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Original Research Article

Occurrence and chemical composition of essential oil from *Lippia multiflora* M. (Verbenaceae) leaves as affected by soil carbon, nitrogen and phosphorus contents in the centre Côte d'Ivoire.

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For generating a strategy of quantitative and qualitative productions of *Lippia multiflora*, influence soil contents of organic carbon (C), total nitrogen (TN), total phosphorus (TP) and available phosphorus (AP) were explored via dominant-abundance index (DAI) of the species as well as the leaves extractable essential oil. The experiment was carried out along three toposéquences in three sites of *L. multiflora* ecosystem in Centre Côte d'Ivoire at four topographic positions: Summit (S), Upper slope (UP), Middle slope (MS) and Foot slope (FS). DAI was recorded coupled with soil and leaves sampling. C, TN, TP and AP were determined as well as the concentrations of essential oils. Occurrence of *L. multiflora* was highest in the MS and FS positions of the landscapes with significant influence of AP also noticed for essential oils mainly characterized by highest concentrations of Citral (Géranial+Néral) and Linalol. It would be possible to grow *L. multiflora*, in centre Côte d'Ivoire applying P and TN for high yields of leaves and essential oils mainly composed of terpenoid derivatives.

Keywords: *Lippia multiflora*, volatile substance, centre Côte d'Ivoire, nutrient interaction.

INTRODUCTION

Lippia multiflora Mondenke is a native aromatic woody shrub plant from tropical areas, which is well known in the province of savannas of Gambia, Nigeria (West Africa), and it is vulgarly called "thé de savanne". In Côte d'Ivoire, it grows from the forest-savanna transition zone to the northern regions through the centre, with increasing interest because of its biomedical virtues: Tea-like infusions are traditionally used as remedy against malaria fever, stress, hypertension, gastro-intestinal trouble and caugh as well as laxative (Abena et al., 2003). Moreover, *L. multiflora* contains some adjutants for cosmetic (Kanko et al., 2003) and pesticides (Etienne et al., 2011) produces. These qualities are attributed to the properties of the leaf extractable essential oils (Irvine, 1961) accounting for 42 volatile compounds from *L. multiflora* with specific properties that could interfere the plant attributes as individual effect (Lahlou, 2004). In the light of these utilities of the extractable chemical compounds of essential oil of *Lippia multiflora*, it may significantly contribute to the development of pharmaceutical and cosmetic manufacturing activities in its natural growing ecosystems, as observed in savanna zone of sub-Saharan Africa. This

Figure 1: Wild population of *Lippia multiflora* in a site

potentiality can substantially contribute to alleviation of poverty in this region where the population wellbeing is more depending on informal economy (PNUD, 2013).

To achieve this goal, it is necessary to produce the essential oil in quantity and quality required to sustainably support such industrialization. However, *Lippia multiflora* is yet an invasive plant characterized by a wide variability in the quality of essential oils (Gouollaly et al., 2010) even within the same ecological zone and for a given genotype involving effects of seasons and environment including the soils (Bassolé et al., 2010). Previous studies of chemotypes in different ecological zones of West Africa were only descriptive (Kanko et al., 1999), missing causal and effect relationship analysis that could guide the control of both qualitative and quantitative productions of essential oil. However, such analysis was possible between soil chemical characteristics and specific weed occurrence in sub-Sahara Africa ecosystems (Koné et al., 2014). Therefore, a survey was conducted in the natural prevailing occurrence zone of *L. multiflora* in Côte d'Ivoire for chemical analysis of essential oils extracted from the leaves sampled at different topographic sections of landscapes considering soil contents of organic carbon (C), total nitrogen (TN), total phosphorus (TP) and available phosphorus (AP). The aim was to identify how and which of these soil chemical characters could affect the occurrence of *L. multiflora* and the composition of its leaves essential oils in order to recommend a strategy for soil fertility management when developing agricultural systems for quantitative and qualitative productions.

MATERIEL AND METHODS

Description of the studied environment

The study site was located in the departments of Bouaflé and Yamoussoukro (Centre Côte d'Ivoire), concerning three sites, naturally colonized by *L. multiflora*. The department of Bouaflé is between the north latitudes 6°30'and 7° and 5°30' and west longitude 6°30' (Chevalier, 1999). Bouaflé region contains a wide variety of formations with a predominance of granitoids, volcano-sedimentary and metavolcanic rocks (Gbele et al., 2013). The climate of the area is humid tropical. Average annual temperature is 28°C, with the maximum temperature in March and the minimum temperature in August. The monthly average temperature varies less than 5 °C during the year. The rainfall pattern is bimodal and the average annual rainfall during the period 1978-98 amounted to 1100 mm with about 80 per cent falling from March to mid-July and from September to November. *L. multiflora* community was encountered along the middle slope and the foot slope.

