

# Decomposition of Plantain Peel Powder and Assessment of its Effects on Soil Physical and Chemical Characteristics

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## Authors' contributions

This work was carried out in collaboration among all authors. Author AKT designed the study, performed the statistical analysis, wrote the protocol, and drafted the first version of the manuscript. Authors GKHR and BEL managed the analyses of the study. All authors read and approved the final manuscript.

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## ABSTRACT

This study aims at assessing the effects of plantain (*Musa paradisiaca*) peel powder on soil physical and chemical properties in the context of sustainable yield management. The experiment took place in the laboratory of plant physiology of the University Félix Houphouët Boigny from July to November 2020. Three designs were set up. Design 1 consisted of 20 g of plantain peel powder added to a 2-cm thick layer of sea sand. Design 2 consisted of 5 g of plantain peel powder added to 250 g of sea sand. Design 3 consisted of a homogeneous mixture of 100 g of peel powder and 200 g of rhizospheric tomato or plantain soil. The designs were regularly watered with distilled water. In the first two designs, the plantain peel powder was added according to two methods. These included surface incorporation and deep incorporation. The experiment allowed us to characterize

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peel powder decomposition and assess its effects on soil physicochemical parameters. The physico-chemical characteristics of the soils were subjected to a one-way analysis of variance (ANOVA 1). STATICA 7.1 software was used to perform all the analyses. Analysis of the results showed that the incorporation method does not influence peel powder decomposition. This decomposition is followed by the release of colored elements. Water retention capacity as well as particle size were improved. The results showed that plantain peel powder is an important source of minerals mainly phosphorus and potassium. It emerges from this study that plantain peel could be a good organic fertilizer for profitable and environmentally friendly agriculture.

**Keywords:** *Plantain peel; decomposition; fertilizer; physical and chemical parameters.*

## 1. INTRODUCTION

In Côte d'Ivoire, cultivable soils are subject to increasingly extensive agricultural exploitation due to the needs generated by population growth [1]. The strong pressure on agricultural land reduces their availability and causes a significant drop in their fertility [2]. Farmers thus resort to the use of synthetic fertilizers to compensate for the nutritional deficit of plants. However, their high cost and negative impact on the environment and the health of populations [3] limit their use [4]. Moreover, the improper application of these mineral fertilizers is usually followed by a process of soil salinization, thus leading to the quick degradation of its fertility [5].

In this two-dimensional context of soil degradation and climate change, new cultivation practices that fit perfectly into sustainable development principles are recommended to farmers [6]. Among these practices, the organic amendment of soils with plant residues has advantages such as greenhouse effect reduction by carbon sequestration, waste mass and volume reduction [7], restoration of physicochemical properties of degraded soils [8]. In addition to these advantages, there is a low cost of production and purchase, making the practice more easily accessible to farmers [9].

Thus, the input of organic products has become an adequate and essential agronomic practice for the restoration of soil physical and physicochemical properties [10].

Indeed, many studies have shown that organic amendments improve various soil properties, which justifies their use [11]. Ayanlaja and Sanwo [12] have shown that the decomposition of plant residues considerably increases the content of nutrients and organic matter in soils. Alla [13] showed that the application of organic manures precisely the combination of chicken manure with potash from the plantain peel

significantly increased the yield of the eggplant variety N'drowa (*Solanum aethiopicum* L.). Furthermore, the dried and crushed plantain peel used alone or mixed with chicken manure compost favored a harmonious growth of young plantain plants [14]. These advantages rank plantain peel amendment as an efficient and competitive means of regenerating the fertility of degraded soils. This organic fertilizer is thus presented as one of the alternatives to the use of mineral fertilizers.

However, little is known about how this fertilizer works on soil physical and chemical properties.

This is the framework for this study, which aims at optimizing the use of plantain peel in agriculture. Specifically, this involves characterizing the decomposition of plantain peel powder and assessing its effects on the physicochemical characteristics of soil under plantain trees and under tomatoes.

## 2. MATERIAL AND METHODS

### 2.1 Material

#### 2.1.1 Soils

Two soils from plantain and tomato cultivation rhizosphere were respectively used in this study due to their intensive exploitation by producers (Fig. 1). Samples were taken from the surface horizon (0-20 cm) in plantations in the town of Songon (town located 10 km from Abidjan). In addition to the soils under tomato and plantain trees, sea sand from the municipality of Port Bouët (Abidjan) was used as a substrate in plantain peel powder decomposition (Fig. 2).

#### 2.1.2 Organic products

The organic material used was plantain peel powder (PPBP). This was produced from household waste, in particular, plantain peels

collected from braised plantain, alloco (*fried ripe plantain*), chips (*fried thinly sliced unripe plantain*) sellers in the city of Abidjan. The peels were dried before being transformed into powder at the mill (Fig. 3).

## 2.2 Methods

### 2.2.1 Characterization of plantain peel powder decomposition

#### 2.2.1.1 Preparation of the substrate

The experiment on plantain peel powder decomposition rate was carried out on sea soil used as an incorporation substrate. The organic matter found in the sea sand samples was destroyed with acetic acid. To this end, 1.165 L of 25% acetic acid was added to 5 kg of sea

sand and then mixed for 30 min. The sand treated with acetic acid was rinsed with distilled water 3 times and then dried for 24 h.

