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IMPACT OF CROP MANAGEMENT AND OPTIMIZED POTASSIUM NUTRITION ON THE PRODUCTIVITY OF OIL PALM TREE (*Elaeis guineensis* Jacq) IN TWO LOCALITIES IN SOUTHEASTERN OF CÔTE D'IVOIRE

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ABSTRACT

In Côte d'Ivoire, oil palm occupies a prominent position in agricultural production, the economy, as well as the fats consumption. The country seeks to double its production from here at the year 2020, through improving the productivity of this culture. The yield still remains low (about 18 tons/ha/year in industrial plantations and only 9 to 10 tons/ha/year in village plantations), even with the improved planting material in the course of popularization whose the productivity is estimated at over 25 tons/ha/year. Tests were installed in the localities of La Mé and Ehania to contribute to improving the productivity of oil palm through a comparative study of the efficiency of potassium fertilization applied in industrial and village plantations. The experiments were conducted in randomized complete block of Fisher including 5 treatments and 4 repetitions. Treatments include 5 doses of potash fertilizer (T1, T2, T3, T4, T5) respectively corresponding to 1; 1.5; 2; 2.5; 3 kg of KCl/tree/year. The results showed that the oil palm yields were progressively improved following types of planting and growing locality by different doses of potassium fertilizer applied. This improvement was significantly higher on industrial plantations and plantations of Ehania compared respectively to village plantations and those of La Mé. The strict adherence to farming itineraries combined with a reasoned potassium fertilization allow better expression of the potential of production of the new plant material of oil palm, in the course of popularization. To this end, it must be applied to small producers, monitoring of operating technical itineraries (cultural practices and contribution of inputs) as on industrial plantations. In this area, a priority should also be given to the supply of potassium fertilizer with optimum doses are defined by the practice of foliar diagnostics leading to profitable oil palm cultivation.

Keywords: technical itineraries, potassium fertilizer, oil palm tree, Southeast, Côte d'Ivoire.

INTRODUCTION

Like most developing countries, the Ivorian economy is still based mainly on agriculture, including the exploitation of industrial crops (cocoa, oil palm, coffee, rubber, etc.). The oil palm, with an annual production of about 400,000 tons, occupies the 2nd place of export products after cocoa (1.3 million tons). The oils of palm and palm kernel relate to Côte d'Ivoire, more than 500 billion CFA francs per year and generate 10 % of national revenues (Anonyme, 2013).

The Côte d'Ivoire occupies the first place in exporting countries of crude palm oil and second place plans of producing countries at the African level (Anonyme, 2013). These performances are the result of a major plantation establishment program undertaken since 1965. This program has involved the creation of industrial units (industrial plantations) several thousand hectares to multiple village plantations. The Ivorian oil palm orchard covers more than 350,000 hectares, divided between village plantations (69 %) and industrial plantations (31 %). With these two types of exploitation, correspond two different production systems. In village plantations, all work is done manually, from felling the forest until the release of the crop. Fertilizers and pesticides are not generally used. Industrial plantations employ mechanization for felling the forest, maintenance of the plantation and transport plans. The use of fertilizers and pesticides is common in industrial plantations. Both types of operation have developed in southern Ivorian forest, on soils with natural fertilities were full and in suitable rainfall conditions.

Because of the importance of oil palm in the country's economy and security of income for rural families (Adjadi, 2008; MAEP, 2009), there is a strong expansion of village plantations, with still low productivity compared to industrial plantations. This mode of extensive exploitation, the population growth and climate change in recent years have contributed to the intensification of land pressure, which resulted in the considerable reduction of natural forest and fallow times (Gala *et al*., 2007). This situation predisposes the grounds with erosion and involves a degradation of their physicochemical properties, as well as the fall of the outputs of the cultures.

To increase productivity and revolutionize the cultivation of oil palm in Côte d'Ivoire, it is necessary to improve soil fertility through application of best cultivation techniques and the rational use of chemical fertilizers (Roose *et al*., 2008). In oil palm-based system, the respect of the crop management allows for better expression of the productive potential of the new vegetal material in the course of popularization. In addition to

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other steps recommended cultivation techniques, the mineral fertilizers, especially potasssic, is crucial for sustained productivity of this speculation. The stages of technical itineraries will first summarize the choice of soil and climatic conditions adapted for economic exploitation of the oil palm. The use of certified germinated seeds, with a period of prenursery and well attended nursery is as unavoidable steps. They follow the sowing of a leguminous plant of cover and planting during the rainy season to the density from 143 to 160 plants/ha. The regular weeding, pruning often, maintaining a round of 2 m ray around each tree, the fertilization and phytosanitary control are essential steps for the success of the palm plantation. Finally, the establishment of a harvesting program is necessary to minimize losses, that is to say 3 passages per month (Ollagnier and Ochs 1981). The whole of these farming stages contribute to improve the growth and development as well as the productivity of the oil palm tree (Eliard, 1979).

Mineral fertilization is to use chemical fertilizers to provide from a direct source, the nutrients needed for growth and productivity of the culture (Morel, 1989). These different stages of the exploitation of palm tree being carefully applied to industrial plantations, allow better growth and sustained production of oil palm. The village plantations deviate from the industrial model by a variety of crop whose main steps are: various associations with food crops at a young age, absence of fertilization, poor management of pruned leaves no round cleaning irregular, non-compliance and planting densities device. It is with this that this research work aimed élaeiculture respectful of the environment through the preservation and / or improvement of soil fertility in palm groves through a reasoned application of the various stages of production between villagers and industrial systems was initiated. The objective of this work is to contribute to improving the productivity of oil palm through a comparison of the efficiency of potassium fertilizers on these crop production systems in the soil and climate conditions of South East of Côte d’Ivoire.

MATERIAL AND METHODS

Characteristics of the study localities

The studies were conducted in the field on two different localities in South East of Côte d'Ivoire. These are the towns of La Mé and Ehania.

The experiments were conducted on four plots distributed in the two localities. The trials were set up on two types of farms, which are industrial plantations and village plantations.

