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Effect of green manures and mining waste composts on the growth and yield of *Abelmoschus esculentus* L., *Corchorius olitorius* L. and *Glycine max* from Togo

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In West Africa, agriculture faces many problems including soil degradation. In this study, the effects of four composts on okra and soybean have been evaluated. The plants were sown using a Fisher block design with 5 treatments and 4 replicates/treatments. The green manure of three selected fertilizer species was also evaluated on the growth and yield of okra and of jute mallow in order to identify the best organic fertilizer. The experimental design for the green manure testing is made of 5 treatments which correspond to the green fertilizers of the three selected species, their mixture and a control treatment without amendment. The surface area of each experimental plot is 6 m². The results showed that the composts which high proportions of nutrients gave the best yield. The highest growth (41.25 cm) and number of fruits (10) were obtained with compost C4 versus 27 and 3 cm for the control treatment for okra plants. However, C1 and C2 significantly improved the growth parameters of soybean. Plants grown in C1 and C4 got the highest yields for soybeans. Among the plants fertilizer tested, the species *C. odorata* and *P. argentea* improved the yields of okra and mallow. In this regard, these species, compost made from green waste, food, calcareous and clay waste could be an alternative to increase crop production.

Key words: Biofertilizers, mining wastes, crop physiology, plant yields.

INTRODUCTION

The rapid growth of the world population in the recent decades caused an uncontrolled exploitation of soils or

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cultivated lands (Palm et al., 2007). In an attempt to meet the populations' growing needs for food, lands were over-exploited and became less fertile over time, which impinged on the yields of food crops (Akibodé, 1986). Therefore, for plant nutrition and restoration on degraded soils, producers resort to chemical fertilizers. However, Goulding et al. (2008) showed in one of their previous work that, at recommended rates, the use of synthetic fertilizers, ideally in combination with organic fertilizers, green manure, and good agricultural practices (conventional agriculture), can generate positive effects on soils quality and on crop production. However, if inappropriately used, organic fertilizers, especially manure, can also cause water contamination, reduce soil fertility, and lead to a poor harvest. In this regard, exploring alternative means for soil fertilization (fallow, composts, manure, green manure) with lesser impact on the environment and the human health has then become an absolute necessity. It is worthy of note that in Togo, the rate of soil degradation has been reported to be incredibly high over several decades (Sogbedji et al., 2006). According to Kanda et al. (2014), vegetable crops production sites are spread across Togo and the yields are sometimes negatively impacted by factors like poor soil quality, insects pest attacks, lack of access to water points and ineffective post-harvest conservation methods (Kirdja, 1991). But that is not peculiar to Togo. In Africa in general, soil degradation is characterized by a loss in structure, a decrease in organic matter and nutrient contents, and a high level of soil acidity (Lalle, 2008). Indeed, the use of organic amendments could be a solution for the management of soil fertility in a bid to ensure sustainable development. In southern Togo, the phenomenon of soil degradation is so serious that it must engage attention. Because cultivable lands in southern Togo which happen to be one of the primary sources of wealth of the rural populations are dedicated to mineral exploitation. These populations have no choice but to look for other lands that are often less fertile to meet their needs for food. In that current bi-dimensional context of soil degradation and climate change, new cultural practices such as soil amendments with composts and green manures have been promoted and are in line with the principles of sustainable development (Attrasi et al., 2005; Toundou et al., 2014, 2017; Toundou, 2016; Bokobana et al., 2017). Actually, the use of compost in agriculture offers a lot of advantages, such as the improvement of the chemical and physical properties of soils namely the texture, granulometry, moisture, pH, oxidation-reduction potential and ionic conductivity (Hadas and Portnoy, 1997; Agassi et al., 1998; Pagliai et al., 2004; Pedra et al., 2007; Movahedi Naeini and Cook, 2010; Pane et al., 2014; Luo et al., 2017), increased water retention capacity and soil permeability (Wong et al., 1996; Bresson et al., 2001). One can say that the use of local spontaneous plant species with fertilizing properties is one way to achieve sustainable agriculture. Carsky et al. (2003) concluded that the fallow of *Mucuna pruriens* and *Pueraria phaseoloides* help to improve the yield of yam while Eaglescham et al. (1982) stated that maize-cowpea crop combinations improve the quantity of nitrogen in soils. The work carried out by Ognalaga et al. (2016) showed that amending soil with the ashes of *Chromolaena odorata* improves the sorrel growth parameters of Guinea corn. Also, some floristic studies highlighted the invasive potential of that plant in Africa and its fertilizing powers that enable it to significantly improve the mineral and organic fertility of low fertility soils (Herren-Gemmill, 1991).

