviation. In general, there is a significant statistical difference regardless of the campaign and measurement period.

For the 2015 season (Figure 5), exception of lifted period, all treatments showed a similar growth of *Sorghum* ears compared to the Control (70 cm - 139 cm). Only BM_S (100 cm - 169 cm), BM+CP(100 cm - 175 cm) and BM+BV(92 cm -162 cm) treatments showed the best height growth compared to control. In 2016 (Figure 6), all treatments-based *Jatropha* leaf (BM_S, BM+CP and BM+BV) showed statistically the best *Sorghum* ears height growth regardless of measurement period compared to the control with the lowest height values (32 cm - 106 cm - 158 cm). For the 2017 season (Figure 7), we have the same observations as in 2016 for the lifted and flowering periods. Treatments BM_S, BM+CP and T+BV gave the best statistical growth in ears height regardless of the measurement period. Control heights recorded were the lowest over the three measurement periods.

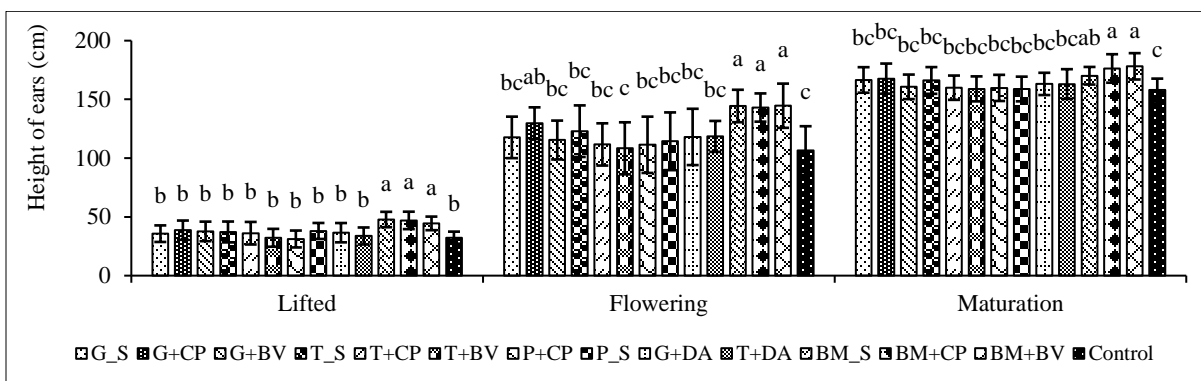
Overall, the 2016 season showed the best growth in *Sorghum* ears height compared to the 2015 and 2017 seasons for all measurement periods.



For each measurement period, values that have the same subscript are not significantly different according to Newman-Keuls test at 5% level.

Legend: G_S (*Jatropha* pod alone), G+CP (*Jatropha* pod + Compost+), G+BV (*Jatropha* pod + Cow dung), T_S (*Jatropha* cake alone), T+CP (*Jatropha* cake + Compost+), T+BV (*Jatropha* cake + Cow dung), P+CP (Straw of sorghum + Compost+), P_S (Straw of sorghum alone), G+DA (*Jatropha* pod + Slaughterhouse waste), T+DA (*Jatropha* cake + Slaughterhouse waste), BM_S (Biomass of *Jatropha* alone), BM+CP (Biomass of *Jatropha* + Compost+), BM+BV (Biomass of *Jatropha* + Cow dung)