- The plot of the CNRA station of La Mé, was chosen for the establishment of industrial plantation test (PI) of the locality.
- The plot of Mr. Abaca of La Mé, was used for the implantation of the trial plantation village (PV) of this locality.
- The plot of PALMCI was chosen for the implementation of the test in PI of Ehania.
- The plot of Mr. Tagio was used to test in PV of Ehania.

The locality of La Mé is located in South East of Côte d'Ivoire, 24 km east of Abidjan. Its geographical coordinates are 05 ° 26' north latitude and 03 ° 50' west longitude. The climate is humid subtropical with distinct seasons and type Attiéen in coastal facies. The annual rainfall, abundant, is very irregular averages 1750 mm over the last decade (Figure-1). The monthly distribution shows a bimodal rainfall cycle made of four seasons with two rainy seasons alternating with two dry seasons. Soils derived from tertiary sands are ferralsols heavily desaturated, deep and sandy surface. The kaolinite type clay has a low exchange capacity. Tables 1 and 2 show some physical and chemical characteristics of soils of La Mé.

The locality of Ehania is located in South East of Côte d'Ivoire, about 40 km of Aboisso. Its geographical coordinates are 05 ° 28' north latitude and 03 ° 12' west longitude. The climate is tropical wet-type elevation marked by four distinct seasons. The average annual rainfall (2000 mm of water) remains high. The soils are sandy clay to coarse sands dominance. These soils are ferralsols heavily desaturated and reworked. These soil formations developed on tertiary sediments are called tertiary sands. The physico-chemical characteristics of the soil are shown in Tables 1 and 2.

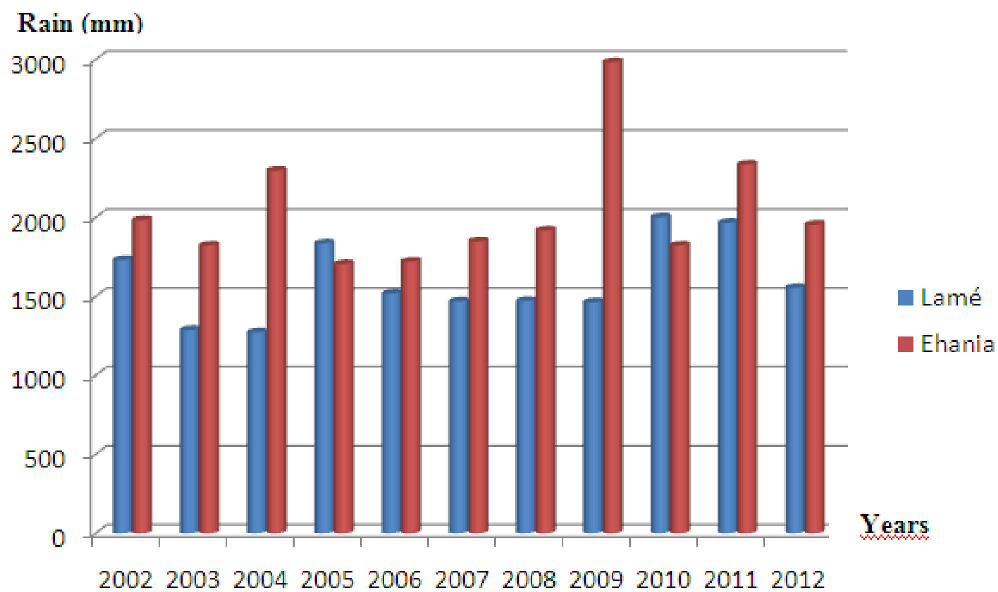

Figure-1. Evolution of the annual rainfall on the two weather stations during the period 2002-2012.

Table-1. Physical properties of soils under palm trees in the two localities of the study.

Towns	**Depth** (cm)	**Clay** ($g\ kg^{-1}$)	**Silt** ($g\ kg^{-1}$)	**Fine sand** ($g\ kg^{-1}$)	**Crude sand** ($g\ kg^{-1}$)
La Mé	0 - 20	7.4	5.6	19.9	67.1
	20 - 40	9.7	4.0	19.8	66.4
	40 - 60	12.3	3.9	20.1	63.7
Ehania	0 - 20	13.0	2.0	25.0	56.0
	20 - 40	18.7	3.7	21.8	53.9
	40 - 60	19.7	4.2	19.6	50.9

Table-2. Chemical properties of soils under oil palm trees in the two localities of the study.

Towns	**Depth** (cm)	**Absorbent complex** ($cmol\ kg^{-1}$)					**pH**	**Organic matter** ($g\ kg^{-1}$)			
		Ca^{2+}	**Mg^{2+}**	**K^{+}**	**Na^{+}**	**CEC**	**Eau**	**MO**	**C**	**N**	**C/N**
La Mé	0 – 20	0.47	0.12	0.06	0.02	1.05	4.8	1.48	0.86	0.09	10
	20 – 40	0.28	0.05	0.02	0.01	0.89	4.8	1.26	0.73	0.05	14
	40 - 60	0.16	0.04	0.01	0.01	0.81	4.7	1.02	0.59	0.05	12
Ehania	0 – 20	0.91	0.50	0.10	0.15	1.66	4.2	2.30	1.40	0.09	14
	20 – 40	0.76	0.20	0.20	0.03	1.05	4.8	2.00	1.20	0.08	13

Vegetal material

The vegetal material consists of hybrid (*Tenera*) oil palm tree obtained by cross between *Dura* (female parent) and *Pisifera* (male parent). *Dura* type is characterized by having a thin fruit pulp and a shell thick while. *Pisifera* type is characterized by a high abortion rate of the fruit and a very thin shell. The hybrid called *Tenera*, belongs to the category C1001F. It is characterized by thick pulp and average tree nuts, high yield and resistance to *Fusarium* advisable for replanting.

Mineral fertilizer

Fertilization of oil palm trees was ensured that by simple fertilizers represented by potassium chloride (KCl), dosed at 60 % of K_2O, in the form of granules.

