Effect of different doses of cocoa shell compost on the agronomic parameters of the Corne 1 plantain variety in Côte d'Ivoire.

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1 ABSTRACT
Plantain is today the third food crop the most important and contributes greatly to the food security of the populations in Côte d'Ivoire. However, its culture is facing a drop in yield, mainly due to soil poverty and the total absence of inputs in production systems. To rectify this, an organic fertilization trial using cocoa shell compost was conducted on the CNRA experimental plot at Azaguié-Abbè in south-eastern Côte d'Ivoire with the Corne 1 plantain variety. The experimental set-up was a randomized complete block design with four treatments and three replications. Plants fertilized with mineral fertilizer (T1; conventional dose) were compared with plants that have received different doses of cocoa shell compost (T2; 7 T/ha), T3 (14 T/ha) and T4 (18 T/ha). The parameters measured included the height and circumference of the banana tree plantains, the number of leaves emitted, the number of functional leaves, and the interval between planting and flowering (PFI). Observations were also made on the state of initial and final fertility of the soil of the study site. The results showed that the doses of 16 and 18 T/ha of compost significantly improved the chemical properties of the soil compared to the mineral fertilizer. The effects of cocoa shell compost on the parameters of growth and development of the banana trees plantains were statistically identical to those of mineral fertilizer. The soil fertilization in banana plantations can be assured by cocoa shell compost, which is accessible to farmers at a lower cost at a dose of 18 T/ha, to improve plantain productivity in the long term while respecting the environment.

2 INTRODUCTION
Plantain is an important source of food and income for all rural populations in the humid tropical regions of Africa (Swennen, 2006). It is grown on more than 6.7 million hectares in the world, with production estimated at 45 million tonnes (FAO, 2021). In Côte d'Ivoire, its growing importance in feeding populations makes it one of the main food crops (N'Guessan and Ganry, 1989). It's the third most cultivated food crop after yam and cassava, with an annual production estimated at 2.12 million tonnes (FAO, 2021). Plantain in Côte d'Ivoire is used in the making of several local foods such as foufou, foutou, cracro and alloko. It's also the subject of many transformations: crisps, chips, fritters, puree, jam, ketchup, alcohol, wine, beer (Lassois *et al.,* 2009). Plantain also constitutes a source of employment and income (Foure and Tezenas, 2000). Despite the importance of plantain cultivation in Côte d'Ivoire, its production still faces many constraints that reduce yields and struggles to cover the food needs of the

constantly growing populations (Thiémélé *et al.,* 2017). Among these constraints, the decline in soil fertility is one of the biggest and most worrying problems. To remedy this situation, the use of mineral fertilizers, by their immediate beneficial effect on the productivity of food crops, has been considered as an alternative solution. However, their high cost makes them almost inaccessible to small farmers (Useni *et al.,* 2013) and their excessive use leads to an increase in acidity and a deterioration in the physical status and a decline in organic matter of the soil (Mulaji, 2011). As a result, soil fertility cannot be maintained in the long term. In view of all the dangers of mineral fertilization, organic fertilization should be an appropriate solution for restoring soil fertility. However, very few studies have been conducted using cocoa shell compost (Moyin-Jesu, 2007), which is available at least cost and accessible to most of the farmers. The present study was therefore initiated to evaluate the effect of cocoa shell compost on the growth and development parameters of Corne 1 plantain cultivated in the southeast of the Côte d'Ivoire.

3 MATERIAL AND METHODS

Description of the study site: The study was conducted on the experimental plot of CNRA in Azaguié-Abbè. Azaguié is a Southeast city of Côte d'Ivoire in the region of Agneby-Tiassa. It is located in the department of Agboville (regional capital) 40 km North of Abidjan at latitude 5°38' N and longitude 4°05' W and at 38 km from Agboville, covering an area of 201.3 km^2 (Ettien *et al.,* 2022). The climate of this locality is of the Attiean type with four seasons with average annual rainfall and temperatures of 1,466.4 mm and 26.7°C (N'guetta, 2017). The soils of the Azaguié site belong to the class of ferralitic soils (Ferralsols) highly desaturated in base.

Plant material: The plant material used in this study was constituted of plantain vivo plants of the Corne 1 variety obtained by the MSD (Multiplication on shelled stump) technique.

