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Vermicomposts improve yields and seeds quality of *Lagenaria siceraria* in Côte d'Ivoire

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Abstract

Among organic amendments, compost is well known for its effectiveness on agricultural productivity increase but little is diffused about vermicompost efficacy. The present study aimed to evaluate the benefits of vermicompost from animal wastes on *Lagenaria siceraria* productivity and its seeds quality compared to compost. Thus, a field experiment was carried out under randomized complete block design with three replicates in Côte d'Ivoire by using compost and vermicompost as fertilizers. The agronomic parameters as "time of fruits maturity, number of fruits per plant, weigh of fruit, yield and heavy metal contents in the seeds were evaluated. For a same type of waste, shorter time to maturity, larger number of fruits per plant, larger number of seeds per fruit, heavier fruits and seeds and higher yields were obtained with vermicompost compared to compost. Heavy metals contents in seeds from vermicomposts were lower than those from composts with the same type of waste. Contents of heavy metals in the seeds from plots that received vermicomposts were all below the maximum residue limits recommended by the Codex Alimentarius. Our results indicated that vermicompost improved more the yield of *L. siceraria* and its seeds quality compared to compost, and hence could be recommended to peasants rather than compost.

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Introduction

Lagenaria siceraria is an oleaginous cucurbit belonging to cucurbitaceae family and cultivated for its fruits, leaves and flowers (Edeoga *et al.*, 2010; Achu *et al.*, 2013). It is one of the most cultivated cucurbits in the world and particularly in tropical and subtropical areas. This cucurbit has been reported to have numerous agronomic and economic potentials for peasants (Chimonyo and Modi, 2013; Maroyi, 2013). Besides that, *L. siceraria* is an excellent fruit in the nature consisting of all the essential constituents that are necessary for normal and good health of human beings (Loukou *et al.*, 2013; Muhammad and Rahila, 2013). Traditionally, *L. siceraria* fruits are known for their beneficial impact on human health as they are used for their general tonic and cardiotonic properties, and as a cardioprotective drug (Sharma *et al.*, 2012). Moreover, people used them as aphrodisiac, diuretic, antidote to certain poisons, scorpion stings, and alternative purgative (Sharma *et al.*, 2012; Ogunbusola *et al.*, 2013). Recently, investigations revealed the increasing role of this cucurbit in human health as it is able to deliver a range of services including antihelmintic, antibacterial, antifungal, immunomodulatory, anti-allergic, analgesic, anti-inflammatory, antioxidant, free radical scavenging, cytotoxic, antihyperlipidemic antidiabetic, hepatoprotective, anxiolytic and memory enhancing properties (Sharma *et al.*, 2012; Ogunbusola *et al.*, 2013; Menpara *et al.*, 2014).

In Côte d'Ivoire where *L. siceraria* is very prized for its nutritional qualities, the productivity is unfortunately low with an average value estimated at 75.1± kg ha^{-1} of husked seeds, which reduces its consumption per capita (Zoro Bi *et al.*, 2006). Soil fertility depletion has been described as one of the major biophysical root cause of declining per capita food production (Khan *et al.*, 2013; Zake *et al.*, 2015). This is most likely due to unsustainable production systems along with continuous nutrient mining without sufficient external inputs for soil fertility replenishment. Low soil carbon stocks as indicator adverse soil quality and fertility (Lal, 2005; Feller *et al.*, 2012), which is a major constraint to increased food production in Sub-Saharan Africa, is a widespread feature of African soils and considered as a large contributor to poverty and food insecurity (Lal, 2005; 2008). It seems therefore imperative to proceed with soil amendment to increase agricultural productivity. Chemical fertilizers are known for their negative effects on soil properties and their high cost. Thus, organic amendments remain one of the cost-effective options to sustain long-term agricultural productivity enhancement (Hartmann *et al.*, 2014; Kumar *et al.*, 2014). Among organic fertilizers, compost is well known in Africa. Natsheh and Mousa (2014) found that compost application is the best management for increasing soil fertility, cucumber yield and decrease the cost of N mineral fertilizers. According to Ehab and Ahmed (2015), compost improves *L. siceraria* yield. It contains organic matter and nutriments that enhance plant growth and biological substances inhibiting diseases pathogens action (Liu *et al.*, 2013; Catello *et al.*, 2014). Compost has numerous advantages in agricultural productivity increase. In recent years, authors worked on another organic amendment called vermicompost. It is demonstrated that vermicompost can provide to plants nutrients and may contains low heavy metal content (Li *et al.*, 2010; Coulibaly *et al.*, 2011; 2014). Vermicompost also contains biologically active substances such as plant growth regulators (Doan *et al.*, 2015; Najar *et al.*, 2015) that are favorable for agricultural productivity increasing. Despite important works on vermicompost, little is known about its effect on plants productivity and yield quality.