#### 2.2.1.2 Plantain peel powder incorporation and incubation

Two incorporation methods made it possible to study plantain peel powder decomposition. These included:

- Surface incorporation (I S): 20 g of plantain peel powder were spread over a 2-cm thick layer of treated sea sand (Fig. 4 a);
- Deep incorporation (I P): 20 g of plantain peel powder were spread over a 2-cm thick layer of treated sand then covered with a second 2-cm thick layer (Fig. 4 b);



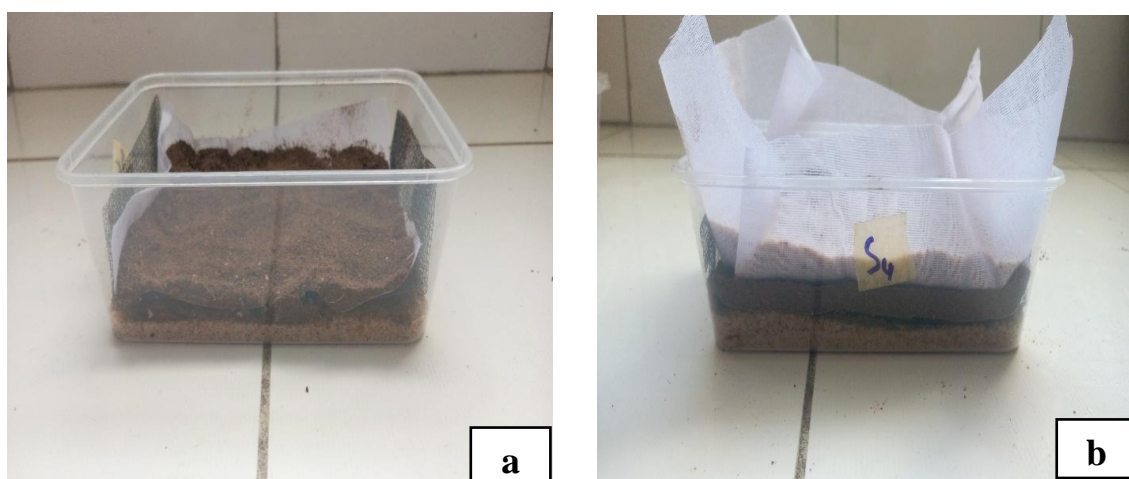
Fig. 1. Soil under plantain tree and under tomato



Fig. 2. Sea sand



Fig. 3. Plantain peel powder



**Fig. 4. Plantain peel powder incorporation methods**  
**a. Surface incorporation, b. Deep incorporation**

The plantain peel powder was separated from sand layers using a muslin cloth mounted on a 1-mm mesh screen. The preparations were placed in transparent plastic trays. Five trays were used per type of incorporation.

#### 2.2.1.3 Weight loss and decomposition rate

Weight loss measurement consisted in determining the quantity of plantain peel that was decomposed over time. To this end, after incorporation, some weighings were carried out every two weeks. The PPBP was collected, dried and then weighed. The weight loss study extended over (2) months.

The decomposition coefficient, which gives an idea of PPBP decomposition rate, was calculated according to the mathematical model established by [15]:

$$K = \frac{\Delta m}{\Delta T} \quad (1)$$

K : decomposition coefficient

$\Delta m$  : mass variation (g)

$\Delta T$  : time variation (j)

#### 2.2.1.4 Study of the physicochemical characteristics of the PPBP percolated extract

In order to study percolation, two designs were set up from 500-ml plastic bottles. The bottles were cut 2/3 from the ring towards the bottom. The upper parts bearing the necks served as a funnel in which the sand treated with acetic acid and the PPBP were placed according to the

structuring for surface incorporation and deep incorporation:

- Surface incorporation: 5 g of PPBP were placed on a 250-g layer of sand treated with acetic acid (Fig. 5 a);
- Deep incorporation: 5 g of PPBP were placed on a first 150-g layer of sand treated with acetic acid and then covered with another 100-g layer of the same sand (Fig. 5 b).

The PPBP was separated from the sand layers by a muslin cloth mounted on a 1-mm mesh screen. Each design was watered with 60-ml distilled water to obtain 20 ml of percolated extract [16]. PPBP percolated extracts were produced every three (3) days for two (2) months.

The percolated extracts collected were analyzed so as to determine their colored compound content, their pH and their conductivities.

- **Percolated extract colored compound contents:** this was studied by determining the optical density at wavelengths of 472 and 665 nm. The measurements were performed using a Jenway spectrometer (Genova Nano).
- **pH:** it represented the overall measurement of hydrogen ions using a pH meter. The pH meter was calibrated using two (2) buffers: pH 4 and pH 7. After calibration, the probe was immersed in the percolated extract and the pH values were read on screen.

- **Electrical conductivity:** This made it possible to assess the salinity of the sample by measuring the concentration of soluble salts. It was measured using an EUTECH conductivity meter CON 700. The probe was immersed in the percolated extract and the conductivity in mS/cm was read on the device screen.

### 2.2.2 Assessment of plantain peel powder effect on the physicochemical characteristics of soil under plantain tree and under tomato

This study was carried out in 500-ml jars. In each jar, 200 g of rhizospheric soil for tomato cultivation were put on the one hand (Fig. 6) and 200 g of rhizospheric soil under plantain tree cultivation were put on the other hand (Fig. 7), added to 100 g of plantain peel powder (PPBP). Everything was homogenized and watered every 2 days for 2 months. 200 g of soil under tomato and under plantain tree subjected to the same watering regime served as control. Five repetitions were performed per treatment. At the end of the 2 months, some samples were taken per treatment so as to assess their physical and chemical characteristics.

