***Original Research Article***

# Physico-chemical and mineral analyses by ICP-AES and AAS of soils under litter of *Blighia welwitchii* (Hiern) Radlk, *Oncoba welwitschii* (Oliv.) Gilgn, *Zanthoxylum gilletii* (De wild) and *Harungana madagascariensis* Lam. ex Poir. in Luki Biosphere Reserve, DR Congo.




## Abstract

The pedological impact of certain agroforestry species in cropland areas remains little known for most agricultural ecosystems because soils react differently according to the nature of the management and the types of crops affected.

The granulometric analyses of its soils show a sandy texture, according to the FAO classification. Clay shows significant difference in the soils under the litter of *Oncoba welwitschii*, compared to the soil under the litter of other plant species. Silt also shows a significant difference. Soils under the litter of *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* show a higher silt content than the soil under the litter of *Blighia welwitchii*.

The organic matter content thus observed in the soils under the litter of these four species did not show any significant difference. The average organic matter content thus observed (21.36%) in the soils under the litter of these four plant species indicates a good decomposition of these litters.

The concentration of major mineral elements recorded in soils under the litter of *Blighia welwitchii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* did not show any significant difference. However, potassium, phosphorus, and magnesium have a high concentration compared to calcium and sodium. Iron concentration is high in soils under the litter of *Blighia welwitchii* (98.33 mg/kg), followed by soils under the litter of *Oncoba welwitschii* (90.33 mg/kg), *Harungana madagascariensis* (85.33 mg/kg) and finally *Zanthoxylum gilletii* (82.33 mg/kg). As for manganese concentration, the soils under the litter of *Blighia welwitchii* showed a

high concentration (77.01 mg/kg), followed by the soils under the litter of *Harungana madagascariensis* (69.11 mg/kg), *Zanthoxylum gilletii* (67.29 mg/kg), and finally the soils under the litter of *Oncoba welwitschii* (63.72 mg/kg). These results are justified by the fact that tropical soils have a high concentration of certain metallic elements, such as iron, aluminum, manganese, etc., which can be found in the soil under Oncoba welwitschii (63.72 mg/kg).

**Keywords:** Litter, ICP-AES and SAA spectroscopy, *Blighia welwitchii*, *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis*, Luki.

## 1. Introduction

The problem of rational management of soils under different plant species is still relevant in the humid tropics. It is increasingly becoming part of a set of reflections on the methodological schemes to be implemented to curb the fragile fertility of tropical soils subject to strong demographic pressure and capable of modifying environmental conditions. According to **Bock** [**1**], the identification and characterisation of agroecological reference sites constitutes one of the major lines of research in natural resource management in order to meet the ever-increasing demand for wood from the forests of the tropics. They should serve as a basis for multidisciplinary applied research in order to initiate harmoniously an integrated development of rural areas [**2**].

The over-exploitation of natural resources by mankind, as a result of strong population growth, has leapt forward in recent years, leading to enormous changes in ecosystems, which also have repercussions on climate, biodiversity and land use. This rate of consumption of natural resources exceeds their rate of renewal [**3**]. Indeed, the functional definition of soils is becoming a must since environmental considerations are increasingly becoming an integral part of most methods of sustainable management of tropical natural resources [**4**]. Soil, which is one of its main components, has been considered for several decades as the environmental interface in communities. As a basic ecosystem, however, its typological diversity in the humid tropics and the complexity of the processes it supports have so far posed problems for ecologists in unearthing problems related to the availability of mineral elements for the maintenance of the physico-chemical quality of soils.

The pedological impact of certain agroforestry species in cropland areas remains little known for most agricultural ecosystems because soils react differently according to the nature of the management and the types of crops affected. According to **Alongo** [**5**], the productive, hydrological and ecological functions of landscapes sometimes change as a result of land use for a given species. Community ecologists have shown that each plant species is restricted to more or less a range of habitats, and that habitat heterogeneity is a main factor that determines the geographical distribution of species, and this also induces a different fertility gradient, depending on the biomass of the decaying species. Pedological analyses aimed at knowing the mutual contributions of the soil-plant relationship in order to satisfy the production needs of forest species (wood) on the one hand and agricultural products on the other are nowadays an absolute necessity.

Overall, the present study, which is in line with "soil-plant" relations in the forest environment and which therefore aims to know the status of mineral and organic elements in soils under litter of 4 plant species, notably *Blighia welwitchii*, *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* in the Luki Biosphere Reserve, in order to quantify the evolution of the said elements. It is based on the hypothesis that the texture and mineral element contents of the littered soil of Harungana madagascariensis provide appreciable texture compared to the littered soils of other species. The objective of this study is to compare the texture and mineral content of the soil under litter of *Blighia welwitchii*, *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* in relation to the plan of their pedogenesis. The aim is to test whether there is a significant difference between the physico-chemical properties of the soils under litter of these forest species.

## 2. Materials and Methods

### 2.1. Study material

The study material consists of soils under the litter of *Blighia welwitchii* (Hiern) Radlk. (*Sapindaceae*), *Oncoba welwitschii* (Oliv.) Gilgn. (*Flacourtiaceae*), *Zanthoxylum gilletii* (De wild) P.G. (*Rutaceae*). Waterman and *Harungana madagascariensis* Lam. ex Poir. (Hypericaceae), harvested in November 2018, in the Luki Biosphere Reserve in the Bas-fleuve Territory, Kongo Central Province, DRC (Image 1). The plants were identified at the Herbarium

of the Institut National d'Etudes et de Recherches Agronomiques (INERA/LUKI) and confirmed by the Laboratory of Systematic Botany and Plant Ecology, Department of Biology, Faculty of Sciences of the University of Kinshasa (UNIKIN).