Yamoussoukro is located between 6 and 7° 15° 35 north latitude and 4°40 and 5 ° 40 west longitudes. Yamoussoukro has an equatorial climate comprising of four seasons:

- A long dry season from mid-November to mid-March.
- A long rainy season from mid-March to mid-July.
- A short-dry season from mid-July to mid-September.
- A short rainy season from mid-September to mid-October.

The mean annual rainfall ranges from 900 mm to 1100 mm with considerable intra-annual and inter-annual variation from one place to another. The mean temperature of the region is about 26°C. The relative humidity ranges between 75% and 85%, dropping to 40% during the Harmattan period and varying between 80% and 85% in the rainy season. *L. multiflora* community was encountered along the middle slope, The soils of both sites belong to the Ferralsols, Cambisols and Gleysols (Yao-Kouamé et al., 2008).This biotope of savanna includes *L. multiflora* associated with different herbaceous species (Figure 1).

Sampling of Plant and Soil

Topographic sections defined as summit, upper slope, middle slope and foot s lope were explored via dominant-

Figure 2: Flowering branch of *Lippia multiflora*

abundance index (DAI) of the species (Braun-Blanquet et al., 1952). In randomly selected area of about 1 ha, equally stratified sampling method (Webster & Olivier, 1990) according to (Rhuhe & Walker, 1968) was applied along the hillside in each topographic sections of the studied site (Bouaflé & Yamoussoukro). Each of topographic section was about 100 – 150 m in length along 500 – 700 m of hillside characterized by a gentle slope (2 – 5%) and high invasion of *L. multiflora* in places. At flowering stage of *L. multiflora* (Figure 2) corresponding to the physiological maturity, leaves were sampled around 11h – 12h from randomly selected 32 plants dispersed within 1 ha. For a given topographic position, samples of leaves were keep together before taking 1kg as composite sample which was save in carboglass before air drying in a room condition during 7 –10 days. This sampling was coupled with soil profile study for characterization and 32 elemental soil samples were taken using hand augur within 0 – 20 cm, 20 – 40 cm, 40 – 60 cm and 60 – 80 cm depth neighboring (5 – 10 cm apart) the plants respectively. In order to compare the shelter as the site *L. multiflora* those sheltering not only the profiles were divided into two groups: (a) profiles in the habitat of *L. multiflora* (Presence) and (b) profiles in savannah that do not support *L. multiflora* (absence).

Estimation of DAI for *L. multiflora*

The dominant-abundance index (DAI) of *L. multiflora* was estimated according to Braun-Blanquet et al. (1952) method of species score (1 – 5) of soil recovering rates: 1 = < 5% of recovering; 2 = 5 – 25% of recovering; 3 = 25 – 50% of recovering; 4 = 50 – 75% of recovering and 5 = 75 – 100%.

Analysis of essential oil

The essential oil from the leaves of *L. multiflora* was extracted by hydrodistillation in a Clevenger-type apparatus (Clevenger, 2006) during 3 hours, yielding 1.0% (v/w). Gas chromatography analyses were performed coupled with spectrometry (Hwelett-Pakard, CG 5890 serial II) for chemical volatile compounds (constituents of mono- and sesquiterpene) identification as described by Etienne et al., (2011) including comparison between the experimental gas chromatographic retention indices (RI) and fragmentation pattern with corresponding reference data (NBS5K/NIST98) as done by Adams (2007). A standard solution of n-alkanes (C7 – C26) was used to obtain the retention indices. Identified elements were grouped according to the molecular radicals as monoterpene and sequiterpene characterized by two isoprene units ($C_{10}H_{16}$) and three ($C_{15}H_{24}$) respectively. Further differentiation was done referring to oxygenated derivatives among both.

