

# Evolution of soil fertility of two experimental plots under *Lippia multiflora* (Verbenaceae) culture in Côte d'Ivoire.

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**Abstract**— The development of a growing system involves knowledge of soil quality and key aspects relating to planting density among others. In general, the understanding and definition of sustainable soil fertility management practices is necessary in enabling better use of soil resources and ultimately improvement of crop productivity. This study was conducted in the communities of Toumodi and Azaguie to assess the influence of The *Lippia multiflora* culture on the initial soil characteristics depending on the study site and planting density. At each of the study sites and ten (10) months after planting, twelve (12) pedological pits, 60 cm x 50 cm x 60 cm, were opened in the immediate environment of the *Lippia multiflora* plants, at the plots of density treatments 4444 plants.ha-1, 20000 plants.ha-1 and 40,000 plants.ha-1, at the rate of three (3) profiles per treatment. A total of thirty-two (32) composite soil samples were collected per study site at the level of the different treatments, i.e. sixteen (16) samples per layer considered, equivalent to four (4) samples per treatment. The results obtained indicate that; after ten (10) months of cultivation, there was at the 0 - 20 cm layers of the soil, of each of the experimental plots, a decrease in the content of clay, organic matter and basic cations as well as acidification soil with planting density, particularly at the Azaguie experimental site. Most of the roots are found in the 0-30 cm layer. The results of this study will play a key role in coming up with technical innovations aimed at improving soil fertility management and agronomic performance of *Lippia multiflora*-based cultivation system development.

**Keywords**— soil quality, planting density, crop productivity, *Lippia multiflora*, Côte d'Ivoire.

## I. INTRODUCTION

*Lippia multiflora* (Verbenaceae), also known as Gambian tea, or savannah tea, is an aromatic plant that grows spontaneously and preferentially in the savannah areas of subtropical Africa (N'guessan and Yao-Kouamé, 2010; N'guessan *et al.*, 2010 and N'guessan *et al.*, 2015). The plant is useful thanks to its leaves whose herbal tea or infusion can be consumed as tea or as a hot drink for breakfast, lunch and dinner (Etou-Ossibi *et al.*, 2005; N'guessan and Yao-Kouamé, 2010). Consumption of *Lippia multiflora* leaves; facilitates digestion, allows good relaxation (Abena *et al.*, 1998), fights constipation, hemorrhoid and fights liver disease, oral and digestive candidiasis (Noamesi *et al.*, 1985). In addition, the essential oil of *Lippia multiflora* leaves has antioxidant properties (Agnaniet *et al.*, 2005), antihypertensive (Etou-Ossibi *et al.*, 2005; Oussou *et al.*, 2008) bactericidal and

anti-diarrheal (Oussou *et al.*, 2008). These oils are also used as cosmetic adjuvants, in shampoos and have pesticide properties (Bassole *et al.*, 2003; Kunle *et al.*, 2003). Today, *Lippia multiflora* dry leaves are sold in markets in Côte d'Ivoire, including a few supermarkets in Abidjan and exported to foreign countries (N'guessan and Yao-Kouamé, 2010). Despite this great potential, *Lippia multiflora* remains a wild plant. In Côte d'Ivoire, the dietary, biomedical and pharmacological importance of *Lippia multiflora* leaves has also been reported (Oussou *et al.*, 2008; Ekissi *et al.*, 2011). However, very little research has been done at the agronomic level on the development of appropriate farming techniques with a view to promoting and popularizing its cultivation in rural areas. Therefore, this study was initiated to assess the impact of The Cultivation of *Lippia multiflora* on the initial characteristics of the soil. With this study, key technical

innovations to improve soil fertility management and agronomic performance of *Lippia multiflora*-based cultivation systems can be developed.

## II. MATERIAL AND METHODS

### 2.1. Study site

This research was carried out on two experimental plots located, one in the town of Azaguié, in southern Côte d'Ivoire, and the other on the Blé research station in the Department of Toumodi, in the wetland area (Fig. 1). These two localities are characterized by bimodal rainfall with four well-marked seasons: two rainy seasons interspersed with two dry seasons. Generally, there is a short dry season in August and a long dry season between December and March. February, March and April are generally the warmest months. On the Site of Wheat (Toumodi), vegetation is dominated by a high-density shrub-density tree savannah with forest islets in places as well as forest galleries along streams. Most of the terrain, a little rugged, is dominated by hills, the most important of which reach 449 m of altitude. It is mainly found in ferrallitic soils (ferralsols), hydromorphic soils (gleysols) and brown soils (cambisols) (Avenard 1971). The natural environment of the study area is characterized by a grassy savannah dotted with shrubs and resting on a ferroallitic soil. In Azaguié, the landscape is mainly made up of forest slits, various plantations and poultry farms. In addition, the yapo-Abbe classified forest, located in the north, between the Azaguié sub-prefecture and agboville. The tests were installed in the middle third of the bottom of a plateau landscape with a low slope estimated at about 2%. Natural vegetation is a secondary forest made up of shrubs. The soil is of ferrallitic type (CPCS, 1967) or Ferralsol highly desaturated, developed on birimian shales with quartzite veins (Tamia *et al.*, 1999); which gives it a gritty character rich in gravel and coarse sands.

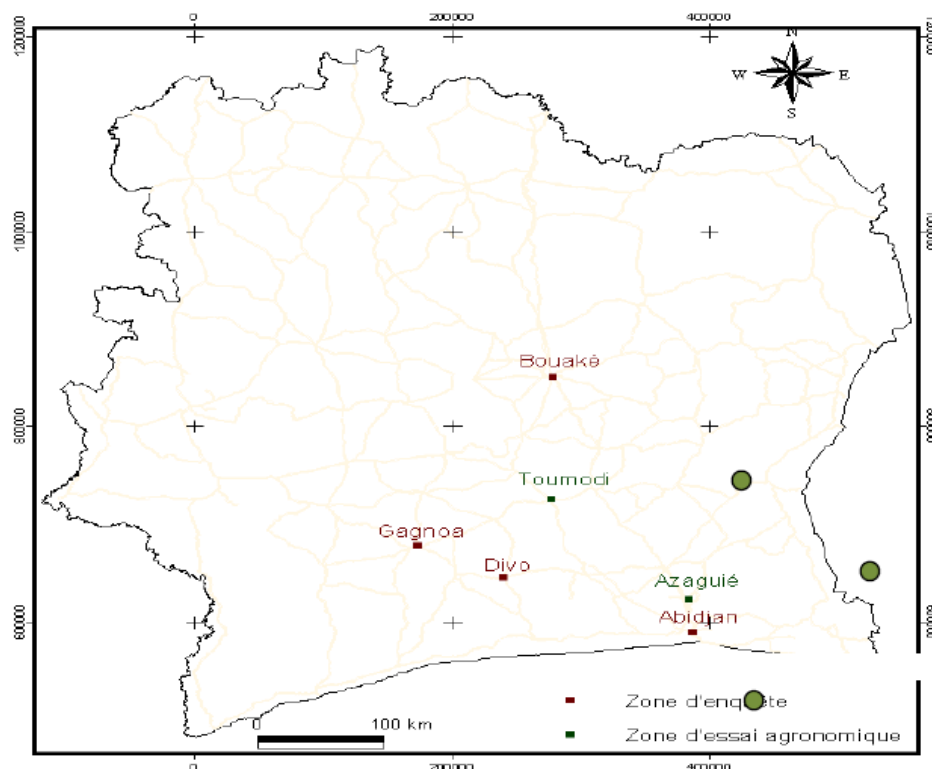
### 2.2. Sampling

During the study of the impact of crop systems on the chemical, physical-chemical and biological parameters of the soil, several authors conducted investigations on the first 20 centimetres of the soil, or more (40 or 60 cm). This was the case in the studies of Azontonde *et al.* (1998), Koutika *et al.* (2001), Bado (2002), Kolawolé *et al.* (2003) and Oorts *et al.* (2003). All of these studies were conducted on long-term crop systems greater than five (5) years. Other authors limited themselves to layer 0- 10 cm or 0-15 cm on short-lived crop systems of less than two (2) years to draw conclusions. This is the case of Ile *et al.* (1996) and Tian *et al.* (2000). Also, given that the period of experimentation is relatively short and that changes