Methods

On each plot, the adopted statistical device is in completely randomized blocks of Fisher, comprising 5 treatments and 4 repetitions. The treatments that have been applied are T1: 1 kg KCl/tree/year corresponds to the control popularized, T2: 1.5 kg KCl/tree/year, T3: 2 kg KCl/tree/year, T4: 2, 5 kg KCl/tree/year and T5: KCl 3 kg/tree/year. The five treatments were applied annually in the period 2011 to 2014. An entire plot consists of 20 (4 x 5) elementary plots, each with 49 trees spread over 7 lines of 7 trees. Of the 49 trees, shafts 25 are useful, in which the measurements were carried out and the other 24 are edge. The entire plot consists of 980 trees corresponding to 6.85 hectares on the theoretical basis of 143 plants per hectare. The mineral manure test installed on the dominant soil unit (on plate) is about a 5 year replanting palm grove. The fertilizer was applied at the end of the rainy season (mid-July) in round 2 meter ray around each tree.

Measured parameters

The determination of the level of mineral nutrition of oil palm in the two localities was made by the leaflets of sample analyzes. The approach has been to take on shafts previously identified two pairs of leaflets from each side of the spine, and in the central portion of the row of sheet 17. The period selected for sampling is the short dry season. A sample was composed of 90 leaflets, freed of their two basal and apical ends, and the central rib. These leaflets dried in an oven at 105°C were analyzed by the Laboratory of Plant and Soil (LAVESO) of INP-HB of Yamoussoukro (Côte d'Ivoire).

Determining the yield represented by the bunch tonnage (TR) and its components, constituted by the number of bunches (NR), bunch weight (PR) and average of bunch weight (PMR) was made on the basis of individual crops. The number of bunches has been obtained by counting all bunches harvested per tree. Bunch weight was determined by weighing all bunches harvested per tree. The average bunch weight was determined from the following relationship:

PMR = PR / NR, where
PMR = Average of bunch weight (kg)
PR = Bunch weight (kg)
NR = Number of bunches

Yield or bunch tonnage (TR/ha/year) was obtained from the following relationship:

TR/ha/year = NR * PMR * D, where
TR/ha/year = bunch tonnage per hectare per year (tons)
NR/tree/year = Number of bunches per tree per year
PMR/tree = Average of bunch weight (kg) per tree,
D = Standard density which is 143 trees/ha.

Statistical analyses

The results were statistically analyzed using the GenStat Release version 10.1 software. The graphics were made using Microsoft Office Excel software, version 2007 (Microsft Software, 2007). The Newman-Keuls test allowed averaging the rankings through an analysis of variance (ANOVA) at the 1 % and 5 %. The means of the variables were separated at the probability level $P < 0.05$ (significant) or $P < 0.01$ (highly significant).

RESULTS

Level of mineral nutrition of oil palm

Table-3 presents the results obtained by analysis of the sheet 17 on all plots studied which indicate the level of mineral nutrition of the trees.

The results reveal that nitrogen (N) contents of the sheet 17 varied between 2.60 and 3.78 % of dry matter (m.s). The highest values were obtained in Ehania, with 3.78 % of dry matter in PI while the PV of La Mé, with 2.60 % of m.s, recorded the lowest content. As for the contents of the sheet 17, phosphorus (P), they oscillated between 0.15 and 0.18 % of m.s. In La Mé, the recorded contents were 0.15 % of m.s on the two selected plots (PI and PV) whereas in Ehania, they were 0.15 % of m.s in PV and 0.18 % of m.s in PI.

The content of the trees in calcium (Ca) was 0.89 and 0.94 % of m.s respectively in PI and in PV of La Mé. The values obtained in Ehania were 0.79 % of m.s in PI and 0.97 % of m.s. in PV. The contents of sheet 17 in magnesium (Mg), presented in Table-3, varied between 0.32 and 1.77 % of m.s according to the dose applied. As for the level of nutrition of trees in potassium (K) in La Mé, the results gave 0.61 % of m.s in PI and 0.54 % of m.s. in PV. In Ehania, the values were 0.87 % of m.s. in PI and 0.50 % of m.s. in PV. With the analysis of Table-3, the results showed that the level of mineral nutrition of trees on PI was substantially identical to that of the PV in both locations. The results also showed that mineral nutrition of oil palm was essentially the same in both areas studied, with the exception of potassium.

Table-3. Mineral elements contents in the leaf of the rank 17 over the whole of the study plantations.

Towns	Plantation types	**Mineral elements** (% of dry matter)				
		N	**P**	**K**	**Ca**	**Mg**
La Mé	PI	3.08	0.15	0.61	0.89	0.37
	PV	2.60	0.15	0.54	0.94	1.77
Ehania	PI	3.78	0.18	0.87	0.79	0.32
	PV	3.45	0.15	0.50	0.97	0.33

PI: Industrial plantation; PV: Village plantation

Effects of different doses of potassium fertilizer on yield and its components

The components of the yield as a whole are made of the number of bunches per tree and per year (NR/tree/year), bunch weight per tree and per year (PR/tree/year), the average bunch weight per tree and per year (PMR/tree/year). The yield of oil palm is represented by of bunches tonnage per hectare and per year (TR/ha/year). The effects of different doses of potassium

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fertilizer on these variables were studied in the two localities and out of the two types of plantations.

The results of the analysis of variance relative to the effects of treatments, localities and technical itineraries on yield components are presented in Table-4. The results of the analysis indicate that treatments, localities, cultural itineraries and their interactions were highly significant effect ($p < 0.05$ to $p < 0.001$) on yield components. Variability is due both to the doses of fertilizers made, to localities and cultural itineraries.

Table-4. Table after analysis of variance to three factors considering treatments, localities and plantation types on the characteristics of the production.

Variation of spring	**df**	**F value**		
		NR	**PTR**	**PMR**
Treatments	4	1.90	8.58***	16.3***
Plantation types	1	619.6***	341.1***	19.1***
Localities	1	30.6***	544.8***	3956***
Treatments* plantation types	4	4.18**	5.04***	1.78
Treatments*localities	4	2.81**	11.02***	19.6***
Plantation types*localities	1	0.30	7.99**	71.2***
Treatments*localities*plantation types	4	25.9**	18.9*	20.9*

NR: Number of bunch; PTR: Total bunches weight; PMR: Average of bunch weight; df: degree of freedom
: < 0.05**; *: < 0.01;** *****: < 0.001**

Case of industrial plantation (PI) of La Mé

The average number of bunches (NR/tree/year), the bunch weight (PR/tree/year) and average bunch weight (PMR/tree/year) are presented in Table-5. The analysis of the variance reveals that there is no significant difference ($p > 0.05$) between the averages of NR, obtained with the different doses applied during the three campaigns. The NR/tree/year, which was growing in the first two campaigns, began to decrease from the third campaign. The application of potassium fertilizer had no significant influence on the bunch production on this plantation of La Mé.