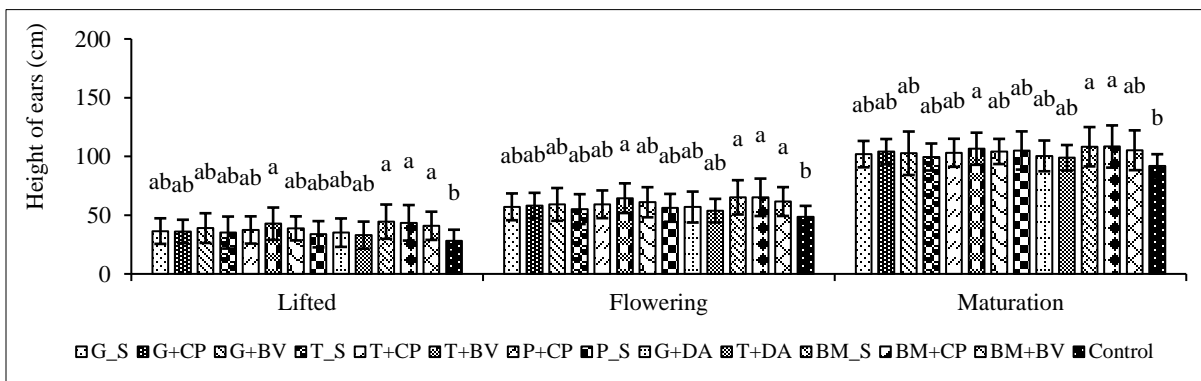
Figure 5: Sorghum's plant height growth, Campaign 2015



For each measurement period, values that have the same subscript are not significantly different according to Newman-Keuls test at 5% level.

Legend: G_S (*Jatropha* pod alone), G+CP (*Jatropha* pod + Compost+), G+BV (*Jatropha* pod + Cow dung), T_S (*Jatropha* cake alone), T+CP (*Jatropha* cake + Compost+), T+BV (*Jatropha* cake + Cow dung), P+CP (Straw of sorghum + Compost+), P_S (Straw of sorghum alone), G+DA (*Jatropha* pod + Slaughterhouse waste), T+DA (*Jatropha* cake + Slaughterhouse waste), BM_S (Biomass of *Jatropha* alone), BM+CP (Biomass of *Jatropha* + Compost+), BM+BV (Biomass of *Jatropha* + Cow dung)

Figure 6: Sorghum's plant height growth, Campaign 2016



For each measurement period, values that have the same subscript are not significantly different according to Newman-Keuls test at 5% level.

Legend: G_S (*Jatropha* pod alone), G+CP (*Jatropha* pod + Compost+), G+BV (*Jatropha* pod + Cow dung), T_S (*Jatropha* cake alone), T+CP (*Jatropha* cake + Compost+), T+BV (*Jatropha* cake + Cow dung), P+CP (Straw of sorghum + Compost+), P_S (Straw of sorghum alone), G+DA (*Jatropha* pod + Slaughterhouse waste), T+DA (*Jatropha* cake + Slaughterhouse waste), BM_S (Biomass of *Jatropha* alone), BM+CP (Biomass of *Jatropha* + Compost+), BM+BV (Biomass of *Jatropha* + Cow dung)

Figure 7: Sorghum's plant height growth, Campaign 2017

3.3 Effect of *Jatropha* composts on sorghum crop yields

Sorghum panicle, seed and straw production yields for the 2015, 2016 and 2017 seasons were summarised in table 5. The results are presented as mean ± standard deviation (n = 4) and expressed in t/ha and in grams for the weight of 100 seeds.

For the 2015 season, there is a statistical difference regardless of the treatment for measured yields. Yield values (in t/ha) range from 1.4 ± 0.2 to 2.7 ± 0.6 for straw, 0.6 ± 0.1 to 1.8 ± 0.1 for panicles, 0.4 ± 0.1 to 1.3 ± 0.5 for seeds. The best straw and seed yields were obtained with the BM+CP treatment and for panicles with the 3 *Jatropha* biomass-based compost treatments (BM_S, BM+CP and BM+BV). The lowest yields were recorded with the control treatment.

All yields in the following two years showed no significant difference regardless of treatment. In 2016, G_S recorded the highest straws yield (6.4 ± 0.8 t/ha) and BM+BV recorded the highest panicle yield (2.5 ± 0.9 t/ha) and seed yield (1.8 ± 0.8 t/ha) compared to the control that gave the lowest values. In 2017, the best straw (1.6 ± 0.0 t/ha), panicle (0.9 ± 0.0 t/ha) and seeds (0.6 ± 0.2 t/ha) yields were obtained with the T_S and BM+CP treatments compared to the other treatments and the control.