Setting up of the test and experimental device: A fallow parcel of 1350 m^2 has been cleared manually to set up a randomized complete block (RCB) with four treatments and three repetitions by treatment (Figure 1). In each treatment, two lines of six of banana trees plantains were planted with a spacing of 2.5 m between the lines and 2 m on the lines. Either a total of 144 plants were planted on all the elementary parcels, excluding border plants. The different treatments were composed of one treatment based on chemical fertilizer: T1 (22 $g.plant^{-1}$ of urea and 55 $g.plant^{-1}$ of KCl) by application (8 times) and three treatments based on cocoa shell compost: T2 (7 $t.ha^{-1}$), T3 (14 $t.ha^{-1}$) and T4 (18 $t.ha^{-1}$) by fractional doses (3 times).

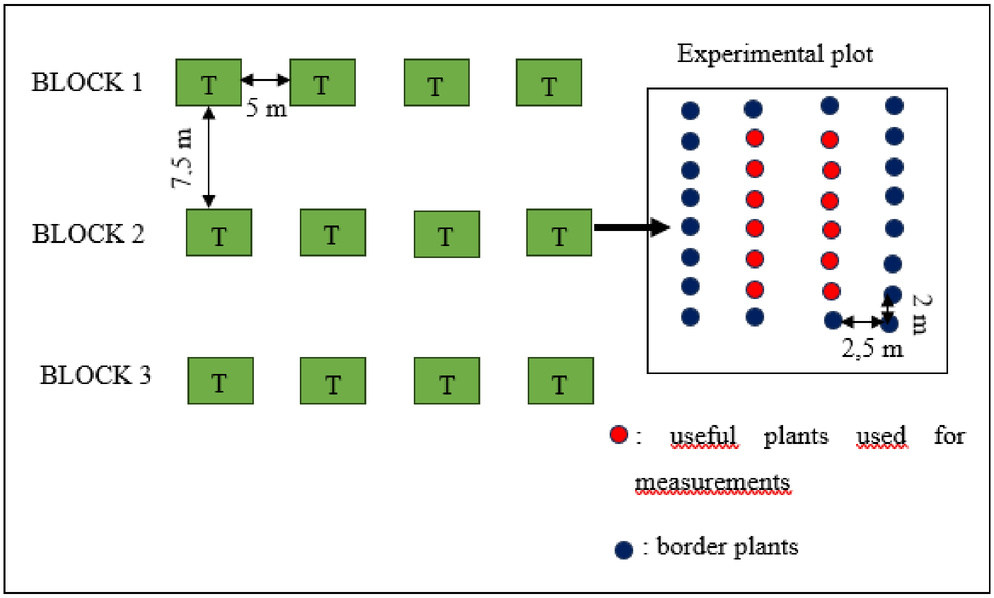

Figure 1: experimental device

Vegetative measurements: Vegetative growth of banana trees plantains was measured monthly and included the following parameters: the pseudostem height (**H**) was measured from the soil level up to "V" formed by the last two leaves and the circumference of the pseudostem was measured at 10 cm (**Circ/10cm**) and 100 cm (**Cir/100 cm**) above the soil level at flowering, the number of leaves emitted (**FE**), the number of functional leaves (**FV**) and the interval between planting and flowering (**IPF**).

Statistical analysis of data: The data of the agronomic parameters of the banana trees plantain and the chemical composition of the soil of the study site before and at the end of the experiment were analysed using the STATISTICA 7.1 software. These data have been submitted to an analysis of variance and when differences among treatments means were significant, mean separation was done using the Newman-Keuls (SNK) test at p = 5%.

RESULTS

Chemical characteristics of the cocoa shell compost: The results of the analysis of the cocoa shell compost are presented in the Table 1. These results have been compared to the French AFNOR standard, and revealed a high organic matter (MO) content (30.20 $g.kg^{-1}$), a high nitrogen content (1.75 $g.kg^{-1}$) and a C/N ratio equal to 10.05. As for the exchangeable bases in the compost, the results showed a high potassium (3.98%) and calcium (4.29%) content. In terms of the acidity of the compost, the pH value was around 7.5.

Table 1: Mineral composition of the cocoa shell compost after laboratory analysis

Parameters	pH	C($g.kg^{-1}$)	MO ($g.kg^{-1}$)	N($g.kg^{-1}$)	C/N	P (%)	K (%)	Ca (%)	Mg (%)
Contents	7.5	17.56	30.20	1.75	10.05	1.54	3.98	4.29	0.25
AFNOR Standard			> 5	> 0.25	< 20		> 1		

Chemical characteristics of the soil of the study site before the experiment: The chemical characteristics of the soil of the study site before the experiment are shown in the

Table 2. By comparing of the results obtained with the threshold values of interpretation of the results of soils according to Lano (2008) shows that the soil of the study site was very acidic (pH = 4.9 < 5.5) with very low contents in exchangeable bases (Ca^{2+}, Mg^{2+} and K^{+}). The cation exchange capacity was around 4.9 $Cmol.kg^{-1}$ and the sum of exchangeable bases (SBE = 1.241) was low.