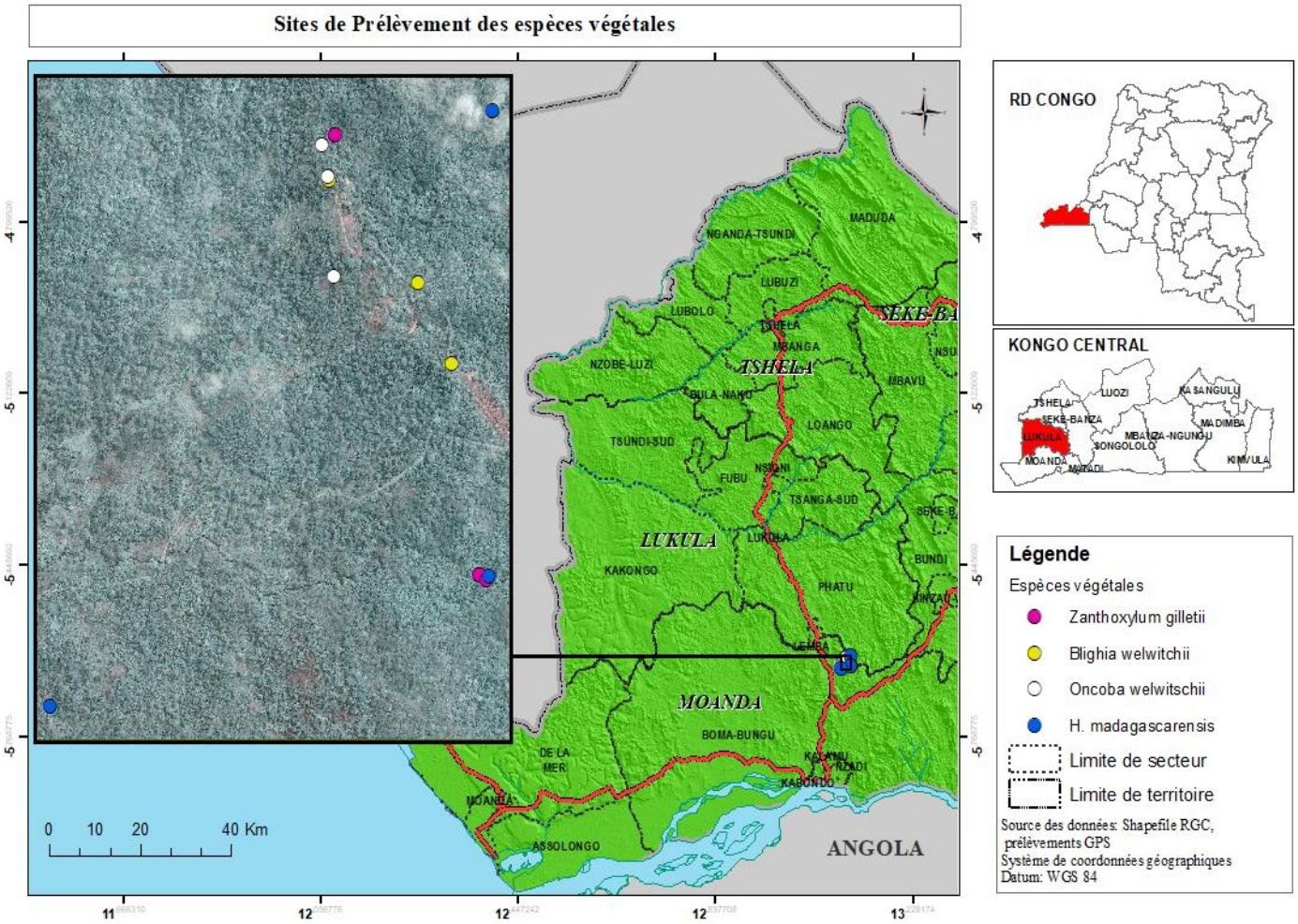


**Image 1**: Soil sampling sites in soils under the litter of the plants under study

## 2.2. Methods of analysis

The soil study consists of a series of successive operations carried out in the field and in the laboratory. In the field, the work was carried out in several stages and consisted in the localization of the different plants under study and an analysis of the site using the topographic map Kongo Central Province 3D at 1/50000, the opening of pits, the description of profiles and finally the taking of samples. In the laboratory, the samples were dried in an oven at 50° C, then submitted to the main physico-chemical and mineral analyses. These analyses were carried out simultaneously at the Laboratory of the Institut des Sciences de l'Environnement/Institut Forel

(University of Geneva, Switzerland), the Mineral Analysis Laboratory of the Office Congolais de Contrôle/Lubumbashi (LAMI/OCC) and the Soil Analysis Laboratory of the Centre Régional d'Etudes Nucléaires de Kinshasa (CREN-K).