under crop systems are more rapid in the surface layer, we considered, in the case of our study, the 0 - 20 layers cm and 20 - 40 cm as levels of soil sampling for laboratory chemical analysis. Thus, on each of the study sites and ten (10) months after planting, twelve (12) pedological pits, of size 60 cm x 50 cm x 60 cm, were opened. There were three (3) soil profiles under natural vegetation and nine (9) profiles on the experimental plot. These nine (9) profiles were opened in the immediate environment of *Lippia multiflora* plants, at the density treatment plots 4444 plants.ha-1, 20,000 plants.ha-1 and 40,000 plants.ha-1, at the rate of three (3) profiles per treatment. A total of thirty-two (32) composite soil samples were collected per study site at the level of the different treatments, i.e. sixteen (16) samples per layer considered, equivalent to four (4) samples per treatment. Each floor sample was packaged in a plastic bag attached with a rubber strap, and labelled with mentions of date, location, depth and type of horizon. For safety, and to minimize the risk of tearing during transport, the bags containing the samples were systematically doubled. In addition, the roots were counted in the 0-5 cm, 5-15 cm, 15-30 cm and 30-50 cm layers, considering (i) the number of fine roots (1 mm), (ii) the number of medium roots (1-5 mm) and the number of large roots (5 mm).

### 2.3. Laboratory analysis

They were carried out in the soil and plant laboratory of the Higher School of Agronomy (E.S.A), of the Félix Houphouët-Boigny National Polytechnic Institute (INP-HB) in Yamoussoukro. The soil samples were first dried on newsprint and then sifted with a 2 mm diameter square mesh sieve. On these fine earth samples, the granulometric analysis was performed using the densimetric method using Robinson's pipette (Gee and Bauder 1986). Five granulometric classes were separated: clays (0-2 Nm); fine silts (2-20 Nm); coarse silts (20-50 Nm); fine sands (50-200 Nm); coarse sands (200-2000 Nm). The water pH measurement was performed by electrometry, in a soil suspension in the water in a ratio of 1/2.5. Organic carbon (C) was dosed using the Walkley and Black method (1934), the result was converted to organic matter (MO) using factor 1.72 (MO - C x 1.72). Total nitrogen was determined by the Kjeldahl method (Bremner 1996). The exchangeable bases and cationic exchange capacity were combined in an ammonium acetate extraction solution (CH<sub>3</sub>COOH 1N) stamped at pH 7 (Thomas 1982). Assimilable Phosphorus was determined by the modified Olsen Dabin method. Total phosphorus was determined by colour, after extraction with perchloric acid (Olsen and Sommers 1982).



#### 2.4. Statistical analysis

Comparison of the averages of the granulometric, physicochemical and chemical data of the soil of each of the study sites, before and 10 months after the culture according to the density of plantation was carried out by the analysis of the variance (ANOVA), the probability threshold 5%. When a significant difference is noted between the factors considered for a given character, the test of the smallest significant difference (ppds) HSD of TUKEY was performed. All these statistical tests were carried out using the STATISTICA 7.1 software.

### III. RESULTS

#### 3.1. Study of the root system

Under the conditions of the experiment ation and at each of the two study sites, the root density of The *Lippia multiflora* plants increases with the depth of the soil to reach the maximum value at the 5-15 cm layer (Figures 2, 3, 4 and 5). In the first two layers of soil (0-5 cm and 5-15 cm), root hair and small roots, as well as medium roots, are most abundant compared to large roots (Figures 2, 3, 4 and 5). Below the 5-15 cm layer, the average number of observable roots (of each type) decreases and, beyond 30 cm, there are only rare roots made up, for the most part, of medium and large roots. Generally speaking, the roots of *Lippia multiflora* have a subhorizontal orientation (Figures 4 and 5). The observation of these figures also reveals that the root dynamics of each type are more intense in the 0-

30 cm layer of the root profiles of Azaguié's *Lippia multiflora* plants compared to those of Wheat. In total, at each of the study sites, most of the roots of The *Lippia multiflora* plants are found in the 0 - 30 cm layer and the root system has not been able to cross 50 cm after 10 months of cultivation. The progression of the root front thus varies from 0.1 to 0.13 cm per day.

#### 3.2. Impact of *Lippia multiflora* culture on the initial characteristics of the soil.

##### 3.2.1. Effect of culture on granulometric composition.

Table I indicates that the cultivation of *Lippia multiflora* had an impact on the soil granulometric composition of each of the study sites according to planting density. After 10 months of cultivation, there was a significant variation in the proportion of clay, fine silt, coarse silt, fine sand and coarse sand in soils under the cultivation of *Lippia multiflora* compared to the control soil, under vegetation Natural. For clay, and at both study sites, the average proportion in the soil decreased in all treatments studied. The decrease is significantly greater in the surface layers than in the depth layers, especially at the Azaguié experimental site. At this site, the proportion of clay decreased from 38.87 per cent, 28.17 per cent and 33.34 per cent in soil surface layers, respectively, for density treatments 4444 plants.ha<sup>-1</sup>, 20,000 plants.ha<sup>-1</sup> and 40,000 plants.ha<sup>-1</sup>, while deep down, the loss is 11.99 per cent, 7.98 per cent and 9.03 per cent, compared to the control soil under natural vegetation. Similarly, on the Wheat

Research Station, the clay content decreased by 26.56 per cent in the soil of the low-density treatment 4,444 plants.ha-1, by 27.59 per cent in the medium density 20,000 plants.ha-1 and by 18.24 per cent in the soil of the high density treatment 40,000 plants.ha-1, both on the surface and in depth, relative to the control soil. No significant differences were observed at the two study sites for clay richness between the soils of the three densities tested. Nevertheless, at both sites, we noted that the clay content decreased relatively with planting density. The results also show that there was more loss of clay than silt and sand in the soil of each of the treatments at the two study sites. For fine silt, the results show a loss in the soil under the cultivation of *Lippia multiflora* from the Azaguié experimental site, while on the Wheat research station, a gain of 29.18% was observed in the high density treatment 40,000 plants.ha-1 1.83% and 1.70%, respectively, in density treatments 4,444 plants.ha-1 and 20,000 plants.ha-1 compared to control soil. Conversely, there was a gain in coarse silt in the soils of all treatments at the Azaguié experimental site, while a loss of this constituent was noted in the soils of the corresponding treatments at the Wheat site. Thus, at both study sites, when a layer of soil

under the cultivation of *Lippia multiflora* loses fine silt, it acquires coarse silt, and vice versa. Table I also shows that at the Azaguié experimental site, the soil richness of fine and coarse silt is statistically identical under the three densities tested, 10 months after planting. On the contrary, on the Wheat research station, density had a significant effect on the dynamics of fine silt in the soil. Indeed, we noted a significant gain of 29.18% fine silt in the soil of the high density treatment 40,000 plants.ha-1, statistically higher than those obtained at the level of other treatments under the cultivation of *Lippia multiflora* and even under vegetation Natural. At the Azaguié experimental site, we observed a loss of 18% of fine sand and 19% of coarse sand in the soil surface layer of the low-density treatment (4,444 plants.ha-1), while in depth there was a 22% gain in fine sand and a loss of 22.56% coarse sand per control soil input. In the same treatment and on the Wheat research station, there was a loss of 3.31% of fine sand compared to a gain of 7.12% coarse sand, both on the surface and in depth. The same is true of the soil of high density treatment (40,000 plants.ha-1) at which a loss of 5.10% of fine sand was observed against a gain of 1.53% coarse sand.