Soil Analysis

Soil composite samples were air dried in a room condition, grounded, and sieved (2 mm) before analytical process including pH measurement with electrode glass in soil/water (1/2.5) solution. The content of organic carbon (C) was determined by colorimetric measurement of unreduced amount of $Cr_2O_7^-$ by C according to Walkley and Black. Kjeldhal method including mineralization of organic matter at 300°C was used to determined soil content of total-N using sulphuric acid ($K_2SO_4 + CuSO_4 + Se$) during

Table 1. Mean values of C, TN, TP and AP in 0 – 20 cm, 20 – 40 cm, 40– 60 cm and 60 – 80 cm soil depths according to topographic sections for the site of Yamoussoukro

Occurrence of *L. multiflora*	Topographic position	Depth (cm)	C (gkg^{-1})	TN (gkg^{-1})	TP ($mgkg^{-1}$)	AP ($mgkg^{-1}$)	DAI
Absence	Summit	0-20	0.18	0.13	79	18	0
		20-40	0.32	0.15	84	14	
		40-60	0.22	0.04	181	17	
		60-80	0.12	0.04	426	16	
	Upper slope	0-20	0.18	0.14	72	13	0
		20-40	0.32	0.16	94	15	
		40-60	0.22	0.05	185	19	
		60-80	0.12	0.04	424	15	
	Middle slope	0-20	0.22	0.14	72	19	0
		20-40	0.12	0.16	99	14	
		40-60	0.18	0.04	185	18	
		60-80	0.12	0.05	421	15	
	Foot slope	0-20	0.22	0.14	82	18	0
		20-40	0.12	0.16	94	15	
		40-60	0.18	0.04	182	19	
		60-80	0.13	0.03	412	17	
Presence	Middle slope	0-20	0.18	0.05	72	23	2
		20-40	0.32	0.04	94	32	
		40-60	0.22	0.03	185	57	
		60-80	0.12	0.03	424	66	

DAI: dominant-abundance index

three hours. Mineralization process and selective extraction were applied to determine the amount of total and available phosphorus using EDTA (Pansu and Gautheryrou, 2003). Results of soil analysis were interpreted according to Baillie (2010) referring to the critical levels respectively.

Statistical Analysis

Mean value of soil pH and the contents of C, N, Pt and Pa were determined by descriptive statistic for every site according to soil depths along the toposequence. Pearson correlation analysis was done between abundance index (DAI) of *L. Multiflora* and soil contents of C, N, Pt and Pa in 0 – 20 cm, 20 – 40 cm, 40 – 60 cm and 60 –80 cm for each topographic positions respectively. Average value of studied chemical contents of soil in 0 – 40 cm and 40 – 80 cm was similarly used, especially, with DAI. Pearson correlation was also processed between soil characters and essential oil concentrations in leave. SAS (version 8) was used for statistical analysis considering $\alpha = 0.05$, meanwhile extension up to 0.10 was accepted for correlation data interpretation.

RESULTS

Tables 1 and 2 reveal that content of C and TN are low (< $1gkg^{-1}$), indifferently to soil depths and topographic positions as well as occurrence without *L. multiflora*, contrasting with soil content of TP, exclusively high (> 50 $mgkg^{-1}$) whatever the topographic position when compared with the critical level respectively. Soil contents of AP is low (< 25 $mgkg^{-1}$) indifferently to soil depths and topographic positions in occurrence without *L. multiflora*, contrasting with soil content of AP, generally >25 $mgkg^{-1}$ in the habitat of *L. multiflora* (Presence). Across the sites surveyed, down slope position (middle and foot slopes) is likely more favorable to *L. multiflora* occurrence than the hill slope position (summit and upper slope). Roughly, there is high affinity between content of TN and AP and occurrences of *L. multiflora*. In fact, at Yamoussoukro, the low content of TN is more related to high PA and the high density of this species. At Bouaflé, presence of L. *multiflora* was associated with low content of TN and high content of PA in 0 – 40 cm depth. These contrasts are not as much for TP and AP referring to the indicators (DAI) of *L. multiflora* occurrence.