According to the weight of 100 seeds, a statistical difference was only noted for the 2017 season but with more or less the same weight values. Nevertheless, slightly heavier seeds are noted for the 2017 season.

In general, the 2016 season was the most productive with higher yields of sorghum straws, panicles and seeds compared to the 2015 and 2017 seasons.

Table 5: Sorghum crop yields and weight of 100 seeds

Treatments	Campaign 2015				Campaign 2016				Campaign 2017			
	Straws (t/ha)	Panicles (t/ha)	Seeds (t/ha)	Weight of 100 seeds (g)	Straws (t/ha)	Panicles (t/ha)	Seeds (t/ha)	Weight of 100 seeds (g)	Straws (t/ha)	Panicles (t/ha)	Seeds (t/ha)	Weight of 100 seeds (g)
G_S	2.1 ± 0.6 ^{ab}	1.2 ± 0.3 ^{ab}	0.9 ± 0.2 ^{abc}	2.5 ± 0.5 ^a	6.4 ± 0.8 ^a	2.1 ± 0.2 ^a	1.6 ± 0.2 ^a	2.2 ± 0.1 ^a	0.9 ± 0.1 ^a	0.6 ± 0.1 ^a	0.3 ± 0.2 ^a	2.4 ± 0.3 ^b
G+CP	1.9 ± 0.2 ^{ab}	0.9 ± 0.2 ^{ab}	0.6 ± 0.2 ^{abc}	2.0 ± 0.1 ^a	5.6 ± 2.3 ^a	2.0 ± 0.3 ^a	1.5 ± 0.3 ^a	2.2 ± 0.2 ^a	0.9 ± 0.1 ^a	0.6 ± 0.2 ^a	0.4 ± 0.2 ^a	2.6 ± 0.1 ^{ab}
G+BV	1.4 ± 0.4 ^b	0.7 ± 0.2 ^b	0.5 ± 0.2 ^{bc}	2.2 ± 0.3 ^a	5.4 ± 0.8 ^a	1.9 ± 0.3 ^a	1.4 ± 0.4 ^a	2.2 ± 0.1 ^a	0.9 ± 0.2 ^a	0.6 ± 0.1 ^a	0.3 ± 0.2 ^a	2.4 ± 0.3 ^b
T_S	1.7 ± 0.4 ^{ab}	1.0 ± 0.5 ^{ab}	0.8 ± 0.4 ^{abc}	2.2 ± 0.3 ^a	5.6 ± 0.8 ^a	2.1 ± 0.2 ^a	1.4 ± 0.2 ^a	2.4 ± 0.2 ^a	1.6 ± 0.0 ^a	0.9 ± 0.0 ^a	0.6 ± 0.2 ^a	2.8 ± 0.1 ^{ab}
T+CP	1.7 ± 0.6 ^{ab}	1.2 ± 0.5 ^{ab}	0.8 ± 0.4 ^{abc}	2.6 ± 0.4 ^a	6.1 ± 2.0 ^a	1.8 ± 0.6 ^a	1.3 ± 0.5 ^a	2.3 ± 0.0 ^a	1.3 ± 0.0 ^a	0.7 ± 0.3 ^a	0.4 ± 0.2 ^a	3.0 ± 0.2 ^a