### 2.2.1. Sample collection

During sampling, an earth carrots about 50 cm long was reconstituted in a half plastic tube. The soil was collected with an auger under litter from the plants under study. The samples were wrapped in plastic film. The carrots were divided into continuous samples every 5 cm. A portion of each sample was placed in a plastic jar to be dried and finely crushed. A second portion was placed in a closed bag for sieve size analysis.

Each sample was then homogenized in a bucket, wrapped in plastic film and labelled. At the end of the sampling, these plastic films are closed and sent to the different soil analysis laboratories.

### 2.2.2. Physico-chemical soil analysis

**a) Physical analysis of the soil**

- **pH-water**

Mix 10 g of sieved soil in 25 ml of distilled water under stirring for 16 h and take the pH with a glass electrode.

- **Water content**

Empty containers are weighed and numbered. The wet samples are placed in these containers, weighed, placed in an oven at 60 °C for 48 hours and then weighed again. The water content of each sample is deduced from the formula: $T_{water}$= (Ph-Ps)/(Ps.100) % Where $T_{water}$ is the water content of the sample, Ph the weight of the wet sample and Ps the weight of the dry sample.

- **Granulometric analysis:**

The granulometric analysis of the various samples is performed at the Forel Institute using a Coulter®LS100 laser diffractometer (Beckman Coulter, Fullerton, USA). This method, based on laser diffraction, establishes the granulometric spectrum of the sample particles whose size ranges from 0.4 µm to 900 µm. It has been described in detail by [**6**]. Following dispersion during 5 minutes by sonication in deionized water.

**b) Chemicals analyses of the soils**

- **Organic matter (OM) and carbonate ($CaCO_3$) contents**

The organic matter content is estimated by the loss of ignition method [**Loss Of Ignition, LOI**] using a Salvis furnace (AG Emmenbrücke, Lucerne, Switzerland), according to the procedure described in detail by [**7**]. Briefly, 1 to 5 g of dry, crushed and sieved soil is weighed, heated at 550 °C for 60 min, and then weighed again. The organic matter content of each sample is estimated by mass loss. In order to estimate the carbonate content, the same samples were heated in the oven at 1000°C for 60 minutes and reweighed. The carbonate content is estimated by the loss in mass during this second firing, multiplied by 2.274 which is the molecular weight ratio between $CaCO_3$ and $CO_2$.

The calcium carbonate content of the first sample is measured by acid etching (HCl 1M) of the dry soil and crushed in carbonate bombs. The carbonate content of each sample is measured by the bomb from the pressure exerted by the $CO_2$ from the vaporized calcium carbonates according to the following reaction : $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2CO_3 \rightarrow H_2O + CO_2 + CaCl_2$ [**7**].

- **Measurement of Total Nitrogen (TN) and Total Organic Carbon (TOC)**

Measurements of Total Nitrogen (TN) and total organic carbon (TOC) were performed using a PE 2400 Series II CHNS/O Elemental Analyzer (Perkin Elmer, USA). For each sample, two capsules containing between 3 and 8 g of crushed dry soil were prepared. One of the two capsules is acidified by adding 50 µl of $H_3PO_4$ (5%). The capsules are placed in the PE® 2400 Series II CHNS/O Elemental Analyzer to undergo complete combustion at 975 °C and then reduced to $CO_2$, $H_2O$, $N_2$ and $SO_2$ at 500 °C. TN measurements are performed on non-acidified capsules and TOC measurements are performed on acidified capsules.

### 2.2.3. Mineral analysis by ICP-AES and AAS

The determination of minerals content was carried out by the method of water and nitric acid and analysis by Inductively Coupled Argon Plasma Optical Emission Spectrometry (**ICP-AES**) and Atomic Absorption Spectrometry (**AAS**) [**8, 9**]. 0,3 g of plant powder diluted in 5mL of distilled water was placed in PM60 Teflon bombs (Analytikjena 40Bar) and heated at 60°C, then 10 mL of nitric acid (65% $HNO_3$) (Merck) were added. The mixture was allowed to react for 30 minutes at room temperature in the bombs were covered with caps and then stripped with $HNO_3/H_2O$

(v/v, 1:1). The bombs are then placed in the high frequency microwave mineralizer (Analytikjena AG TOPwave: 2.5 Ghz, Germany) controlled by microcomputer by choosing the Vegetable Leave mode as a digestion mode at 180°C, 50bar for 1 hour. At the end of mixing, the digester is stopped by letting the bombs rest for 3 hours until completely cooled. The cooled analyte is thus carefully transferred from bombs by filtration on Whatman filter paper, to 50 mL volumetric flasks previously stripped. The initial volume was diluted to 50 mL with distilled water and 13 mL of analyte were placed in 15 mL conical flask previously stripped for reading by Inductively Coupled Argon-Plasma Atomic Emission Spectrometry (ICP-AES) (Optima 8300 Perkin Elmer, USA). The analysis was performed in triplicate.

The grades of these different minerals are studied P, Ca, Mg, Na, Co, K, Zn, Mn, Se and Cr by Induction Coupled Plasma Optical Emission Spectroscopy (ICP-AES) and also by Atomic Absorption Spectroscopy (AAS) the Fe and Cu.

An aliquot part of the solution (Analyte) is sucked into the instrument (AAS/ICP-AES) for the determination of metals/minerals, namely P, Ca, Mg, Na, Co, K, Fe, Zn, Mn, Cu, Se, and Cr.