The present study was carried out to evaluate the effect of vermicompost on *L. siceraria* productivity and on its seeds quality compared to compost. It was hypothesized that vermicompost increases more the productivity of *L. siceraria* and its seeds quality than compost.

Materials and methods

Study site

The study was carried out at the experimental station of the University of Nangui-Abrogoua (Abidjan, Côte d'Ivoire) located in Abidjan (latitudes 5°17 N - 5°31 N and longitudes 3°45W - 4°22W). The experimental plots were limited in the north by a field of *Manihot esculenta* (Euphorbiaceae) field, in the west by a plantation of *Hevea brasiliensis* (Euphorbiaceae), in the east and south respectively by a plot of *Vigna subterranea* (Papilionaceae) and *Citrillus lanatus* (Cucurbitaceae).

Biological materials

According to Djiakariya (2004), large quantities of cow waste (two million tons), pig (five thousand four hundred and fifty-four tons), sheep (two hundred tons) and chicken (one hundred tons) are produced per year. These wastes were collected in different farms in Abidjan to be used. The excreta were constituted of a mixture of faeces and urine without any bedding material. In order to facilitate their manipulation and reduce smell, the wastes were air-dried before their use.

Some healthy adults of *Eudrilus eugeniae* weighing 500-1200 g obtained from the University of Abobo-Adjamé were used in the experiment for vermicomposting. The seeds of *Lagenaria siceraria* were provided by the Laboratory of Functional Genomics and Breeding of the University of Nangui Abrogoua through the bank of genes registered under the number ‶NI260″.

Preparation of compost and vermicompost

For compost preparation, 4 pits (1 m × 1 m × 1 m) with their bottom cemented to avoid nutriments loss were dug and 50 kilos of each dried animal waste were put in each of them. The content of the different pits was returned thrice according to the "Indienne Indore method" (FAO, 1980). Four other pits with the same design containing 50 kilos of dried waste were established to host earthworm species that are key to the preparation of the vermicompost. The whole system was watered with tap water and the mixtures were turned over manually every day for 15 days in order to eliminate volatile gases, which may be potentially toxic to the earthworms. The moisture content of the pits was also regularly adjusted to 70–80%. After pre-composting, each of the four pits received 750 individuals of *E. eugeniae* and covered up with the help of coconut palm leaves to avoid colonization by pests and to maintain humidity for three months.

Experimental design

The experimental design is a randomized complete block with eight plots (16 m × 12 m); each corresponding to a treatment. The treatments were represented in part by the different types of vermicomposts and composts from cow, sheep, pig and chicken wastes and the compost treatments were used as control. The plots were separated from each other by an aisle of 5 m. Seedlings of *L. siceraria* were made three crop cycles. Sowing was done on the same day for all treatments with 3 seeds per hole at a depth of 2 to 3 cm at each cropping cycle. The lifting occurred 15 days after the sowing and seedlings were thinned to keep only the strongest at each sowing point. A total of 2.5 kg of compost or vermicompost were used as organic inputs spread on the ground and further buried on the same day at 15 cm in soil with a hoe to avoid leaching and facilitate nutrients absorption.

In order to monitor the impact of effectiveness of organic amendments in improving plant growth and productivity, five agronomic parameters including stem growth, foliar growth, flowers growth, fruits production and seeds productivity were evaluated. Seeds quality were assessed through the measurement of heavy metal contents like zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd), nickel (Ni), chromium (Cr) and arsenic (As) in the seeds produced taking into account the type of animal wastes with their stabilization method. Heavy metal contents were determined by means of atomic absorption spectrophotometer (AA-220 FS) after digestion of the samples with concentrated HNO_3: concentrated $HClO_4$ (4:1, v/v).

Statistical analyses

Data were analyzed by factorial analysis of variance (ANOVA) using the general linear model (GLM) procedure of the SAS statistical package (SAS, 1999). They were given as mean followed by standard deviation (M ± SD). Least Significant Difference (LSD) multiple range-tests were used to constitute homogenous groups. Significant differences were determined at $P \leq 0.05$.