As for the PMR, analysis of variance revealed that there is no significant difference ($p > 0.05$) during the first campaign between means of different doses applied. During this campaign, the PMR has varied between 6.6 and 6.9 kg depending on the doses. However, at the time of the second and third campaign, the analysis of variance revealed that there are significant differences ($p < 0.05$) between the averages the different land applied doses. The classification according to the Newman-Keuls test has resulted in three distinct groups during these two campaigns. This is the dose of the treatment T1, which had the least effect, statistically different of the doses of T2 and T3 treatments, forming the second group. The third group is formed by the dose of T4 and T5 treatments. The trees fertilized with the highest dose treatments (T3, T4 and T5) were given a high PMR unlike what was observed with those of the lower doses (T1 and T2). These results showed that the potassium fertilizer significantly improved the PMR and the PR on this plot of La Mé (Table-5).

The tonnage of bunches or yield (TR/ha/year) average of the three campaigns varied between 18.8 t/ha/year (T1) and 22.1 t/ha/year (T3). The analysis of variance revealed that there are significant differences ($p < 0.05$) between the means obtained with the different doses applied (Table-6). The classification according to the Newman-Keuls test has led to two distinct groups. The first group is formed by the doses of treatments (1 and 2) which their effects are statistically different of the doses of the other three treatments (3, 4 and 5). The yield was improved by the application of potassium fertilizer.

Table-5. Effect of different doses of KCl on yield components on the industrial plantation (PI) of La Mé during the three campaigns.

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Treatments	Campaigns								
	2011 - 2012			2012 - 2013			2013 - 2014		
	NR	PR (kg)	PMR (kg)	NR	PR (kg)	PMR (kg)	NR	PR (kg)	PMR (kg)
T1	16 a	107 a	6.6 a	17 a	143 a	8,4 a	15 a	144 a	9.6 a
T2	15 a	99 a	6.6 a	17 a	151 a	8,9 a	16 a	157 a	9.8 a
T3	16 a	107 a	6.7 a	18 a	160 ab	8,9 a	17 a	182 b	10.7 b
T4	16 a	107 a	6.7 a	18 a	171 b	9,5 b	16 a	178 b	11.1 b
T5	16 a	110 a	6.9 a	18 a	175 b	9,7 b	16 a	178 b	11.1 b
CV	5.4	11.2	10.0	9.1	10.0	9.4	14.1	12.5	9.6
P	0.296	0.504	0.751	0.503	0.013	0.025	0.982	0.010	0.002

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
PR: Bunche's weight per tree per year (kg/tree/year); NR: Number of bunches per tree per year; PMR: Average of bunch weight (kg)
T1: 1; T2: 1, 5; T3: 2; T4: 2, 5; T5: 3 (dose of KCl in kg/tree/year)

Table-6. Effects of different doses of KCl on the average yield of the three campaigns and its components on the industrial plantation of La Mé.

Traitements	Yield and its components		
	NR/ha/year	**TR** (TR/ha/year)	**PMR** (kg)
T1	2288 a	18.8 a	8.2 a
T2	2289 a	19.3 a	8.4 a
T3	2431 a	22.1 b	9.1 b
T4	2383 a	21.4 b	9.1 b
T5	2382 a	21.3 b	9.0 b
CV	6.4	6.7	8.7
P	0.793	0.023	0.015

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
TR: Tonnage of bunch (TR/ha/year); NR/ha/year: Number of bunch per hectare per year on the basis of 143 trees per hectare; PMR: Average of bunch weight (kg)
T1: 1; T2: 1, 5; T3: 2; T4: 2, 5; T5: 3 (dose of KCl in kg/tree/year)

Case of industrial plantation (PI) of Ehania

The effects of different doses on NR/tree/year, on PMR/tree/year and on the PR/tree/year achieved during the three campaigns are presented in Table-7. The analysis of variance revealed that there is no significant difference ($p > 0.05$) between means in NR, obtained with the different doses applied during the three campaigns. The contribution of the KCl had no significant effect on the bunch production.

As regards PMR (Table-7), it varied between 7.3 kg (T2) and 7.6 kg (T4 and T5) during the campaign 2011 - 2012, 9.4 kg (T1) to 11.5 kg (T5) during the campaign 2012 - 2013 and 10.4 kg (T1) to 12.8 kg (T5) according to the dose applied. The analysis of variance revealed that there is no significant difference ($p > 0.05$) between the means obtained with the various treatments during the first campaign. However, during the second and third campaign of the significant differences ($p < 0.05$) were observed between the mean of the different doses applied.

The effects of different treatments on the average of the yield of the three campaigns are presented in Table-8. The mean varied between 21.2 (T1) and 25.6 TR/ha/year (T4) made the following doses. The analysis of variance revealed that there is significant difference ($p < 0.05$) between the mean obtained. The highest yields were obtained with the doses of the treatments T2, T3, T4 and T5. Their effects were the second homogeneous group and the first group was formed by the doses of the treatments T1 as classified by the test of Newman-Keuls. It appears from the above, that the applied potassium fertilizer significantly improved the average bunch weight and yield over the three campaigns.

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Table-7. Effects of different doses of KCl on yield components of the industrial plantation of Ehania during the three campaigns.