#### 2.2.2.1 Physical characteristics

- **Particle size**

The study of the particle size of the studied soils was carried out according to the method of

particle size analysis by Densitometry Control and treated samples of each type of soil were dried and ground in a mortar and then sieved through a 2-mm mesh sieve. To 50 g of sieve underflow were added 50 ml of 5% sodium hexametaphosphate and 100 ml of distilled water. The whole was homogenized and left to stand for 24 hours. The mixture was transferred to a graduated cylinder. A hydrometer was introduced into the cylinder and the volume was made up to 1 liter. The hydrometer was subsequently removed, the soil was suspended by successive overturning and straightening of the cylinder which was obstructed. The cylinder was placed on a flat surface. The hydrometer was introduced into the container again and the reading was performed 40 seconds later. A second reading was performed after standing the mixture for 3 hours. The temperature of the mixture was read after each removal of the hydrometer. The first reading (H1) corresponded to the concentration of suspended clay and silt and the second (H2) to the (total) clay concentration  $\geq 2 \mu$  in suspension. The following formulas were used to calculate the clay, silt and sand contents of the control and treated soils:

$$\% \text{ Sand} = 100 - [H_1 + 0,36 (T_1 - 20) - 2] \times 2 \quad (2)$$

$$\% \text{ Clay} = [H_2 + [0,36 (T_2 - 20) - 2] \times 2] \quad (3)$$

$$\% \text{ Silt} = 100 - (\% \text{ sand} + \% \text{ clay}) \quad (4)$$

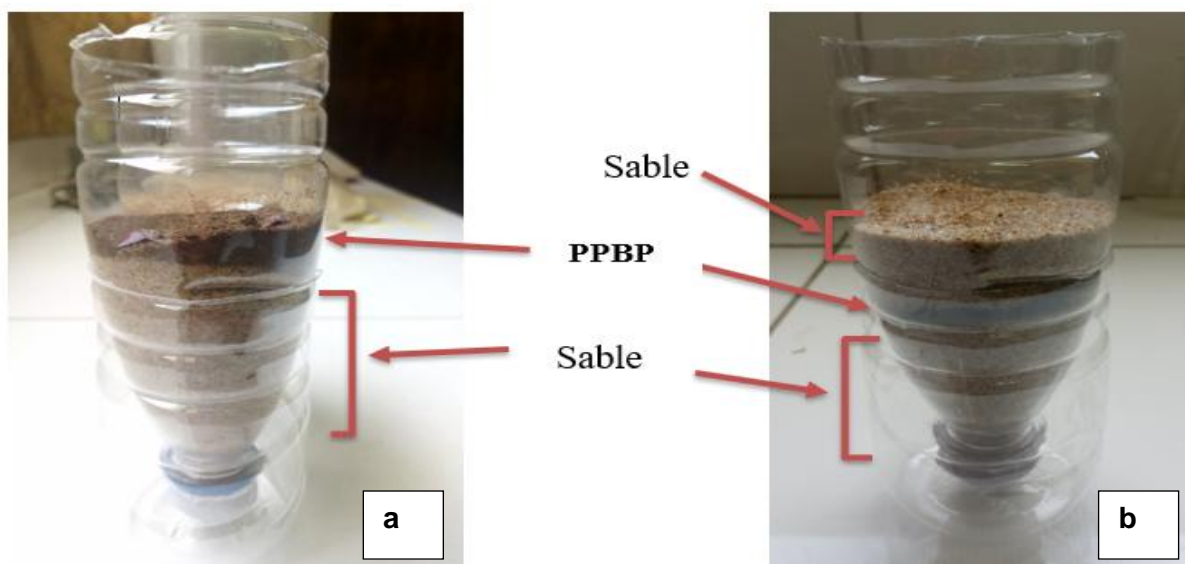
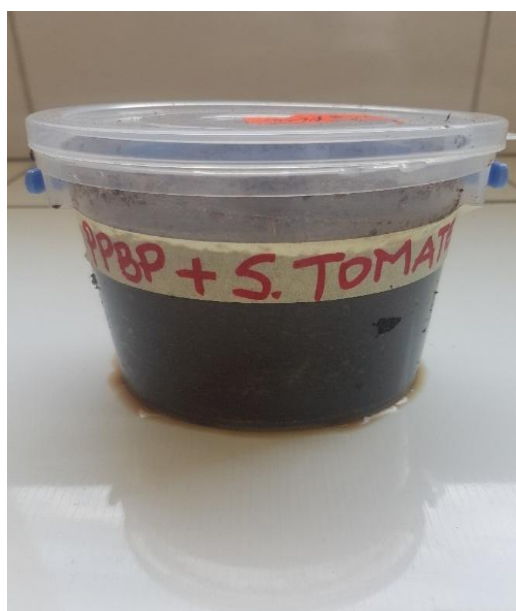
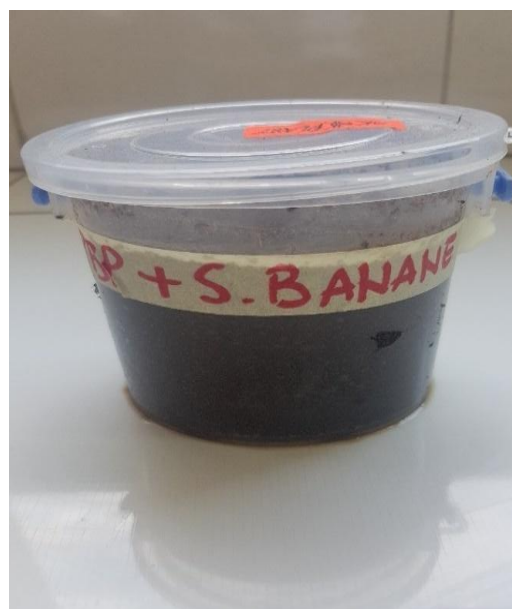


Fig. 5. PPBP percolated extract production design  
a. Surface incorporation b. Deep incorporation



**Fig. 6. Mixture of PPBP and soil under tomato**



**Fig. 7. Mixture of PPBP: and soil under plantain tree**

- **Water content (TE)**

The water content represents the percentage of water in a material under consideration. To measure it, a 100 g wet weight (PF) sample of wet soil was oven dried at 70 °C for 48 h. The dry weight (PS) obtained was determined and the water content (TE) calculated according to the following formula:

$$TE = \frac{(PF-PS)}{PS} \times 100 \quad (5)$$

### 2.2.2.2 Chemical characteristics

The chemical parameters of control soils treated with plantain peel powder were measured at experiment start and end. These included the potassium (K), sodium (Na), total organic carbon (Corg) and total organic nitrogen (NT) content.