The calibration of the ICP-AES is performed using the working standard prepared from the commercially available standard multielement solution 3 at two points (1mg/L and 2.5mg/L, Perkin Elmer, USA). The most appropriate wavelength, gaseous argon flow, plasma stabilization and other ICP-AES instrument parameters for minerals are selected and measurements are made in the linear range of the working standards used for calibration.

Working conditions were: Instrument: ICP-AES (Optima 8300 Perkin Elmer, USA); Power of Rf: 1500Watt; Plasma gas flow (Ar): 8 L/min; Nebulizer: 0.70 L/min; Auxiliary gas flow (Ar): 0.2 L/min; Viewing size: 5-22 mm; Copy and playback time: 1-5s (maximum 45s); Flow time: 1s (maximum 10s); View: Radial.

Calibration of the AAS is performed using a working standard prepared from commercially available metal/minerai standard solutions (1 mg/L, Perkin Elmer, USA). The wavelength, weakened cathode lamp current, gas mixture flow rate, gap width and other parameters of the AAS for metals/minerals were selected as specified in the instrument manual, and a background correction was used in the determination of metals/minerals. Measurements were made within the linear range of working standards used for calibration [**8, 9**].

Working conditions were: Instrument: AAS (Aanalyst 400 Perkin Elmer, USA); Flame temperature: 2800° C, Acetylene pressure: 0.9-1.0bar, Atmospheric pressure: 4.5-5 bar, Playback time: 1-10 seconds (maximum 60 seconds), Flow time: 3-4 seconds (maximum 10 seconds).

The concentrations of all minerals are expressed in mg/kg dry weight of the sample. Each value is the mean of the determination in three replicates ± standard deviation.

## 3. RESULTS AND DISCUSSION

### 3.1. RESULTS

#### 3.1.1. Physico-chimical analyses

##### a) Granulometric analysis

The results related to the granulometric analysis of soils under the litter of the identified plant species are presented in **Table 1**.

**Table 1**. Particle size analysis of sub-bedded soils

| N° | Plant species | Clay (< 2µ) | Silt (2 - 50µ) | Sands (50 - 2000µ) |
|---|---|---|---|---|
| | | Percentage by volume | | |
| 1. | *Blighia welwitchii* | 15,0 ± 0,064b | 4,28 ± 3,986b | 95,57 ± 3,962 |
| 2. | *Oncoba welwitschii* | 21,0 ± 0,108a | 9,37 ± 2,277a | 90,42 ± 2,350 |
| 3. | *Zanthoxylum gilletii* | 13,0 ± 0,05b | 8,25 ± 5,886a | 91,62 ± 5,929 |
| 4. | *Harungana madagascariensis* | 18,0 ± 0,181b | 9,62 ± 3,540a | 90,13 ± 3,714 |

The elements in this table show that under these plant species, the soils have a sandy structure. The recorded clay contents show very low values of this soil component under these plant species. The average values of these grades are shown in **Figure 1** below.

The minerals in this figure show that the soils underneath the litter of *Blighia welwitchii*, *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* have evolved so much that they are in a very advanced stage of alteration. With at least 90% sand and 19% clay, these soils are in the category of sandy-clay soils according to the FAO classification.

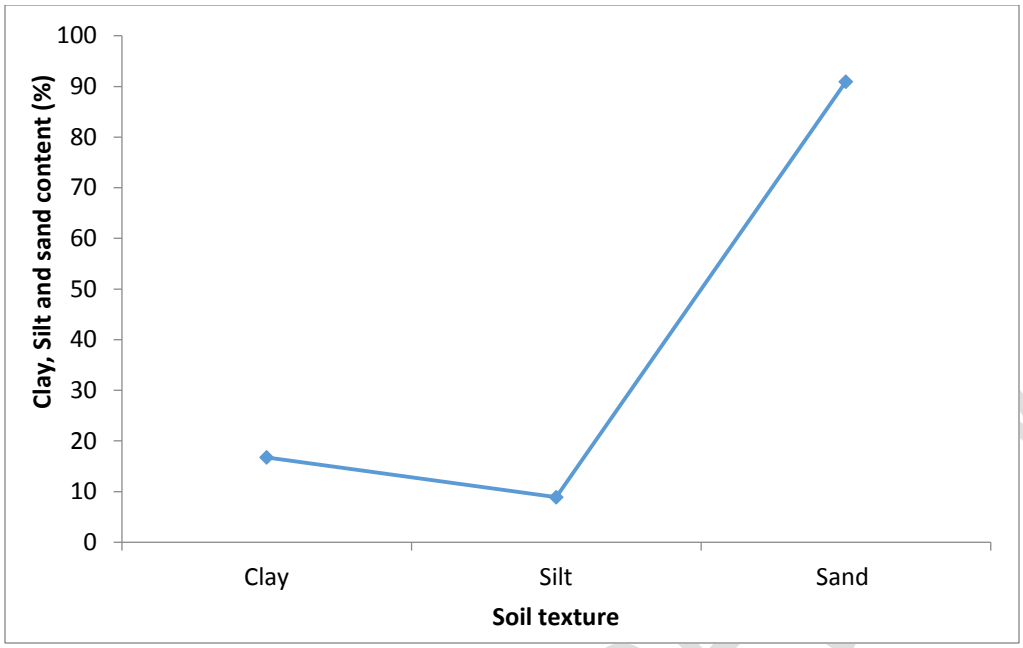


**Figure 1**: Evolution of the average clay, silt and sand contents in soils under bedding

### b) Chemical analysis

The results related to the chemical composition of the soils and the litter of its plant species are shown in the following **Table 2**.