Table 3 shows the qualitative and quantitative analyses of the essential oils obtained from *L. multiflora.* In total, 41 compounds were identified in the essential oil of *L. multiflora*. All of these oils are distinguished by their high content of oxygenated monoterpenes. From a quantitative point of view, the essential oil from Yamoussoukro was observed to contain a larger amount of oxygenated monoterpenes and sesquiterpenes. While in Bouaflé sites were observed to contain a larger amount of hydrocarbon monoterpenes and hydrocarbon sesquiterpenes. The major constituents of the essential oil at in Bouaflé sites were: Citral (neral + geranial), α-Phellandrene, Para-Cymene, (E) -

Table 2. Mean values of C, TN, TP and AP in 0 – 20 cm, 20 – 40 cm, 40– 60 cm and 60 – 80 cm soil depths according to topographic sections for the two sites of Bouaflé

Occurrence of *L. multiflora*	Topographic position	Depth (cm)	C (gkg^{-1})	TN (gkg^{-1})	TP ($mgkg^{-1}$)	AP ($mgkg^{-1}$)	DAI
Absence	Summit	0-20	0.6	0.05	121	15	0
		20-40	0.21	0.04	87	17	
		40-60	0.09	0.03	103	16	
		60-80	0.07	0.02	101	15	
	Upper slope	0-20	0.81	0.02	108	18	0
		20-40	0.88	0.03	89	12	
		40-60	0.25	0.02	104	15	
		60-80	0.09	0.01	95	17	
	Middle slope	0-20	0.94	0.03	109	15	0
		20-40	0.87	0.02	87	16	
		40-60	0.24	0.03	101	14	
		60-80	0.08	0.02	98	13	
	Foot slope	0-20	0.67	0.03	79	17	0
		20-40	0.22	0.02	58	16	
		40-60	0.05	0.03	91	14	
		60-80	0.07	0.01	91	15	
Presence	Middle slope	0-20	0.9	0.08	118	33	2
		20-40	0.81	0.06	87	26	
		40-60	0.25	0.04	107	30	
		60-80	0.09	0.02	98	28	
	Foot slope	0-20	0.64	0.06	71	32	2
		20-40	0.22	0.05	57	22	
		40-60	0.08	0.006	94	25	
		60-80	0.07	0.004	98	27	

DAI: dominant-abundance index
organic carbon (C), total nitrogen (TN), total phosphorus (TP) and available phosphorus (AP

β-farnesene and β-Limonnène + Phellandrene. Among these components, citral (neral + geranial) dominates, with more than 47%. In Bouaflé sites, chemotype Citral was the essential oil composition of *L. multiflora*. However, in Yamoussoukro site, the major essential oil composition are linalool, (E) -Nérolidol, germacrene D, (E) -β-Caryophyllene and α-humulene, with Linalool chemotype, which dominates with 40.9%.

Table 4 presents the correlation coefficients between soil nutrients and DAI. Table IV shows a non-significant correlation ($p> 0.05$) between the levels of soil C, TP and TN, between 40 and 80 cm of soil depth and the DAI. However, there is a strong positive correlation ($r \geq 0.75$) and significant ($p <0.05$) between the DAI and AP and TN in 0 – 40 cm depth.

According to Table 5 and 6, no significant correlation ($0.01 < r < 0.41$) significant ($P_{value} >0.05$) is noticed between major volatile substance of *L. multiflora* and soil parameters (C, TP), contrasting with the correlated values ($0.75 < r < 0.99$) significantly observed ($P_{value} < 0.05$) for TN and AP.

DISCUSSION

The contents of carbon and nitrogen in soil of *L. multiflora* occurrence are low. Soil with poor content of carbon and nitrogen can be favorable to *L. multiflora* occurrence as asserted by Yao-Kouamé & Fako (2008). Significant positive correlation ($r> 0.56$) was observed in all depths between the AP content and DAI, for $\alpha = 0.05$. There was trend of soil contents of P across the studied sites in relation with DAI. P is likely the most important nutrient for the cultivation of *L. multiflora* when developing specific agricultural systems (Yao-Kouamé & Fako, 2008). Our study confirms that soil chemical degradation is more related to invasive vegetation occurrence (Koné et al., 2013b) emphasizing the importance of soil cations in this process. It is phosphorus which plays a major role in the nutrition of *L. multiflora*, because this plant grows where the available phosphorus content is high. According to Dabin (2007), the level of availability of different forms of orthophosphate varies greatly. Some quickly find themselves in solution, others migrate more slowly, from the solid phase to the solution, and others only dissolve with the activity of living organisms (Lompo et al*.,* 2008).

Preferential occurrence of *L. multiflora* was noticed along the toposequence during the survey: Lowest occurrence accounted for the hill slope (summit and upper slope) position of landscape contrasting with the highest

Table 3. Mean value of the chemical composition of essential oil from *L. multiflora* leaves according to the flowering stage.

