PRESENT PHYSICAL AND CHEMICAL FERTILITY STATE OF PALM GROVE SOILS AND THE LEVEL OF MINERAL NUTRITION OF PALM TREE (*ELAEIS GUINEESIS* JACQ.) FARMED IN DIFFERENT REGIONS OF CÔTE D'IVOIRE

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Abstract:

The diagnosis on the physical and chemical state of the palm grove soil in Côte d'Ivoire was made in different regions of the palm tree farming. For that purpose two methods were used namely the analysis of granulometric and chemical features of the soils in one hand and in other hand, the analysis of palm tree leaves in order to determine their mineral nutrition level. The question was to assess the fertility level of the soils used to farm palm tree in order to set up new fertilizer scale appropriated to the new conditions of the farming of this speculation. The analysis confirmed the lack in phosphorus and in potassium which contents vary respectively between 125 and 226 ppm and from 0.02 to 0.03 méq/100 g of soil. The contents are below the threshold of the lack in phosphorus (300 ppm) and in potassium (0.2 méq/100 g of soil). The levels of the palm tree nutrition in phosphorus and in potassium vary respectively from 0.12 to 0.18 % and 0.50 to 0.88 % of dry matter. The contents which have been obtained are below the critical threshold for these elements fixed on 1 % of dry matter for the potassium and on 0.15 % of dry matter for the phosphorus. The lack in potassium is the main chemical constraint which limits the palm tree farming in all the production area in Côte d'Ivoire. However, the nutrition level in nitrogen, calcium and magnesium are acceptable for a good growth of the palm tree. The soils of palm tree grove progresses towards a new state of chemical fertility which is more and more unfavorable to the farming unless we take necessary precautions during the preparations of the soil. Thus, it is necessary to set up a middle scale of fertilizer especially potassic appropriate to the particularities of the farming zone of palm tree in Côte d'Ivoire.

Keywords: Côte d'Ivoire, soil, fertility, palm tree, critical level, leaf 17

Introduction

In Côte d'Ivoire, the palm tree farming has been developed in the south forest where the soil profile and climatic conditions are favorable (Anonyme, 2007). Up to now, more than 350000 hectares shared out among the sector of industrial (industrial plantation) and village sector (village plantation) are exploited. The palm tree provides a living for about 1 million persons and generates more than 300 billion CFA to Côte d'Ivoire.

This crop represents after the cocoa, the 2nd pillar of the country economy. However, this crop is subjected to many constraints especially the rain which is more and more irregular (Yao *et al.*, 1995) and the decline of the soil fertility (Hartmann, 1991; Quencez, 1996; Kabrah and Ballo, 2000). This decline of the soils fertility is due to an anthrophic pressure on the land, the farming practice characterized by a lower supply in fertilizer and an over exploitation of the soils (Sanchez *et al.*, 1982). The disappearance of long standing fallow and the replantation on the old orchard of palm tree, lead to a degradation more and more increased of the productive environment. The general observation is that there is a trend to a fall of the yield in the order of 30 % in all the Ivorian area of farming (Quencez, 1996).

The studies on the evolution of the soils fertility state in Côte d'Ivoire pointed out the confirmation of the fall of contents in mineral elements especially in potassium, phosphorus, nitrogen and magnesium (Sanchez *et al.*, 1982; Hartmann, 1991). The mineral nutrition of the palm tree is almost insufficient in these mineral elements.

The measures and the fertilizers formula which have been popularized at the moment in all the palm tree production area of the country have been set up for more than thirty years. In this interval of time, there was some changing in the chemical unbalanced of the mineral elements of the soils for palm tree farming with the appearance of new lack in the different regions of production or an intensification of those which already existed.

Considering the observations, the agronomical research must deepen its studies and propose long lasting technical solutions and economically profitable to farmers and appropriated to new conditions of the tree farming. From this point of view, a study of the current state of the soil has been made through the main areas of the palm tree farming and some test of fertilizer were set up in rural and industrial areas in order to establish a new appropriated scale of mineral fertilizer.