**Table 2**: Chemical composition of soils under litter

| Plant species | pH | $TH_2O$ (%) | OM (%) | $CaCO_3$ (ppm) | TOC (%) | TN (%) | C/N (%) |
|---|---|---|---|---|---|---|---|
| *Blighia welwitchii* | 5,7 ± 0,40 | 35,37 ± 5,87 | 15,93 ± 0,78 | 0,21 ± 0,03 | 0,07 ± 0,001 | 0,28 ± 0,02 | 0,25 |
| *Oncoba welwitschii* | 5,3 ± 0,56 | 45,63 ± 3,59 | 21,74 ± 0,86 | 0,27 ± 0,07 | 0,97 ± 0,027 | 0,16 ± 0,022 | 6,06 |
| *Zanthoxylum gilletii* | 5,7 ± 0,32 | 44,99 ± 4,26 | 25,27 ± 2,16 | 0,21 ± 0,10 | 1,215 ± 0,03 | 0,09 ± 0,002 | 13,5 |
| *H. madagascariensis* | 4,9 ± 0,20 | 39,21 ± 4,40 | 22,56 ± 0,87 | 0,24 ± 0,03 | 0,32 ± 0,32 | 0,13 ± 0,08 | 2,46 |

The elements listed in this table show that the pH of the soil under the litter of these species is acidic. It varies from pH 4.9 for soils under the litter of *Harungana madagascariensis* to pH 5.7 for soils under the litter of *Blighia welwitchii* and *Zanthoxylum gilletii*.

For moisture content, the soils under the litter of *Oncoba welwitschii* have a moisture content of 45.63% slightly higher than the litter soils under other plant species. This is followed by soils under *Zanthoxylum gilletii* (44.99% water), *Harungana madagascariensis* (39.21%) and *Blighia welwitchii* with 35.37% water.

The organic matter (OM) content evolves in almost the same way in all these soils. A particularity for the soils under the litter of *Zanthoxylum gilletii* (25.27% of O.M.), *Harungana madagascariensis* (22.56% of O.M.) and *Oncoba welwitschii* (21.74% of O.M.).

Calcium carbonate also evolves in almost the same way in these soils. It varies from 0.21% in soils under the litter of *Zanthoxylum gilletii* to 0.27% in soils under the litter of *Oncoba welwitschii.*

### 3.1.2. Mineral analysis of soils under the litter by AAS and ICP-AES

#### a) Concentration of major minerals (mg/kg)

Results related to the concentration of major soil elements under the litter of *Blighia welwitchii*, *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* are presented in the following **figures 2, 3, 4** and **5**.

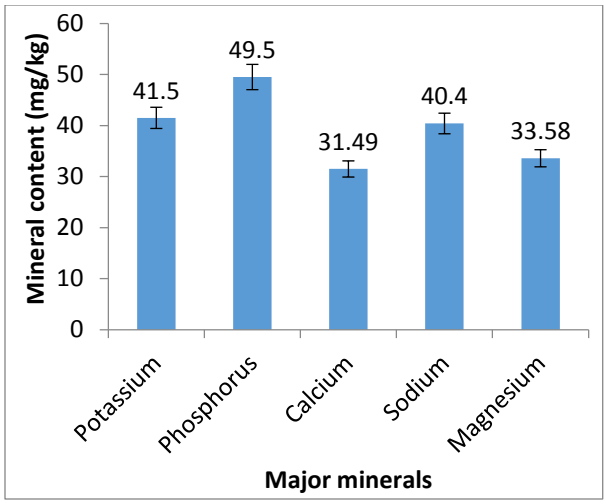


**Figure 2**: Concentration (mg/kg) of major minerals in soils under the litter of *Blighia welwitchii*

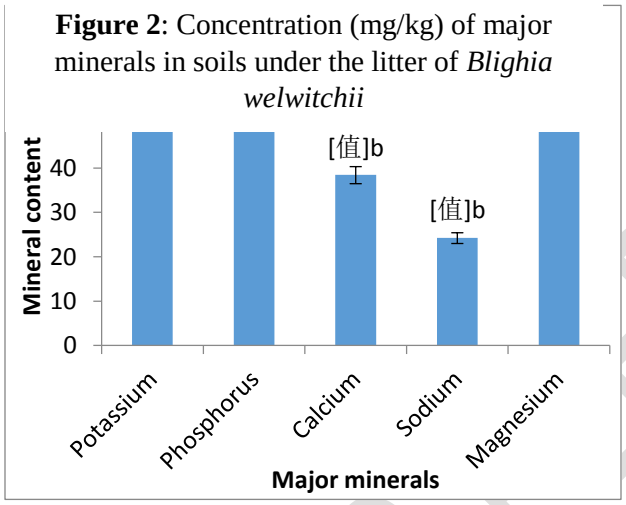


**Figure 3**: Concentration (mg/kg) of major minerals in soils under the litter of *Oncoba welwitschii*

The elements reported in **Figures 2** and **3** show that in soils under *Blighia welwitchii* litter, phosphorus has a concentration of 49.5 mg/kg, followed by potassium (41.5 mg/kg), sodium (40.4 mg/kg), magnesium and calcium each have a concentration of 33.58 mg/kg and 31.49 mg/kg respectively. While for soils under *Oncoba welwitschii* litter, the concentration of magnesium is 58.03 mg/kg, followed by potassium (56.88 mg/kg), and phosphorus (53.37 mg/kg); finally calcium (38.42 mg/kg) and sodium (24.23 mg/kg).