In Togo, several studies have focused on the use of *Cajanus cajan* and *Vigna unguiculata* to improve the quality of some degraded soils (Sogbedji et al., 2006). In that line, Ayeva (1993) showed that *Crotalaria* species, used as cover crops, helps to improve the structure and fertility of degraded lands in the northern part of the country. Other studies focused on *Cassia occidentalis* L., an invasive plant with fertilizing properties used as green manure and compost (Toundou et al., 2014; Bokobana et al., 2017). Despite the research already carried out, the trends still show a high level of soil degradation, especially in mining areas. The practical purpose of this work is to contribute to soil restoration using wastes composts and three green manures to improve the growth and the yield of *Abelmoschus esculentus* L., *Corchorius olitorius* L. and *Glycine max* L. crops in the southern part of Togo.

MATERIALS AND METHODS

Experimental site location and physicochemical parameters of the studied soil

The experimental site is located in the eco-floristic area five (V) of Togo, specifically in a limestone quarry of the SCANTOGO mine plant based in Sika-Kondji (Togo) at 06°36'48.7'' N and 1°34'44.1'' E. In that area (14 km^2), the land is characterized by vast farmlands around villages, dotted with palm tree plantations. Table 1 shows the physical-chemical characteristics of the studied soil.

Elaborated composts and fertilizer plants tested

Four composts were prepared by mixing different types of putrescible wastes (green and food wastes) produced inside a mining plant (SCANTOGO) and a natural adjuvant that was a mixture of limestone and clay wastes from Tabligbo East quarry (Sika-Kondji). The initial compost material was mixed and allowed to degrade in a heap. The moisture content was measured twice a week using a thermohygrometer (REOTEMP Backyard Moisture Meter (MM15) with a popular brand made in USA) and maintained at 50 to 60% throughout the active composting period. The mixture was turned on days 2, 4, 8, 16, 30, 60 and 90, to maintain porosity. The thermophilic stage (>55°C) lasted for about 50 days. After the day 120 of the composting process, the temperature of the mixture reached the ambient temperature level. The compost was then left for curing for about 4 weeks that it might turn to a suitable substrate. These composts were C1 (green wastes), C2 (green + food wastes), C3 (green wastes + limestone and clays), and C4

Table 1. Physical-chemical characteristics of the experimental soil.

Parameter	Value
pH	6.800
Electrical conductivity (dS/m)	140.600
TOM(% d.m.)	7.600
TOC (%d.m.)	4.410
N (% d.m.)	0.080
P (% d.m.)	0.270
K (% d.m.)	0.022
Ca (% d.m.)	0.202
Clay 2µ (%)	49.500
Fine silt 2 to 20µ (%)	17.500
Coarse silt 20 to 50µ (%)	04.350
Fine sand 50 to 200µ (%)	16.700
Coarse sand 200 to 2000µ (%)	7.800
Elements 2 mm (%)	0.000
Texture	Clay soil

TOM= Total organic matter; TOC= Total organic carbon.

Table 2. Composition of the developed composts.

Compost	Green wastes		Food wastes		Limestones and clay	
	m (kg)	P (%)	m (kg)	P (%)	m (kg)	P (%)
C1	300	100	0	0	0	0
C2	230	76.7	70	23.3	0	0
C3	200	66.7	0	0	100	33.3
C4	250	83.3	20	6.7	30	10

m - mass of wastes or adjuvant; P - percentage of waste or adjuvant relative to the total mass of the pile.

(green + food wastes + limestone and clays). Table 2 shows composition of the different composts.

To select the fertilizer species, an ethnobotanical survey, floristic inventories and bibliographic research were carried out. Three species (*C. odorata*, *Lonchocarpus sericeus* and *Pseudovigna argentea*) were selected according to their citation index in the literature and population. Table 3 shows the chemical characteristics of these composts.