The purpose of this study is to make the current physic and chemical state of fertility of the soils under the palm grove and to assess the level of the mineral nutrition of the palm trees in the south of Côte d'Ivoire for the future correction of the lack.

Material and methods

Characteristic of areas of study

The studies of the soil and leaflet of palm tree sampling were made on 4 representative sites of the main areas of palm tree in Côte d'Ivoire.

The sites which were chosen are:

- La Mé, in the south-east,
- Ehania, in the south-east,
- Boubo, in the south-centre,
- Iboké, in the south-west.

On every site, two plot of land were chosen for this study: one in village plantation and the other in industrial plantation. These types of plantations are different from the cultural techniques applied. The table I present the different characteristic according to the location, to the rain, to the water deficit and to the type of soil encountered on every site.

The plots of land which were chosen are located on the dominant soil unit of the area and on the low altitude plateau. All the plantations were set up in 2007.

Vegetal material

The vegetal material is composed of hybrids of palm tree, from C1001F category, seeds which allow fusariose. It has been obtained by the cross between the *Dura* variety (female) and the *Pisifera* variety (male). This hybrid called *Tenera*, is characterized by a precocity, a high yield and strong content in oil. This material has been improved by the National Agronomical Research Center (CNRA) and is now popularized in all palm tree production area of Côte d'Ivoire.

Edaphically material

The edaphically material used is composed of soils which stand these hybrids of palm tree. The soils are located on low altitude of plateau of the different regions chosen for this study. These soils derive from sedimentation at the beginning of the formations of detritical sandy-clayish of dominant rough sand (Perraud, 1971). The process of pedogenesis of which the deterioration, the decomposition, the leaching, the desaturation and the redeposit permitted to settle different types of soils in Côte d'Ivoire.

Soil sampling

The soils sampling have been made to analyze the granulometric and chemical on each of the plot of land in depth of 0 to 30 cm. This depth has been chosen according to Jourdan (1995) and Jourdan and Rey (1997) method, and because most of the absorbent roots of the palm tree are on this lay of soil.

In one plantation, the sampling made on three different sites: the circle of 4 meters of diameter around the palm tree, the swathed space and the free space. A mixed sample composed a mixture of about ten elementary samples on 3 points of sampling.

The soils sampling were made with a drill. These samples were dried out in the open and sieved at 2 mm. they were packed in plastic bag and transmitted to the soils and vegetal laboratory (LAVESO) of INP-HB of Yamoussoukro (Côte d'Ivoire) for analysis. The results of the analysis were used to compare to the threshold value or reference content.

The main methods and expressions of the results used in the laboratory are described by Pauwels *et al*. (1992):

- some granulometry, by the sedimentation method using the pipette of Robinson-Köhn,
- some water pH, by the measure on a suspension soil-distilled water in a ratio of 1/1.5 by the electronic method «glass electrode»,
- some absorbent complex, by saturation containing ammonium acetate at pH 7,
- some assimilable phosphorus by Olsen (1938) method modified by Dabin (1956),
- some organic carbone, by a cold sulfo-chronic attack, by Walkley and Black (1934) method,
- some full nitrogen, by the Kjedahl de Rittember (1882) method city by Dabin (1967),
- some exchangeable aluminum, by extraction with ammonium oxalate,
- the full elements (essentially oxide), by triacid of Harrison attack.

Leaflet of palm tree sampling

The leaflet of palm tree sampling were made on the leaves of same rank (leaf of rank 17), because of the mineral concentration change according to the phyllotaxic position of the leaves (Martin-Prevel *et al*., 1984).

On the plot of land, it has been chosen thirty palm trees (the diagonal of plantation) on which are samples the leaflets to compose the sampling. The moment chosen for the sampling in the short dry season or moment of less rain, according to the method of Ochs and Olivin (1975), at that period the content in mineral elements is more stable.