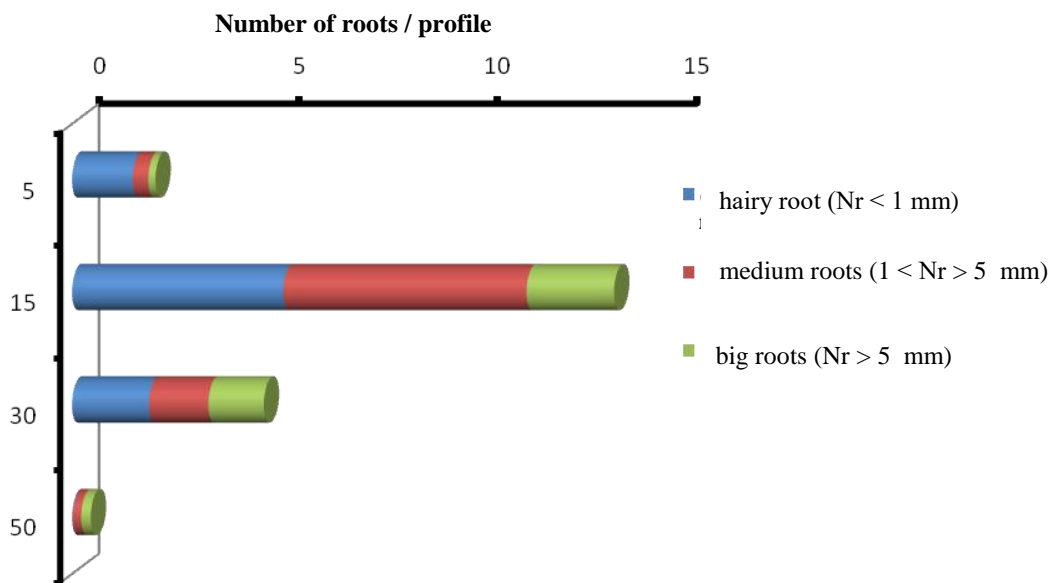


Figure 2: Root profile of plants grown on the Wheat Research Station. (Nr: root diameter)

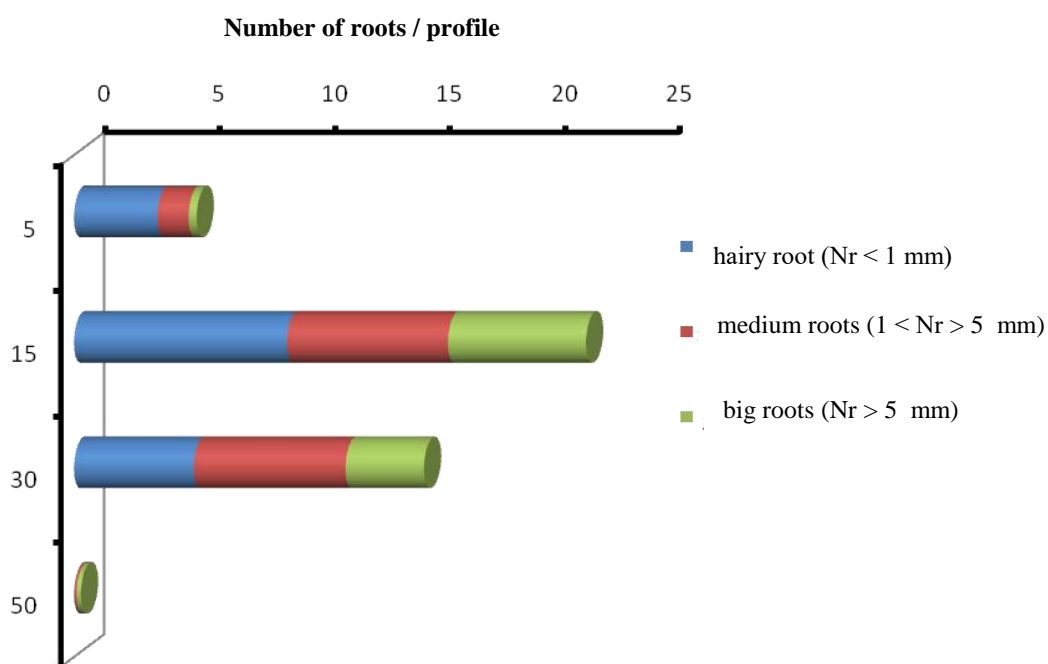


Figure 3 : Root profile of plants grown on the azaguié experimental plot (Nr: root diameter)

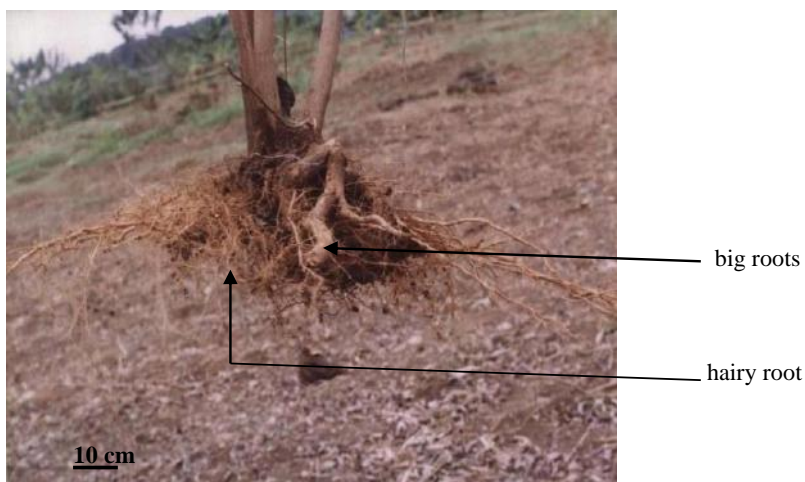


Figure 4 : Highlighting the roots of *Lippia multiflora* from a plant at the Azaguié experimental site.



Figure 5 : Evidence of the rooting of *Lippia multiflora* from a plant grown on the Wheat Research Station

Table I. Granulometric composition of soils under natural vegetation and under cultivation of *Lippia multiflora* following the study site 10 months after planting.