Treatments	Campaigns								
	2011 - 2012			2012 - 2013			2013 - 2014		
	NR	PR (kg)	PMR (kg)	NR	PR (kg)	PMR (kg)	NR	PR (kg)	PMR (kg)
T1	16 a	120 a	7.5 a	18 a	169 a	9.4a	15 a	156 a	10.4 a
T2	16 a	119 a	7.3 a	18 a	193 a	10.7 b	16 a	194 ab	11.5 b
T3	16 a	120 a	7.5 a	19 a	207 ab	10.9b	17 a	200 b	11.8 bc
T4	17 a	129 a	7.6 a	19 a	209 b	11.0 c	17 a	213 c	12.5 c
T5	16 a	122 a	7.6 a	18 a	207 b	11.5c	18 a	230 c	12.8 c
CV	9.1	10.9	2.7	11.3	11.2	2.9	12.3	12.8	3.2
P	0.784	0.260	0.444	0.159	0.001	0.001	0.088	0.003	0.001

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
PR: Bunche's weight per tree per year (kg/tree/year); NR: Number of bunches per tree per year; PMR: Average of bunch weight (kg)
T1: 1; T2: 1, 5; T3: 2; T4: 2, 5; T5: 3 (dose of KCl in kg/tree/year)

Table-8. Effects of different doses of KCl on the average yield of the three campaigns and its components on the industrial plantation of Ehania.

Treatments	Yield and its components		
	NR/ha/year	**TR** (TR/ha/year)	**PMR** (kg)
T1	2336 a	21.2 a	9.1 a
T2	2383 a	24.8 b	10.4 b
T3	2415 a	25.6 b	10.6 b
T4	2420 a	25.2 b	10.5 b
T5	2352 a	24.7 b	10.5 b
CV	7.5	8.7	2.4
P	0.131	0.015	< 0.001

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
TR: Tonnage of bunch (TR/ha/year); NR/ha/year: Number of bunch per hectare per year on the basis of 143 trees per hectare; PMR: Average of bunch weight (kg)
T1: 1; T2: 1, 5; T3: 2; T4: 2, 5; T5: 3 (dose of KCl in kg/tree/year)

Case of the village plantation (PV) La Mé

Table-9 shows the effects of different treatments on the NR/tree/year, on PMR/tree/year and on PR/tree/year during the three campaigns. The analysis of variance revealed that there is no significant difference ($p > 0.05$) between the averages of NR obtained with the different doses over the three campaigns. The NR/tree/year decreased from the third campaign when he was growing during the first two campaigns. The potash fertilizer therefore has no significant effect on the bunch production.

As regards the PMR, it appears in Table 9 that the averages varied between 5.4 to 5.6 kg depending on the dose applied during the first season (2011-2012). During this campaign, the analysis of variance revealed no significant difference ($p > 0.05$) between the averages. In the two other campaigns (2nd and 3rd year), the analysis of variance revealed that there are significant differences ($p < 0.05$) between the average obtained with the various treatments applied. The PMR has varied between 7.1 (T1) and 8.2 kg (T4 and T5) during the second year and 8.0 (T1) to 9.7 kg (T4 and T5) at the third campaign by the doses applied. We can increase the average bunch weight by making potash fertilizer.

The average of yield on three seasons varied between 12.6 (T1) and 15.6 TR/ha/year (T4) based on the doses applied (Table-10). The analysis of variance revealed that there are significant differences ($p < 0.05$) between the means obtained with the various treatments applied. The yield was significantly improved by applying potash fertilizer.

Table-9. Effects of different doses of KCl on yield components of the village plantation (PV) of La Mé during the three campaigns.

Treatments	Campaigns								
	2011 - 2012			2012 - 2013			2013 - 2014		
	NR	PR (kg)	PMR (kg)	NR	PR (kg)	PMR (kg)	NR	PR (kg)	PMR (kg)
T1	12 a	65 a	5.4 a	14 a	100 a	7.1 a	13 a	104 a	8.0 a
T2	12 a	67 a	5.6 a	15 a	109 a	7.3 a	14 a	119 a	8.5 a
T3	12 a	66 a	5.5 a	15 a	119 b	7.9 b	15 a	144 b	9.6 b
T4	12 a	66 a	5.5 a	15 a	123 b	8.2 b	15 a	146 b	9.7 b
T5	12 a	65 a	5.4 a	16 a	131 b	8.2 b	15 a	146 b	9.7 b
CV	15.9	19.3	8.4	11.9	13.4	7.3	16.4	17.2	5.2
P	0.985	0.845	0.859	0.333	0.002	0.025	0.420	0.016	0.005

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
PR: Bunche's weight per tree per year (kg/tree/year); NR: Number of bunches per tree per year; PMR: Average of bunch weight (kg)
T1 : 1 ; T2 : 1,5 ; T3 : 2 ; T4 : 2,5 ; T5 : 3 (dose of KCl in kg/tree/year)

Table-10. Effects of different doses of KCl on the average yield of the three campaigns and its components on the village plantation (PV) of La Mé.

Treatments	Yield and its components		
	NR/ha/year	**TR** (TR/ha/year)	**PMR** (kg)
T1	1859 a	12.6 a	6.8 a
T2	2002 a	14.2 b	7.1 a
T3	2006 a	15.4 b	7.7 b
T4	2007 a	15.6 b	7.8 b
T5	2007 a	15.3 b	7.8 b
CV	9.0	10.9	5.3
P	0.191	0.009	0.043

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
TR: Tonnage of bunch (TR/ha/year); NR/ha/year: Number of bunch per hectare per year on the basis of 143 trees per hectare; PMR: Average of bunch weight (kg)
T1: 1; T2: 1, 5; T3: 2; T4: 2, 5; T5: 3 (dose of KCl in kg/tree/year)

Case of the village plantation (PV) of Ehania

The mean of NR/tree/year, of PMR and of PR/tree/year are shown in Table-11. The analysis of variance revealed no significant difference ($p > 0.05$) between the averages of NR obtained with different treatments applied during the three campaigns. The application of potassium fertilizer had no effect on the bunch production.

As for the PMR, the average varied between 6.1 (T2) and 6.3 kg (T4) during the campaign 2011 - 2012, 8.0 (T1) to 9.5 kg (T4) during the Campaign 2012 - 2013 and 9.2 kg (T1) to 10.5 kg (T4) during the campaign 2013 - 2014 depending on the doses applied. Highly significant differences ($p < 0.01$) were observed during the second and third campaign in means different doses while it was not significant ($p > 0.05$) during the first campaign (Table 11). The PMR highest averages were obtained with doses of treatments T3, T4 and T5 and lowest with doses of T1 and T2 treatments. The application of KCl improved the PMR significantly.