We sample 4 leaflets situated in the median part of the leaf 17 per tree to compose a sampling of 90 leaflets. On each leaflet, two apical and basal extremities, the central vein and the 2 mm marginal are thrown and only the median part is kept. These leaflets are dried with a drier at 105 °C for 24 hours. They were parked in plastic bags and transmitted to LAVESO to determine the content in mineral element (especially the N, P, K, Mg and Ca) in the palm trees leaves. The principles, the method of the results used in the laboratory are described by Bonvalet and Servant (1973):

- ✓ the full nitrogen, by colorimeter measurement according to the Berthelot method,
- ✓ the full phosphorus by phosphovanado-molybdic mineralization,
- ✓ the potassium, by spectrophotometer Beckman mineralization,
- ✓ the calcium and the magnesium, by atomic absorption with a single ray Perkin Elmer 290B spectrophotometer.

The results of the analysis were used to compare with the critical level or threshold of the mineral elements.

Results and discussion

Physical characteristic of the soils

The results of the analysis of the physical characteristic of the soils of all sites are summarized in the table II.

On all sites, the content in sand was generally the granulometric fraction the most representative in the lay of the soil sampled (0 – 30 cm) and the alluvium, the less represented.

These soils have a sandy-clayish texture either at La Mé, Ehania, Boubo and Iboké with a sandy surface. The content in sand (fine and rough) varied between 48 and 87 % per quantity of soil, with strong content in the south-east, that is to say at La Mé and at Ehania and the weakest content in the south-center that is to say at Boubo. Concerning the clay, the content varied between 8 and 34 % per quantity of soil with the highest content at Boubo and the weakest content at La Mé.

These soils are all ferrallitic which derived from rocks that have undergone and advanced process of decomposition under the last influence of a hot and cold climate (Muller, 1987; Tardy, 1993; Lucas *et al*., 1996). These soils have a great depth and are favorable to a good rooting of the palm trees (Hartmann, 1991).

The studies of Kabra and Ballo (2000) showed that the granulometric compositions (clay, alluvium and fine sand above all) are decreasing slightly in palm grove by opposition to the content in forest. These studies have confirmed those of Boyer and Combeau (1960), of Blic and Moreau (1979) and of Cointepas and Makilo (1982) who asserted that the physical features of the ferrallitic soils are generally damaged by the long lasting crops like the palm tree.

According to these authors, the damage of the physical features of the soils by the crops is due to a sudden changing of cold and dry which lead to a break of the link between iron and clay. This break provokes the destruction of the aggregate created by the link iron-clay. This destruction leads to the decline of the soils structures and the lost of the small elements (Chauvel and Monnier, 1967; Chauvel, 1977).

To allow the expression and to preserve the productivity potential of the new popularized vegetal material, we must adopt a good cultural technique and a reasonable supply of organic matter associated to mineral fertilizers will allow reducing the degradation of the physical properties of the palm grove soils.

Chemical features of the soils

General features of the organic matter

The results of the analysis of the chemical features of soils are presented in the table III. It shows some important disparities between the different sites. The content of the soils, on all the sites, in organic matter are superior to 1 % per g of soil which is the threshold fixed to appreciate the fertility level of a soil in organic matter (Traoré *et al*., 2007). The content in organic matter varies between 1.5 and 3 % per g of soil, with the highest rate at Iboké and the lowest rate at La Mé. The content in organic matter is enough for palm tree farming. The fertility level in organic matter under the Ivorian palm grove is at the moment acceptable for the trees nutrition. This organic matter, because of its strong content in the soils studied, is widely involved in the process of cationic exchange. This situation has a positive consequence on the stability of the soil structure as Ben Hassine *et al*. (2008) proved it.

But, the studies of Feller and Milleville (1977), Cointepas and Makilo (1982) and of Kabrah and Ballo (2000), have shown that in tropical Africa, the organic matter is decreasing under the effect of extended farming especially the palm tree. This would lead a reducing of the organic stock according to the weather conditions and the way of exploitation.

According to Moureaux (1967) and Bachelier (1968), the lost in organic matter derive from the biological imbalance to which it's added the exportations by erosion, leaching and a higher mineralization (increasing of the temperature, changing between drying and dampening and the pH change).

As it is presented in the table III, the content in carbon and nitrogen of all the sites vary respectively between 0.7 and 2.5 % per g of soil and between 0.09 to 0.3 % per g of soil. The weakest content in carbon and nitrogen are met in the south east of the country (La Mé and Ehania).