Aromatic compounds	Yamoussoukro Middle slope	Bouaflé Middle slope	Foot slope
	Volatile substance concentrations(%)		
Monoterpene Hydrocarbons			
α-Thujène	-	-	-
α-Pinène	0.2	0.5	0.7
Sabinène	0.6	1	0.7
Myrcène	0.2	1	1
α-Phellandrène	0.6	3.7	12.4
δ-3-Carène	-	-	-
para-Cymène	0.6	5.6	6.7
Limonnène+ β-Phellandrène	0.7	4.2	4.6
(Z)-β-Ocimène	-	-	-
(E)-β-Ocimène	-	0.5	1.2
Terpinolène	-	-	-
Total (%)	**2.9**	**16.5**	**27.3**
Oxygenated monoterpenes			
1,8 Cinéole	1,2	1.9	1.3
6-methyl-5-hepten-2-one	0.6	1.9	1.5
1-Octen-3-ol	0.2	-	-
Linalol	40.9	1.4	1.4
Cis-para-menth-2-en-1-ol	-	-	0.3
Citronellal	-	0.4	0.4
(Z)-Isocitral	-	0.9	1
Epoxide rosefuran	-	0.4	0.2
(E)-Isocitral	-	1.6	1.5
Cryptone	-	-	0.2
α-Terpinéol	-	0.7	0.6
Nérol	.	-	0.4
Néral	2.1	25.9	21.3
Géraniol	0.4	0.6	0.5
Géranial	2.8	34	26
Thymol	-	-	-
Total (%)	**48.2**	**69.7**	**56.6**
Sesquiterpene hydrocarbons			
α-Copaène	0.2	0.5	0.3
β-Bourbonène	0.8	-	0.2
β-Cubébène	0.7	0,5	0.3
β-Elemène	0.5	-	-
(E)-β-Caryophyllène	8.6	2,7	2.7
α-Humulène	6.8	-	-
(E)-β-Farnésène	2.2	4,6	4.8
Sesquisabinène	-	0.5	0.4
Germacrène D	10.1	2.1	2.4
α-Muurolène	0.7	-	0.2
β-Bisabolène	0.6	-	0.2
δ-Cadinène	1	0.5	0.3
Total (%)	**32.2**	**11.4**	**11.8**
Oxygenated sesquiterpenes			
Epi-Cubébol	0.3	-	-
Cubébol	0.6	-	-
(E)-Nérolidol	13.3	-	0.2
Oxide de Caryophyllène	1	0.9	0.4
Total	**15.2**	**0.9**	**0.6**
TOTAL (%)	**98.5**	**98.5**	**96.3**

occurrence observed along the down slope (middle and foot slope) position. According to Koné et al. (2010), soil morphological variability along the landscapes could be involved in this clustering. In fact, there is highest content

Table 4. Coefficients (r) of Pearson correlation between DAI and soil parameters

soil parameters	Correlation Coefficient (r)							
	Bouafle				Yamoussoukro			
	DAI				DAI			
	0-20	20-40	40-60	60-80	0-20	20-40	40-60	60-80
C	r=0.05 p=0.91	r=-0.04 p=0.93	r=0.04 p=0.94	r=0.13 p=0.80	r=-0.41 p=0.49	r=0.41 p=.495	r=0.4082 p=.495	r=-0.25 p=0.68
TN	r=0.86 p=.029	r=0.87 p=.024	r=-0.20 p=0.71	r=-0.22 p=0.67	r=-0.99 p=0.00	r=-0.99 p=0.00	r=-0.79 p=0.11	r=-0.53 p=0.35
TP	r=-0.24 p=0.65	p=-0.27 p=0.61	p=0.06 p=0.91	p=0.26 p=0.61	r=-0.40 p=0.51	r=0.10 p=0.87	r=0.40 p=0.50	r=0.26 p=0.67
AP	r=0.99 p=0.00	r=0.90 p=0.01	p=0.97 p=0.00	p=0.98 p=0.00	r=0.75 p=0.04	r=0.99 p=0.00	r=0.99 p=.000	r=0.99 p=.000