Chemical characteristics of the soil of the study site at the end of the experiment: At the end of the experimentation, the chemical properties of the soil recorded in the Table 3 showed that the C/N ratio, assimilable phosphorus and exchangeable potassium (K^{+}) content are statistically identical for all treatments. Taken individually, the T4 treatment has more favoured the improvement of the C/N ratio while the T3 treatment produced a greater improvement of the exchangeable potassium (K^{+}) compared to the T1 treatment and the initial soil values. However, the types of fertilizer influenced significantly the pH (P = 0.045), the organic carbon content and the organic matter content (P = 0.005), the nitrogen content (P = 0.001), the CEC and the exchangeable base content (Ca^{2+} and Mg^{2+}; P = 0.0001). The T4 Treatment obtained the highest mean values compared to the T1 treatment and the initial soil values before the planting of plantain vivo plants.

Table 2: Chemical properties of the soil of the study site before the experiment

	Chemical properties								
Acidity	**Organic Matters**					**Adsorbent complex**			
pH	C ($g.kg^{-1}$)	Nt ($g.kg^{-1}$)	MO	C/N	P.ass ($mg.kg^{-1}$)	CEC	Ca^{2+} ($cmol.kg^{-1}$)	Mg^{2+} ($cmol.kg^{-1}$)	K^{+} ($cmol.kg^{-1}$)
4.9	9.5	1.2	16.3	7.9	49	4.9	0.736	0.419	0.086
<5.5		1<N<1.5				<9	<1	<0.5	<0.1

MO: Organic Matter; CEC: cation exchange capacity; Pass : assimilable phosphorus

Table 3: Chemical characteristics of the soil of the study site at the end of the experiment

Treatments	**pH**	**C ($g.kg^{-1}$)**	**N ($g.kg^{-1}$)**	**C/N**	**MO**	**CEC ($cmol.kg^{-1}$)**	**Ca^{2+} ($cmol.kg^{-1}$)**	**Mg^{2+} ($cmol.kg^{-1}$)**	**K^{+} ($cmol.kg^{-1}$)**	**SBE**
T1	5.80 ± 0.56^{b}	11.42 ± 1.22^{b}	1.22 ± 0.08^{b}	9.73 ± 1.69^{a}	20.28 ± 2.11^{b}	7.38 ± 0.00^{b}	4.50 ± 0.04^{c}	0.97 ± 0.00^{b}	0.38 ± 0.00^{a}	5.85 ± 0.04^{c}
T2	6.05 ± 0.60^{ab}	12.92 ± 0.58^{b}	1.07 ± 0.00^{c}	12.08 ± 0.54^{a}	22.22 ± 1.00^{b}	6.26 ± 0.03^{c}	5.03 ± 0.00^{b}	0.94 ± 0.00^{d}	0.34 ± 0.04^{a}	6.30 ± 0.04^{b}
T3	6.40 ± 0.00^{ab}	13.10 ± 0.50^{b}	1.26 ± 0.00^{ab}	10.37 ± 0.39^{a}	22.54 ± 0.86^{b}	7.38 ± 0.06^{b}	4.44 ± 0.07^{c}	0.97 ± 0.00^{c}	0.39 ± 0.00^{a}	5.80 ± 0.07^{c}
T4	6.90 ± 0.54^{a}	14.96 ± 0.03^{a}	1.34 ± 0.03^{a}	11.18 ± 0.23^{a}	25.74 ± 0.06^{a}	8.29 ± 0.39^{a}	5.28 ± 0.00^{a}	0.98 ± 0.00^{a}	0.37 ± 0.00^{a}	6.63 ± 0.00^{a}
P	0.045	0.005	0.001	0.062	0.005	0.0001	0.0001	0.0001	0.082	0.0001

The letters a, b and c indicate the significantly different mean values in the column at the threshold a=0.05 according to the Student Newman-Keuls test.
T1: 22g of urea + 55 g of Kcl; T2: 7 T/ha of cocoa shell compost; T3: 14 T/ha of cocoa shell compost; T4: 18 T/ha of cocoa shell compost; MO: organic matter; CEC: cation exchange capacity; Pass: assimilable phosphorus, SBE: sum of exchangeable bases