The means of the average yield of the three campaigns are presented in Table-12. These averages varied between 15.9 (T1) and 19.3 TR/ha/year (T4) following the doses applied. Highly significant differences ($p < 0.01$) were observed between the averages obtained with the various treatments applied. The potassium fertilizers improved the PMR significantly therefore yield during the observation period.

Table-11. Effects of different doses of KCl on yield components of the village plantation (PV) of Ehania during the three campaigns.

Treatments	Campaigns								
	2011 - 2012			2012 - 2013			2013 - 2014		
	NR	PR (kg)	PMR (kg)	NR	PR (kg)	PMR (kg)	NR	PR (kg)	PMR (kg)
T1	15 a	93 a	6.2a	15 a	120 a	8.0 a	13 a	120 a	9.2 a
T2	14 a	86 a	6.1a	15 a	123 a	8.2 a	14 a	130 b	9.3 a
T3	14 a	87 a	6.2a	16 a	146 b	9.1 b	14 a	144 b	10.3 a
T4	15 a	94 a	6.3a	16 a	152 b	9.5 b	15 a	158 c	10.5 b
T5	15 a	93 a	6.2a	16 a	147 b	9.2 b	15 a	156 c	10.4 b
CV	7.9	8.1	2.8	7.7	8.2	33	7.7	8.2	3.1
P	0.848	0.720	0.705	0.158	0.002	0.001	0.158	0.003	0.001

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
PR: Bunche's weight per tree per year (kg/tree/year); NR: Number of bunches per tree per year; PMR: Average of bunch weight (kg)
T1: 1; T2: 1, 5; T3: 2; T4: 2, 5; T5: 3 (dose of KCl in kg/tree/year)

Table-12. Effects of different doses of KCl on the average yield of three campaigns and its components on the village plantation (PV) of Ehania.

Treatments	Yield and its components		
	NR/ha/year	TR (T/ha/year)	PMR (kg)
T1	2050 a	15.9 a	7.8 a
T2	2058 a	16.2 a	7.9 a
T3	2187 a	19.1 b	8.7 b
T4	2193 a	19.3 b	8.8 b
T5	2192 a	19.0 b	8.7 b
CV	7.0	6.6	2.6
P	0.146	0.002	<0.001

Means followed by the same letter in the same column are not statistically different at the 0.05 by Newman Keuls test
TR: Tonnage of bunch (TR/ha/year); NR/ha/year: Number of bunch per hectare per year on the basis of 143 trees per hectare; PMR: Average of bunch weight (kg)
T1: 1; T2: 1, 5; T3: 2; T4: 2, 5; T5: 3 (dose of KCl in kg/tree/year)

Presentation the number of bunches (NR/tree/year) on four plots of the study

Figure-2 presents the comparative evolution of NR/tree/year according to the different treatments on all the plots studied. On analysis of this figure, it is observed the formation of two distinct groups. The first group is formed by the averages recorded on PI of the two localities, which produced the NR higher. The second group consisted of the averages obtained on the PV. At the group consisting of PI, average of Ehania obtained was significantly higher than those recorded in La Mé. As for the second group, the PV of Ehania produced a larger number of bunches than La Mé. Depending on the technical itineraries and the locality, the plantations of Ehania produced a NR significantly higher compared to the plots of La Mé. The cultural itineraries and the localities have an influence on the efficiency of potassium fertilizer in improving the productivity of oil palm.

Presentation of the average bunch weight (PMR) on four plots of the study

The compared evolution of the PMR for the different treatments applied to all parcels is presented by Figure-3. It released from this figure of the constitution of four distinct elements. The first element is the average recorded on the PI of Ehania which produced widely bunches with higher PMR, with a maximum of 10.6 kg. The PI of La Mé, with up to 9.1 kg, forms the second element. The averages on the PV of Ehania and La Mé were significantly weaker, constituting respectively the third and the fourth element. The potassium fertilizer allowed a better improvement of the PMR on PI compared

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to the PV, according to the technical itineraries. This while, depending on the locality, the plantations of Ehania produced bunches having a PMR significantly higher compared to those of La Mé. These results show that localities and cultural itineraries influence the efficiency of potassium fertilizer in improving this component of the yield.

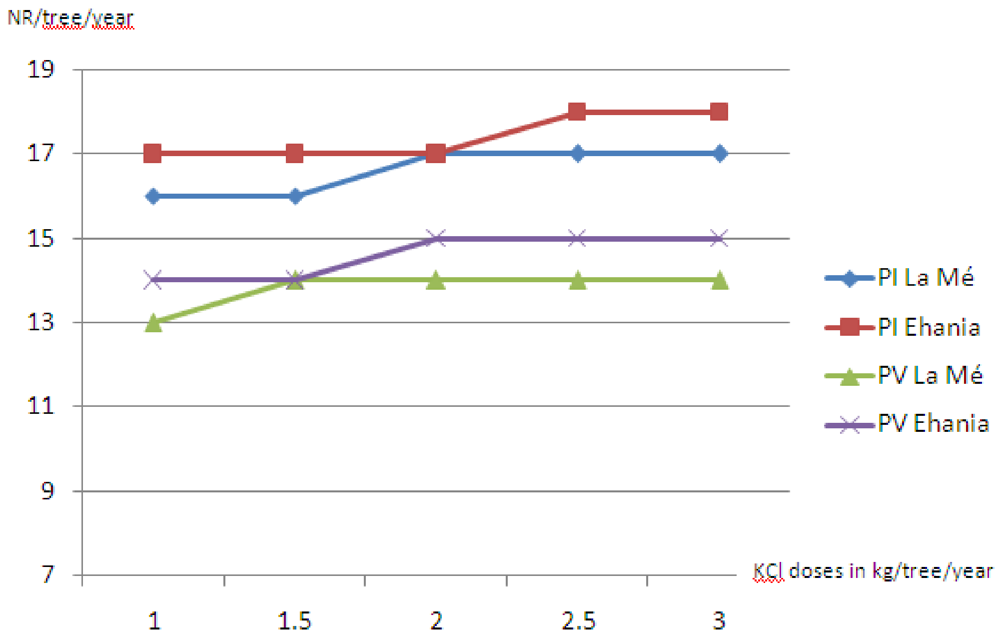

Figure-2. Evolution compared of the effect of different doses of KCl on the number of bunches (NR) per tree per year on all parcels of the study.