DAI: dominant-abundance index

Table 5. Coefficients (r) of Pearson correlation between soil parameters of Bouaflé and volatile substance of *L. multiflora*

soil parameters	Correlation Coefficient (r)					
	Volatile substance concentrations					
	Geranial	Neral	Para-cymene	(E)-β-Farnesene	Limonene+β-Phellandrene	α-Phellandrene
C	r=0.14 p=0.78	r=0.12 p=0.82	r=-0.01 p=0.99	r=0.04 p=0.94	r=0.02 p=0.97	r=-0.27 p=0.60
N	r=0.89 p=.017	r=0.88 p=.019	r=0.82 p=.045	r=0.85 p=.032	r=0.84 p=.036	r=0.75 p=0.04
PT	r=-0.12 p=0.82	r=-0.15 p=0.77	r=0.32 p=0.54	r=-0.26 p=0.62	r=-0.28 p=0.59	r=-.59 p=0.22
PA	r=0.98 p=.000	r=0.98 p=.000	r=0.98 p=.001	r=0.98 p=.000	r=0.99 p=.000	r=0.80 p=0.04

Table 6. Coefficients (r) of Pearson correlation between soil parameters of Yamoussoukro and volatile substance of *L. multiflora*

soil parameters	Correlation Coefficient (r)				
	Volatile substance concentrations				
	Linalol	(E)-Nerolidol	Germacrene D	(E)-β-Caryohyllene	α-Humulene
C	r=0.41 p=0.49	r=0.41 p=.495	r=0.41 p=.495	r=0.41 p=.495	r=0.41 p=.495
TN	r=-0.99 p=0.00	r=-0.99 p=0.00	r=-0.99 p=0.00	r=-0.99 p=0.00	r=-0.99 p=0.00
TP	r=0.10 p=0.87	r=0.10 p=0.87	r=0.10 p=0.87	r=0.10 p=0.87	r=0.10 p=0.87
AP	r=0.99 p=0.00	r=0.99 p=0.00	r=0.99 p=0.00	r=0.99 p=0.00	r=0.99 p=0.00

of gravels in the soil of hill slope contrasting with that of juxtaposed soils of down slope position which are dominated by colluviums from hill slope. This mechanical constraint could have impaired the root development of *L. multiflora* as described for similar species in such conditions (Yao-Kouamé & Fako, 2008).

In total, 41 components were identified in the essential oil of *L. multiflora*. It can be concluded that the essential oil produced by *L. multiflora* is rich in chemical compounds compared with the essential oils extracted from *Ruta chalepensis* (Rutaceae) and *Aframomum latifolium* (Zingiberaceae) which include an average of 20 and 38 chemical compounds, respectively (Merghache et al., 2009). The monoterpenes compounds (51.1 – 86.2 %) were the most important chemical components of the essential oils as extracted from the leaves of *L. multiflora* harvested across the studied sites. This result is concordant with that obtained by Bruneton (1993). In our study, the highest concentrations of oxygenated derivatives as monoterpenoids further confirm the work done by Oussou et al. (2008). However, the major volatile substances were identified as Citral (Neral + geranial) in Bouaflé and Linalol in Yamoussoukro. The difference observed can account for genetic diversity of *L. multiflora* (Adou et al., 2011) at certain level in addition to the effect of the latitude variation (Purseglove et al., 1981).

According to Besombes (2008), environment effect can stand out among variability factors of essential oil quality in a restricted area as much as our studied region. That is why, soil contents of TN and AP have shown significant influences on the concentrations of major volatile substances determined in extractable essential oils. There was highly significant between AP and Citral then between AP and linalool. These results reveal potential effects of P-nutrition in essential oil production were tested by Tunctürk and Tunctürk (2006). P plays an important role in the physiology of aromatic plants, such as *L. multiflora* (Simard et al., 2013). Nutrition plays a key role in the growth and development of *L. multiflora*. Optimum rate of AP content was about 40 kg Pha^{-1}; but, no similar investigation was known for the production of essential oil of *L. multiflora* (Diomandé, 2014).

Therefore, further studies should explore the effect of P-rates in quantitative and qualitative productions of volatile substances contained in the essential oil of this aromatic plant. In fact, P is a component of active isoprene (Isopentenyl pyrophosphate), the radical of terpenoid compounds (Nes & Mckean, 1977) known to be widely involved in the physiology of aromatic plants with significant influence of phosphorus in biosynthesis of essential oils (Olle & Bender, 2010). The actual study mainly contributed to identify the components of mineral nutrition of *L. multiflora* emphasizing their influence on chemotype variability of the extractable essential oil. Therefore, knowledge is improve for development of sustainable production strategy of this species with high economical potential but still growing as invasive vegetal.