- **Sodium (Na) and potassium (K) contents**

Five g of each soil sample (control and treated) were incinerated in a muffle furnace at a temperature of 600 °C for 6 hours. The ash obtained was dissolved in 20 ml of hydrochloric acid and the resulting solution was filtered one hour later on Whatman paper into a 100-ml volumetric flask. The filtrate was made up to 100 ml with distilled water. Sodium and potassium

were determined using an Ependorf Gertebau brand flame spectrometer. Butane gas was used for the assay.

- **Total organic nitrogen (NT)**

The nitrogen assay was performed using the kjeldhal method. It is a wet mineralization which consists in destroying organic matter by boiling in the presence of sulfuric acid. Under these conditions, the nitrogen is transformed into ammonia fixed by sulfuric acid. By alkalization of the ammonium sulphate solution obtained, the ammonia is displaced, driven by a stream of water vapor. It is assayed by colorimetry with sulfuric acid.

- **Organic carbon**

The organic carbon content was determined from the organic matter one. Five (5) g of dry sample (m1) was calcined at 600 °C for 6 hours in a muffle oven [17]. The mass of the calcined sample (m2) was determined and the organic matter content was calculated from the following formula:

$$MO(\%) = \frac{m1-m2}{m1} \times 100 \quad (6)$$

The content of organic carbon (Corg) was deduced according to the following relation:

$$Corg = \frac{MO(\%)-1,5}{1,4} \quad (7)$$

- **C/N ratio**

The ratio between the amount of carbon and the amount of nitrogen contained in the mixture was determined. This data allows a very rough estimate of the speed of nitrogen mineralization of mixtures. The higher this ratio, the less quickly nitrogen is available.

- **Phosphorus**

The phosphoric acid was assayed colorimetrically on the chloridic solution of the ash thanks to the yellow color it gives with the vanadomolybdc reagent. To carry out the assay, we had to take up the ashes in 5 ml of approximately 3 M hydrochloric acid and pour the solution obtained into a 100-ml volumetric flask. We had to rinse the capsule with approximately 50 ml of distilled water and pour this wash water into the flask. We had to add exactly measured 25 ml of vanadomolybdc reagent. We had to shake, allow the color to develop for 15 to 20 min. We had to bring the flask content to 100 ml with distilled water. We had to examine with a spectrophotometer at 400 nm. At the same time, the calibration range was prepared. In 100-ml volumetric flasks, 5, 10, 15, 20 and 25 ml of the solution titrating 0.1 g of P<sub>2</sub>O<sub>5</sub>/l were put. The volume was brought to about 50 ml with distilled water, then 25 ml of vanadomolybdc reagent was added. The content of each flask was brought to 100 ml for the determination of absorbances at 400 nm. The total phosphorus content was obtained by plotting the absorbance determined on each sample on the calibration curve.

### 2.2.3 Data processing

Data on PPBP decomposition rate, water content and soil chemical characteristics were subjected to a one-way analysis of variance (ANOVA 1). In case of rejection of the average equality hypothesis, the Newman keuls average separation test was applied at 5% threshold. The STATICA 7.1 software was used to perform all the analyses.

## 3. RESULTS

### 3.1 Characteristics of Plantain Peel Powder Decomposition

#### 3.1.1 Weight loss and decomposition coefficient

Weight loss at surface incorporation went through 3 phases (Fig. 8). The first one, which

started from day 0 to day 14 after incorporation was characterized by a quick decomposition of PPBP (2.150 g / d) (Table 1). The decomposition rate was reduced (1.268 g / d) during the second phase (14-28 d after incorporation). This reduction was accentuated during the third phase (28-56 days after incorporation). The weight losses of PPBP with deep incorporation showed in its evolution phases that were identical to those of surface incorporation (Fig. 8). They were also characterized by a gradual decrease in the decomposition rate. They were respectively 2.073; 1.350 and 0.026 respectively for phases 1, 2 and 3 (Table 1). The comparison of PPBP decomposition rates according to the 2 incorporation methods showed that they were not significantly different for the whole process and for the different phases (K0-14, K14-28, K28-56) (Table 1).

#### 3.1.2 Characteristics of percolated extracts

- **pH**

The pH of the percolated extract during PPBP decomposition whether in surface or deep incorporation went from neutral values to basic values (Fig. 9). It fluctuated between a minimum value of 7.0 and 7.62 for surface incorporation and between 7 and 7.8 for deep incorporation.

- **Conductivity**

The electrical conductivity values of percolated extracts were between 6670 mS/cm and 39 mS/cm in the two PPBP incorporation designs (IS and IP) (Fig. 10). The evolution of electrical conductivity occurred in three phases in both incorporation methods. The first phase (day 0-3) showed high conductivity (>5500 mS / cm). The second phase (day 3-24) was characterized by a quick drop ranging from 6670 mS/cm to 450 mS/cm. The last one, day 24-60, showed conductivity stabilization (<450 ms/cm).