The content in nitrogen on all the sites is superior to 0.1 % per g of soil which has been defined as the lack threshold in nitrogen in the tropical soil (Boyer, 1982). Following the classification of Landon (1991), the present content in nitrogen of the palm grove soil are enough for a good grown up of the palm tree.

Concerning the content in carbon, it is superior to the indicated level of the features of the appropriate soil for the palm tree farming in Côte d'Ivoire. By taking into account the critical level fixed to 1 % per g of soil by Jacquemard (1995), these soils have enough content in carbon for a good grown up of the palm tree. The studies of Kabrah and Ballo (2000) pointed out the content in carbon and in nitrogen of the palm grove soil are decreasing by contrast to the soil of the forest. The content in carbon and in nitrogen is evaluated in forest, respectively to 1.67 % and 0.14 % per g of soil. According to Feller *et al*. (1991c), the palm tree farming provokes a relative decrease of the carbon and nitrogen stocks in the granulometric fraction of 50 to 76 % for the sandy fraction, 15 to 30 % for the alluvium fraction and only 7 to 19 % for the clay fraction compared with the content in forest.

According to Ollagnier *et al*. (1978) and Soltner (1985), the litter in palm grove is composed of palm leaf and dead roots containing strong lignin. This litter seems to decay slowly in view to the supply in heaps which reduces the contact between the organic matter and the soil. Sokpon and Lejoly (1991) consider that the quantities of restored matter to the soil are this case weak in the conditions where the rain is more and more decreasing and lead an increasing of the water deficit.

The supply of organic matter to a ratio C/N lower enough (manure) mixed with the mineral fertilizer can be a solution to solve the problem of the fall in organic matter, carbon and nitrogen content of soil under palm trees grove (Sibiri, 1995).

General features of the phosphorus and pH

On the whole sites, the contents in available phosphorus vary between 37 and 78 ppm (table III). The weakest contents are met in the south-west and the strongest contents are obtained in the south-east. In all the plot of land, the content in phosphorus is situated beyond 30 ppm, considered as the threshold of the lack in phosphorus of the features of the tropical soils (Berger *et al*., 1987). But, these contents in total phosphorus on all the sites are inferior to the indicated level of the features of the soils appropriate to the palm tree farming. This indicated level according to Jacquemard (1995) varies between 300 and 400 ppm, because the contents in total phosphorus on all the sites vary between 150 and 226 ppm. This confirms the weakest content in phosphorus in south soils of Côte d'Ivoire (Nguyen *et al*., 1981).

But generally, all the soils have some available content in phosphorus is superior to the level of lack; consequently, they are acceptable for the palm tree farming.

The pH values are between 4.2 and 5.6 (table III), indicate that these soils are acid with the weakest values met in the south-east and the strong values obtained in the south-center. This strong acidity could indicate the beginning of the appearance of exchangeable aluminum which can provoke some phenomenon of toxicity to the palm tree. Although the palm tree allows acid soils, the optimal values situated between 4 and 7 were fixed for a well grown up of the trees. The pH of the soils of all sites is situated in that indicated interval, appropriated to the palm tree farming.

The pH has an impact on the palm tree yield by its influence on the biological activity of the soil (Domengues, 1953 and 1956a), the jamming of phosphorus available form (Dabin, 1963 and 1968) and the great availability of some heavy metal (Landon, 1991).

According to Soltner (1985) and Kabrah and Ballo (2000), although the absorbent complex is desaturated under the palm grove, the acidity (pH) of these soils remains unchanged by contrast to the soils of forest. The pH of the soils of the different sites is appropriate for the palm tree farming.

Exchangeable bases

The content in calcium (Ca^{2+}) of the soils of the different sites are situated between 0.35 and 1.30 méq/100 g of soil (table III), with the highest values at Boubo (south-center). Only the values of Boubo are superior to the indicated level of the features of the soil appropriate to the palm tree farming fixed to 0.7 méq/100 g of soil by Jacquemard (1995). On the other sites (La Mé, Ehania and Iboké), the contents in Ca^{2+} are inferior to this indicated level of the appropriate soil to the palm tree farming. According to the classification of Landon (1991), these soils are considered poor in Ca^{2+}.