Treatments	Depths (cm)	clay		Fine limon		Coarse limon		Sandy		Rough sand	
		A (g.kg <sup>-1</sup> )	V/T (%)	Lf (g.kg <sup>-1</sup> )	V/T (%)	Lg (g.kg <sup>-1</sup> )	V/T (%)	Sf (g.kg <sup>-1</sup> )	V/T (%)	Sg (g.kg <sup>-1</sup> )	V/T (%)
Sample soil	0 – 20 Sa	70,21 ± 0,00 <sup>e</sup>	-	8,28 ± 0,16 <sup>c</sup>	-	4,11 ± 0,19 <sup>ab</sup>	-	8,19 ± 0,00 <sup>a</sup>	-	9,17 ± 0,00 <sup>a</sup>	-
	20 – 40 Sa	72,28 ± 0,01 <sup>e</sup>	-	8,76 ± 0,02 <sup>c</sup>	-	3,53 ± 0,00 <sup>a</sup>	-	8,06 ± 0,01 <sup>a</sup>	-	7,37 ± 0,02 <sup>a</sup>	-
	0 – 20 St	7,03±1,01 <sup>ab</sup>	-	4,02 ± 0,23 <sup>a</sup>	-	5,38 ± 0,37 <sup>c</sup>	-	22,83 ± 0,78 <sup>b</sup>	-	60,33 ± 2,06 <sup>b</sup>	-
	20 – 40 St	8,79±1,27 <sup>b</sup>	-	4,66 ± 0,26 <sup>ab</sup>	-	4,52 ± 0,31 <sup>b</sup>	-	21,92 ± 0,75 <sup>b</sup>	-	62,75 ± 2,14 <sup>b</sup>	-
D <sub>1</sub>	0 – 20 Sa	50,56 ± 0,01 <sup>c</sup>	-38,87	7,96 ± 0,02 <sup>c</sup>	-3,76	4,31 ± 0,01 <sup>ab</sup>	5,61	8,18 ± 0,00 <sup>a</sup>	-0,18	9,15 ± 0,02 <sup>a</sup>	-0,19
	20 – 40 Sa	63,61 ± 0,01 <sup>d</sup>	-11,99	8,73 ± 0,04 <sup>c</sup>	-0,37	3,53 ± 0,01 <sup>a</sup>	0,07	8,08 ± 0,02 <sup>a</sup>	0,22	5,70 ± 1,12 <sup>a</sup>	-22,56
	0 – 20 St	4,90 ± 0,12 <sup>a</sup>	-26,56	4,03 ± 0,12 <sup>a</sup>	1,83	4,75 ± 0,05 <sup>c</sup>	-10,08	21,97 ± 0,57 <sup>b</sup>	-3,31	64,40 ± 0,60 <sup>b</sup>	7,12
	20 – 40 St	6,13 ± 0,15 <sup>a</sup>	-26,56	4,68 ± 0,14 <sup>ab</sup>	1,83	3,99 ± 0,04 <sup>b</sup>	-10,08	21,09 ± 0,55 <sup>b</sup>	-3,31	66,98 ± 0,63 <sup>b</sup>	7,12
D <sub>2</sub>	0 – 20 Sa	54,78 ± 0,03 <sup>c</sup>	-28,17	7,95 ± 0,00 <sup>c</sup>	-3,93	4,30 ± 0,02 <sup>ab</sup>	5,40	8,20 ± 0,01 <sup>a</sup>	0,03	9,18 ± 0,00 <sup>a</sup>	0,11
	20 – 40 Sa	66,51 ± 0,03 <sup>d</sup>	-7,98	8,71 ± 0,03 <sup>c</sup>	-0,59	3,55 ± 0,02 <sup>a</sup>	0,57	8,08 ± 0,03 <sup>a</sup>	0,25	7,40 ± 0,00 <sup>a</sup>	0,37
	0 – 20 St	4,77 ± 0,14 <sup>a</sup>	-27,59	4,03 ± 0,21 <sup>a</sup>	1,70	4,83 ± 0,10 <sup>c</sup>	-8,33	22,67 ± 0,67 <sup>b</sup>	7,81	62,67 ± 0,82 <sup>b</sup>	-6,40
	20 – 40 St	5,96 ± 0,18 <sup>a</sup>	-27,59	4,68 ± 0,24 <sup>ab</sup>	1,70	4,06 ± 0,09 <sup>b</sup>	-8,33	21,76 ± 0,65 <sup>b</sup>	-0,24	65,17 ± 0,85 <sup>b</sup>	4,35
D <sub>3</sub>	0 – 20 Sa	52,65 ± 0,00 <sup>c</sup>	-33,34	8,04 ± 0,00 <sup>c</sup>	-2,81	4,32 ± 0,00 <sup>ab</sup>	5,87	8,19 ± 0,01 <sup>a</sup>	-0,03	9,17 ± 0,01 <sup>a</sup>	0,03
	20 – 40 Sa	65,75 ± 0,00 <sup>d</sup>	-9,03	8,76 ± 0,02 <sup>c</sup>	0,03	3,52 ± 0,00 <sup>a</sup>	-0,35	8,05 ± 0,01 <sup>a</sup>	-0,19	6,96 ± 0,42 <sup>a</sup>	-5,54
	0 – 20 St	5,33 ± 0,31 <sup>a</sup>	-18,24	5,10 ± 0,39 <sup>b</sup>	29,18	5,03 ± 0,24 <sup>c</sup>	-5,23	21,57 ± 0,59 <sup>b</sup>	-5,10	60,93 ± 1,19 <sup>b</sup>	1,53
	20 – 40 St	6,67 ± 0,39 <sup>ab</sup>	-18,24	5,92 ± 0,45 <sup>b</sup>	29,18	4,23 ± 0,20 <sup>b</sup>	-5,23	20,70 ± 0,57 <sup>b</sup>	-5,10	63,37 ± 1,24 <sup>b</sup>	1,53
<b>ANOVA</b>											
	<b>F</b>	465,6**		100,26**		12,87**		240,34**		84,82**	
	<b>P</b>	< 0,00001		< 0,00001		< 0,00001		< 0,00001		< 0,00001	

In the same column, the averages followed by the same letter are not significantly different to P-0.05. Its: soil layer of the experimental plot of Azaguie; St: soil layer of the research station in the village of Blé; D<sub>1</sub>: low-density treatment 4,444 plants.ha<sup>-1</sup>; D<sub>2</sub>: medium density treatment 20,000 plants.ha<sup>-1</sup>; D<sub>3</sub>: high-density treatment 40,000 plants.ha<sup>-1</sup> A: clay; Lf: fine silt; Lg: coarse silt; Sf: fine sand; Sg: coarse sand; V/T: level of variation from the control floor. Highly significant.

On the contrary, an increase in the proportion of fine and coarse sand was noted in the medium density treatment (20,000 plants.ha<sup>-1</sup>) of the Azaguié experimental site. In this treatment, there was a 25% increase in fine sand content and 37% increase in coarse sand at depth. Similarly, at the Wheat site, there was a gain of 7.81% in fine sand versus a loss of 6.40% coarse sand on the surface, as opposed to the depth layer where a loss of 0.24% of fine sand was noted against a gain of 4.35% coarse sand (Table I)

### 3.2.2. Effect of culture on physicochemical properties

As with granulometry, the cultivation of *Lippia multiflora* had an impact on the physical-chemical properties of the soil at each of the study sites compared to the control soil under corresponding natural vegetation (Table II). Indeed, all treatments induced acidification of the surface layers of soils under the cultivation of *Lippia multiflora* compared to the corresponding control soil. Soil acidification increased significantly with planting density, particularly at the Azaguié experimental site (Table II). At this site, the acidity of the surface layer dropped further in the soils of high density treatments (9.35%) (8.75%), than at ground level of low-density treatment (3.65%) compared to the control floor. The statistical analysis did not find a significant difference between the three densities tested at the Wheat Research Station, for soil acidity or pH, 10 months after planting. Apart from the decrease in acidity observed in the high-density treatments of the Azaguié experimental site and that of the average density of the Wheat Research Station, the results reveal a slight increase in soil acidity or pH in soil depth layers at each of the study sites. In the soil surface layers of each of the study sites, there was a decrease in the proportion of organic carbon and total nitrogen, along with planting density. At the Azaguié experimental site, losses of organic carbon and total nitrogen were 15.75 per cent and 49.86 per cent, respectively, in the soil of the low-density treatment, 19.02 per cent and 52.86 per cent in the average density, and 23.93 per cent and 62.13 per cent in the high-density soil. Similarly, on the Wheat Research Station, the record loss was 11.52% and 31.52% in the soil of the low density treatment, then 11.67% and 34.48% in the medium density, and finally 18.23% and 39.15% in the soil of high density. At each of the study sites, losses of organic carbon and total nitrogen were greater in the surface layers than in depth. For total phosphorus, and at each of the study sites, there was a percentage gain, both in the surface layer and in the soil depth of all the treatments studied in relation to the control soil. However, on the Wheat Research Station,

the results indicate an 8.08% decrease in phosphorus levels in the soil of medium-density treatment.