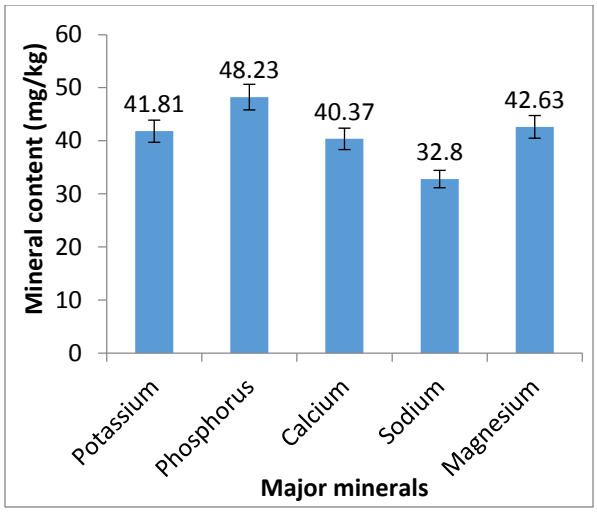


**Figure 4**. Concentration (mg/kg) of major minerals in soils under the litter of *Zanthoxylum gilletii*

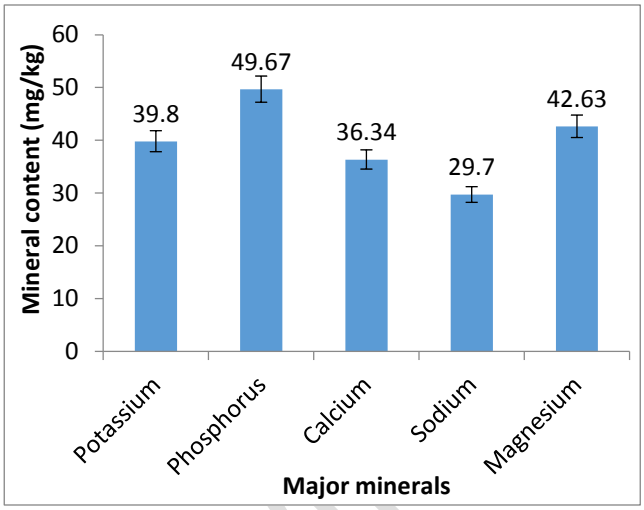


**Figure 5**. Concentration (mg/kg) of major minerals in soils under the litter of *Harungana madagascariensis*

The minerals shown in figures 4 and 5 show that the phosphorus concentration is always higher in soils under the litter of *Zanthoxylum gilletii* (48.23 mg/kg) and *Harungana madagascariensis* (49.67 mg/kg), followed by the magnesium concentration 42.63 mg/kg respectively for soils under the litter of *Zanthoxylum gilletii* and *Harungana madagascariensis*. It is noted that the sodium concentration is low in the soils under the litter of these two plant species.

**b) Concentration of traces minerals (mg/kg)**

Results related to the concentration of trace minerals in soils under the litter of *Blighia welwitchii*, *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* are presented in the following **figures 6, 7, 8** and **9**.