According to the same author, the lack in this element appears in the soil with low capacity of cationic exchange and with pH inferior to 5.5.

The values obtained for the magnesium (Mg^{2+}) vary (table III) between 0.11 and 0.30 méq/100 g of soil. These values are all inferior to 0.40 méq/100 g of soil, defined as the indicated level of the features of the soils appropriate to the palm tree farming (Jacquemard, 1995) and as threshold of lack of the soils in this element in the tropical areas (Mbonigaba, 2009). It appears a lack in Mg^{2+} in the soils of the palm tree on all the sites.

On the whole sites of the study, the content in potassium (K^{+}) vary between 0.02 and 0.03 méq/100 g of soil (table III). These values in K^{+} are on the whole inferior to the indicated level of the soils appropriate to the palm tree farming and the lack of the tropical soils fixed respectively to 0.2 méq/100 g of soil and to 0.05 méq/100 g of soil (Jacquemard, 1995).

According to the classification of Dabin and Leneuf (1960) and of Charreau and Fauck (1969), the soils of the different regions of palm tree production are characterized by a lack in potassium. This lack in this element comes from the fact that all the soils of the study are ferrallitic which come from mother rock very poor in potassium.

Generally, the lack in potassium is obvious particularly in the sandy soils but it appears after some years of farming in most soils. Moreover the exportations by the harvesting of bunches of the palm which are very important, the potassium undergo strong lost by lixiviation (Roose, 1981).

Because of the essential role played by the potassium in the production of the palm tree (Ochs *et al*., 1991; Caliman *et al*., 1994; Ballo, 2009), the supply in potassium fertilizer appears necessary to increase the content of these soils in this element. The potassium constitutes the first factor that limiting the production of the palm tree. It is the main element to obtain a good yield in palm bunches. The potassium is the nutritive element the most required and the most important in the production of the palm tree. Consequently, the objective of the highest yield of oil cannot be reached without an adequate supply in this fertilizing element.

The content in capacity of cationic exchange (CEC) of the soils of all the sites remain weaker with the values varying between 1.03 to 2.63 méq/100 g of soil (table III). The studies of Soltner (1985) pointed out that the content in CEC remains weaker in the palm grove in response to their decreasing by contrast to the soil in forest. According to this author, this decreasing can be attributed to a leaching of the clay and especially to a less polymerized fertilizer dominated by fulvic acid which is unable to form a clayish-humic complex. According to Boyer (1982), the decreasing of the CEC is due to a lixiviation of the bases which is linking to the abundant rain, the permeability of the soils and the density of the roots system of the palm tree in the superficial horizon.

Under the palm grove of Côte d'Ivoire, the contents in mineral elements especially in potassium, in magnesium and in phosphorus are below the indicated level of the appropriate soils for the palm tree farming. This remark was made by Roose (1981) and Cointepas and Makilo (1982). According to these authors, the summary of mineral elements of the palm tree soils appears always negative, in the absence of an appropriated fertilization. These lacks as identified could be corrected by a good farming technique and supply in organic matter mixed with mineral fertilizer especially potassic for the improvement of the palm tree production.

Mineral nutrition

The table IV presents the level of mineral nutrition of the palm tree after analyzing of the leaf 17 on all the sites of the study.

The contents in nitrogen (N) of the leaf 17 of the different areas vary between 2.60 and 3.78 % of dry matter. The contents in nitrogen obtained are superior at the critical level of the leaf 17 which has been fixed at 2.25 % of dry matter by Tampubolon *et al*. (1990). The contents obtained show that the level of nutrition of the palm tree in this element is bluntly acceptable for a better growth of the sprout. The nitrogen constitutes the element which needs are fundamental for the sprout (Belder *et al*., 2005) till the production stage.