T+BV	1.9 ± 0.3 ^{ab}	1.1 ± 0.1 ^{ab}	0.7 ± 0.1 ^{abc}	2.3 ± 0.1 ^a	4.4 ± 0.4 ^a	1.9 ± 0.3 ^a	1.3 ± 0.4 ^a	2.3 ± 0.1 ^a	0.7 ± 0.2 ^a	0.5 ± 0.0 ^a	0.3 ± 0.0 ^a	2.7 ± 0.1 ^{ab}
P+CP	1.8 ± 0.5 ^{ab}	0.9 ± 0.2 ^{ab}	0.6 ± 0.2 ^{abc}	2.3 ± 0.3 ^a	5.4 ± 0.7 ^a	1.9 ± 0.4 ^a	1.3 ± 0.3 ^a	2.2 ± 0.1 ^a	0.5 ± 0.2 ^a	0.4 ± 0.1 ^a	0.3 ± 0.1 ^a	2.6 ± 0.3 ^{ab}
P_S	1.6 ± 0.2 ^{ab}	0.7 ± 0.4 ^b	0.5 ± 0.3 ^{bc}	2.1 ± 0.2 ^a	4.2 ± 1.3 ^a	1.6 ± 0.4 ^a	1.1 ± 0.3 ^a	2.2 ± 0.2 ^a	0.6 ± 0.1 ^a	0.4 ± 0.1 ^a	0.2 ± 0.0 ^a	2.4 ± 0.3 ^b
G+DA	1.8 ± 0.5 ^{ab}	1.0 ± 0.2 ^{ab}	0.7 ± 0.2 ^{abc}	2.3 ± 0.1 ^a	4.4 ± 2.0 ^a	2.0 ± 0.6 ^a	1.4 ± 0.5 ^a	2.3 ± 0.2 ^a	1.2 ± 0.0 ^a	0.7 ± 0.4 ^a	0.5 ± 0.2 ^a	2.3 ± 0.2 ^b
T+DA	1.5 ± 0.3 ^{ab}	0.9 ± 0.3 ^{ab}	0.7 ± 0.3 ^{abc}	2.5 ± 0.4 ^a	5.5 ± 1.1 ^a	2.2 ± 0.6 ^a	1.6 ± 0.7 ^a	2.3 ± 0.1 ^a	0.5 ± 0.2 ^a	0.4 ± 0.1 ^a	0.2 ± 0.1 ^a	2.3 ± 0.2 ^b
BM_S	2.5 ± 0.8 ^{ab}	1.7 ± 0.7 ^a	1.2 ± 0.6 ^{ab}	2.1 ± 0.1 ^a	5.7 ± 1.6 ^a	2.2 ± 0.4 ^a	1.6 ± 0.3 ^a	2.4 ± 0.1 ^a	1.3 ± 0.1 ^a	0.7 ± 0.3 ^a	0.5 ± 0.1 ^a	2.5 ± 0.1 ^{ab}
BM+CP	2.7 ± 0.6 ^a	1.8 ± 0.5 ^a	1.3 ± 0.5 ^a	2.2 ± 0.3 ^a	5.0 ± 1.9 ^a	2.3 ± 0.8 ^a	1.6 ± 0.6 ^a	2.3 ± 0.0 ^a	1.5 ± 0.3 ^a	0.9 ± 0.2 ^a	0.6 ± 0.2 ^a	2.6 ± 0.3 ^{ab}
BM+BV	2.6 ± 0.9 ^{ab}	1.7 ± 0.6 ^a	1.2 ± 0.6 ^{ab}	2.3 ± 0.2 ^a	5.9 ± 2.5 ^a	2.5 ± 0.9 ^a	1.8 ± 0.8 ^a	2.3 ± 0.1 ^a	1.4 ± 0.3 ^a	0.8 ± 0.2 ^a	0.5 ± 0.1 ^a	2.8 ± 0.2 ^{ab}
Control	1.4 ± 0.2 ^b	0.6 ± 0.1 ^b	0.4 ± 0.1 ^c	1.9 ± 0.0 ^a	3.3 ± 1.0 ^a	1.5 ± 0.2 ^a	1.1 ± 0.2 ^a	2.1 ± 0.1 ^a	1.0 ± 0.2 ^a	0.6 ± 0.2 ^a	0.3 ± 0.1 ^a	2.5 ± 0.4 ^{ab}
Pr > F	0.005	0.000	0.002	0.043	0.276	0.362	0.566	0.061	0.191	0.322	0.129	0.003
Significant	Yes	Yes	Yes	No	No	No	No	No	No	No	No	Yes