CONCLUSION

In addition to soil acidity already identified as criteria of the occurrence of *L. multiflora* in West Africa ecosystems, our study revealed the importance of mechanical constraints as induced by soil morphology and that of bioavailability of phosphorus. The major volatile substances were Citral (Géranial+Néral) and Linalol. Phosphorus has influenced their concentrations respectively. Study of response to the rates of P was suggested considering different ecologies conditions in order to deepen knowledge for quantitative and qualitative productions of *L. multiflora*

REFERENCES

Abena AA, Diatewa AM, Gakossoa G, Gbeassor M, Hondi-Assaha TH, Ouamba JM (2003). Fitoterapia, 74: 231–236.

Adam's RP (2007). Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry (4th ed.). United States, U.S: Carol stream.

Adou KE, N'guetta ASP, Kouassi A, Kanko C, Yao-Kouamé A, Sokouri DP, Coulibaly MY (2011). Caractérisation agromorphologique et identification de populations de *Lippia multiflora*, une verbénacée sauvage. J. Appl. Biosci., 37: 2441-2452. Retrieved from www.m.elewa.org/JABS/2011/37/4.

Baillie I (2010). Autralian soil and land survey field handbook –by National Committee on Soil and Terrain. European Journal of Soil Science, 61(1): 1-153.Crossref.

Bassolé IHN, Méda AL, Bayala B, Tirogo S, Franz C, Novak J, Dicko M H (2010). Composition and antimicrobial activities of Lippia multiflora Moldenke, Mentha x piperita L. and *Ocimum basilicum* L. Essential oils and their major monoterpènes alcohols alone and in combinaition. Molecules, 15(11) : 7825-7839.Crossref.

Besombes C (2008). Contribution à l'étude des phénomènes d'extraction hydro-thermomécanique d'herbes aromatiques: Applications généralisées. Journal of Clinical Investigation, 118 : 879-893.Crossref.

Braun-Blanquet J, Roussine N, Negre R (1952). Les groupements végétaux de la France méditerranéenne. Dir. Carte Gr. Vég. Afr. Nord, CNRS, 292 p.

Bruneton J. (1993). Pharmacognosie: phytochimie, plantes médicinales (4ème ed.). Paris: Tec & Doc, Lavoisier.

Chevalier JF (1999). Evaluation of high spatial resolution imagery for mapping and monitoring of vegetation cover of protected areas and their surrounding area. Case of the National Park Marahoué. Master's thesis on remote sensing applied to vegetation. University of Cocody, Côte d'Ivoire, pp12-20.

Clevenger JF (2006). Apparatus for the determination of volatile oil. J. Am. Pharm. Assoc., 17: 345-349.Crossref.

Dabin B (2007). Les sols tropicaux acides. Cah. ORSTOM, Sér. Pédol., vol, XXI, n°1, 1985, 13 p.

Diomandé LB (2014). Incidence des caractéristiques morphologiques et chimiques du sol sur l'occurrence du théier de savane (*Lippia multiflora*, Verbenaceae) et la composition chimique de son huile essentielle extraite des feuilles en régions nord de la Côte d'Ivoire. Thèse de doctorat, Université Félix Houphouët-Boigny, Abidjan, 86 p.

Etienne VT, Augustin AA, Sebastien LN, Gnago A, Jean TMP L, Menut C (2011). Natural Product Communications, 6 (8): 1183-1188.

Gbele O, Gnammytchet B K, Gnanzou A (2013). Related Structures Linked to the Emplacement of the Dianfla Pluton (Central Côte d'Ivoire): Contribution to the Understanding of Gold Mineralization in the Birimian Area of West Africa. Int. J. Eng. Sci., 2(8): 404-414

Gouollaly T, Nkounkou LC, Mahmout Y, Ouamba JM, Abena A A, Chalcat JC, Figueredo, G (2010). Variation in the chemical composition of the essential oils of different organs of domesticated Lippia multiflora Moldenke. Afri. J. Biotechnol., 9(41): 7009-7013.Crossref.

Irvine FR (1961). "Woody plants of Ghana, with special reference to their uses". (1st ed). London: Oxford University Press, 158p.