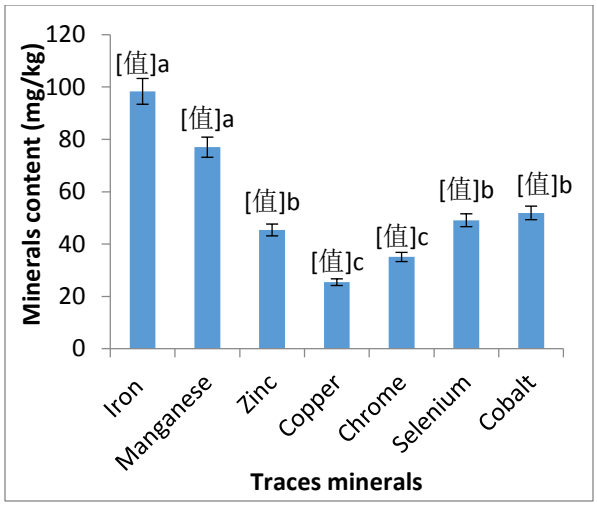


**Figure 6**. Concentration (mg/kg) of traces minerals in soils under the litter *B. welwitchii*

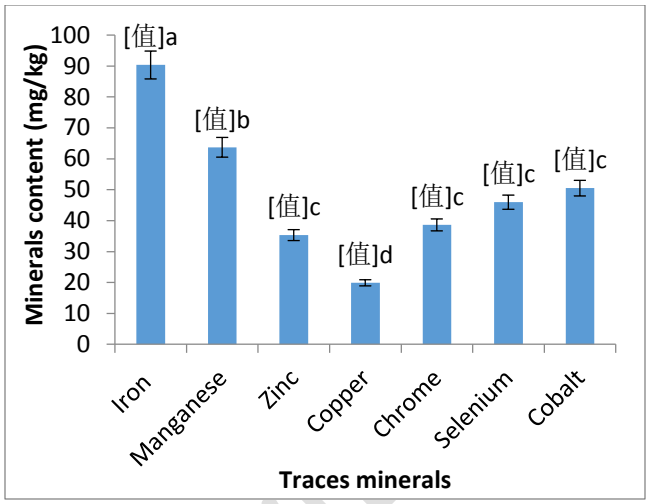


**Figure 7**. Concentration (mg/kg) of traces minerals in soils under the litter *O. welwitschii*

The data in **Figures 6** and **7** show that iron concentration is high in soils under the litter of *Blighia welwitchii* (98.33 mg/kg) and *Oncoba welwitschii* (90.33 mg/kg). Followed by the manganese concentration 77.01 mg/kg for the soils under the *Blighia welwitchii* litter and 63.72 mg/kg for the soils under the *Oncoba welwitschii* litter. Copper, zinc, and chromium are trace minerals with low concentrations in soils under the litter of these two species. As for cobalt, it has a concentration of 51.91 mg/kg in the soil under the *Blighia welwitchii* litter and 50.5 mg/kg in the soil under the *Oncoba welwitschii* litter.

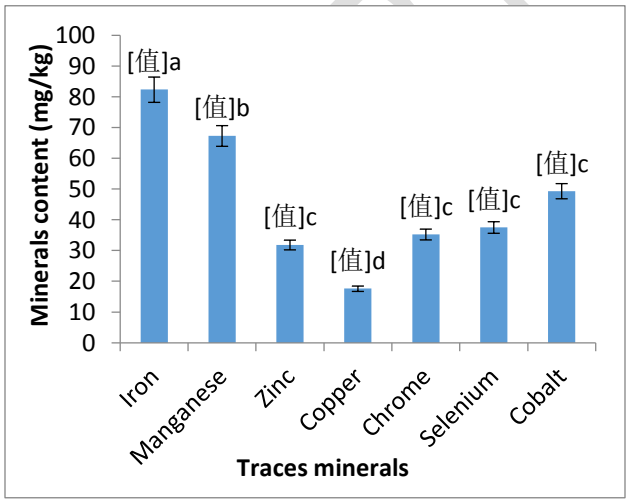


**Figure 8**. Concentration (mg/kg) of traces minerals in soils under the litter *Zanthoxylum gillettii*

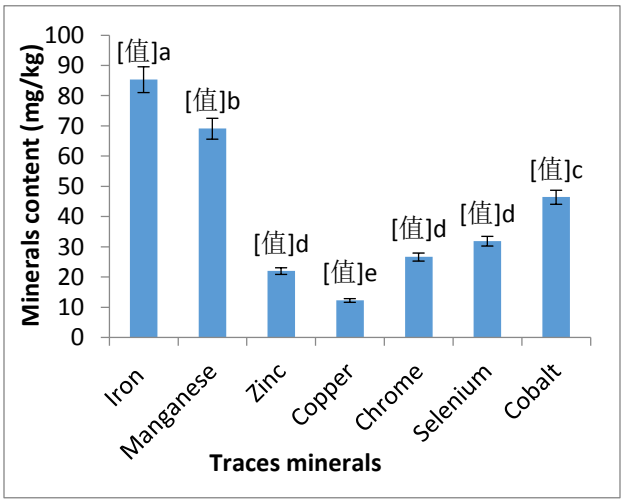


**Figure 9**. Concentration (mg/kg) of traces minerals in soils under the litter *H. madagascariensis*

The minerals in Figures 8 and 9 show that in soils under *Zanthoxylum gillettii* litter, the iron concentration is high (82.33 mg/kg) relative to other elements, followed by manganese (67.29 mg/kg). The same trend is also observed in soils under the litter of *H. madagascariensis*. Iron and manganese are the trace minerals that have a high concentration. While zinc and copper have low concentrations in these soils.

## 3.2. DISCUSSION

### a) Granulometric Analysis

The granulometric analyses of its soils show a sandy texture, according to the FAO classification. Clay shows significant difference in the soils under the litter of *Oncoba welwitschii*, compared to the soil under the litter of other plant species. Silt also shows a significant difference. Soils under the litter of *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* show a higher silt content than the soil under the litter of *Blighia welwitchii*. Although studies on the influence of agricultural practices on the properties of tropical soils [**5**] rarely show a change in soil texture, the present study highlighted the influence of *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* species on the content of grain size fractions by following slices of simple biodynamic solum samples from reference pits.

Clay is the most active granulometric fraction because not only does it associate with humified organic matter, but it also has a high water retention capacity and contributes to the fixation of cations and anions on its exchange sites with plant species [**10, 11**]. Clay sufficiently influences the texture and thus the behaviour of a soil. In this case, in the American triangle, beyond 20% the term clay is used in the denomination of textural classes at the prefix or suffix level [**12**]. The same applies to Congolese soils with the difference that here, we consider rather the content of fine elements (clay + silt), with the lower limit of 15%. As for the role of silts and sands, it must be taken into account when the sample contains less than 35% clay [**10**]. The silt content, which is very low and characteristic of ferrallitic soils [**13**] is numerically similar, but significantly very different in the different soils under different litters of the plant species studied.

