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Physico-Chemical Analysis of Soils Used for Pineapple Cultivation in the Sub-Prefectures of Maferinyah and Friguiagbé (Prefectures of Forécariah and Kindia) Republic of Guinea

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Abstract

Over the years, pineapple production in the Republic of Guinea has become less competitive in the West African sub-region, with a world ranking of 144th. It is therefore only natural to review certain parameters in order to improve this ranking. To do this, certain physico-chemical parameters of soil samples from Friguiagbé and Maferinyah (in the Kindia and Forécariah prefectures) were taken and analysed using the following techniques: Pipette de Robinson, Anne, Bray II, Kapen HICDVITZ, Mc. Lead (1982). The analytical results show that the soils at Friguiagbé in Kindia and Maferinyah in Forécariah are acidic, with pH values of 4.4 and 4.7 (fields I and II) and 4.8 and 4.7 (fields I and II) respectively. The soils have a silty-sandy texture. This study could therefore serve as a guide for the Ministry of Agriculture of the Republic of Guinea.

Keywords

Soil, Pineapple Crop, Physico-Chemical Analysis

1. Introduction

For centuries, soil has been considered as a natural resource used by man to carry out certain activities for his survival, including agriculture, housing, road construction, etc. [1]. However, it must be protected because it contains substances that are essential for maintaining ecosystems and human populations [2]. The African continent has the potential in arable land, water and oceans to feed its populations, eradicate hunger and ensure food security for its people, and even become a major player in international markets [3]. Aware of this natural opportunity, 10 years ago the African Union opted for agriculture as one of the mainstays of the new Partnership for Africa's Development [3]. Agriculture is an essential part of the economy in all African countries; for example: Ghana, Togo, Zambia, Burundi, Burkina Faso, Mali, Niger, Congo, Senegal, Ethiopia and Malawi have all increased their investment in agriculture, resulting in higher productivity. The Republic of Guinea is a West African country with an estimated arable area of 6 million ha, or around 25% of the national territory. The main crops are cereals (rice, millet and maize), tubers (cassava and potatoes) and fruit, while exports include coffee, cocoa, pineapple and cotton [4]. The agricultural sector employs more than 80% of the population, the majority of whom are women. This activity is the backbone of the national economy. It is the main source of income and employment for almost 54% of the working population [5]. However, pineapple cultivation is specific to Lower Guinea, mainly to the prefectures of Forécariah and Kindia on the coast, due to the average temperature of 25 to 30˚C, as too much or too little heat can disrupt pineapple growth [6]. This crop was introduced to Guinea in the 1930s by the French colonisers. Agricultural engineers at the time identified the soil in lower Guinea (Kindia and Forécariah) as sandy-loam, with sunshine and rainfall favourable to pineapple cultivation. Kindia (Friguiagbe) accounts for 52% of production, compared with 48% in Forécariah (Maferinya). The cultivable area is estimated at 450 ha, *i.e.* 233 ha in Kindia and 217 ha in Forécariah, with an estimated yield of 40 tonnes/ha [6]. Despite the best environmental conditions for production and the existence of numerous production areas owned by cooperatives, the sector remains modest, with production of 5000 to 10,000 tonnes/year. This decline is probably due not only to poor soil fertility and poorly developed pineapple production techniques, but also to the practice of intercropping (mixing of species) and the demands of European market standards due to the presence of synthetic pesticides and chemical fertilisers in the fruit [7] [8]. Numerous studies have been reported on pineapple cultivation, export and processing [9] [10] [11] [12]. The aim of this study is to continue the work already carried out by our predecessors by carrying out a physico-chemical analysis of the soils in the two pineapple-growing areas (Maferinya in Forécariah and Friguiagbe in Kindia) using the following techniques: Robinson pipette, Anne, Metson, etc.