For each campaign and variable, values that have the same subscript are not significantly different according to Newman-Keuls test at 5% level

Legend: G_S (*Jatropha* pod alone).G+CP (*Jatropha* pod + Compost+).G+BV (*Jatropha* pod + Cow dung). T_S (*Jatropha* cake alone). T+CP (*Jatropha* cake + Compost+). T+BV (*Jatropha* cake + Cow dung). P+CP (Straw of sorghum + Compost+).P_S (Straw of sorghum alone).G+DA (*Jatropha* pod + Slaughterhouse waste). T+DA (*Jatropha* cake + Slaughterhouse waste). BM_S (Biomass of *Jatropha* alone). BM+CP (Biomass of *Jatropha* + Compost+). BM+BV (Biomass of *Jatropha* + Cow dung)

3.4 Effect of treatments on agronomic parameters and comparison between campaigns

The table 6 shows the effect of the seasons on the parameters studied. It shows that the 2016 season gave the best growth in height of sorghum ears and the best production yields compared to the 2015 and 2017 seasons. However, the 2017 season presented the heaviest seeds.

Table 6: Effect of seasons on studied parameters

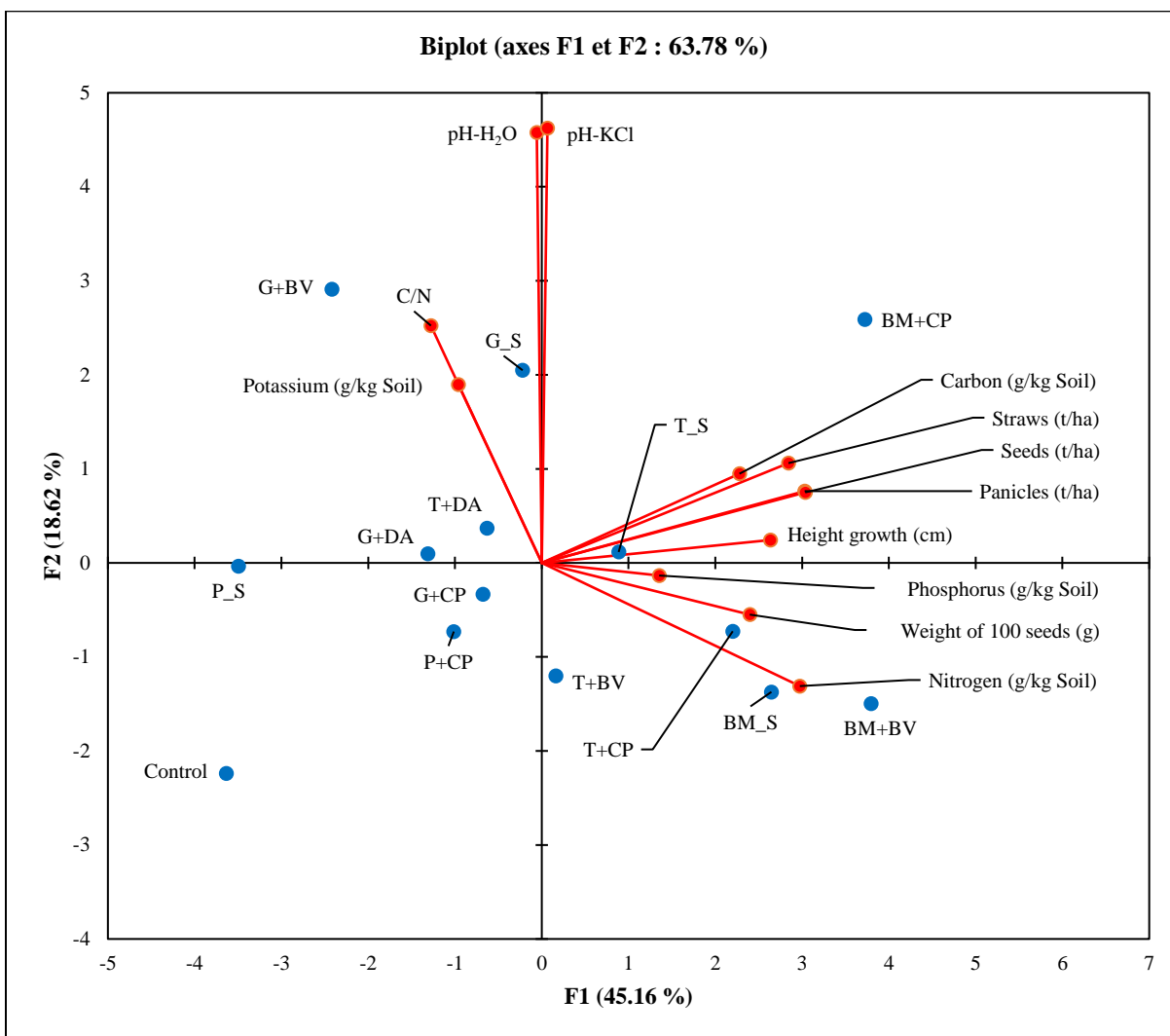
Campaigns	Height growth (cm)	Panicles (t/ha)	Seeds (t/ha)	Straws (t/ha)	Weight of 100 seeds (g)
2016	164 ^a	2.0 ^a	1.4 ^a	5.2 ^a	2.3 ^b
2015	144 ^b	1.1 ^b	0.8 ^b	1.9 ^b	2.2 ^b
2017	101 ^c	0.6 ^c	0.4 ^c	1.0 ^c	2.6 ^a
Pr > F	0.000	0.000	0.000	0.000	0.000
Significant	Yes	Yes	Yes	Yes	Yes