### 3.2.3. Effect of *Lippia multiflora* culture on chemical properties

After 10 months of culture, the treatments induced at the soil level of each of the study sites, a significant variation of the cation exchange capacity, the exchangeable base contents and the base saturation level of the complex by relative to the control soil (Table III). For the cation exchange capacity, the results reveal a fall in its mean value with planting density, especially at the level of the soil surface layers of all treatments at the Azaguié experimental site. At the level of these layers, the results show that the average value of this parameter decreased further in the soil of the high-density treatment (40,000 plants.ha<sup>-1</sup>) with 31,81%, against 23,96% and 21,42 %, respectively, in the soils of medium density (20,000 plants.ha<sup>-1</sup>) and low density (4,444 plants.ha<sup>-1</sup>) treatments compared to the control soil. The losses were 8.17%, 7.65% and 7.78% in the soil depth layers of the corresponding treatments. The results also reveal that the cation exchange capacity fell more in the soil of all the treatments of the research station of Wheat than in those resulting from the same treatments on the experimental site of Azaguié.

Table II : Evolution of the physical-chemical properties of the soil of all treatments at each of the study sites compared to the corresponding control soil, 10 months after planting.

Treatments	Depths (cm)	Soil acidity		Organic carbon		Total nitrogen		C / N ratio		Total phosphorus	
		pHeau	V/T (%)	C (g.Kg <sup>-1</sup> )	V/T (%)	N (g.Kg <sup>-1</sup> )	V/T (%)	C/N	V/T (%)	Pt (mg.Kg <sup>-1</sup> )	V/T (%)
Sample soil	0 – 20 Sa	5,37 ± 0,04 <sup>b</sup>	-	5,78 ± 0,00 <sup>f</sup>	-	0,11 ± 0,00 <sup>a</sup>	-	51,85 ± 2,74 <sup>b</sup>	-	229,08 ± 4,18 <sup>a</sup>	-
	20 – 40 Sa	5,22 ± 0,07 <sup>ab</sup>	-	3,38 ± 0,01 <sup>c</sup>	-	0,05 ± 0,00 <sup>a</sup>	-	64,84 ± 2,89 <sup>cb</sup>	-	214,75 ± 0,48 <sup>a</sup>	-
	0 – 20 St	5,93 ± 0,06 <sup>c</sup>	-	1,48 ± 0,15 <sup>b</sup>	-	0,29 ± 0,09 <sup>b</sup>	-	6,45 ± 1,06 <sup>a</sup>	-	490,33 ± 17,48 <sup>d</sup>	-
	20 – 40 St	5,93 ± 0,06 <sup>c</sup>	-	1,42 ± 0,15 <sup>ab</sup>	-	0,18 ± 0,06 <sup>ab</sup>	-	9,19 ± 1,67 <sup>a</sup>	-	397,17 ± 14,16 <sup>cd</sup>	-
D <sub>1</sub>	0 – 20 Sa	5,19 ± 0,09 <sup>ab</sup>	-3,65	4,87 ± 0,00 <sup>e</sup>	-15,78	0,06 ± 0,00 <sup>a</sup>	-49,86	87,14 ± 3,13 <sup>c</sup>	68,94	234,72 ± 1,11 <sup>a</sup>	2,54
	20 – 40 Sa	5,25 ± 0,11 <sup>ab</sup>	0,62	3,23 ± 0,00 <sup>c</sup>	-4,51	0,04 ± 0,00 <sup>a</sup>	-17,05	75,71 ± 4,07 <sup>cb</sup>	18,43	217,33 ± 1,03 <sup>a</sup>	1,20
	0 – 20 St	5,83 ± 0,06 <sup>c</sup>	-1,64	1,27 ± 0,00 <sup>ab</sup>	-11,52	0,15 ± 0,00 <sup>ab</sup>	-31,52	8,50 ± 0,35 <sup>a</sup>	49,02	545,67 ± 20,71 <sup>d</sup>	12,21
	20 – 40 St	5,95 ± 0,06 <sup>c</sup>	0,33	1,41 ± 0,01 <sup>ab</sup>	3,23	0,17 ± 0,00 <sup>ab</sup>	18,78	8,57 ± 0,35 <sup>a</sup>	5,60	441,99 ± 16,77 <sup>c</sup>	12,21
D <sub>2</sub>	0 – 20 Sa	4,92 ± 0,06 <sup>a</sup>	-8,75	4,68 ± 0,01 <sup>ed</sup>	-19,02	0,05 ± 0,00 <sup>a</sup>	-52,86	90,14 ± 6,67 <sup>c</sup>	74,54	251,64 ± 1,32 <sup>a</sup>	9,96
	20 – 40 Sa	5,21 ± 0,06 <sup>ab</sup>	0,01	3,20 ± 0,01 <sup>c</sup>	-5,35	0,05 ± 0,00 <sup>a</sup>	-14,50	77,12 ± 14,22 <sup>cb</sup>	18,48	215,00 ± 0,71 <sup>a</sup>	0,12
	0 – 20 St	5,80 ± 0,04 <sup>c</sup>	-2,19	1,27 ± 0,00 <sup>ab</sup>	-11,67	0,14 ± 0,00 <sup>a</sup>	-34,48	8,69 ± 0,33 <sup>a</sup>	49,75	449,00 ± 20,12 <sup>cd</sup>	-8,08
	20 – 40 St	5,92 ± 0,04 <sup>c</sup>	-0,24	1,41 ± 0,00 <sup>ab</sup>	3,06	0,16 ± 0,00 <sup>ab</sup>	13,64	8,76 ± 0,34 <sup>a</sup>	6,19	363,69 ± 16,29 <sup>b</sup>	-8,08
D <sub>3</sub>	0 – 20 Sa	4,89 ± 0,08 <sup>a</sup>	-9,35	4,39 ± 0,01 <sup>d</sup>	-23,93	0,04 ± 0,00 <sup>a</sup>	-62,13	105,87 ± 6,31 <sup>c</sup>	106,93	244,71 ± 5,01 <sup>a</sup>	6,86
	20 – 40 Sa	5,15 ± 0,09 <sup>ab</sup>	-1,22	3,21 ± 0,01 <sup>c</sup>	-5,06	0,04 ± 0,00 <sup>a</sup>	-20,27	82,37 ± 13,18 <sup>c</sup>	27,43	215,58 ± 0,92 <sup>a</sup>	0,39
	0 – 20 St	5,90 ± 0,07 <sup>c</sup>	-0,49	1,16 ± 0,05 <sup>a</sup>	-18,23	0,13 ± 0,00 <sup>a</sup>	-39,15	8,51 ± 0,48 <sup>a</sup>	43,19	539,00 ± 23,09 <sup>d</sup>	10,03
	20 – 40 St	6,02 ± 0,07 <sup>c</sup>	1,50	1,30 ± 0,05 <sup>ab</sup>	-4,61	0,15 ± 0,00 <sup>ab</sup>	5,54	8,59 ± 0,48 <sup>a</sup>	1,79	436,59 ± 18,70 <sup>c</sup>	10,03
<b>ANOVA</b>											
<b>F</b>		34,42**		76,87**		6,86**		46,32**		91,58**	
<b>P</b>		< 0,00001		< 0,00001		< 0,00001		< 0,00001		< 0,00001	

In the same column, the averages followed by the same letter are not significantly different at P-0.05. Its: soil layer of the experimental plot of Azaguie; St: soil layer of the research station in the village of Blé; D<sub>1</sub>: low-density treatment 4.444 plants.ha<sup>-1</sup>; D<sub>2</sub>: medium density treatment 20,000 plants.ha<sup>-1</sup>; D<sub>3</sub>: high-density treatment 40,000 plants.ha<sup>-1</sup>; C: organic carbon; N: nitrogen; C/N: carbone-to-nitrogen ratio; Pt: total phosphorus; V/T: level of variation from the control floor. Highly significant.