Results

Effect of compost and vermicompost on stem growth parameters of L. siceraria

The parameters on growth and development of the stem studied were the time of occurrence of tendrils (TOT), the length of the stem (LeSt), the number of branches (NBr) and the stem diameter collar (SDC). These parameters varied from one treatment to another (Fig. 1). The mean time of occurrence of tendrils (TOT) was shorter (20.2 days) with pig vermicompost and longer (26.4 days) with chicken compost. The maximum length of the stem (13.3 m) was obtained with chicken vermicompost and the minimum (5.2 m) was recorded with cow compost. As for number of branches, the highest (70.6) was obtained with sheep vermicompost and the lowest (39) with sheep compost. Relative to the diameter of stem collar, larger diameters (2.7 cm) were observed with sheep vermicompost while the smaller diameters (1.3 cm) were recorded with the compost of the same type of waste. For a same type of waste, vermicompost treatment has more effective action on each of the parameters of growth of stem relative to compost.

Table 1. Characteristics of the leaves of *L. siceraria* in function of organic inputs.

Cco: compost of cow waste; Csh: compost of sheep waste; Cpi : compost of pig waste; Cch : compost of chicken waste; Vco : vermicompost of cow waste; Vsh : vermicompost of sheep waste; Vpi : vermicompost of pig waste; Vch : vermicompost of chicken waste; LeLi: Lengh of limbe; WiLi: Width of limbe; LePe: Lengh of petiole.

Parameters	Organic inputs								Statistical parameters	
	Cco	Csh	Cpi	Cch	Vco	Vsh	Vpi	Vch	*F*	*P*
LeLi (cm)	15.44±4.11^{f}	19.87±4.21^{c}	18.73±7.24^{d}	19.88±7.21^{c}	17.21±6.24^{e}	23.74±7.41^{b}	20.19±7.66^{c}	25.13±8.42^{a}	80.56	<0.001
WiLi (cm)	20.17±5.55^{e}	27.51±6.23^{c}	25.63±6.27^{d}	27.89±6.84^{c}	25.33±8.54^{d}	28.83±8.65^{b}	26.17±7.24^{d}	30.49±6.24^{a}	55.27	<0.001
LePe (cm)	16.42±6.47^{c}	17.11±7.23^{bc}	17.69±6.28^{b}	18.14±8.21^{ab}	16.71±6.74^{c}	17.68±4.22^{b}	18.23±9.11^{ab}	18.89±6.28^{a}	110.6	<0.001

Values followed by the same letter in a row are not significantly different ($P > 0.05$) using LSD.

Effect of compost and vermicompost on foliar growth parameters of L. siceraria

Table 1 depicts leaves growth parameters evaluated in this study (length of limb (LeLi), width of limb (WiLi) and the length of the petiole (LePe)). It appeared that growth parameters of leaves differed significantly in function of the type of inputs ($P \leq 0.05$).

The longest (25.1 cm) and the widest leaves (30.5 cm) were obtained with chicken vermicompost while shorter (15.4 cm) and narrower (20.2 cm) were observed with cow compost. Longer petioles were obtained with chicken (18.9 cm) and pig vermicomposts (18.2 cm). As for the shorter, they were obtained with cow compost (16.4 cm) and cow vermicompost (16.7 cm).

Effect of compost and vermicompost on flowers growth parameters of L. siceraria

The appearance time of male flowers (ATMfl), the appearance time of female flowers (ATFfl), the size of male flowers (SMfl) and the size of female flowers (SFfl) were estimated. The average values of these parameters related to floral development differed significantly ($P \leq 0.05$) with the type of organic fertilizers used (Fig. 2). The time of appearance of the male flowers (30.4 days) and females flowers (49.73 days) were shorter with pig vermicompost and longer with chicken compost (male flowers: 42.2 days; female flowers: 63.4 days). Moreover, the larger sizes of the male flowers (11.3 cm) and female flowers (9.8 cm) were obtained with chicken vermicompost. As for the smaller sizes of the male flowers (9.2 cm), they were observed with cow compost while the smaller sizes of the female flowers were obtained with cow compost (7.7 cm), chicken compost (7.8 cm) and sheep compost (7.9 cm). Stalks of the male flowers were longer with chicken vermicompost (17.2 cm) and shorter with the sheep compost (12.6 cm). In the same way the female flower stalks were longer with chicken vermicompost (8.8 cm) and shorter with sheep compost (7.5 cm).

Table 2. *L. siceraria* fruits production parameters in function of organic inputs.