For each variable, values that have the same subscript are not significantly different according to Newman-Keuls test at 5% level

3.5 Compost properties and correlations between studied parameters

The figure 8 shows a principal component analysis based on the physicochemical properties of the soil and the agronomic traits of the sorghum of the different composts. The results show a positive correlation between ear height and straw, seed and panicle yields. Ear height was negatively correlated with seed weight. In addition, ear height, straw, seed and panicle yields were strongly associated with BM_S, BM+CP and BM+BV treatments. Seed weight was associated with the G_S, T_S and T+CP treatments.

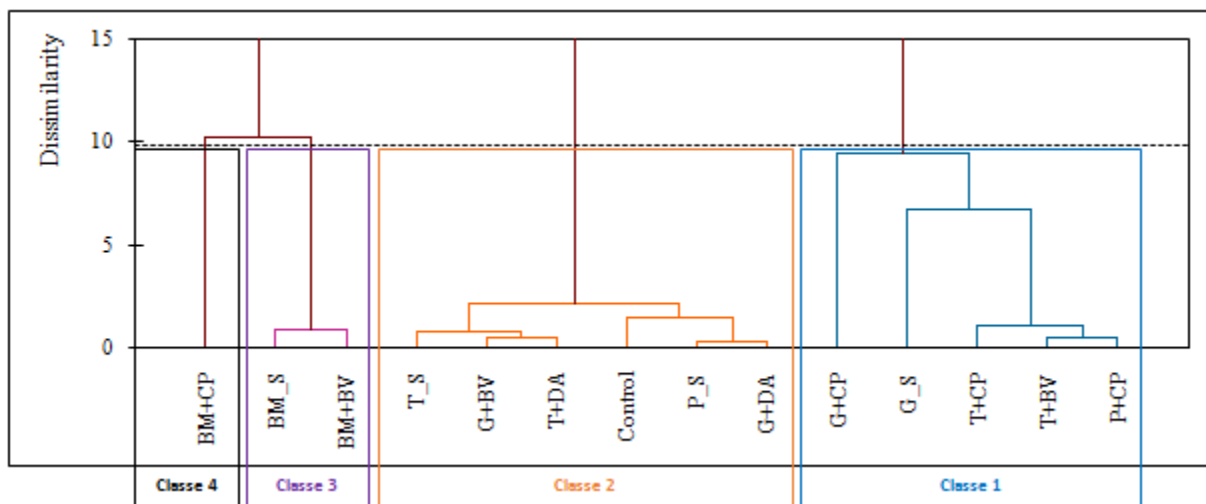
Regarding the chemical composition of the soil, treatments BM_S, BM+CP, BM+BV, T_S, T+CP and T+BV were strongly associated with nitrogen, carbon and phosphorus content while treatments G_S and G+BV were associated with C/N ratio, pH-H₂O and pH-KCl.