- **Colored compounds content**

Fig. 11 A and B shows the staining intensity of PPBP aqueous extracts in two incorporation methods at two wavelengths (472 and 665 nm). On day 3 of decomposition, the staining intensity showed an identical peak in both incorporation methods at both wavelengths (0.837 at 472 nm and 0.353 at 665 nm). Over the 3-60-day period, the staining intensity showed another peak (on day 9) in deep incorporation (0.303 at 472 nm and 0.147 at 665 nm) before stabilizing while in

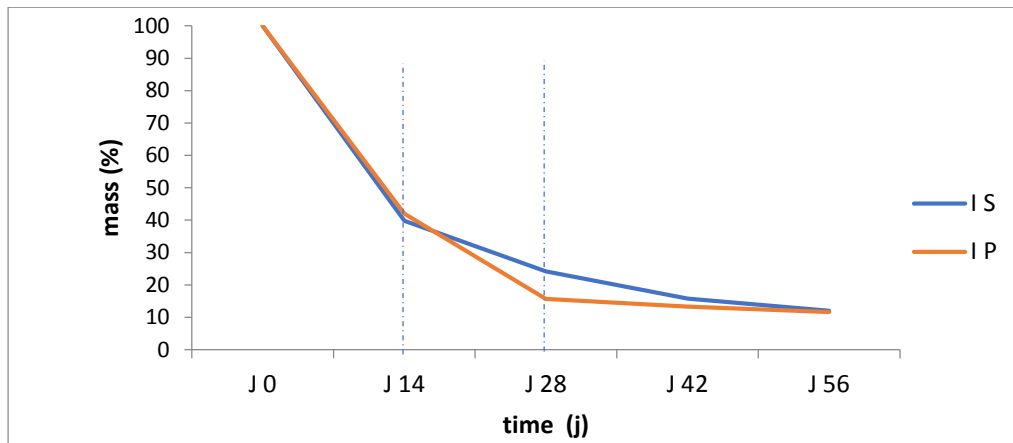


Fig. 8. PPBP weight loss depending on time and soil incorporation method

Table 1. Decomposition rate according to PPBP incorporation method

	Decomposition rate (g/d)		
	K 0-14	K 14-28	K 28-58
Surface Incorporation	2.150±0.173a	1.268±0.185a	0.031±0.013a
Deep Incorporation	2.073±0.247a	1.350±0.265a	0.026±0.018a

*In the same column, the averages followed by the same letter are not significantly different at 5% threshold*

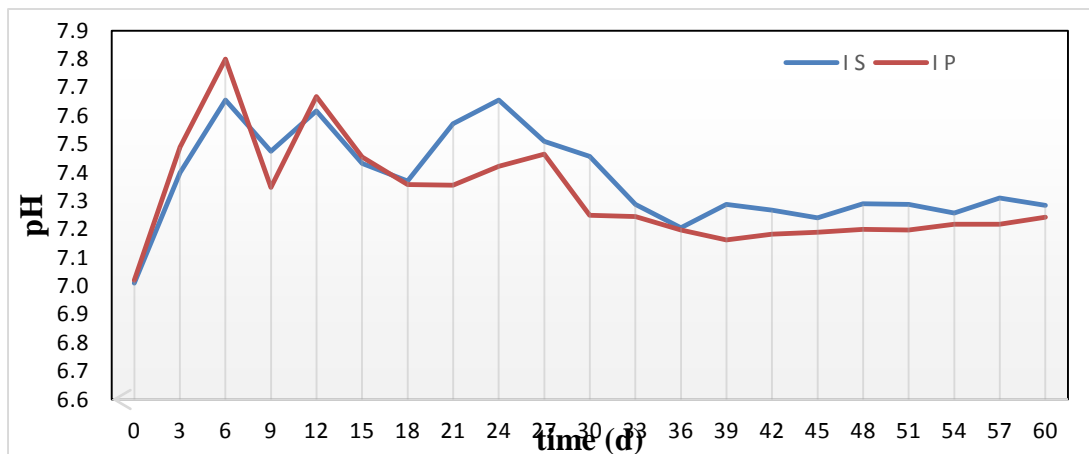


Fig. 9. pH of PPBP decomposing percolated extracts

surface incorporation, the staining intensity stabilized from the day 6.

### 3.2 Effect of Plantain Peel Powder on the Physicochemical Characteristics of Soil under Plantain Tree and under Tomato

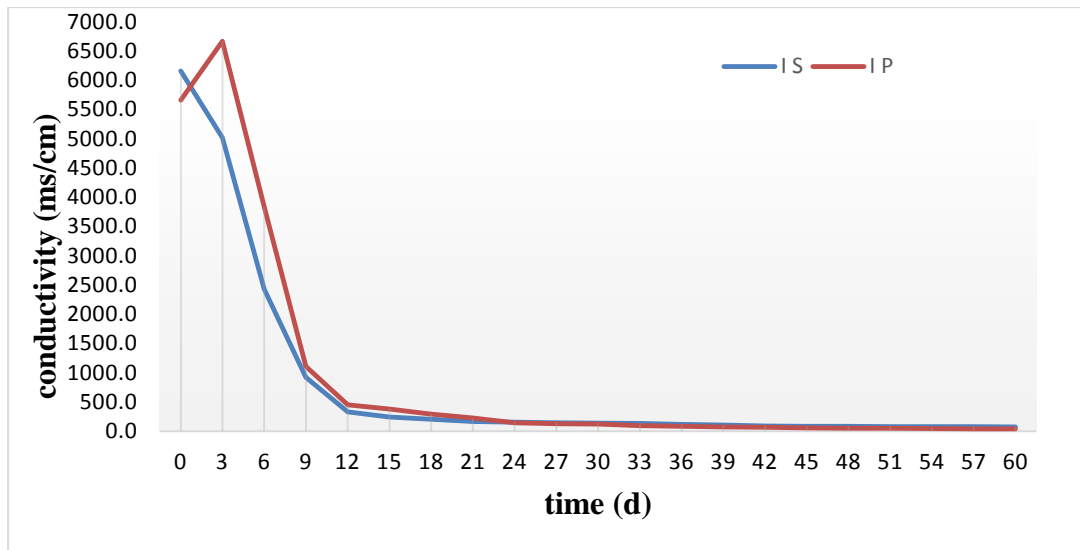
#### 3.2.1 Soil physical characteristics