Cco: compost of cow waste; Csh: compost of sheep waste; Cpi : compost of pig waste; Cch : compost of chicken waste; Vco : vermicompost of cow waste; Vsh : vermicompost of sheep waste; Vpi : vermicompost of pig waste; Vch : vermicompost of chicken waste; TFrR: time for fruit ripening ; NFrPl : number of fruit per plant; WeFr : weight of fruit; WiFr: width of fruit; LeFr : Lengh of fruit.

Parameters	Organic inputs								Statistical parameters	
	Cco	Csh	Cpi	Cch	Vco	Vsh	Vpi	Vch	*F*	*P*
TFrR (days)	106.21 ± 4.66^{b}	104.12 ± 6.52^{b}	96.38 ± 6.57^{c}	115.74 ± 8.67^{a}	96.54 ± 12.03^{c}	95.87 ± 9.66^{c}	90.93 ± 7.68^{d}	103 ± 8.79^{bd}	27.74	<0.001
NFrP	3.73 ± 2.12^{f}	5.59 ± 3.71^{dc}	5.86 ± 4.15^{dc}	4.83 ± 3.38^{de}	5.4 ± 3.43^{e}	7.36 ± 4.8^{b}	6.01 ± 3.87^{c}	8.78 ± 5.79^{a}	6.22	<0.001
WeFr (kg)	1.211 ± 0.32^{f}	1.419 ± 0.38^{d}	1.348 ± 0.3^{e}	1.488 ± 0.35^{c}	1.299 ± 0.35^{e}	1.562 ± 0.49^{b}	1.417 ± 0.38^{d}	1.876 ± 0.54^{a}	6.72	<0.001
WiFr (cm)	11.88 ± 1.28^{ab}	11.98 ± 1.11^{ab}	10.79 ± 1.31^{c}	11.02 ± 1.13^{c}	11.99 ± 1.54^{ab}	11.05 ± 2.28^{c}	11.29 ± 1.47^{bc}	12.5 ± 1.6^{a}	5.87	<0.001
LeFr (cm)	21.4 ± 2.68^{b}	21.83 ± 4.82^{b}	21.3 ± 3.77^{b}	20.91 ± 3.82^{b}	20.61 ± 3.13^{b}	22.75 ± 5.19^{ab}	20.93 ± 4.24^{b}	24.67 ± 5.65^{a}	3.76	<0.001

Values followed by the same letter in a row are not significantly different ($P > 0.05$) using LSD.

Effect of compost and vermicompost on fruits production parameters of L. siceraria

Fruits production parameters as the time for fruit ripening (TFrR), the number of fruits per plant (NFrPl), the weight of fruit (WeFr), the length of fruits (LeFr) and the width of fruits (WiFr) are summarized in table 2. The organic inputs influenced differently fruit production parameters ($P \leq 0.05$). The first mature fruits were obtained after 90.9 days with pig vermicompost while fruits have taken more time to mature with chicken compost (115.7 days). The mean number of fruits per plant was higher with chicken vermicompost (8.8) and lower with cow compost (3.7). Besides that, fruits with higher weights were obtained with chicken vermicompost (1.8 kg) while those with lower weights were recorded with cow compost (1.2 kg). Regarding fruit size, larger diameter (12.5 cm) were obtained on plants which were fertilized with chicken vermicompost while smaller were obtained with pig compost (10.8 cm), chicken compost (11.0 cm) and sheep vermicompost (11.0 cm). The longest fruits (24.7 cm) were produced on the plots supplemented with chicken vermicompost while shorter (21.8 cm) were obtained on the plots fertilized with other organic inputs.

Table 3. *L. siceraria* seeds productivity parameters in function of organic inputs.

Cco: compost of cow waste; Csh: compost of sheep waste; Cpi : compost of pig waste; Cch : compost of chicken waste; Vco : vermicompost of cow waste; Vsh : vermicompost of sheep waste; Vpi : vermicompost of pig waste; Vch : vermicompost of chicken waste; NSFr : number of seeds per fruit; WeS_{100} : weight of 100 seeds; LeSe: length of seed; WiSe: width of seed; Yi: yield.