Effects of cocoa shell compost and mineral fertilizer on agronomic parameters of the banana trees plantains: At the flowering stage, the different fertilizers treatments significantly influenced the height (P= 0.0001) and circumference of the pseudostem (P= 0.004) measured at 1 meter from the soil. Banana trees plantains in the T1 treatment recorded the highest mean heights (316 cm) and girth (51 cm). For the plants that received cocoa shell compost, the mean values for height and girth evolved with the increase in the dose of compost. At this flowering stage, the number of functional leaves, the number of leaves emitted and the interval between planting and flowering (IPF) were statistically identical for each treatment. Indeed, the number of functional leaves (FV) to the exit of the inflorescence reached a total of 7 to 8 leaves (Table 4). In addition, banana plants from the T2, T3 and T4 treatments produced as many leaves as those from parcels fertilized with the mineral fertilizer.The duration of the vegetative phase of the banana plants was earlier in the parcels fertilized with the mineral fertilizer (T1) than those in the parcels fertilized with the cocoa shell compost. Plants in the T4, T3 and T2 treatments flowered respectively 6, 10 and 21 days after those in the T1 treatment.

DISCUSSION

Compost belongs to the category of fertilizers and cultivation support, as organic amendments or fertilizers. The quality of the cocoa shell compost used to fertilize the soil was assessed on the basis of its chemical characteristics. The C/N ratio obtained was around 10.05, indicating that the compost used in this study was mature. According to the work of Mustin (1987), when this ratio is between $10 < C/N < 15$, the compost is mature and rich in nitrogen. The pH value obtained after laboratory analysis was 7.5, within the range of pH values (7 to 9) for mature compost (Albrecht, 2007). This pH value indicates a high content of exchangeable bases (calcium and magnesium) in the compost produced. Indeed, in presence of the values of pH near of the neutrality, exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}) bind to the soil's absorbent complex, thereby reducing the number of adsorbed H^{+} ions, which are a source of soil acidity (Ye, 2007). The works of Tremier *et al.* (2007) showed that composts with an acid pH are generally characterized by poor stabilization of organic matter and a risk of negative agronomic impact when returned to the soil. The compost produced had a high organic matter content, a high nitrogen (N) content, a high C/N ratio and a high content of exchangeable bases (K) compared with the threshold values of the AFNOR standard of appreciation of the organic substances. These results testify that the compost produced is of high quality and can be recommended for managing soil fertility and improving crops productivity. The results of the chemical parameters of the soil of the study site showed a significant improvement of the content of organic matter (MO) in the soil, of the cation exchange capacity (CEC) and of the exchangeable base content with the application of fertilizers. The T4 treatment however, recorded the highest average values. This strong improvement in soil composition by applying the highest dose of cocoa shell compost (T4 = 18 T/ha) confirms the works of Bouadou *et al.* (2014) and Biaou (2017), and al who showed that applying organic fertilizers to the soil improves its physical, chemical and biological properties. Likewise, according to Abobi *et al.* (2014), the increase in CEC is due to organic amendments that would have affected the phenomena of fixing exchangeable cations on the soil adsorbent complex. The CEC is in fact linked to the clay-humus complex (CHC) formed by humus and mineral particles by the Ca^{2+}, Fe^{2+} and Al^{3+} cations responsible for improving soil properties that compost contributes to form (Charland *et al.,* 2001). Thus, more the organic matter is raised, more the CEC is also raised and more the soil keeps the nutrients to make them available to plants for their growth (Weill and Duval, 2009). As far as the soil pH is concerned, the averages were significantly different between treatments. These results showed that the application of 18 T/ha of cocoa shell compost led to a considerable drop in soil acidity. The soil pH has gone from very acidic (pH = 4.9 < 5.5) to neutral (6.5 < pH < 7). According to Djébré (2008) and Abobi *et al.* (2014), this increase of the soil pH would be linked, on the one hand, to the buffering effect of the organic matter and, on the other hand, to the high cation exchange capacity of the divalent ions (Ca^{2+} and Mg^{2+}) which in despite being removed by the banana plants are in sufficient quantities in the compost to neutralize the H^{+} and Al^{3+} ions responsible for the acidity. The T1 treatment obtained the lowest pH value. However, the application of mineral fertilizer increased the soil pH to 0.9 compared to the initial soil pH, passing the soil from very acidic to acidic. These results are contrary to those of Mulaji (2011) who explains that the exclusive use of mineral fertilizers leads to an increase of the acidity, a deterioration of the physical status and a decrease of the organic matter of the soil. According to the nitrogen content in the soil at the end of the experimentation, the results showed that the application of the highest dose (18 $t.ha^{-1}$) of cocoa shell compost gave the highest average content compared to the treatment with mineral fertilizer (T1) and the initial state of the soil. The compost contains relatively little nitrogen (0.5 to 0.6 p.c.), depending on its basic components, so their contribution in quantity can provide the complementary nitrogen and trigger its dynamic in the soil (N'Dienor, 2006). According to Nyembo *et al.