Legend: G_S (*Jatropha* pod alone), G+CP (*Jatropha* pod + Compost+), G+BV (*Jatropha* pod + Cow dung), T_S (*Jatropha* cake alone), T+CP (*Jatropha* cake + Compost+), T+BV (*Jatropha* cake + Cow dung), P+CP (Straw of sorghum + Compost+), P_S (Straw of sorghum alone), G+DA (*Jatropha* pod + Slaughterhouse waste), T+DA (*Jatropha* cake + Slaughterhouse waste), BM_S (Biomass of *Jatropha* alone), BM+CP (Biomass of *Jatropha* + Compost+), BM+BV (Biomass of *Jatropha* + Cow dung)

Figure 8: Principal Components Analysis

The hierarchical ascending classification (Figure 9) allowed the composts to be divided into four classes. Class 1 consists of the composts G_S, G+CP, T+CP, T+BV and P+CP. Class 2 consists of the control treatment and the treatments P_S, T_S, T+DA, G+BV and G+DA. Class 3 consists of the BM_S and BM+BV treatment. Class 4 consists of the composts BM+CP. In this classification, class 3 and class 4 composts are of particular interest as they are strongly associated with seed, straw and panicle yields, ear height and improving soil fertility.



Legend: G_S (*Jatropha* pod alone), G+CP (*Jatropha* pod + Compost+), G+BV (*Jatropha* pod + Cow dung), T_S (*Jatropha* cake alone), T+CP (*Jatropha* cake + Compost+), T+BV (*Jatropha* cake + Cow dung), P+CP (Straw of sorghum + Compost+), P_S (Straw of sorghum alone), G+DA (*Jatropha* pod + Slaughterhouse waste), T+DA (*Jatropha* cake + Slaughterhouse waste), BM_S (Biomass of *Jatropha* alone), BM+CP (Biomass of *Jatropha* + Compost+), BM+BV (Biomass of *Jatropha* + Cow dung)

Figure 9: Dendrogram of dissimilarity

4. DISCUSSION

Nutrient and organic matter deficiency is one of the major factors limiting crops production (Venkateswarlu et al., 2016). *Jatropha* by-products can act as an excellent organic fertilizer and soil amendment due to its richness in organic matter and nutrients (Liu et al., 2016; Bai et al., 2017). The present study demonstrated that *jatropha* by-products amendment could effectively raise soil fertility by increasing pH and nutrient contents. Indeed, the results revealed that the application of some composts based on the by-products of *Jatropha* was of great interest, especially in improving soil fertilization and sorghum growth and production parameters. The application of composts-based *Jatropha* by-products have improved soil pH, nitrogen, carbon and potassium contents compared to the control treatment. In addition, they also have the best C/N ratios. The direction of the change in soil pH as a result of treatments application reflected the initial pH of the amendment material. The rise in the soil pH level of the experimental soil after harvesting is an indication of the buffering capacity of compost with *Jatropha* by-product applied. This enhanced the availability of the soil nutrients resulting in increased crop growth and yield. The increase in C, N, K content and C/N ratio of the different treatments compared to the control treatment could be explained by the application of composts into soil, because of the high salinity of composts, increases the salt content as well as soil electrical conductivity (Angelova et al., 2013). The soil carbon increased with the compost application was reported by

Belal-Hossen and Akther-Hossain (2015) who explain it by the nature of the raw materials used for composting (**Atiyeh et al., 2001**).