2. Materials and Methods

2.1. Presentation of the Study Area

This study was carried out in the Kindia region (specifically in the prefectures of Kindia and Forécariah). (**Figure 1**) It is located in the north between 10˚15' and 13˚00' west, with a surface area of 28,873 km^2 and a population of 1,561,336 [13]. It offers a mosaic of environments with diverse potential (ocean, estuaries, rivers, mangrove swamps, freshwater lakes, lowlands, foothills, mountains). It has a hot, humid tropical climate, influenced by the monsoon, with abundant rainfall in excess of 2500 mm per year, averaging 1429.8 mm over six (6) months (mid-May to mid-November). Average annual temperatures range from 25 to 27˚C and average relative humidity hovers around 70%. This essentially agricultural region, with a predominance of fruit and vegetables, is one of the eight (8) administrative regions of the Republic of Guinea. It is made up of five prefectures or urban communes: Coyah, Dubréka, Forécariah, Kindia and Telimélé. Two of these prefectures were chosen on the basis of the volume of pineapple produced and the length of time they have been producing pineapples. These were Kindia and Forécariah.

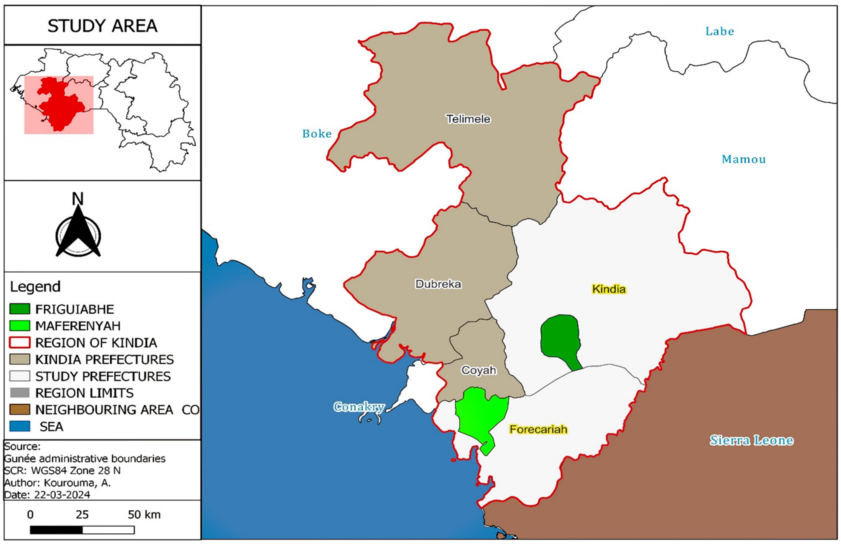

Figure 1. Map of the Republic of Guinea (right and top) showing the Kindia region.

2.2. Study Setting

The laboratory of the national soil service (SENASOL) in Conakry and the chemistry laboratory of the Institut Supérieur de Technologie in Mamou were used for the study.

2.3. Materials and Reagents Used

2.3.1. Reagents and Solvents

- Sulphuric acid
- Mohr's salt
- Hydrochloric acid
- Ammonium acetate
- Soda
- Phenolphthalein
- Diphenylamine
- Sodium fluoride
- Potassium dichromate
- Distilled water

2.3.2. Equipment

- pH meter
- Test tubes
- Erlenmeyer flasks
- Volumetric flask
- Heating plate
- Desiccator
- Analytical balance
- Beakers

2.3.3. Sampling

The soil samples (Figure 2) used for this study were collected using a jar and shovel in the prefectures of Kindia (Friguiagbe) and Forécariah (Maferinya) in the Republic of Guinea between 9 am and 12 pm. The soil surface was cleaned to remove any organic or other residues, then the shovel was driven into a depth of 20 cm, and the samples were taken to the laboratories to be dried, conditioned and then analysed.

Figure 2. Soil samples collected for analysis.

2.4. Method

2.4.1. Survey of Farmers

The survey was conducted between June and July 2022 in Friguiagbé and Maferinyah. The survey was supplemented by field observations. A total of 10 pineapple farmers were interviewed on their respective farms during routine field work (clearing and ploughing). These farmers were randomly distributed in each prefecture, *i.e.* 05 farmers in Kindia and 05 in Forécariah. The questions administered were open-ended and closed-ended in order to obtain primary information on the socio-economic characteristics of the farmers (gender, age, occupation) and technical itineraries (cropping system, production, cultivated area, fertilisation and pest management). The data collected was entered into an Excel spreadsheet before being analysed. Univariate and bivariate descriptive analyses were carried out to represent the static series in the tables in the form of frequency, mean and percentage. R and Excel were used to analyse the data.