Parameters	Type of inputs								Statistical parameters	
	Cco	Csh	Cpi	Cch	Vco	Vsh	Vpi	Vch	*F*	*P*
NSFr	237.84 ± 87.73^{f}	311.33 ± 81.37^{d}	276.25 ± 82.49^{e}	351.69 ± 93.25^{c}	$301.94\pm92.5C3^{d}$	431.61 ± 113.71^{b}	349.47 ± 92.46^{c}	478.88 ± 94.92^{a}	4.03	<0.001
WeS_{100}(g)	16.24 ± 4.8^{b}	18.76 ± 3.14^{ab}	18.11 ± 3.82^{ab}	19.31 ± 3.46^{ab}	17.89 ± 4.44^{b}	20.94 ± 3.9^{a}	19.74 ± 2.77^{ab}	21.63 ± 3.05^{a}	3.95	<0.001
LeSe(mm)	14.4 ± 2.77^{f}	18.12 ± 5.28^{c}	15.31 ± 6.29^{e}	17.94 ± 6.52^{c}	16.75 ± 9.27^{d}	20.43 ± 8.24^{b}	18.35 ± 5.62^{c}	22.11 ± 7.31^{a}	12.32	<0.001
WiSe(mm)	6.21 ± 1.32^{e}	7.66 ± 1.27^{bc}	6.84 ± 1.14^{d}	7.7 ± 1.37^{bc}	7.48 ± 1.43^{c}	8.11 ± 2.34^{ab}	7.57 ± 1.34^{c}	8.3 ± 2.43^{a}	5.87	<0.001
Yi (t/ha)	0.15 ± 0.08^{f}	0.34 ± 0.124^{d}	0.305 ± 0.178^{e}	0.341 ± 0.195^{d}	0.303 ± 0.186^{e}	0.692 ± 0.289^{b}	0.431 ± 0.215^{c}	0.947 ± 0.435^{a}	19.74	<0.001

Values followed by the same letter in a row are not significantly different ($P > 0.05$) using LSD.

Effect of compost and vermicompost on seeds productivity of L. siceraria

Table 3 shows seeds productivity parameters , which are number of seeds per fruit (NSeFr), weight of 100 seeds (WeS_{100}), length of seeds (LeSe), width of seeds (WiSe) and yields (Yi). The average values of these parameters relative to the seeds of *L. siceraria* varied significantly ($P \leq 0.05$) according to the type of organic inputs. The largest number of seeds per fruit (478.9) was obtained with chicken vermicompost and the smallest (237.8) with cow compost. Besides that, the highest weight of 100 seeds was obtained with chicken vermicompost (21.6 g) and sheep vermicompost (20.9 g) while the lowest weight of 100 seeds was recorded with cow compost (16.2 g) and cow vermicompost (17.9 g). However, the longest seeds (22.1 mm) and the largest (8.3 mm) were produced on the plots supplemented with chicken vermicompost compared to those using cow compost (length: 14.4 mm; width: 6.2 mm) as input. The highest yield (0.95 t ha^{-1}) was registered under the effect of chicken vermicompost and the lowest (0.15 t ha^{-1}) with cow compost. For each type of agronomic parameter, the most successful results were obtained with the vermicompost treatment for a given type of animal waste.