Experimental design and agrotechnical works

The research was conducted over 5 months (from May to September 2016). The experiment was carried out in a randomized complete block design (RCBD) with four replicates per treatment. Four composts (C1, C2, C3, and C4) were tested and compared to a control treatment (without amendment (T)) with 4 replicates per treatment. A dose of 10 t ha^{-1} divided in two parts or applications (before sowing and at flowering for *G. max* and *A. esculentus*) was applied for compost treatments. Each elementary plot (replicate) occupies a surface area of 4 m^2 (2 m × 2 m). A variety of *A. esculentus* lasting 75 days and a local variety of *G. max* (120 days) were used. Seeds were sown one week after plot preparation (clearing, weeding, and plowing) and compost amendment at the rate of 10 t/ha. Mean spaces of 50 cm × 50 cm were respected between line and pocket and 4 grains were sown per pocket. After two weeks of growth, two plants were left per pocket.

Three fertilizer plant species *(C. odorata, P. argentea* and *L. sericeus*) have been evaluated as green manures. Thus, their biomass (leaves and young stems) was harvested, dried for one week at ambient temperature level, and buried in soils at 1 kg m^{-2} one week before sowing. The experimental design consisted of four treatments corresponding to green manures of these species, and a control treatment without amendment (T). Each experimental plot occupies an area of 6 m^2 (3 m × 2 m). Two main cultivated vegetables (*A. esculentus* and *C. olitorius*) of the study area were selected for the agronomic tests. Agrotechnical works of land preparation, sowing, transplanting, parcel maintenance, and harvesting were performed. Data about growth and yield parameters were collected. Plant height, and number of leaves are the growth parameters measured and number of fruits and fruit circumference are the main yield parameters evaluated at 60 days after sowing for soybean and 75 days for okra. Fruit circumference was also assessed using a ribbon. Total rainfall and mean temperature during the test were respectively 500 mm and 30°C.

Statistical analysis

The simple analysis of variance (ANOVA) was used to analyze the data using the SPSS 22.0 program. Significant differences between means were compared using Fisher's least-significant difference

Table 3. Macronutrient contents and chemical characteristics of the tested composts.

Compost	TOM (% d.m.)	TOC (% d.m.)	N (% d.m.)	C/N	P (% d.m.)	K (% d.m.)	Ca (% d.m.)	pH	Ec (µS/cm)
C1	11.00	6.39	0.64	09,98	0.36	0.48	0.92	7.80	1833
C2	15.20	8.83	1.20	07,35	0.45	0.60	1.10	8.14	3080
C3	11.20	6.51	0.41	15,87	0.26	0.35	1.63	8.11	1297
C4	14.00	8.14	0.75	10,85	0.38	0.42	1.28	8.00	2450

d.m.- dry matter; TOM - total organic matter; TOC - total organic carbon.

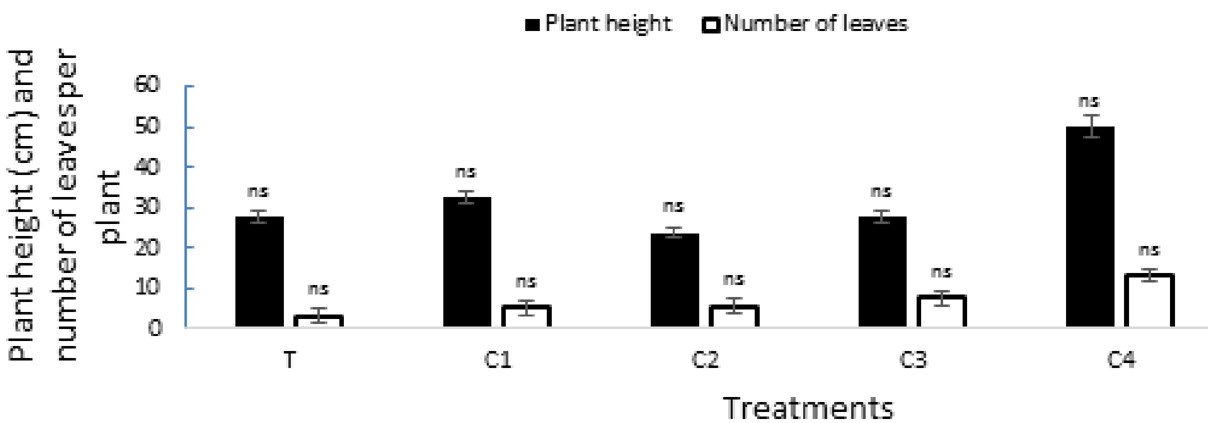

Figure 1. Effect of composts on plant height and number of leaves 75 days after sowing. T - control Treatment; C1 - Compost C1 (green wastes); C2 - Compost C2 (green + food wastes); C3- Compost C3 (green wastes + limestone and clays) and C4 -Compost C4 (green + food + lime and clay wastes. Means with the same letters are not significantly different according to LSD (P<0.05).