2.4.2. Laboratory Soil Analysis

1) Determination of pH by the McLead method (1982)

Procedure

Weigh 10 g of dry soil sieved to 2 mm and add 25 ml of distilled water to a 100 ml beaker. Stir mechanically for 2 hours. Shake the beaker by hand before measuring the pH. Place the electrode in the suspension and take the reading once the value is stable [14].

2) Determination of the sum of exchangeable bases using the Kapen HICDVITZ method.

Procedure

Weigh 10 g of dry soil sieved to 2 mm and place in an Erlenmeyer flask; add 50 ml of chloridric acid (0.1 N HCl), shake for one hour; filter into an Erlenmeyer flask; take 25 ml of this filtrate into a 100 ml beaker, boil for 2 min on a hot plate and add 3 drops of 1% phenolphthalein. Titrate with a 0.1 N solution of sodium hydroxide (NaOH) until a pale pink colour is obtained which is maintained for 1 min [14]. Calculate using the following formula:

$$S = (Af1 - Bf2) \times 10/P\ (10\ g)$$

P = Weight of sample

S = Sum of exchangeable bases in meq/100g

A = Control (NaOH value used for control titration)

(f1 * f2) = Correction factors for normality of 0.1 N chloridric acid

10 = Transformation coefficient for results in meq/100g soil

B = Quantity of ml of sodium hydroxide used for titration.

3) Determination of Organic Matter by the Anne method

Procedure

Weigh out 0.25 to 1g of ground soil. Pour into a 100 to 150 ml flask with 10 ml of 8% aqueous potassium dichromate solution and 15 ml pure H_2SO_4. Bring to the boil slowly. The flask is connected to an ascending condenser. Count the time from the first condensed drop. Allow to boil for 5 min. Allow to cool. Transfer to a 100 mL flask. Make up with rinse water. Take 20 mL (V) and pour it into a 400 mL beaker. Dilute to 200 mL. Add 1.5 g NaF to make the colour change more visible. Add 3 to 4 drops of diphenylamine. Titrate with 0.2 N Mohr's salt solution. The initial blackish-brown or violet liquor turns green. A very sensitive change [14].

Calculation

The organic matter (OM) content in the soil is estimated from the organic carbon (C) content using the following equation:

$$\mathbf{C\% = 0.24\ (a - b) \times (13/V)/g}$$

a = volume poured for the blank

b = volume poured for the sample

V: volume poured for the Fe (II) solution control

g: sample weight

$$\mathbf{MO\% = C\% \times 1.72}$$

1.72: Average carbon coefficient in soil organic matter.

4) Determination of the Cation Exchange Capacity (CEC)

Procedure

Weigh out 2.5 g of soil and mix well with 10 g of purified sand. Place a cotton swab at the bottom of a percolation tube and place a 1cm layer of sand (approximately 5 g) on top. Then introduce the mixture of soil and sand into the tube and cover with a 1 cm layer of sand (5 g). Leach the soil with 50 ml of 1 M ammonium acetate, collecting the percolate in 50 ml volumetric flasks. Percolate slowly at a rate of 30 drops per minute. Make up the volume with 1 M ammonium acetate and save for the determination of exchangeable bases. To remove excess ammonium acetate, wash with 50 ml of 96% ethanol. After washing, percolate 50 ml of acidified sodium chloride into a 50 ml volumetric flask, then make up the volume. For the blank test (purified sand only), proceed in the same way. Run the standard range, blanks and samples through the auto-analyser, total nitrogen manifold, sensitivity 0.60 for 50 mV.

Calculation

Draw the baseline and measure the peak heights of the standard range, blanks and samples relative to this line. Using the range, calculate the CEC values of the blanks and samples.