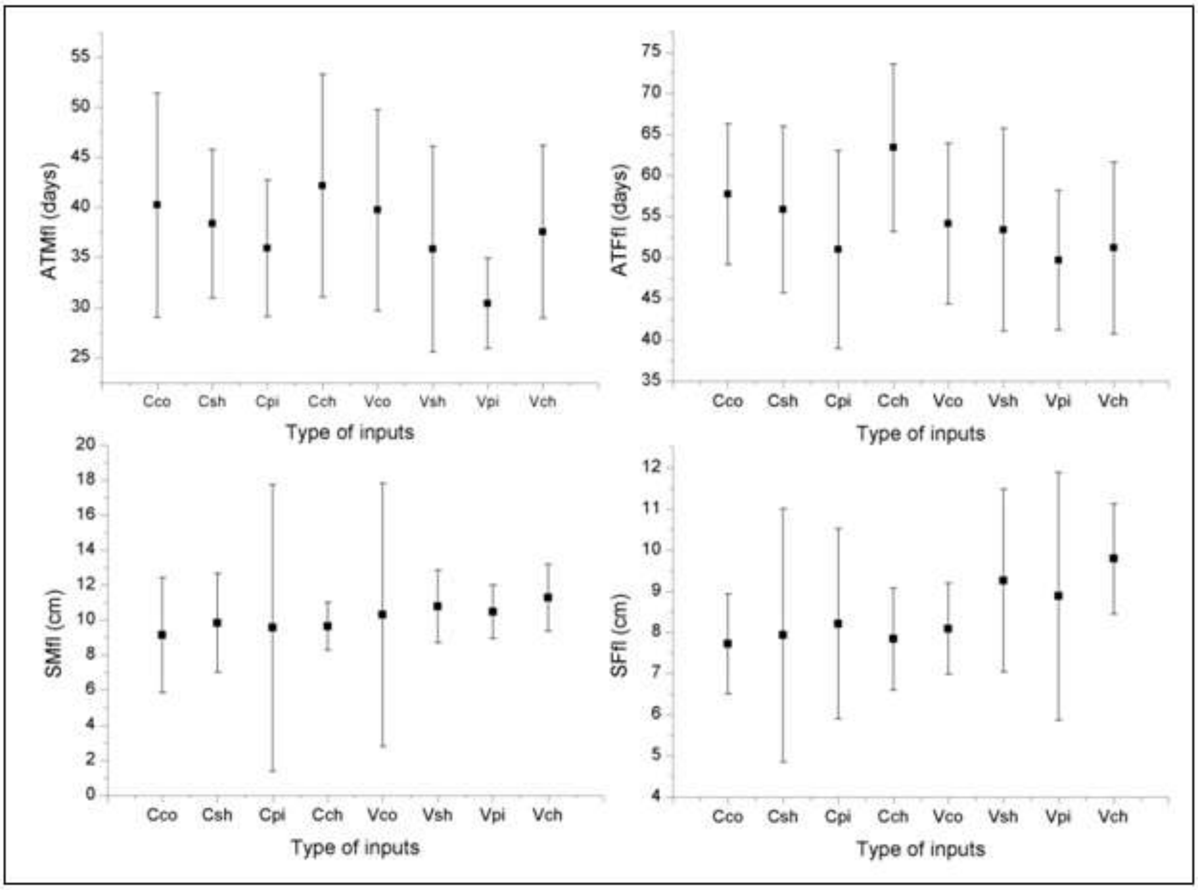

Fig. 1. Gowth parameters of *L. siceraria* stem in function of organic inputs.

Cco: compost of cow waste ; Csh: compost of sheep waste; Cpi : compost of pig waste ; Cch : compost of chicken waste; Vco : vermicompost of cow waste; Vsh : vermicompost of sheep waste; Vpi : vermicompost of pig waste; Vch : vermicompost of chicken waste; TOT : time of occurrence of tendrils; LeSt : length of stem; NBr: number of branches; DCo: diameter of the stem collar.

Heavy metals content in the seeds of L. siceraria in function of organic inputs

The heavy metal contents in the seeds of *L. siceraria* are registered in table 4 that shows the highest Zn content (31.3 mg kg^{-1}) to be obtained with chicken compost and the lowest with cow vermicompost (9.6 mg kg^{-1}) together with sheep vermicompost (10.5 mg kg^{-1}). As regards Cu content, the highest value (12.3

mg kg-1) was observed with pig compost and the lowest with vermicomposts. Relatively to Pb, Cd, Ni, Cr, and As contents, the lowest values in seeds were dispalyed by vermicompost treatments while compost showed the highest contents.

Discussion

Production of L. siceraria in function of the type of organic inputs

For each type of agronomic parameter, the most successful results were obtained with the vermicompost treatment for a given type of animal waste. This result could be explained by the higher nutritional value of vermicompost compared to composts. Indeed during vermicomposting, transit of waste through the digestive tract of earthworms would have a better mineralization and consequently increase the content of minerals in vermicomposts (Ndegwa and Thompson, 2001). The mucus secreted by earthworms during vermicomposting process increases nitrogen content. It has also been shown by Tripathi and Bhardwaj (2004), Suthar (2007) that earthworms have in their mucus nitrogenous substances as well as growth hormones and enzymes that promote plant growth. The assimilation of nitrogen by plants could favorably influence the agronomic parameters mentioned above, which differ significantly with the type of vermicomposts and composts as well. The difference observed is likely to be related to the initial chemical composition of each type of waste. The time of appearance of flowers in plots amended with vermicomposts, composts of cow, sheep and pig in this study is lower than that obtained by Achigan-Dako *et al.* (2008) in Benin. Unlike previous composts, the time of appearance of flowers obtained with chicken compost is longer than that observed by Achigan-Dako *et al.* (2008) with *L. siceraria*. That discrepancy in time could be explained by the positive impact of different composts on the cycle of *L. siceraria*.