* (2014), organic fertilizers release nitrogen in a form that can be assimilated by the plant, and their actions are slow and progressive. The fertilizing value of the nitrogen contained in compost is therefore generally low, but should not be neglected in the case of important inputs. The results at the flowering stage showed that the application of cocoa shell compost and mineral fertilizer had positive effects on all the growth parameters (height and circumference of the pseudostem measured at 1 meter from the soil) of the banana plants. In the case of fertilization with cocoa shell compost, the increase of the compost led to an increase of the height and circumference of the banana plants. Kouadio *et al.* (2018) obtained similar results working on the effect of the teguments of cocoa beans on the chemical fertility of a ferralsol and some parameters of cassava growth. However, these results are more superior to those obtained by Tchigossou *et al.* (2019) who studied the agromorphological parameters of plantain (*Musa* spp.): the case of two Faux-corne cultivars in southern Benin. These authors obtained an average of 195 cm for Aloga cultivars compared with 245 cm for Big Ebanga cultivars at flowering. These differences in the pseudostem and the height could be explained by the variations of the environmental conditions, the type and the application dose of fertilizer used. At the flowering stage, the types of fertilizer had no significant effect on the average number of leaves emitted, the average number of living leaves and the IPF. In fact, the average number of leaves emitted in the parcel that received the highest dose of cocoa shell compost (T4) was 42, while the parcel enriched with mineral fertilizer (T1) was 41. Bomisso *et al.* (2018) obtained similar results working on the effect of the mixture of the plantain peels and the chicken droppings compost on the growth of plantain flaked shoots, of the variety Big Ebanga. In their study, the number of leaves emitted by plants treated with organic fertilizers was higher than those treated with NPK. These results could be explained by the nitrogen content in the compost, which stimulates the foliar meristem and enables more quickly the plantain to complete its crop cycle in the parcel fertilized with compost, contrary to the parcel fertilized with mineral fertilizer. The number of functional leaves at flowering is a good indicator of correct or incorrect fruit development. These results are similar to those of Lassois *et al.* (2009), who showed that the condition so that the banana fruit develop themselves correctly, there must be at least 8 living leaves at the flowering and 4 at the harvest. The IPF of banana plants obtained in the parcel with mineral fertilizer was not statistically different from those obtained with cocoa shell compost. However, T1 treatment plants flowered 6 days, 10 days and 21 days earlier than T4, T3 and T2 treatments respectively. These results corroborate those of

Lassoudière (2007), who showed that, under favourable growing conditions, the banana tree has an optimal growth, so a cycle shorter and shorter. In addition, Hossain and Haque (2013) and Jambulingum *et al.* (2011) reported that the application of increased levels of nitrogen and potassium improved flowering, what confirmed the results obtained. The knowledge of the IPF is very important, because it permits us to predict in advance the period fruit ripening and to plan the next harvests.

CONCLUSION

At the end of this experimental study of the effect of cocoa shell compost on the growth and development of banana trees plantains, we retained that the doses of cocoa shell compost (T3 and T4) improved the growth and development parameters of the banana trees as much as the mineral fertilizer. Regarding the quality of the cocoa shell compost produced, the organic matter, nitrogen and assimilable cation (K^+) content was good compared with the French AFNOR standard. Also, the C/N ratio and pH revealed that the compost produced is mature and of good quality, enabling it to play the role of soil improver and fertilizer. The dose of 18 T/ha of cocoa shell compost improved the chemical properties of the soil more. Cocoa shell compost reduced the soil acidity and increased the organic matter, the nitrogen, the CEC and the assimilable cations (Ca^{2+} and Mg^{2+}) content. It would therefore be advantageous and profitable for farmers to favor the use of cocoa shell compost to improve the soil fertility and the productivity of the crops.

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