CEC (meq/100g) = (a − b) h (cm)

Where a = value in meq/100g for the sample.

b = value in meq/100g for the blank.

h = height of the peak

Accuracy: 0.1

5) Determination of assimilable phosphorus in HCl-NH4F extract (Bray II method)

Procedure

Weigh 1 g of air-dried soil in a test tube and add 7 ml of the extraction solution (ammonium fluoride and 0.2 M chloridric acid). Shake for 1 minute and filter immediately. Make a blank and collect the filtrate in a test tube. If the solution is not clear, filter through the same filter. Measure the phosphorus concentration of the range, samples and blanks on the autoanalyser, P-Bray manifold, sensitivity 1.00 for 50 mv. The concentration was calculated as follows: Draw the baseline and measure the peak heights of the standard range, blanks and samples in relation to this line. Using the range, calculate the phosphorus concentration of the blanks and samples.

P-Bray ppm = 7 × (a − b)

a = ppm P measurement for the sample

b = ppm P measurement for blank

Accurate to within 1 ppm

Note: the soil/solution extraction ratio and stirring time vary between laboratories.

6) Determination of Total Nitrogen

Procedure

Weigh 0.5 g of air-dried, finely ground (<0.5 mm) soil into a 50 ml volumetric flask. Add 0.75 g of catalyst, a few grains of carborundum and 1 or 2 drops of distilled water to moisten the soil. Then add 5 ml of concentrated sulphuric acid. The added water stimulates the decomposition of the soil particles and promotes good mixing with the sulphuric acid. Place the vials on a hot plate and heat to 200˚C for 1 hour. Then continue at 350˚C, until a clear or pale green mineralisate is obtained, then continue to boil gently for 30 minutes. Remove the flasks from the plate and leave to cool. Slowly add about 25 ml of distilled water in small portions. Leave to cool, make up the volume and mix well. Allow the mineralisate to settle to obtain a clear supernatant. Run the standard range and the digest through the auto-analyser, total nitrogen manifold, sensitivity 6.00 for 50 mV.

Calculation

Draw the baseline and measure the height of the peak of the standard range, blanks and samples in relation to this line. Then, using the range, calculate the nitrogen concentrations of the blanks and samples.

$\%N = 0.01 * (a - b)$

Or a = ppm N for the sample

b = ppm for the blanks.

Accurate to within 0.01.

7) Determination of Potassium

Procedure

Weigh 2.5 g of air-dried soil and transfer it to a shaker bottle. Make a blank. Add 25 ml of the extraction solution and shake mechanically for one hour. Filter through a fine filter immediately afterwards. Measure the potassium concentration of the range, samples and blanks. Calculation method:

K in mg/100g soil = (a − b)

K_2O in mg/100g soil = 1.2 (a − b)

Or a = ppm K measured for the sample

b = ppm K measured for the blank

Accurate to within 0.01 ppm.

8) Determination of particle size composition

The particle size analysis was carried out using the Robinson pipette method [14].

This method consists of destroying the organic matter, followed by dispersing the sample in distilled water in test tubes for 15 minutes. Shake the bouyouce cylinder by hand for a few minutes to homogenise the suspension. Place the cylinder on the bench and start the stopwatch. Gently dip the graduated density meter into the test tubes containing the suspension (water and soil) and take the density readings at 40 s and 4 min, *i.e.* the densities (D1 and D2). Shake the cylinder containing the suspension again for a few minutes, place the cylinder on the bench and wait 1 hour. A few minutes before the time has elapsed, note the temperature and gently dip the densimeter back into the suspension. Note the temperature and take the D3 density reading. Repeat after 2 hours: if it is identical to the previous reading; if it is different, continue the readings at 3 hours, until it is constant (then take this value as D3 (**Figure 3**).