Kanko C, Koukoua G, N'guessan YT (1999). Composition and intraspecific variability of the leaf oil of *Lippiamultiflora* Mold. from the Ivory Coast. J. of Essential Oil Res., 11(2): 153-158.Crossref.

Kanko C, Sawaliho BE, Koné S, Koukoua G, N'guessan YT (2003). Étude des propriétés physico-chimiques des huiles essentielles de Lippia multiflora, *Cymbopogon citratus*, *Cymbopogon nardus*, *Cymbopogon giganteus*. Comptes Rendus Chimie, 7 : 1039-1042. Crossref

Koné B, Amadji GL, Touré A, Togola A, Mariko M, Huat J (2013b). Soil characteristic and *Cyperus* spp. Occurrence along a toposequence. Afri. J. Ecol, 51(3): 402 – 408.Crossref.

Koné B, Ettien JB, Amadji G L, Diatta S, Camara M (2010). Effets d'engrais phosphatés de différentes origines sur la production rizicole pluviale des sols acides en zone de forêt semi-montagneuse sous climats tropicaux: Cas des hyperdystricferralsols sous jachères en Côte d'Ivoire. Etude et Gestion des Sols, 17(1): 7-17. Retrieved from www.afes.fr/afes/egs/EGS_17_1_EGS_17_1_web_Kone.pdf.

Koné B, Traoré K, Touré A (2014). Basal Fertilizer Effects on Weed Occurrence and Rice Yield in Acid Upland Soil of West Africa at Bénin. J. Plant Sci., 2(1): 14-22.Crossref.

Lahlou M (2004). Methods to study phytochemistry and bioactivity of essential oils. Phytotherapy Research, 18, 435-448.Crossref.

Lompo F, Bonzi M, Bado BV, Gnankambary Z, Ouandaogo N, Sedogo MP, Assa A (2008). Int. J. Biol. Chem. Sci., 2 (2): 175 – 184.

Merghache S, Hamza M, Tabti B (2009). Afrique Science, 05(1) : 67-81.

Nes WR, McKean ML (1977). Biochemistry of steroids and other isoprenoids. pp 690. Baltimore, MD: University Park Press.

Olle M, Bender I (2010). The content of oils in umbelliferous crops and its formation. Agron. Res., 8(3): 687-696. Retrieved from http://agronomy.emu.ee/vol08Spec3/p08s322.pdf.

Oussou KR, Yolou S, Boti JB, Guessennd KN, Kanko C, Ahibo C, Casanova J (2008). European J. Sci. Res., 24 (1): 94-103.

Pansu M, Gautheyrou J (2003). L'analyse du sol - minéralogique, organique et minérale (2ème ed.). Paris: Springer-verlag.

Programme des Nations Unies pour le Développement (2013). A propos de la Côte d'Ivoire: Données nationales. Banque mondiale: Pnud/rdh. Retrieved from http://www.ci.undp.org/content/cotedivoire/fr/home/country.info.

Purseglove JW, Brown EG, Green CL, Robbins SRJ (1981). Spices. London & New York, pp.744–769.

Rhuhe RV, Walker PH (1968). Hillslope models and soil formation: II. Open systems. Proceedings of 9th Congress of the International Soil Science Society. Adelaide, Autralia: International Soil Science Society. Retrieved from http://geomorphometry.org/content/hillslope-models-and-soil-formation-ii-open-systems.

Simard F, Rioux JA, Trépanier M, Lamy MP (2013). Stimulation par les champignons endomycorhiziens de la synthèse de composés nutraceutiques et aromatiques dans les fruits et légumes. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Québec : Canada, 2p.

Tunctürk R, Tunctürk M (2006). Effects of different phosphorus levels on the yiled and quality components of Cumin (*Cuminum cyminum* L.). Res. J. Agric. Biol. Sci., 2: 336-340. Retrieved from www.aensiweb.com/aeb/2011/371-374.pdf.

Webster R, Olivier MA (1990). Statistical methods for soil and land resource survey. Oxford University Press, 316 p.

Yao-Kouamé A, Fako K (2008). Biochemical characteristic of *Lippia multiflora* (Verbenaceae) leaves with respect to fertilizer applied to the soil. J. Plant Sci., 3(4): 287-291.Crossref.

Yao-Kouamé A, Yao GF, Alui A K, N'Guessan AK, Tiemoko TP, Kloman YK (2008). Afrique Science, 04(3) : 426 – 451.