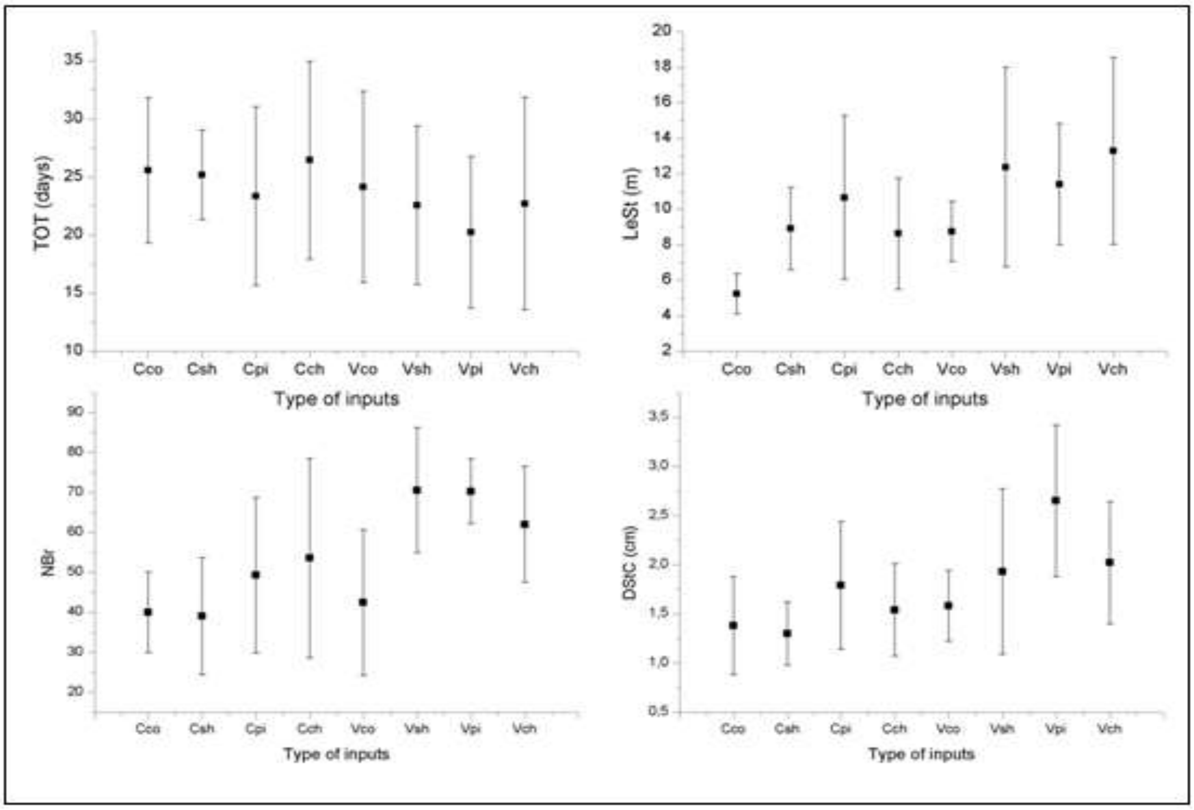

Fig. 2. Characteristics of *L. siceraria* flowers in function of organic inputs.

Cco: compost of cow waste; Csh: compost of sheep waste; Cpi : compost of pig waste; Cch : compost of chicken waste; Vco : vermicompost of cow waste; Vsh : vermicompost of sheep waste; Vpi : vermicompost of pig waste; Vch : vermicompost of chicken waste; ATMfl : appearance time of male flowers; ATFfl : appearance time of female flowers; SMfl : size of male flowers; SFfl: size of female flowers.