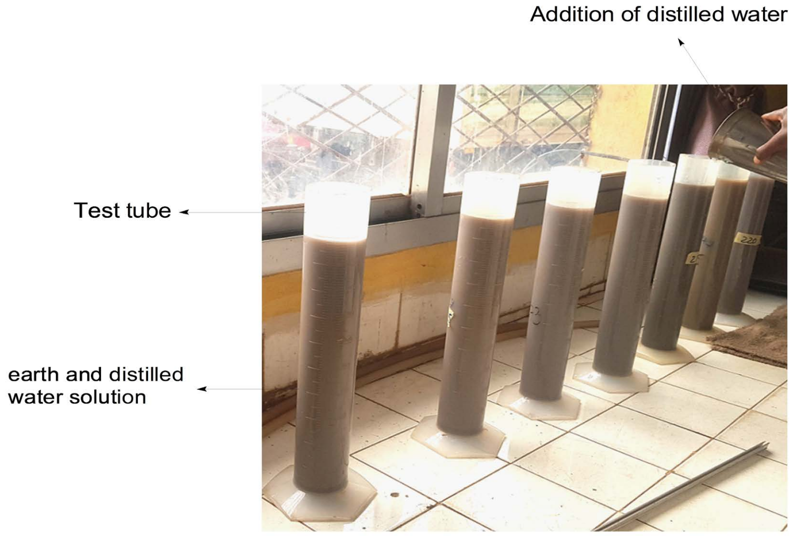

Figure 3. Showing the distilled water and soil solution in the test tubes (Robinson technique).

3. Results

The percentages of each element and the levels of certain chemical elements in the soils before pineapple cultivation in the prefectures (Kindia and Forécariah in the Republic of Guinea) are shown in **Tables 1-3** and **Table 4**.

Table 1. Percentage of each element in the sample, and two physical parameters.

Parameters		Friguiagbé (Kindia) Upstream		Standards	Criteria
		Field I	Field II		
Particle size (%)	Clay	16	16	0 - 20%	Texture Sandy loam
	Weak silt	6	4	0 - 50%	
	Coarse silt	4	6		
	Fine sand	29.6	30	42 - 85 %	
	Coarse sand	44.4	44		
pH		4.4	4.7	6 - 7.5	Very acidic
Bulk density g/cm^3		1.31	1.11	2.4 - 2.8	-

Table 2. Levels of certain chemical elements.

Parameters	Friguiagbé (Kindia) Upstream		Criteria
	Field I	Field II	
Organic Matter (%)	2.32	2.32	Moderately rich
Organic carbon (%)	1.35	1.35	-
Available nitrogen (mg/k)	5.5	5.5	Weak
Total nitrogen (mg/k)	0.11	0.11	-
Carbon-Nitrogen ratio	12.27	12.27	Good mineralisation

Continued

Assimilable phosphorus (mg/kg)	29.16	6.53	Low
Potassium (mg/kg)	101.52	59.22	Rich
Sum of bases (meq/100)	1.2	0.7	Very Low
Cation exchange capacity (meq/100)	5.4	4.3	Very low

Table 3. Percentage of each element in the specimen, and two physical parameters.

Paramètres		Maferinyah (Forécariah) upstream		Standards	Criteria
		Field I	Field II		
Particle size (%)	Clay	18	16	0 - 20%	Texture Sandy loam
	Weak silt	4	2	0 - 50%	
	Coarse silt	4	2		
	Fine sand	29.6	31.2	42 - 85%	
	Coarse sand	44.4	46.8		
pH		4.8	4.7	6 - 7.5	Very acidic
Bulk density g/cm^3		1.31	1.27	-	-

Table 4. Levels of certain chemical elements.

Parameters	Maferinyah (Forécariah) Upstream		Criteria
	Field I	Field II	
Organic Matter (%)	2.32	2.11	Moderately rich
Organic carbon (%)	1.35	1.23	-
Assimilable nitrogen (mg/k)	5.5	5	Weak
Total nitrogen (mg/k)	0.11	0.10	-
Carbon-Nitrogen ratio	12.27	12.3	Good mineralisation
Assimilable phosphorus (mg/kg)	6.53	4.81	Low
Potassium (mg/kg)	177.66	169.2	Rich
Sum of bases (meq/100)	2.1	2.0	Very Low
Cation exchange capacity (meq/100)	4.46	4.27	Very low