Concerning the contents of the leaf 17, in phosphorus of all the sites, they vary between 0.12 and 0.18 % of dry matter. The weakest contents were obtained in the south-west and in south-center and the highest values were observed in the south-east of the country (Table IV). These contents obtained at Boubo and at Iboké are inferior to the critical level in this element which was fixed at 0.15 % of dry matter by Ollagnier and Ochs (1981) and Ollagnier *et al.* (1981). This weak level of nutrition of the palm tree in phosphorus is due to a relative poverty of south-west and south-center soils of the country in this element. The correction of the lack by the supply in phosphorus fertilizer will improve the nutrition level in this element and will allow the absorption of great quantities of other elements which will influence the growing and the yield (Manciot *et al*., 1979).

The table IV also presents the contents of the leaf 17 in calcium, on all the sites of this study. These values vary between 0.79 and 1.02 % of dry matter. The contents are all superior to the critical threshold of the calcium which is fixed by Ollagnier and Prevot (1956) to 0.6 % of dry matter.

Concerning the contents of the leaf 17 in magnesium presented in the table IV, they vary between 0.28 and 1.77 % of dry matter. The level of nutrition in magnesium of the palm tree is superior to the critical value in this element which is fixed to 0.24 % of dry matter by Ummar *et al.* (1976) and Ollangier and Ochs (1981).

The nutrition level of the palm tree is almost satisfactory in magnesium and in calcium are the results of a good availability of these elements in the soils of the different sites. These levels are bluntly acceptable for a good growth of the palm tree in all the farming areas of Côte d'Ivoire.

The table IV presents the contents in potassium obtained after analyzing the leaf 17. These values vary between 0.50 and 0.88 % of dry matter. The weakest values were obtained at La Mé (south-east) and the highest contents were recorded in Iboké (south-west).

The contents in potassium of the leaf 17 obtained on all the sites are inferior to the critical threshold fixed at 1 % of dry matter by Ollagnier *et al.* (1987) and Diomandé *et al.* (2001). The mineral nutrition level weaker of the palm tree in potassium comes from the lack in this element in all the soils of the different productions areas.

According to IRHO (1992), the lack in potassium concerns all the farming zones of the palm tree in the tropical world. These lacks come from at the same time of the exportations by the farming and the poverty in potassium of the desatureted ferrallitic soils, derived from the granite, the sandstone and sedimentary sand. But it is possible to correct these lacks in potassium on these types of soils if the palm trees are not deeply and irreversibly affected (Ollagnier and Olivin, 1984).

Because of the essential role played by the potassium in the mineral nutrition and particularly in the production of palm tree bunches (Ochs *et al*., 1991; Caliman *et al*., 1994; Ballo, 2009), it is necessary to correct these lacks by some supply of potassic fertilizer to keep the level of production of the new vegetal material.

The mineral balance sheet of the analysis of the leaf 17 has permitted to highlight in one hand the satisfactory nutrition in nitrogen, in calcium and in magnesium and in other hand the existence of a lack in potassium and in phosphorus in all the farming areas of the palm tree. But this lack in potassium seems the mains chemical constraint which limits the production of the palm tree in all the Ivorian regions. Some strict solutions must be taken to solve this problem which threats seriously the palm tree culture in the entire inter-tropical zone because of the damage of the physical properties and chemical soils.

Conclusion

Apart from the nitrogen, the calcium and the magnesium which have a satisfactory nutrition level, the most pronounced lack concern the potassium and the phosphorus for the palm tree farming in Côte d'Ivoire. It appears that the weakest values of the potassium obtained in the soils and at the level of the palm tree nutrition represent the main chemical constraint which limits the production in the palm trees zones of the country.

The level of the organic matter and the granulometric constitutes which is the clay; the alluvium and the fine sand are decreasing in the palm grove by contrast to the soils of forest in the entire farming zone. This degradation of the physico-chemical features of the soil of the palm tree will constitute at the end a real constraint for this crop in Côte d'Ivoire if the decreasing trend of the rain continues. In these weather conditions, the reasonable and sustainable production of palm bunches require a higher attention to the soil. It will be benefit to these soils to adopt farming techniques which allow keeping or increasing their level of fertility. This will contribute to improve the mineral nutrition of the trees by playing a benefic role on the yield.