- Particle size

Figs. 12 and 13 show the proportions of sand, clay and silt in the two (2) types of soil that

received plantain peel powder. Concerning the soil under tomato, the control and the treated soil showed different particle size especially with regard to clay (without PPBP: 2.8; with PPBP: 4) and silt (without PPBP: 5.5; with PPBP: 4.4) contents. The treated soil contained more clay and less silt. As for the soil under plantain tree, the difference between the control and treated soil was more marked for sand (without PPBP: 90; with PPBP: 92.1) and silt (without PPBP: 7; with PPBP: 5) contents. The treated soil contained more sand and less silt.





**Fig. 10. Conductivity of PPBP decomposing percolated extracts**

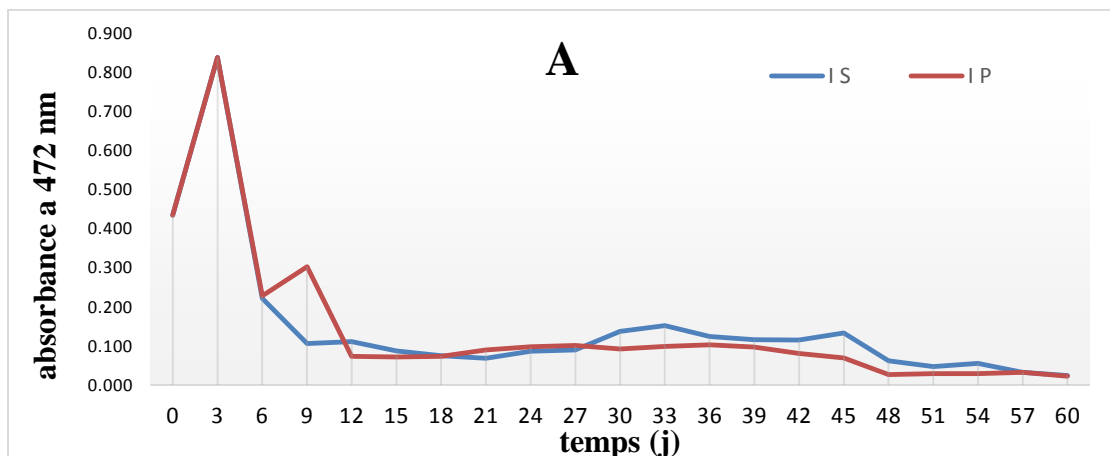
- **Water content (TE)**

The water retention capacity of the control and treated soils (with PPBP) after two months of monitoring is shown in Fig. 14. The analysis of the results revealed a significant difference ( $p < 5\%$ ) between the soils having received plantain peel powder and those that have received nothing. The retention capacities were higher in treated soils than in the control, for the soil under tomato (without PPBP: 19.17%; with PPBP: 46.14%) as well as for the one under plantain tree (without PPBP: 20, 11%; with PPBP: 42.68%).

and acidity reserve of the control and treated soils (under tomatoes and under plantain tree) are shown in Table 2. Analysis of the table shows a significant difference between control and treated soils for K, Na, P and NT contents in soil under tomato as well as in the one under plantain tree. The values were higher for treated soils except for NT content. Regarding Corg content and C/N ratio, no significant difference was observed between control and treated soils under tomato. In contrast, in the soil under plantain tree, C/N ratio value was higher in the treated soil. Water pH values of soils were higher in the treated soil concerning the soil under plantain trees. In the soil under tomato no significant difference was observed between the recorded values. The acid reserve in the two types of soil was higher in the treated soils than in the control (Table 2).

### 3.2.2 Soil chemical characteristics

The results relating to mineral content (K, Na, P, Corg, NT), carbon/nitrogen ratio (C/N), water pH



**Fig. 11A. Staining intensity of PPBP percolated extracts during decomposition at 472 nm**

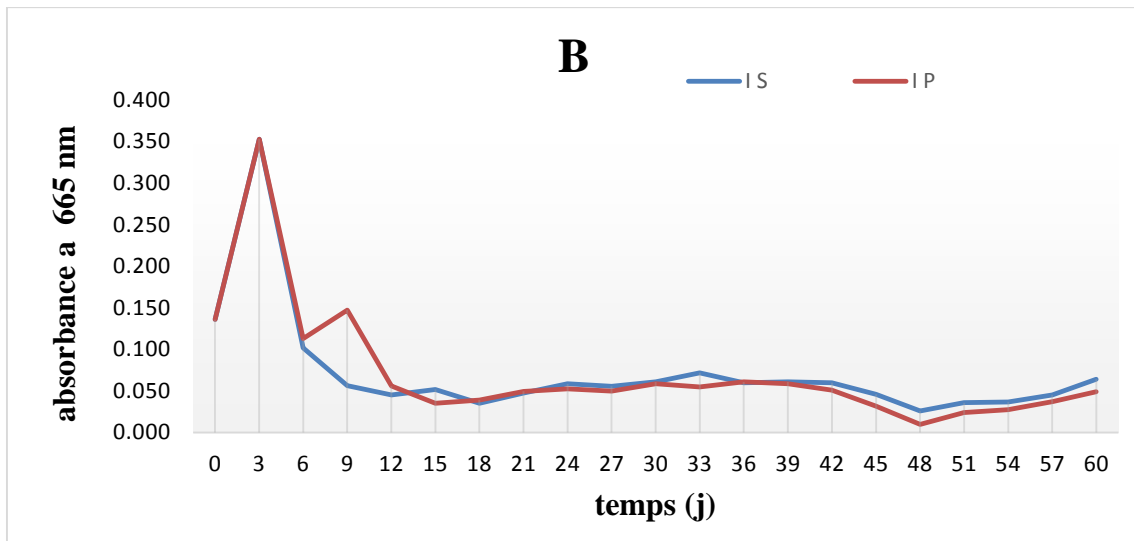


Fig. 11 B. Staining intensity of PPBP percolated extracts during decomposition at 665 nm