Table III : Characteristics of the adsorbent complex of soils under natural vegetation and under *Lippia multiflora* culture, 10 months after planting.

Treatments	Depths (cm)	Cation exchange capacity		Sum of exchangeable bases		Saturation rate in bases	
		CEC (cmol.kg <sup>-1</sup> )	V/T (%)	S (cmol.kg <sup>-1</sup> )	V/T (%)	V (%)	V/T (%)
Sample soil	0 – 20 Sa	5,41 ± 0,00 <sup>b</sup>		2,72 ± 0,00 <sup>c</sup>		50,27 ± 0,12 <sup>c</sup>	
	20 – 40 Sa	5,26 ± 0,00 <sup>b</sup>		1,88 ± 0,01 <sup>b</sup>		35,66 ± 0,26 <sup>c</sup>	
	0 – 20 St	14,45 ± 0,54 <sup>e</sup>		2,61 ± 0,23 <sup>c</sup>		18,01 ± 1,13 <sup>ab</sup>	
	20 – 40 St	11,56 ± 0,43 <sup>e</sup>		2,09 ± 0,18 <sup>b</sup>		18,07 ± 1,13 <sup>ab</sup>	
D <sub>1</sub>	0 – 20 Sa	4,25 ± 0,06 <sup>ab</sup>	-21,42	1,95 ± 0,00 <sup>b</sup>	-28,17	45,98 ± 0,81 <sup>de</sup>	-8,52
	20 – 40 Sa	4,83 ± 0,00 <sup>ab</sup>	-8,17	1,79 ± 0,03 <sup>b</sup>	-4,34	37,14 ± 0,63 <sup>c</sup>	4,17
	0 – 20 St	5,59 ± 0,15 <sup>b</sup>	-61,17	3,52 ± 0,06 <sup>d</sup>	37,53	63,10 ± 2,30 <sup>f</sup>	255,22
	20 – 40 St	7,82 ± 0,21 <sup>c</sup>	-32,04	2,80 ± 0,05 <sup>c</sup>	36,56	35,93 ± 1,34 <sup>c</sup>	101,56
D <sub>2</sub>	0 – 20 Sa	4,11 ± 0,00 <sup>a</sup>	-23,96	1,85 ± 0,01 <sup>b</sup>	-32,08	44,90 ± 0,36 <sup>d</sup>	-10,67
	20 – 40 Sa	4,86 ± 0,01 <sup>ab</sup>	-7,65	1,73 ± 0,00 <sup>b</sup>	-7,98	35,52 ± 0,16 <sup>c</sup>	-0,36
	0 – 20 St	7,15 ± 0,32 <sup>c</sup>	-50,46	1,61 ± 0,03 <sup>b</sup>	-37,06	22,65 ± 0,64 <sup>b</sup>	27,82
	20 – 40 St	10,01 ± 0,45 <sup>d</sup>	-13,30	1,47 ± 0,03 <sup>ab</sup>	-28,28	14,79 ± 0,45 <sup>a</sup>	-16,75
D <sub>3</sub>	0 – 20 Sa	3,69 ± 0,05 <sup>a</sup>	-31,81	1,66 ± 0,00 <sup>b</sup>	-38,84	45,12 ± 0,86 <sup>d</sup>	-10,23
	20 – 40 Sa	4,85 ± 0,01 <sup>ab</sup>	-7,78	1,75 ± 0,01 <sup>b</sup>	-6,45	36,17 ± 0,40 <sup>c</sup>	1,46
	0 – 20 St	5,25 ± 0,09 <sup>b</sup>	-63,48	1,09 ± 0,01 <sup>a</sup>	-57,26	20,81 ± 0,66 <sup>b</sup>	17,01
	20 – 40 St	7,34 ± 0,14 <sup>c</sup>	-36,09	1,03 ± 0,01 <sup>a</sup>	-49,77	14,02 ± 0,44 <sup>a</sup>	-21,44
<b>ANOVA</b>							
	<b>F</b>	161,98**		69,71**		251,94**	
	<b>P</b>	< 0,0001		< 0,0001		< 0,0001	

In the same column, the averages followed by the same letter are not significantly different at P-0.05. Its: soils of the experimental plot of Azaguie; St: soils of the research station of the village of Blé; D1: low-density treatment 4,444 plants.ha-1; D2: medium density treatment 20,000 plants.ha-1; D3: high density treatment 40,000 plants.ha-1. CEC: cationic exchange capacity; SBE: sum of exchangeable bases; V: complex saturation rate; V/T: level of variation from the control. Highly significant.

Indeed, on the Wheat research station, the cationic exchange capacity decreased by 61.17%, 50.46% and 63.48%, respectively, in the soil of the low density treatment (4,444 plants.ha-1), medium density (20,000 plants.ha-1) and high density (40,000 plants.ha-1) per control soil input, while in depth, the recorded decreases were 32.04%, 13.30% and 36.09%. Like the cationic exchange capacity, the levels of exchangeable bases have dropped in the soil of all treatments at the Azagué experimental site relative to the control soil (Table III). The same was true at the Wheat Research Station, with the exception of the low-density treatment soil, at which there was a gain of 37.53 per cent and 36.56 per cent, respectively, in surface and depth. Statistical analysis revealed that at both study sites, soil content in exchangeable bases, including calcium, magnesium and potassium, decreased with planting density. At the

Azagué experimental site, calcium content decreased by 25.10%, 29% and 35.28%, respectively, in soil surface layers of low-density, medium-density and high-density treatments relative to control soil. In the same order, magnesium content fell by 32.39 per cent, 37.51 per cent and 45.14 per cent in the soil of these corresponding treatments. As a result, the complex's saturation rate decreased by 8.52%, 10.67% and 10.23%, respectively, in the soil of the low-density, medium-density and high-density treatment compared to the control soil. On the Wheat Research Station, there was a gain of 25.06 per cent calcium, 62.85 per cent magnesium and 6.29 per cent potassium in the surface layer of the low-density treatment (4,444 plants.ha-1), while these layers were observed, a decrease of 29.02% and 23.84% in calcium, 47.78% and 77.85% of magnesium, respectively, in medium- and high-density treatments (Table IV). The increase in the content

of exchangeable bases led to a high saturation of the low-density processing soil exchange complex (Table IV) on the Wheat Research Station. At the Azaguíe experimental site, potassium content decreased further in the soil surface layers of low-density treatment at 46.38%, compared to 32.30% and 33.60%, respectively, in medium- and high-density treatments. On the other hand, on the Wheat

research station, there was a 6.29 per cent and 64.36 per cent gain in potassium in the surface layers of the soils of low- and medium-density treatments and, on the other hand, a 41.55 per cent decrease in the soil of the f treatment density orte. At both study sites, decreases in calcium, magnesium and potassium levels were greater in the surface layers than in depth.

Table IV : Evolution of calcium, magnesium and potassium content in the soil under natural vegetation and under cultivation of *Lippia multiflora*, 10 months after planting.