(LSD) test at a probability level of 95% (P≤0.05). The Pearson correlation test was used to study the correlations between the chemical properties of composts and the growth parameters of the plants.

RESULTS

Effect of composts on the growth and yield of *A. esculentus*

Based on the height of plants and number of leaves, composts do not have any statistically significant effect on plant growth. Plants on composts C1, C3 and C4 showed mean height of 41.25 cm and 10 leaves versus 23.5 cm and 6 leaves for compost C2 (Figure 1). Compost C4 obtained the best number of fruits per plant (Figure 2).

The correlation analysis shows that the height of the plants is negatively correlated with the composts contents in nitrogen, potassium and calcium while the number of leaves is positively correlated with them. Also, the circumference is negatively correlated with the nitrogen and calcium contents of the compost (Table 4).

Effects of composts on the growth and yield of *G. max*

Figure 3 shows that composts significantly improved the growth of plants comparatively to the control. The best growth (height and number of leaves) was obtained with composts C1 (green wastes) and C2 (green + food wastes). Plants growth on these composts had an average height of 46.25 cm while the height of plants on control treatment was 31.25 cm. In the same vein, plants grown on composts C1 and C2 produced more leaves (P<0.05).

Effects of green manure of fertilizer plant species on growth and yields of *A. esculentus* and *C. olitorius*

Statistically, green manures did not show significant effects on okra growth and production (P<0.05). However, green manures of *C. odorata* and *P. argentea* enabled a higher growth and yield of okra plants than the control treatment without fertilizer (Figures 5 and 6). The best yields of okra fruits and leaves of *C. Olitorius* were

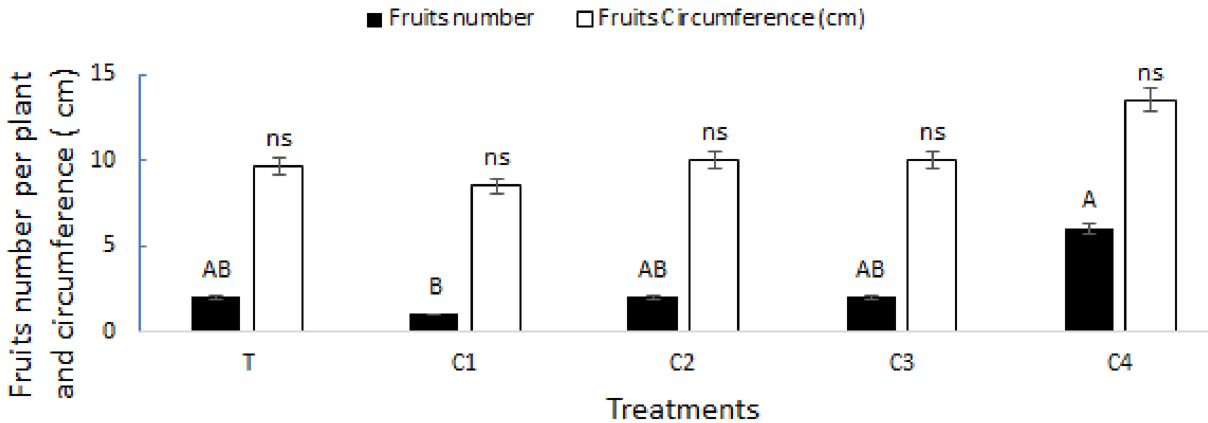

Figure 2. Effect of composts on the number of okra fruits and their circumference 90 days after sowing. T - control Treatments; C1 - Compost C1 (green wastes); C2 - Compost C2(green + food wastes); C3 - Compost C3 (green wastes + limestone and clays) and C4 - Compost C4 (green + food + lime and clay wastes). Means with the same letters are not significantly different according to LSD (P<0.05).