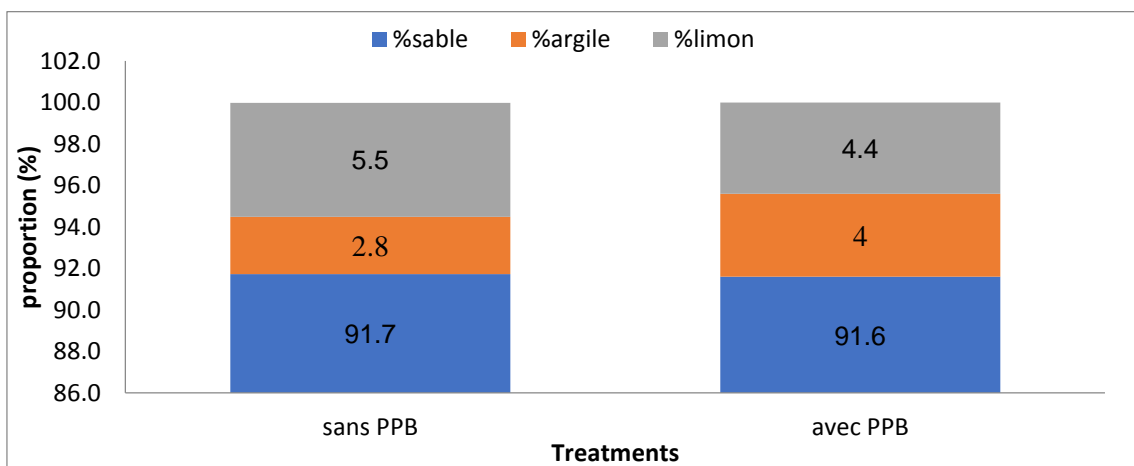


Fig. 12. Proportion of sand, silt and clay in soils under tomato

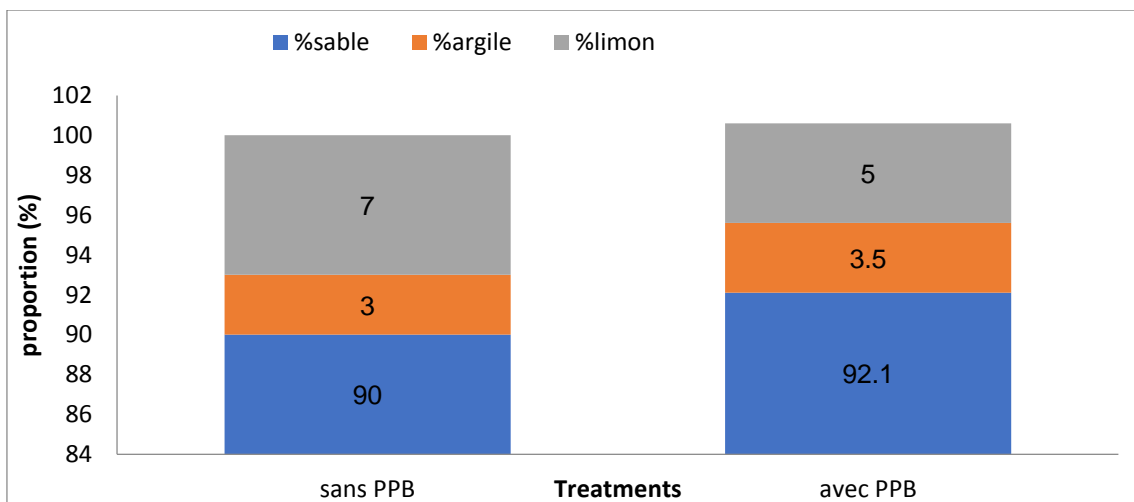


Fig. 13. Proportion of sand, silt and clay in soils under plantain tree

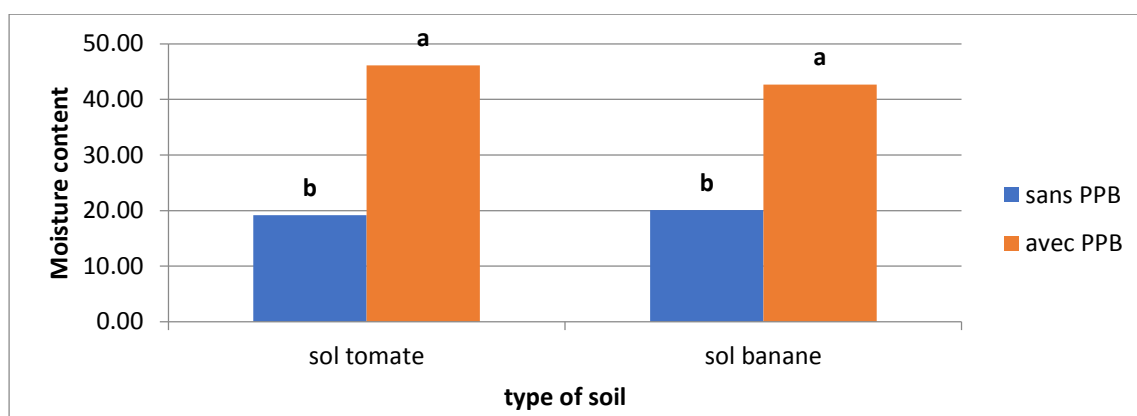


Fig. 14. Moisture content of control soils and soils treated with PPBP depending on the type of soil