Treatments	Depths (cm)	Calcium		Magnesium		Potassium	
		Ca (cmol.kg <sup>-1</sup> )	V/T (%)	Mg (cmol.kg <sup>-1</sup> )	V/T (%)	K (cmol.kg <sup>-1</sup> )	V/T (%)
Sample soil	0 – 20 Sa	1,72 ± 0,00 <sup>c</sup>		0,94 ± 0,00 <sup>d</sup>		0,06 ± 0,00 <sup>b</sup>	
	20 – 40 Sa	1,32 ± 0,02 <sup>b</sup>		0,52 ± 0,00 <sup>b</sup>		0,04 ± 0,00 <sup>ab</sup>	
	0 – 20 St	1,21 ± 0,22 <sup>b</sup>		1,27 ± 0,03 <sup>e</sup>		0,11 ± 0,00 <sup>d</sup>	
	20 – 40 St	0,97 ± 0,18 <sup>ab</sup>		1,01 ± 0,02 <sup>d</sup>		0,09 ± 0,00 <sup>d</sup>	
D <sub>1</sub>	0 – 20 Sa	1,29 ± 0,00 <sup>b</sup>	-25,10	0,64 ± 0,00 <sup>c</sup>	-32,39	0,02 ± 0,00 <sup>a</sup>	-46,38
	20 – 40 Sa	1,27 ± 0,04 <sup>b</sup>	-3,60	0,48 ± 0,01 <sup>b</sup>	-6,91	0,04 ± 0,00 <sup>ab</sup>	7,27
	0 – 20 St	1,31 ± 0,01 <sup>b</sup>	25,06	2,06 ± 0,05 <sup>g</sup>	62,85	0,12 ± 0,00 <sup>d</sup>	6,29
	20 – 40 St	0,92 ± 0,00 <sup>ab</sup>	9,43	1,77 ± 0,04 <sup>f</sup>	75,06	0,09 ± 0,00 <sup>d</sup>	-3,60
D <sub>2</sub>	0 – 20 Sa	1,22 ± 0,00 <sup>b</sup>	-29,00	0,59 ± 0,00 <sup>bc</sup>	-37,51	0,04 ± 0,00 <sup>ab</sup>	-32,30
	20 – 40 Sa	1,21 ± 0,01 <sup>b</sup>	-8,54	0,48 ± 0,01 <sup>b</sup>	-6,91	0,04 ± 0,00 <sup>ab</sup>	-0,87
	0 – 20 St	0,74 ± 0,00 <sup>a</sup>	-29,02	0,66 ± 0,02 <sup>bc</sup>	-47,78	0,18 ± 0,00 <sup>f</sup>	64,36
	20 – 40 St	0,74 ± 0,00 <sup>a</sup>	-11,28	0,57 ± 0,02 <sup>bc</sup>	-43,86	0,14 ± 0,00 <sup>e</sup>	49,07
D <sub>3</sub>	0 – 20 Sa	1,11 ± 0,00 <sup>b</sup>	-35,28	0,52 ± 0,00 <sup>b</sup>	-45,14	0,03 ± 0,00 <sup>ab</sup>	-33,63
	20 – 40 Sa	1,24 ± 0,01 <sup>b</sup>	-6,43	0,48 ± 0,01 <sup>b</sup>	-6,81	0,04 ± 0,00 <sup>ab</sup>	3,21
	0 – 20 St	0,70 ± 0,00 <sup>a</sup>	-23,84	0,28 ± 0,00 <sup>a</sup>	-77,85	0,06 ± 0,00 <sup>b</sup>	-41,55
	20 – 40 St	0,70 ± 0,00 <sup>a</sup>	-16,09	0,24 ± 0,00 <sup>a</sup>	-76,19	0,05 ± 0,00 <sup>b</sup>	-46,99
<b>ANOVA</b>							
	<b>F</b>	15,61**		53,49**		90,91**	
	<b>P</b>	< 0,0001		< 0,0001		< 0,0001	

In the same column, the averages followed by the same letter are not significantly different at P=0.05. Its: soils of the experimental plot of Azaguíe; St: soils of the research station in the village of Blé; D1: low-density treatment 4,444 plants.ha-1; D2: medium density treatment 20,000 plants.ha-1; D3: high density treatment 40,000 plants.ha-1. That: calcium; Mg: magnesium; K: potassium; V/T: level of variation from the control.témoin.

### 3.3. Mineral balance of both soil types, 10 months after planting.

After 10 months of cultivation and at the Azaguíe experimental site, the ca/Mg (Table V) ratio values remain optimal (1.5 Ca/Mg 5), regardless of planting density, while on the Wheat Research Station, this ratio increases with density in fact, the Ca/Mg ratio, which decreased by 32.63 per cent in the low-density treatment (4,444 plants.ha-1) of the Wheat Research Station, increased by 17.89 per cent in the medium density treatment (20,000 plants.ha-1) to reach the optimum density (40,000

plants.ha-1). This result suggests that in Azaguíe treatments, the balance between calcium and magnesium is maintained constant regardless of density. On the contrary, on the research station of the village of Blé, the significant decrease in magnesium content (47.78%, 77.85%) compared to calcium (29.02%, 23.84 per cent), with planting density, the balance between calcium and magnesium at the high density (40,000 plants.ha-1). In fact, calcium deficiency compared to magnesium has decreased in low-density treatment (4,444 plants.ha-1) compared to témoin soil under natural vegetation. Table V

also reveals that the values of the Mg / K ratio are very high (Mg / K > 4) in the soils of all the treatments of each of the study sites, with the exception of layer 0 - 20 cm of the average density treatment (20,000 plants.ha<sup>-1</sup>) of the wheat research station, at which the value is optimal (3 < Mg / K < 4). In these soils, magnesium remains in excess of potassium. This is more pronounced in the Azaguié site than in the wheat site. Although this equilibrium is maintained, 68.22% and 61.71% of the Mg / K ratio are observed in the 0-20 cm layers and 59.57% and 54.85% respectively in the layers. 20 - 40 cm from the soils of medium and high density treatments at the Wheat Research Station. After 10 months of culture, the values of

the Ca / K ratio remain very high (Ca / K > 12) in the soil of all the treatments of the experimental site of Azaguié whereas they correspond to the optimal one ( 6 < Ca / K < 12) in the soil of low-density treatments 4,444 and 40,000 plants.ha<sup>-1</sup> from the Wheat Research Station. Specifically, this ratio, which decreased by 62.64% and 48.19% respectively in the 0-20 cm and 20-40 cm layers, became weak (4 < Ca / K < 6) at the treatment level. average (Table V) compared to control soil under natural vegetation. It follows from the above that calcium remains in excess of potassium in all treatments of the Azaguié experimental site compared to the control soil.

Table V : Mineral balance in both soil types, 10 months after planting

Settings	Treatments	Azaguié		Toumodi (Blé)	
		0 - 20 cm	20 - 40 cm	0 - 20 cm	20 - 40 cm
Ca/Mg	sample	1,83	2,54	0,95	0,96
	D <sub>1</sub>	2,02	2,65	0,64	0,52
	D <sub>2</sub>	2,07	2,52	1,12	1,30
	D <sub>3</sub>	2,13	2,58	2,50	2,92
Mg/K	sample	15,67	13,00	11,55	10,63
	D <sub>1</sub>	32,00	12,00	17,17	19,67
	D <sub>2</sub>	14,75	12,00	3,67	4,07
	D <sub>3</sub>	17,33	12,00	4,67	4,80
Ca/K	sample	28,67	33,00	11,00	10,21
	D <sub>1</sub>	64,50	31,75	10,92	10,22
	D <sub>2</sub>	30,50	30,25	4,11	5,29
	D <sub>3</sub>	37,00	31,00	11,67	14,00
K/(Ca+Mg)	sample	0,02	0,02	0,04	0,05
	D <sub>1</sub>	0,01	0,02	0,04	0,03
	D <sub>2</sub>	0,02	0,02	0,13	0,11
	D <sub>3</sub>	0,02	0,02	0,06	0,05
K/CEC	sample	0,01	0,01	0,01	0,01
	D <sub>1</sub>	0,00	0,01	0,02	0,01
	D <sub>2</sub>	0,01	0,01	0,03	0,01
	D <sub>3</sub>	0,01	0,01	0,01	0,01