Furthermore, the flowering time of *L. siceraria* obtained by Taffouo *et al.* (2008) is lower to those obtained with the vermicomposts in this study. According to Ndegwa and Thompson (2001), macronutrients such as nitrogen, potassium, phosphorus and calcium were made more soluble and available by earthworms in vermicomposting for the plant. Therefore the availability of macronutrients would have hastened the appearance of certain organs during the development of *L. siceraria* such as tendrils and flowers as well as shortening the fruit ripening period. Contrary to vermicomposts, nutrients are not released faster in composts and therefore are not available in the required amount at the appropriate time for the plant. As a result, that would lead to a delay in the development of the plant. Moreover, among the vermicomposts and composts, pig waste quickly fostered tendrils appearance, male and female flowers appearance, and fruit ripening compared to other type of wastes. Unlike the pig waste, chicken waste has a very slow effect on the development of the plant. The more rapid appearance of flowers and tendrils and the shortening of fruit ripening time with treatments of pig waste could be explained by its ability to release more easily phosphorus as shown by El Hassani and Persoons (1994). According to them, phosphorus shortens the growth cycle and accelerates the ripening of fruits. It could also be that the nutrients in this amendment are taken up by the plant upon application. The efficacy of pig waste to release nutrients has most likely accelerated the development of *L. sicera*ria. Unlike pig waste, other wastes particularly chicken gradually liberated nutrients to the plant with the proximate consequence of delaying the appearance of tendrils, male and female flowers and lengthen the lifecycle of the plant *L. sicera*ria. For the same type of waste, the fruit weight, the number of seeds per fruit and the yield are higher in plots, which received vermicomposts compared to the ones that have been amended with composts. These parameter values obtained in this study are higher than those obtained by Taffouo *et al.* (2008) in the culture of *L. siceraria* on soils with 0% and 4% of sodium in Sudan. Yields in this study were 1.2 to 2.4 times higher than values obtained by Taffouo *et al.* (2008) in the unsalted soil and 1.5 to 9.56 times higher than the yield in the salted soil at 4%. They are also higher than the 75.2 kg ha^{-1} showed by Zoro Bi *et al.* (2006).

Heavy metals content in the seeds of L. siceraria in function of organic inputs

Heavy metals content in seeds of *L. siceraria* from the various treatments revealed lower values seeds produce with vermicomposts than in those produce with the compost for the same type of animal waste. That difference could be related to the stabilization of waste by earthworms during vermicomposting as their activity are likely to cause a reduction in heavy metals content due to their assimilation into their bodies (Li *et al.*, 2010; Torri Puelles, 2010). Higher concentrations of heavy metals in seeds from plots fertilized with composts could be explained by greater mobility of these in composts and thus their absorption by *L. siceraria*. The higher levels of heavy metals in the seeds from plants fertilized with composts witness their presence in these organic fertilizers. Contrary to composts, vermicomposts would develop a heavy metal sequestration system thereby reducing their absorption by the plant. Furthermore, the concentrations of heavy metals in seeds are of less importance compared to those observed initially in the raw animal wastes, composts and in the vermicomposts as indicated by Coulibaly *et al.* (2014). This could be explained by a partial absorption of heavy metals or their accumulation in other plant parts (roots, leaves, stems, etc.). It follows that low concentrations of heavy metals have arrived at the level of the fruits. Adriano (1986), Kabata - Pendias and Pendias (1992), Baker and Senft (1995) and Juste *et al.* (1995) observed a significant Cu accumulation in roots of several plants than in the leaves and fruits. According Bisson *et al.* (2003), the amount of Pb absorbed by plants is rapidly immobilized in the vacuoles of root cells or restraint by the walls of the endoderm that explain the higher Pb content in the roots than in leaves and the fruits of plants. Furthermore, quantities of heavy metals obtained in our study are smaller than those recorded by Kouakou (2009) in lettuce leaves, spinach and amaranth. The difference could lay in amendments characteristics used as well as the nature of irrigation water. Indeed, the water used to irrigate plants in our study came from tap while that used by Kouakou (2009) was sourced from of a well that had received wastewater. On the other hand, the contents of Zn, Cu, Cr, Ni and As obtained with vermicomposts in the present study are respectively low compared to the 18.8; 7.2; 0.06; 1.2; and 0.2 $mgkg^{-1}$ detected by Jean-Charles *et al.* (2005) in oilseeds in France. Concentrations of Cu, Pb, Cd and As in seeds obtained with vermicomposts are also lower respectively than the 0.4; 0.2 ; 0.1 and 0.1 mg kg^{-1} reported by the Codex Alimentarius as the maximum limit in raw oils and dried vegetables. That might explain the efficiency of vermicompost for improving seeds quality. However, these heavy metal contents in seeds obtained with composts are higher than those recommended by the Codex Alimentarius as the maximum limit in oils and dried vegetables indicating the inconvenience linked to compost utilization on seeds quality.

Conclusion

It can be concluded that for the same type of waste, vermicomposting treatments increase agronomic parameters than composting treatment. Earthworms have shown the ability to reduce the levels of heavy metals in organic wastes with the consequence of seeds of *L. siceraria* supplemented containing the lowest concentration of this lethal metals. Furthermore, the values of heavy metals in seeds from plots that received vermicomposts are below the maximum residue limits (MRL) recommended by the Codex Alimentarius. Thus, vermicompost produced from animal waste have the potential to increase more the yield and the quality of the seeds of *L. siceraria* than compost.

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