Table 2. Mineral content of soils under tomato and plantain tree

Minerals	Tomato		Plantain tree	
	Without PPBP	With PPBP	Without PPBP	With PPBP
NT	3.240±0.020a	2.870±0.036b	3.213±0.025a	2.900±0.046b
P	0.347±0.027b	0.521±0.128a	0.368±0.006b	0.591±0.033a
K (ppm)	0.333±0.577b	29.666±1.527a	0.666±0.577b	56.333±1.527a
Na (ppm)	0.000±0.000b	4.333±0.577a	0.333±0.577b	7.666±0.577a
Corg (%)	11.642±4.083a	7.119±0.359a	11.642±4.083a	6.261±3.563a
C/N	3.594±1.261a	2.480±0.097a	0.585±0.099b	1.519±0.140a
pH H <sub>2</sub> O	7.467±0.681a	6.933±0.058a	6.600±0.173b	7.033±0.173a
Acidity reserve	0.400±0.200b	0.867±0.153a	0.467±0.153b	1.200±0.100a
C/N	3.594±1.261a	2.480±0.097a	0.585±0.099b	1.519±0.140a
pH H <sub>2</sub> O	7.467±0.681a	6.933±0.058a	6.600±0.173b	7.033±0.173a

PPBP : Plantain Peel Powder

#### 4. DISCUSSION

Analysis of the results relating to the characterization of plantain peel powder decomposition is shown by an analysis of the weight loss and the decomposition coefficient followed by the study of percolated extract. For weight loss and decomposition coefficient, the results showed that regardless of plantain peel powder incorporation method, decomposition occurs at the same rate. We could notice in the first two weeks a quick decomposition rate and a decrease in the latter over time. The quick decomposition rate observed in the first weeks might be due to the size of the particles constituting plantain peel powder (PPBP). Indeed, according to [18], the average diameter of PPBP particles might be around 363-48 µm. This idea is confirmed by [19], during the study on the factors of variation of wheat decomposition rate in which he concluded that the fineness of grinding is a technique for

increasing decomposition rate. This quick decomposition could also be explained by the presence of maggots observed during the first two weeks.

The physicochemical characterization of the percolated extract consisted in the analysis of the results relating to optical density, conductivity and pH. The results relating to conductivity and optical density, which give an idea of the concentration of ions and colored compounds, showed a strong release of these elements during the first two weeks and a decrease over time. This could be explained by the fact that the undecomposed PPBP has a high content of colored elements and that after regular watering these elements are released; which indicates leaching. These results are consistent with those of [20] which indicate that leaching is an abiotic process during which the soluble fraction is carried away by water. As a result, this action can lead to the migration of soluble fractions

deep into the soil. Overall pH results showed basic pH in both incorporation methods. This is mainly due to the release of acid groups from this amendment [21]. According to [22], the pH depends on the concentration of H<sup>+</sup> ions stemming from the oxidation of carbon in organic matter.

In addition to the characterization of plantain peel powder decomposition according to different incorporation methods, our study also made it possible to assess the effect of plantain peel on the physicochemical characteristics of soil under plantain trees and under tomato. The results showed that PPBP alters soil physical properties. Indeed, the particle size shows an increase in clay content for soils under tomato, silt and sand for soils under plantain trees treated with plantain peel. Likewise, the results reveal an increase in the water retention capacity in treated soils under tomato as well as under plantain tree compared to the control. These results suggest that the addition of PPBP increases the moisture content of the substrate. This observation could be due to the high mucilage content of plantain peel powder [18]. Mucilage are plant substances, made up of polysaccharides, which swell in contact with water, taking on a viscous, sometimes sticky consistency, similar to gelatin. [23] also showed that organic amendments significantly increased (35%) soil moisture to field capacity. In general, organic matter physically holds more water than mineral compounds in the soil (sand, silt and clay). Thus, it increases soil water retention [24]. Our results are in agreement with those of Ahmed et al. (2007) who showed that the addition of organic matter to sandy soil with high permeability increases water retention capacity.

Finally, a high potassium content in the soil after plantain peel powder supply was found in the results and this could be explained by the fact that plantain peel powder has a high potassium and phosphorus content. Biego [25] confirm this finding when they show that the veins of mature plantain peels are highly concentrated in potassium. Furthermore, the results also showed that the addition of plantain peel powder caused the nitrogen content in the soil to decrease. This could be due to interactions between mineral elements. Indeed, the different nutrients interact with each other. A competitive situation (antagonism) can be created depending on their composition in the soil solution. Thus, the high potassium (K) content of the peel would have disrupted the release of nitrogen (N) [26].

## **5. CONCLUSION**

This study allowed us on the one hand to characterize plantain peel powder decomposition and on the other hand to assess the effects of such plantain peel on the physical and chemical characteristics of soils under tomato and under plantain tree. The results showed that the incorporation method did not influence plantain peel powder decomposition rate. Regarding the pH, depending on the two incorporation methods, it changed from neutrality to basicity. The electrical conductivity, after adding plantain peel powder depending on the two incorporation methods, increased sharply until it reached its maximum before dropping and remaining constant. Soil texture and water retention capacity improved after adding plantain peel powder. Plantain peel powder is an important source of minerals. We learned from this study that plantain peel powder decomposes quickly and is a good fertilizer for improving soil physical and chemical properties.

## **CONSENT**

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

## **ETHICAL APPROVAL**

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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