D<sub>1</sub> : 4.444 plants.ha<sup>-1</sup> ; D<sub>2</sub> : 20.000 plants.ha<sup>-1</sup> ; D<sub>3</sub> : 40.000 plants.ha<sup>-1</sup>

On the other hand, the calcium and potassium balance is maintained in the soil of low density treatments 4,444 and 40,000 plants.ha<sup>-1</sup> of the Wheat Research Station, 10 months after planting. The results also show that over all treatments at each of the study sites, the respective values of the K/(Ca-Mg) and K/CEC ratios remain very low ((K/(Ca-Mg) - 2 and K/CEC - 2), 10 months after planting. Potassium then remains deficient in relation to the sum of calcium and magnesium on the soil adsorbant complex of each study site.

#### IV. DISCUSSION

The results of the study revealed that the cultivation of *Lippia multiflora* had an impact on the granulometric composition as well as on the physical-chemical and chemical properties of the soils corresponding to the treatments of each of the study sites compared to the control soil under natural vegetation. At the granulometric level, there has been an impoverishment of the surface layer of the soils of the various treatments in fine elements, especially clay and silt, compared to the control soil under corresponding natural vegetation. The movement of these elements within the soil and their deep accumulation may be related to clay leaching, which is induced by the vertical movement of water in the soil (Soltner 1992b; Ballo, 2009). Our results showed that these top-down migrations decreased relatively with planting density. This is because low-density crop cover does not provide complete soil protection compared to high-density crop cover. These results corroborate those of Greenpeace (2007) and Ballo (2009), which described a similar process on the oil palm. As a result, water infiltration and the formation of soluble or suspended elements in the soil are all the more severe because the soil is not covered by plant debris, exposing it to the impact of large drops of water. The results also reveal that there was more loss of clay than silt and sand in the surface layers of the soils of all treatments at each of the study sites. This is to be related to the phenomenon of particle selectivity during the erosion process. Clays are eliminated as a priority. This translates into absolute impoverishment in fine elements, and relative enrichment in silt and sand, as our field data have shown. Finally, fine sands and coarse sands have also been migrated. This finding corroborates the conclusions of Soltner (1992b) which confirms that silica, very slightly soluble, can be driven. Like the soil under natural vegetation, the cultivation of *Lippia multiflora* induced the acidification of the soil of the corresponding treatments at each of the study sites and influenced the mineralization of organic matter as well as the saturation rate in Bases. This acidification has made phosphorus non-exchangeable, especially at the Azaguie level. The main cause of the

acidification of these soils is the gradual loss of the basic cations of the exchange complex and their replacement by H-ions (Dabin 1985 and Soltner 1992a). A secondary cause is believed to be related to micro-organism activity and root respiration (Soltner, 1992a) that may intensify with planting density. The base saturation rate therefore appears to be a good approach to assessing soil acidification. Higher C/N ratios under the cultivation of *Lippia multiflora* reflect a faster evolution of soil organic matter, in relation to the destruction of binders that hold soil particles between them, especially in low-lying environments (Barthès *et al.*, 2008) as is the case in Wheat. Reducing soil organic matter is equivalent to a decrease in the soil's ability to grow and produce plants (Koutika *et al.*, 2008; Mafongoya *et al.*, 2006; Ballo *et al.*, 2009). It also leads to a loss of soil stability and a decrease in its ability to withstand erosion (Barthès *et al.*, 2008; Ballo, 2009): organic matter being an essential binder between soil particles. Our results are also consistent with those of Tchienkoua (1999), which reports, in central Cameroon, and 3 years after cultivation by food plants installed after a clearing that stripped the soil, the loss of 51% of total carbon, 43% of total nitrogen, 20% of the labile phosphorus and 30% of the fine sands. Yemefack *et al.* (2004) reported similar results on soils in southern Cameroon. Takeda *et al.* (2009) have obtained similar results about soybeans grown on Andosols in Japan. In Côte d'Ivoire, Ballo (2009) recorded losses of 70% of total carbon, 64% of total nitrogen and 17% of the C/N ratio to the control soil under natural vegetation in the 0- to 20 cm layer after 20 years of oil palm cultivation. However, our results are contrary to those reported by Obatolu and Agboola (1993). The researchers found a 41% increase in soil organic matter content under *Chromolaena odorata* in an alfisol in Nigeria. They also reported soil enrichment in Ca and Mg under *Chromolaena odorata*, compared to a continuous yam crop. Recently, an improvement in soil fertility, under a 2-year-old *chromolaena odorata* fallow, at a level similar to that of *Pueraria phaseoloides* of the same age, has been observed in a forest region of Cameroon (Koutika *et al.*, 2004). Improvement in soil fertility by *Chromolaena odorata* has also been reported in the work of Koné *et al.* (2008). This difference in result could be explained by the fact that under culture of *Lippia multiflora*, the contributions of fresh vegetable residues are less than under natural forest, whatever the site of study. In addition, as this is an annual crop, the soil is then exposed directly to the sun and weather part of the year. This increases the temperature of the soil, slows the mineralization of organic matter and promotes selective erosion that affects the fine elements, rich in humus. In addition to the lack of litter of *Lippia multiflora* on the

ground, there is a lack of knowledge of its rate of decomposition. For a change of vegetation results in a gradual replacement of the organic matter resulting from the previous vegetation by that resulting from the contributions of the new (Van Noordwijk *et al.*, 1997). For the cation exchange capacity, the decline in its value in soils under *Lippia multiflora* cultivation may be a consequence of the reduction of the content of these soils in fine elements and in organic matter. Because, according to Ballo (2009), the properties of the soil adsorbent complex are ensured by the fine elements such as clay minerals and organic colloids. The decrease in soil content in exchangeable bases is accentuated by the leaching of the adsorbent complex (Kanemegne *et al.*, 2006). Out of all the treatments at each of the study sites, either a loss or a gain in soil nutrient stores was observed, particularly in alkaline (K + and Na +) and alkaline earth (Ca<sup>2+</sup> + and Mg<sup>2+</sup>) at the surface layers. This would be due either to exports of mineral elements by the *Lippia multiflora* plants, or to the leaching phenomenon or biological removals as described by Soltner (1992b). The entrainment of these soluble salts and their accumulation would be at the origin of the increase of the acidity or pH of the soil depth layers of all the treatments, on each of the study sites, compared to the control soil under natural vegetation.

## V. CONCLUSION

At the end of this work, it can be remembered that the cultivation of *Lippia multiflora* has induced the depletion of surface layers into fine elements and enrichment in coarse elements. At the chemical and physical-chemical levels, there was a decrease in the ability of the cationic exchange capacity (CEC), the sum of the exchangeable bases (SBE), the saturation state of the complex and the levels of organic matter and total nitrogen. The gradual loss of the basic cations of the adsorbent complex was accompanied by the acidification of the soils with the density of planting, especially at the experimental site of Azaguié. At this site, soil acidification negatively influenced the mineralization of organic matter, base saturation and decreased the availability of phosphorus for plants. On the other hand, on the Wheat research station, the heavy load of soil in coarse sands had a negative impact on the mineral nutrition of the *Lippia multiflora* plants. The definition of sustainable soil fertility management practices is necessary to enable better use of soil resources and therefore improve productivity.

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