4. Discussion

For this study, 10 pineapple farmers (05 in Kindia and 05 in Forécariah) were interviewed. The questions were based on gender, age, area cultivated, years of operation, fertilisers and phytosanitary products used. The majority of respondents were men, aged between 30 and 65. The surface area of cultivable land is 2 to 5 hectares for 5 to 10 years of operation with different fertilising products used. The values in Table 1 of the soil (Field I and II) of Friguiagbe in Kindia before pineapple cultivation, the clay contents are identical *i.e.* (16%); the sum of the silt (weak + coarse silt) and sand (fine + coarse sand) contents of the two fields (I and II) are (10%) and (74%) respectively. All these values are within the standard ranges shown in **Table 1**. These values for clay, silt (fine + coarse sands) and sand (weak + coarse silt), compared with those found by [15], are: 8.75 and 9.4%; 6.6 and 3.9%; 84.29 and 86.41% (in the Ze and Toffo zones, Republic of Benin). We note that our clay values are higher than its values. However, its sand values are higher than our values. The water pH value of field II is higher than that of field I, *i.e.* 4.7 and 4.4 with a slight difference of 0.3, and the apparent density of 1.31 of field I is higher than that of field II, which is 1.11 g/cm^3 with a slight difference of 0.2 g/cm^3. These values are lower than those found by [15], which are 6.47 and 6.82. These differences may probably be due to the way in which the fertilisers are used by the growers. **Table 2** shows the results of the chemical analysis of the soil. According to the results, the percentage of organic matter (2.32%); organic carbon (1.35%); nitrogen content (0.11 mg/k); assimilable nitrogen (5.5 mg/k) essential elements for pineapple growth; carbon-nitrogen ratio (12.7) of the two fields (I and II) are equal. However, the values for assimilable phosphorus (29.16 mg/kg), potassium (101.52 mg/kg), sum of bases (1.2 meq/100) and cation exchange capacity (5.4 meq/100) for field I are higher than those for field II, *i.e.*, (6.53 mg/kg); (59.22 mg/kg); (0.7 meq/100); (4.3 meq/100) respectively. Analysis of the values in **Table 3** (Maferinya in Forécariah) shows that the clay content of Field I (18%) is higher than that of Field II (16%). The silt content (weak + coarse silt) of field I is higher than that of field II, *i.e.* a total of (silt) field I (8%) and field II (4%) respectively. The sand content (fine + coarse sand) in Field II (78%) was higher than in Field I (74%), all of which complied with the standard. The water pH (4.8) and bulk density (1.31 g/cm^3) of field II are higher than the water pH (4.7) and bulk density (1.27 g/cm^3) of field I. If we compare these values with those found by [15], we can see that only the pH and sand values are higher than our values. Our pH values are better suited to pineapple cultivation [16]. In **Table 4**, the percentage of organic matter (2.32%); organic carbon (1.35%); nitrogen content (0.11 mg/k); assimilable nitrogen (5.5 mg/k); carbon-nitrogen ratio (12.27 mg/k); assimilable phosphorus (6.53 mg/kg); potassium (177.66 mg/kg); sum of bases (2.1 meq/100); cation exchange capacity (4.46 meq/100); of field I are higher than those of field II, *i.e.,* (2.11%) (1.23%); (0.10 mg/k); (5 mg/k); (12.3 mg/k); (4.81 mg/kg); (169.2 mg/kg); (2 meq/100); (4.27 meq/100) respectively.

5. Conclusion

In the present work, we studied certain physico-chemical characteristics of samples of pineapple cultivable land before cultivation, taken in two localities, namely Friguiagbé and Maferinyah (Kindia and Forécariah) respectively. The following technical methods were used: Mc. Lead, Anne, Kapen HICDVITZ, pipette Robinson, Bray II… These methods showed that all four fields (in Kindia and Forécariah) have a sandy loam texture according to the texture triangle. The pH values found show that these different very acidic soils are favourable for pineapple cultivation, at 4.4, 4.7, 4.8 and 4.7. According to the chemical analyses, the organic matter content of the four fields was moderately low. Assimilable nitrogen and assimilable phosphorus levels were low, potassium levels were high, and the sum of bases and cation exchange capacity was very low, with good mineralisation (carbon-nitrogen ratio). However, further studies are recommended as this document can be used by the Ministry of Agriculture and Livestock to improve pineapple cultivation in the Republic of Guinea.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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