The supply of organic matter mixed to mineral fertilizer which will be established, especially potassic will solve the problem of degradation of the physic-chemical features of the soils of the palm grove in order to keep the level of the new vegetal material productivity.

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Table I: Some characteristics of the experimental areas

Areas	**Localization**	**Characteristics**		
		Rain	**Water deficit**	**Soils type**
La Mé (Alépé)	South-east	1287 à 2000 mm/year Mean : **1600 mm/year**	Mean : **285 mm of water/year**	**Tertiary sand** : ferrallitic soil greatly desatureted
Ehania (Aboisso)	South-east	1500 à 2900 mm/year Mean : **1960 mm/year**	Mean : **217 mm of water/year**	**Tertiary sand** : ferrallitic soil greatly desatureted
Boubo (Divo)	South-center	980 à 1980 mm/year Mean **: 1500 mm/year**	Mean : **450 mm of water/year**	Ferrallitic meanly desatureted
Iboké (Tabou)	South-west	1750 à 3300 mm/year Mean **: 2400 mm/year**	Mean **: 40 mm of water/year**	**Old plinth** : ferrallitic soil greatly desatureted

Table II: Physicals characteristics of the soils of the experimental areas

Town	Plantations type	Clay (%)	Silt (%)	Fine sand (%)	Crude sand (%)
La Mé (Alépé)	**PI**	7,4	5,6	19,9	67,1
	PV	7,3	5,5	19,7	67,0
Ehania (Aboisso)	**PI**	13,0	2,0	25,0	56,0
	PV	13,1	2,1	25,2	56,2
Boubo (Divo)	**PI**	34,0	16,2	37,6	9,8
	PV	34,1	16,3	37,4	10,0
Iboké (Tabou)	**PI**	21,2	6,5	32,0	36,2
	PV	21,3	6,6	32,4	36,3

PI = Industrial plantation ; PV = Village plantation

Table III: Chemicals characteristics of the soils of the experimental areas

Town	Plantations type	Organic matter (%)				PH	P.ass (ppm)	Absorbent complex (méq/100 g)				
		MO	C	N	C/N			Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC
La Mé (Alépé)	**PI**	1,5	0,8	0,09	9	4,8	78	0,49	0,14	0,03	0,05	1,05
	PV	1,5	0,7	0,09	8	4,9	37	0,35	0,14	0,02	0,05	1,03
Ehania (Aboisso)	**PI**	2,3	1,4	0,09	14	4,2	56	0,47	0,16	0,03	0,09	1,66
	PV	2,2	1,3	0,09	14	4,3	63	0,58	0,12	0,02	0,07	1,50
Boubo (Divo)	**PI**	2,1	2,5	0,3	8,6	5,5	58	1,30	0,30	0,03	0,06	1,40
	PV	2,0	2,0	0,25	8	5,6	35	0,96	0,16	0,03	0,06	1,32
Iboké (Tabou)	**PI**	3,0	1,7	0,13	13	5,3	40	0,48	0,11	0,03	0,06	2,63
	PV	2,8	1,7	0,12	13	5,2	50	0,44	0,12	0,03	0,07	2,60

PI : Industrial plantation ; PV : Village plantation

Table IV: Mineral elements contents in the leaf 17 of palm trees on the experimental areas

Town	Plantations type	Mineral elements (% of dry matter)				
		N	P	K	Ca	Mg
La Mé (Alépé)	**PI**	2,60	0,15	0,61	0,89	0,37
	PV	3,08	0,15	0,54	0,94	1,77
Ehania (Aboisso)	**PI**	3,78	0,18	0,87	0,79	0,32
	PV	3,45	0,15	0,50	0,97	0,33
Boubo (Divo)	**PI**	2,86	0,14	0,79	0,87	0,31
	PV	3,05	0,13	0,71	1,02	0,28
Iboké (Tabou)	**PI**	3,56	0,13	0,88	0,83	0,32
	PV	3,30	0,12	0,82	0,94	0,32

PI = Industrial plantation ; PV = Village plantation