Table 4. Correlation between the chemical properties of composts and plant growth and yield parameters.

Correlation	TOM	pH	EC	N	P	K	Ca
H	-0.40	-0.3	-0.26	**-0.75**	-0.36	**-0.75**	-0.**75**
NL	0.17	0.6	0.05	0.06	-0.58	0.06	0.06
NF	0.49	0.5	0.29	**0.87**	0.23	**0.87**	**0.87**
CIR	-0.56	-1.0	-0.28	**-0.76**	0.35	-0.76	**-0.76**

TOM - Total organic matter; EC - electrical conductivity; N - nitrogen; P - phosphorus; K - potassium; Ca - calcium; H - height; NL - number of leaves; NF - number of fruits, CIR - circumference of fruits.

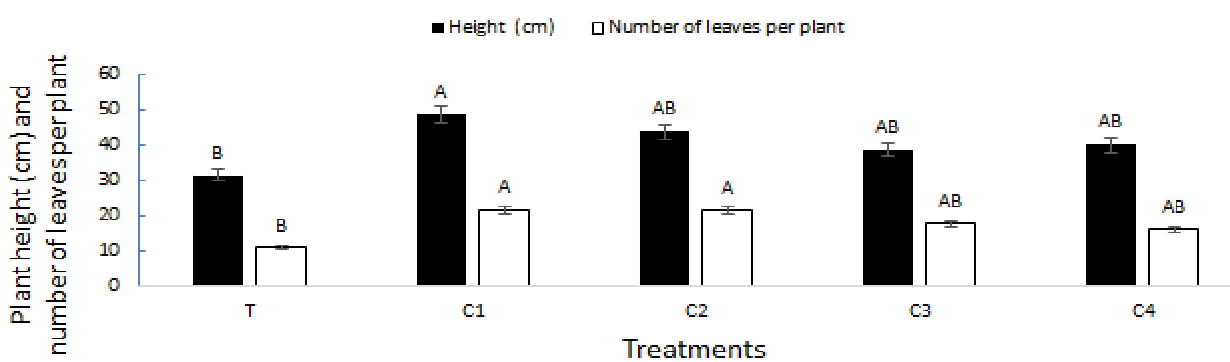

Figure 3. Effect of composts on soybean plants height and number of leaves on day 60 after sowing. T - control Treatments; C1 - Compost C1 (green wastes); C2 - Compost C2 (green + food wastes); C3 - Compost C3 (green wastes + limestone and clays) and C4 - Compost C4 (green + food + lime and clay wastes). Means with the same letters are not significantly different according to LSD (P<0.05).

respectively obtained on soils amended with green manures of *P. argentea* (130 fruits per plot) and *C. odorata* (20 leaves per plant) while the control treatment yielded 75 fruits and 14 leaves. The green manure of *P. argentea* improved the height of plants of garden coret to 19 cm while the *L. sericeus* and *C. odorata* treatments produced an average plant height of 13 cm for other composts.

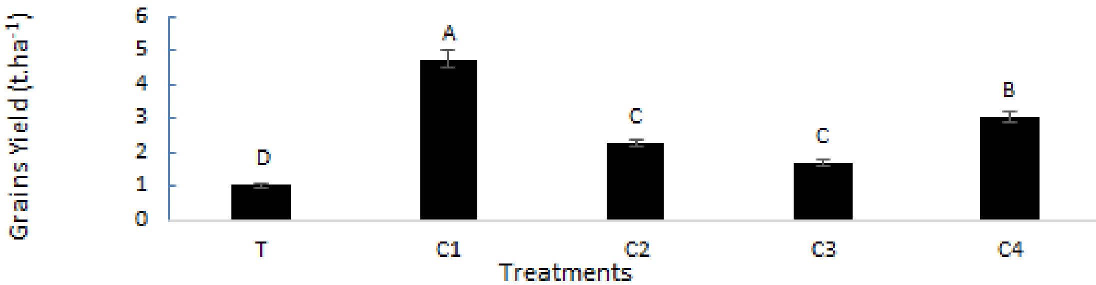

Figure 4. Effects of composts on the yield of soybean.