**b) Chemical analysis : (pH, $TH_2O$, OM and $CaCO_3$)**

The pH results observed these soils in the slightly acidic soil category. This acidity is said to be due to the transfer of acidic elements, especially oxides and hydroxides of iron and aluminum. These metals are found in large quantities in tropical soils and induce an aluminic and ferric acidity that can lower the pH of the soil. Similar results were found by **Yemefack *et al.*** [**14**] in Southern Cameroon. These authors found that soils under certain plant species had pH values ranging from 4.5 to 5.7 and that the distribution of horizons from surface to depth influenced the decrease in pH values. Also, some plant species in the tropics have substances that acidify soils after decomposition.

The water content observed in the soils under the litter of its four plant species, namely *Blighia welwitchii*, *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* did not show any significant difference between these different species. However, the water contents thus obtained in soils under the litter of *Oncoba welwitschii* (45.63%) and *Zanthoxylum gilletii* (44.99%) were higher than those in soils under the litter of *Blighia welwitchii* (35.37%) and *Harungana madagascariensis* (39.31%). These results are justified by the fact that the decomposition of the leaves of the species *Oncoba welwitschii* and *Zanthoxylum gilletii* increases the moisture in the soils, as the leaves of these species accumulate large amounts of water in their tissues compared to the other two plant species. **Van Wambeke** [**15**] had long argued that tropical soils under the litter of some plant species have water contents of more than 30%. The tropical dense forest, because of its ecological diversity and density, intercepts quantities of water during rainy episodes, resulting in the regulation of infiltration and evapotranspiration as well as an increase in soil moisture.

Organic matter is the very important element capable of providing, after mineralization, the essential mineral elements in soils. The organic matter content thus observed in the soils under the litter of these four species did not show any significant difference. However, soils under the litter of *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* showed higher organic matter contents than soils under the litter of *Blighia welwitchii*. The average organic matter content thus observed (21.36%) in the soils under the litter of these four plant species indicates a good decomposition of these litters. The richness in mineral elements in the

tissues of these species favours the humification process, which leads to the obtention of a good humus capable of enriching these soils in major mineral elements.

### c) Mineral analysis (Major and Trace minerals)

Mineralization is a very important process in soils, because through it, matter passes from the organic state to the mineral state. This passage is always accompanied by the release of a large number of mineral elements in several forms and at different concentrations. The concentration of major mineral elements recorded in soils under the litter of *Blighia welwitchii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* by the spectrometry method AAS and ICP-AES did not show any significant difference. However, potassium, phosphorus, and magnesium have a high concentration compared to calcium and sodium. While the concentration of these mineral elements is significantly different in soils under *Oncoba welwitschii* litter. Phosphorus, magnesium and potassium were found to be more concentrated in these soils than calcium and sodium. These results are justified by the fact that this species concentrates phosphorus, magnesium and potassium in the tissues during its mineral nutrition; and after the leaves and branches fall, the decomposition-mineralization process enriches the soils with these elements.

The concentration of trace minerals in soils under the litter of these four plant species showed significant differences. Iron concentration is high in soils under the litter of *Blighia welwitchii* (98.33 mg/kg), followed by soils under the litter of *Oncoba welwitschii* (90.33 mg/kg), *Harungana madagascariensis* (85.33 mg/kg) and finally *Zanthoxylum gilletii* (82.33 mg/kg). As for manganese concentration, the soils under the litter of *Blighia welwitchii* showed a high concentration (77.01 mg/kg), followed by the soils under the litter of *Harungana madagascariensis* (69.11 mg/kg), *Zanthoxylum gilletii* (67.29 mg/kg), and finally the soils under the litter of *Oncoba welwitschii* (63.72 mg/kg). These results are justified by the fact that tropical soils have a high concentration of certain metallic elements, such as iron, aluminum, manganese, etc., which can be found in the soil under Oncoba welwitschii (63.72 mg/kg). These trace elements usually combine with oxides and hydroxides to form chelate groups consisting of iron and aluminum oxyhydroxides. Manganese can replace magnesium in the weathering complex. The consequence of this phenomenon is a decrease in the pH of the soil. These results are similar to those found by **Sombo *et al*. [16]** in Batéké Plateau soils. These authors stated that iron and manganese as well as other trace minerals, notably copper, and zinc are still present in the soils

and at different concentrations. During mineral nutrition, these elements accumulate in plant tissues and can return to the soil surface through the life cycle upwelling mechanism.

## CONCLUSION

The objective of this work was to compare the texture and mineral element contents of soils under the litter of *Blighia welwitchii*, *Oncoba welwitschii*, *Zanthoxylum gilletii* and *Harungana madagascariensis* in relation to the plan of their pedogenesis. The interpretation of the results of the different analyses has led to the conclusion that from the physico-chemical analyses alone, significant differences in the mineralogical and granulometric composition of a soil under different plant species can be found. It was circumscribed within the framework of the soil-plant relationship which is an indicator par excellence of the knowledge of the pedogenetic status of the different soils evolving in the humid tropics. Thus, each plant species influences the soil with regard to its biological, chemical and biochemical nature. The results obtained showed that the soils under the litter of the above-mentioned plant species are slightly acidic with a sufficient organic matter content to enrich different horizons with major mineral elements as well as trace minerals. Among the major minerals, phosphorus, potassium and magnesium have a high concentration in these soils compared to the other elements. While for trace elements, iron and manganese have a very high concentration compared to the other elements. However, the difference in soil concentration of these elements is not statistically significant between soils under the litter of these four plant species.

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