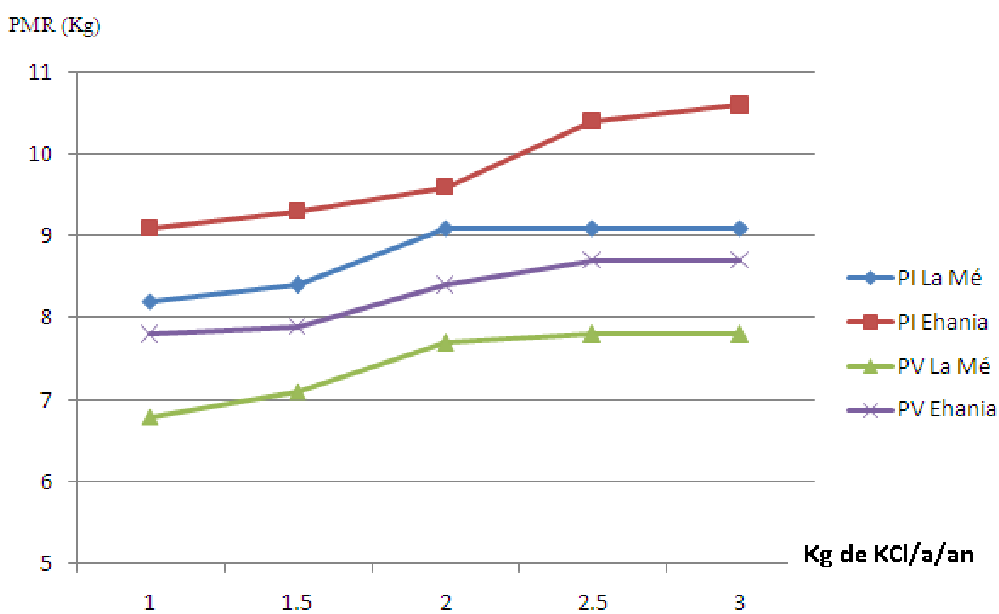

Figure-3. Evolution compared of the effect of different doses of KCl on the average of bunch weight (PMR) on all parcels of the study.

DISCUSSIONS

The nitrogen contents obtained in the sheet of row 17 on all parcels are greater than the critical level of this element, which has been set at 2.25 % of m.s by Tampubolon *et al*. (1990). These values show that the level of nitrogen nutrition of trees is clearly sufficient for a proper development of the oil palm. Nitrogen is the element whose needs are paramount in the juvenile stage (Belder *et al*., 2005) until the entry into production. The phosphorus levels, ranging between 0.15 and 0.18 % of

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m.s, exceed the critical threshold of this element, fixed at 0.15 % of ms (Ollagnier and Ochs, 1981; Ollagnier *et al*., 1987). The level of nutrition out of phosphorus is sufficient to allow proper development and optimal growth of the oil palm. The nutrition of the almost satisfactory trees in nitrogen, magnesium and calcium may be explained by the good availability of these elements in soils. For according Hellali (2002), the absorption of an element by a plant is proportional to its concentration in the soil solution.

The potassium content of the sheet 17 on all parcels varied between 0.50 and 0.87 % of m.s. These values are below the critical threshold, set at 1% of ms (Ollagnier *et al*., 1987). The level of mineral nutrition, insufficient out of potassium, results from its low in all soils studied. The soils studied are tertiary sands which are characterized by their potassium deficiency. These deficiencies result from both the importance of exports by oil palm and of potassium poverty of the desatured ferralsols, derived from granites, sandstones and sedimentary sands (IRHO, 1992). The lower content of the oil palm out of potassium on the PV on the two localities would be due to a lack of supply of potassium fertilizer to correct deficiencies native of the ferralsols. The follow-up of the cultural itineraries and regular intake of potassium fertilizer explain the significantly higher potassium contents on the PI of Ehania. Because of the essential role played by potassium in mineral nutrition, and in particular in the bunch production (Ochs *et al*, 1991; Caliman *et al*., 1994; Ballo, 2009), it is necessary to correct the deficiency by potassium fertilizers to maintain or enhance the production of new material.

The mineral assessment of the analysis of the sheet 17, has enabled us to identify the one hand a satisfactory level of nutrition nitrogen, calcium, phosphorus and magnesium, and on the other hand, the confirmation of Potassium deficiency in the south-east of Côte d'Ivoire. These results corroborate those of Ballo (2009) which had already noted the very low level of potassium nutrition of oil palm in La Mé, with contents of 0.67 % of m.s in this element. Indeed, the potassium deficiency appears to be the main chemical constraint limiting the production of palm oil in all Ivorian growing regions of this speculation. Rigorous solutions, including the supply of potassium fertilizer, must be taken to solve this problem which is becoming a serious threat to oil palm cultivation, due to the degradation of soil and climatic conditions.

In our experiments, we obtained an improvement in yield of over 27 % and 25 %, with an intake of 2 kg KCl/tree/year (T3) compared to the dose of 1 kg of KCl/tree/year (T1) respectively on PI and PV of La Mé. As for plots of Ehania, yield improvement was 30 % on PI, with the addition of 1.5 kg of KCl/tree/year and 26 % in PV, with the addition of 2 kg of KCl/tree/year compared with the standard dose (T1). These results show that there is a better response to the oil palm potassium-based fertilizers on Ferralsols localities of La Mé and Ehania.

The different doses of KCl applied gradually improve the yield of oil palm through a consequent increase in average bunch weight (PMR). The efficiency of potassium fertilization on yield confirms earlier results obtained to Cameroon by Rafflegeau (2008); to Côte d'Ivoire by Caliman *et al*. (1994) and Ballo (2009); to South-east of Asia by Othman *et al*. (2005) and to Oceania by Breure (1982). Potassium, by its specific action enhancer transport of assimilates from leaves to storage organs possible to induce a good return through a significant increase of the PMR (Ballo 2009). Potassium plays an active role in the reproduction and metabolism in water stress resistance process (Braconnier and d'Auzac, 1985). The increase in the PMR would be linked to the large number of fruits on the bunch (Ballo 2009). A good potassium nutrition active growth, increases reserves stem organs, and improve fruit set and fruit enlargement. The improvement of the PMR by the fertilizer became significant only after two campaigns. These results are in conformity those of Ollagnier and Ochs (1981) which showed that the yield of kilos of different diets until at least 20 months after fertilization. The increase in yield after intake of potassium fertilizer recorded during the second and third year is explained by the fact that potassium fertilization occurs during the active growth phase of the inflorescence which lasts 23-20 months before the bunch harvesting (Bredas and Scuvie, 1960).