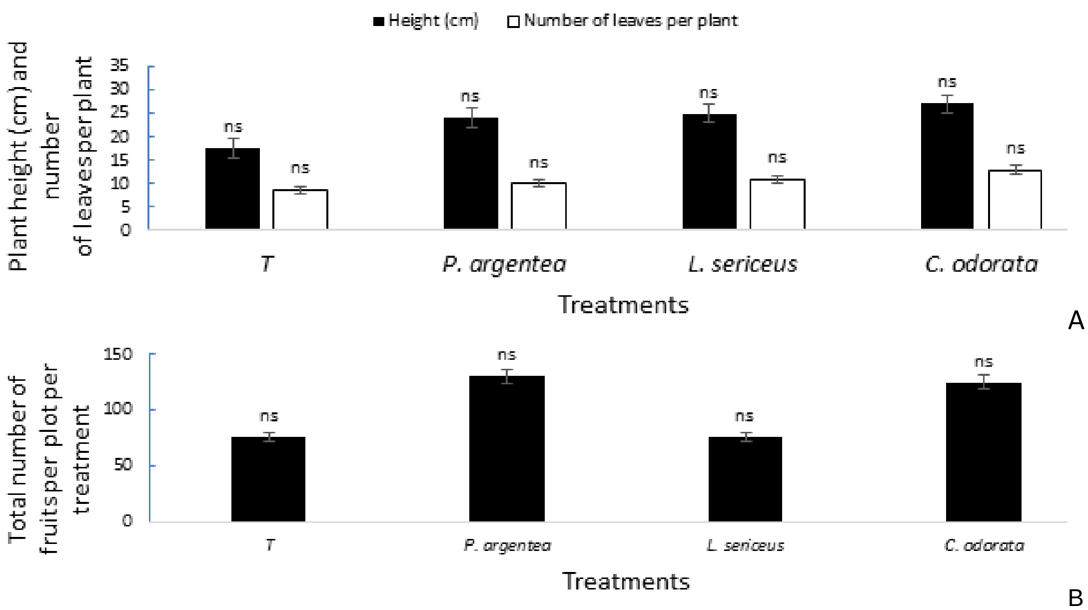

Figure 5. (A) Plant height number of leaves per plant (at 7 weeks) and (B) number of fruits at harvest of okra plants grown on different green manure treatments (T - Control Treatment).

DISCUSSION

The presence of limestone and clay wastes in composts C3 and C4 is the factor behind the growth and yield of Okra plants (Hamon and Charrier, 1985; Siemonsma and Hamon, 2004). Indeed, according to some works, sandy loam soils rich in organic matter were discovered to significantly improve the growth and production of *A. esculentus* (Lim and Chai, 2007; Dada and Adejumo, 2015). The okra grown on compost C4 produced more fruits with large sizes without significant differences. About 1.2 fruits per plant were obtained on compost C1 while one plant grown on compost C4 produced about six fruits. As concerned with the circumference of the fruits, apart from compost C4, the composts C2 and C3 also seem to be efficient. The chemical composition of composts C2 and C4 shows that they have the highest macronutrients content (N, P and K), which might impact plant development and fruit production. According to Majanbu et al. (1985), nitrogen and potassium are essential for the production of okra.

The correlation analysis shows a positive correlation between calcium, potassium, and nitrogen contents of composts and the number of fruits. This observation confirms the positive effects of calcium and potassium on the production of *A. esculentus*. The height and number of leaves of soybean plants grown on compost C2 (green + food wastes) could be explained by its high nutrient contents (Kakar et al., 2002; Milić et al., 2002; Farhad et al., 2010). This observation agrees with the study of Mulaji (2011) that showed that the effects of compost on soybean growth are more pronounced when the compost is rich in nutrients. Treatments which improved the crops' height also improved the yield parameters (Figure 4). Indeed, the highest yields were obtained with the composts C1 and C4 with an average dose of 3.88 $t.ha^{-1}$