In accordance with the observed improvement of soil fertility parameters, the growth of sorghum was stimulated by compost-based *Jatropha* by-products. The best results for the growth parameters were obtained with the BM+CP, BM+BV and BM_S treatments made respectively from *Jatropha* cake + Slaughterhouse waste, Biomass of *Jatropha* alone and Biomass of *Jatropha* + Compost+. These same treatments presented the best panicles yield while BM+CP treatment presented the best straw and seed yields. The T+CP (*Jatropha* cake + Compost+) treatment also resulted in the best weights of 100 seeds. The promotion effect was much more significant with BM_S, BM+CP and BM+BV based *Jatropha* and Slaughterhouse or cow dawn. The positive effects of *Jatropha* composts on plant growth were also observed by other authors (**Van Groenigen et al., 2014; Bityutskii et al., 2016; Ros et al., 2017; Agapit et al., 2018**), who found that organic compost impact nutrient availability and thereby increase plant growth and nutrient uptake. The ability of these composts to improve growth and production parameters is therefore linked to their ability to improve soil fertility. These composts probably provided the supply of macronutrients (N, P, K) to the plants as compared to control from by contributing in releasing of nutrients. Indeed, according to **Ndoutoumou et al. (2019)**, the mineral element contents of *Jatropha curcas* cake (3.8 to 6.4 % nitrogen, 0.9 to 2.8 % phosphorus, 1 to 1.8 % potassium) reveal *Jatropha curcas* potential for improvement in agronomy in the context of fertilization. The presence of mineral elements and their content in the substrates plays a major role in plant growth. The plant's vegetative development is closely linked to the presence of nitrogen (**Ndoum, 2010**). Similar results were reported by **Elnasikh et al. (2016)** who reported that *Jatropha* seed cake with its rich nitrogen content can be used to improve nitrogen content of cellulosic wastes with high C/N ratio for producing valuable composts.

The comparison of the production parameters between the 3 years of the study shows that the 2016 season was the most productive. The 2016 season had the highest panicle, straw and seed yields. This better productivity of the 2016 season could be explained by the rainfall. Indeed, rainfall records from the Saria station showed that the agricultural season recorded the best rainfall compared to the others. Similar results were reported by **Laporte et al. (2002)**. Their works predict that increases in temperature, precipitation and longer growing seasons associated with climate change should lead to increased net productivity of agricultural crops where soils permit. According to (**Huang and Zhang, 2016**), water is the key limiting factor to plant growth and productivity in arid and semiarid areas. And precipitation, as the sole source of water replenishment, plays an important role in sustaining particularly in the desert ecosystem and determines the mass transfer process in the soil and vegetation system.

5. CONCLUSION

Modern agriculture faces to new challenges and problems. One of the greatest threats is depletion in soil fertility. Therefore, we must search for news biotechnology to maintain soil fertility and renewal of its natural properties. In this order, the effect of various composts-based *Jatropha* by products was evaluated. The study showed that *Jatropha* by-products amendment could effectively raise soil fertility by increasing pH and nutrient contents and improved Sorghum growth and production parameters. The results also showed positive and significant correlations between panicles yield and seeds yield as well as straws yield. Positive and significant correlations were recorded between seeds yield and straws yield and weight of 100 seeds. These correlations between the different parameters are important of simultaneous improving of growth and crops yield of sorghum. The ACP performed based on measurement parameters permitted to identify the appropriate formulation for any interest parameter. These results supported the best effects of the application of various compost-based by-products of *Jatropha curcas* in *Sorghumbicolor* production. Based on these results, we conclude that the application of composts-based *Jatropha* by-products has positive effect on soil fertility and Sorghum growth and production parameters. The use of these composts constitutes practical benefits of employing organic manure and a good solution for a sustainable farming system.

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