The high potassium needs of the oil palm are combined with mineral poverty of tropical soils of our sites of culture. To this end, the fertilization must be effective to compensate for export and to increase the potassium content of the soil to a level such that the absorption capacity is sufficient to cover the needs of the tree. According Pettigrew (2008), the quantity of potassium absorbed by the plant depends on the crop species, potassium available soil and environmental conditions. The quantities absorbed by the plant evolve correspondingly with the amount of fertilizer made and peaked with the maximum dose, ensuring the best yield, and they decrease as the amount of fertilizer becomes toxic (Laarabi, 2006). The new vegetal material, in the course of popularization, is characterized by high efficiency but the expression of this potential is accompanied by strong export minerals (Ng, 1977). Under these conditions, the corresponding treatment to high doses establishes a good balance between exports and plant nutrition in minerals leading to higher yields. The drop in yield observed with the highest doses, showed that seeds filling phase is a key stage in the development of performance and it would have been disturbed (Nyembo *et al*., 2012). For Lafitte (2002), high doses generate high water requirements that the plant cannot be covered, which would reduce yield.

Our results show that the effects of different doses on yield and its components (TR, NR, PR and PMR) are related to cultural itineraries, applied to industrial plantations (PI) and village (PV). The largest increases were recorded performance on the PI compared to the PV, who got weaker improvements with the doses applied. This difference in efficiency of fertilizers on the yield between these two types of plantations would be linked to a difference in the application of technical itineraries.

Cultivation techniques, recommended for oil palm cultivation, have been defined by Ollagnier and Ochs (1981). It involves the use of certified vegetal material, to a period of prenursery and well attended nursery to a planting before the rainy season to the density of 143 to 160 plants/ha and planting of leguminous cover. The regular weeding, frequent pruning, maintaining a round of 2 m ray around each tree, phytosanitary control and potassium fertilization are essential steps for success of the palm plantation. The chronogram for bunches harvesting should be established, namely 3 passes per month. These different stages of cultural itineraries, thoroughly respected on PI, have been developed thanks to the important contribution of agricultural research whose results were used in a system where everything is planned, budgeted and arranged hierarchically (Rafflegeau, 2008). These modern technologies of cultivation contribute to limiting soil depletion, to enrich in minerals, including potassium, on the absorbent complex and a reduction of competition between oil palm and weeds (Caliman *et al*., 1994).

For cons, on the PV, technical itineraries frequently associate food crops to oil palm seedlings in their young age and collection of pruned palms. These associations, according Chaléard (2002), generate income to the farmers and their livelihood before the entry into production of oil palm, but strongly involved in the degradation of the physico-chemical properties of soils. For Corley and Tinker (2003), the collection of palms contributes to a loss of organic matter and minerals across the entire plot. In village's plantations, the absence of palms leads according Aholoukpè *et al*. (2013), an annual export of over 10 tons of dry matter per hectare. Must be associated with these factors a lack of fertilization village palm groves and diversification of applied techniques that move away from crop itineraries disseminated. The main factors of variation according Rafflegeau (2008) are: the plant material used, monitoring of the nursery, the swath of pruned palms, the associations of food crops in youth culture, the fertilization, planting cover leguminous plants, the folding frequency, the maintenance of the rounds and sanitary control. These differences between industrial and village practices lead to a potassium fertilizer's effectiveness inequality applied to the growth and productivity of the oil palm.

Moreover, our results showed that the effects of different doses of KCl in improving yield components are also related to the locality in which the plantation is established. The yields recorded on the plantations of Ehania were significantly higher compared to those of La Mé. Besides the cultural itineraries applied, the production of the oil palm is strongly influenced by climatic and soil factors of the locality.

Rainfall appears as the main climatic parameter for better productivity of the oil palm. The annual maximum is estimated to need about 1800 mm of rainfall, well distributed throughout the year (Yao *et al*., 1995). Houssou (1985) showed that the rainfall deficit has a negative effect on the process of the production of oil palm. For Chaudhary *et al*. (2003), water stress would be, apart from any other edaphic factor responsible for the low productivity of crops including oil palm. The rainfall of Ehania is significantly higher compared to that of the Mé. This factor is mainly responsible for the higher productivity recorded on the plots of Ehania (PI and PV) compared to those of La Mé. In 1977, Ochs and Ollagnier supported that yields of the new popularized material could reach 25 TR/ha year, but exceptionally 30 tons, if the rainfall is abundant and well distributed enough to ensure permanent water supply. Rainfall appears therefore as the most important ecological factor in ensuring an abundant and regular fructification of oil palm. Thus, the production recorded on the plantations of La Mé, less sprinkled, rarely exceeds 22 TR/ha/year, while in Ehania it frequently reaches 25 TR/ha/year, with a reasoned mineral fertilization.

CONCLUSIONS

The foliar analysis confirmed the potassium deficiency for the cultivation of oil palm in Southeast Côte d'Ivoire. To this end, the supply of potash fertilizer is needed to correct the potassium loss and improved performance of this speculation.

The follow-up of the cultural itineraries and the contribution of potassium fertilizer allow the oil palm to express all its potential production, as well as significantly improving its agronomic performance. The contribution 2 kg of KCl/tree/year provides the highest productivity under the agropedoclimatic conditions of the Southeast of Côte d'Ivoire. The application of the appropriate cultural itineraries combined with the potassium fertilization could enable farmers to significantly increase their performance. Under these conditions, the current yield from 8 to 9 TR/ha/year, recorded on the village plantations, could pass to more 15 TR/ha/year, compared to the industrial plantations. Thus, the exploitation of oil palms become profitable, would increase the national production and would make it possible the country to achieve its objectives by 2020.

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