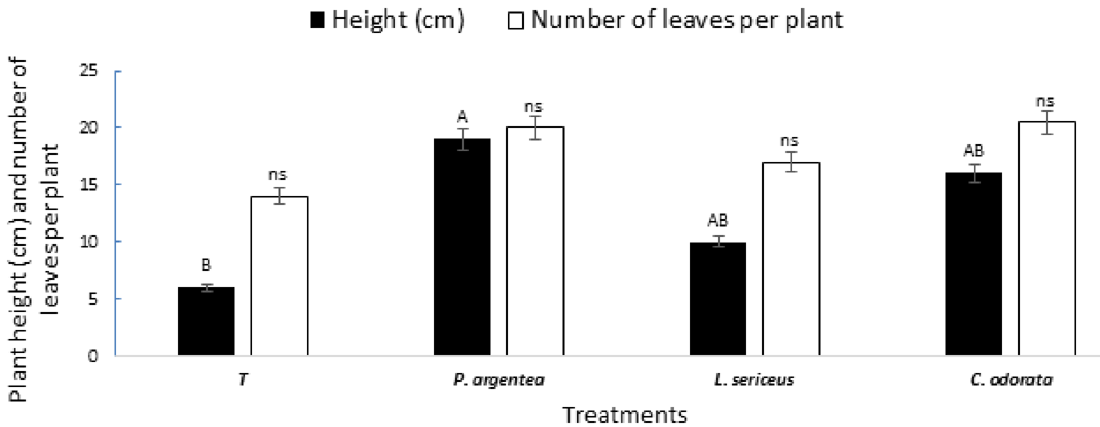

Figure 6. Height and number of leaves per plant of garden coret on different green manure treatments (T= Control treatment).

versus 1.01 $t.ha^{-1}$ for the control treatment. Compost C1 has a low calcium content (0.92% d.m.) and basic pH (7.80). According to N'Gbesso et al. (2013), such conditions are favorable for the production of soybean. These results indicate that the high levels of phosphorus and potassium in the composts C1, C2, and C4 versus C3 might lead to a high production of soybeans. Kakar et al. (2002) and Farhad et al. (2010) showed that phosphorus and potassium are the most important nutrients for the growth and production of soybean. Soybean growth and production could mainly depend on the phosphorus and potassium content of fertilizers or soils (Billore et al., 1994; Kolar and Grewal, 1994). The current results are similar to those of Wijayanto et al. (2016) that showed a high soybean production (3 t ha^{-1}) with compost treatments.

Thus said, the best yields obtained on green manure of *C. odorata* and *P. argentea* could be explained by the nutritional properties of these species and their rapid transformation into organic matter and nutrients. The work of Ognalaga et al. (2016) shows that soil amendment with ashes of *C. odorata* can improve the growth of Guinea sorrel while Tshinyangu et al. (2017) demonstrated the positive effect of *C. odorata* biomass on maize yield. However, several other studies have reported the invasive potential of this plant in Africa, a plant whose fertilizing powers can significantly improve the mineral and organic fertility of soils (Agbim, 1987; Assa, 1987). It would then be ecologically appropriate to reduce this invasive plant in the wild by valorizing it as green manure or compost.

The results obtained for plants grown on *P. argentea* manure can be explained by the ability of that plant to fix atmospheric nitrogen. The work of Sanginga et al. (1996) showed that that plant is capable of forming several nodules that may contain nitrogen-fixing microorganisms, which, once in contact with the atmospheric nitrogen, can transform that nitrogen into nitrogen needed for crop nutrition. On the other hand, the leaves of *L. sericeus* do not decompose easily and could also be poor in nutrients. This would explain the low growth and yield parameters obtained on the plots treated with this species.

Conclusion

The composts produced exhibited positive effects by improving the growth and agronomic parameters of the vegetables on the mining-clay soil tested. However, composts made with green, food, limestone, and clay wastes are the most efficient for okra production on that soil. As a matter of consequence, to improve okra production it will be preferable to add some calcium adjuvant (6 to 8%) to the compost in order to improve its nutritional value. It is also necessary to study the effects of calcium and potassium fertilizers on the physiology and yield of okra in order to improve the production of the plant. The macronutrients content of composts C1 (green waste) and C2 (green and food wastes) led to the best growth of soybeans. It will be wise, before any soybean cultivation on the studied soil, to adjust the pH by acidic pH amendments by the use of food wastes. In addition, the use of composts with high phosphorus and potassium content would be effective to optimize soybean production in the study area.

The green manure species used in this study for *A. esculentus*, *G. max* and *C. olitorius* production show that *C. odorata* and *P. argentea* are the two main spontaneous fertilizing plant species that will help improve vegetable crop production in the study area. However, because the leaves of *L. sericeus* do not easily decompose, transforming its organic matter and releasing of nutrients into the soil become difficult. It would then be more advisable to grind it into biomass before using it.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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