

Nutrient contents of Young Oil Palm Trees as Affected by Genetic Materials, Including Some Inbred Progenies

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Abstract — This study analyzes the composition of the 9th oil palm leaves for major and trace elements, as affected by the genetic variations of planted materials. The main objective is to evaluate how the genetic variations influenced the nutrient contents of leaves. The second purpose is to study the effect of inbreeding on the mineral composition of oil palm leaves.

The experiment was conducted with 10 oil palm progenies planted in randomized blocks. Two of the 10 were sib-crosses materials.

The leaf anions contents (N and P) showed low variation while the cations (K and Mg) revealed high variability, with the highest variations for the microelements. Significant differences for the 3 major elements (N, K and Mg) were found between the progenies. However, no significant differences were observed for P and all the trace elements (Mn, Fe, Zn, Cu). The trace elements were significantly correlated with the anions (N, P), except Fe.

It was also revealed that the oil palm inbreeding influences the nutrient contents in the 9th oil palm leaf by the form of reduced N and Mg and increased K.

Keywords — Oil Palm, Leaf Samples, Nutrient Contents, Inbreeding, Correlation.

I. INTRODUCTION

The optimal production of any crop is related to human and agronomic factors. Agronomic factors include the cultivation methods, the genetic materials and the mineral nutrition. As a perennial crop, the oil palm (*Elaeis guineensis* Jacq.) requires for its best growth and yield large number of mineral nutrients such as nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg). The nutritional status of this tree is usually evaluated by the determination of the leaf mineral composition, known as foliar diagnosis (FD). The actual mineral contents of leaves are compared with the optimal and critical levels. Reference [1] called the lowest leaf concentration at which the maximum yield is obtained the critical deficiency content (CDC), the critical concentration, or the critical level.

The studies carried out by the French organization "Institut de Recherches pour les Huiles et Oléagineux" (IRHO) have specified the critical levels of the main mineral elements for the 9th and 17th leaves of the oil palm in West Africa [2]. However, significant variations have been highlighted in the mineral levels, depending on the rank of the leaf analyzed, the age of the tree, the season or the year, the planting density, the fertilization, etc. ([3], [4], [5]). This often complicates the interpretation of the data. The genetic variation of the materials also exerts a significant effect on the mineral elements levels, although this aspect of the problem has apparently not been widely

discussed [6]. However, reference [7] has noted, for example, that an oil palm progeny shows a somewhat higher magnesium leaf concentration (Mg) equal to the double of other crosses planted in a same experience.

In the genetic program of oil palm improvement, it is necessary to inbreed some trees for the reproduction of the best materials ([1], [2], [8]). The high level of inbreeding, due to auto-pollination, significantly reduces the growth and production of palm oil [9]. Its effect on mineral contents, however, has never been demonstrated.

This study analyzes the effect of various genetic materials on the leaf mineral composition of the palm oil. In addition, the mineral contents of elements of sib-crosses are compared with those of the heterozygous progenies. The influence of inbreeding on the composition of the main mineral elements is therefore investigated.

II. MATERIALS AND METHODS

A. Experimental Site and Materials

The experiment was conducted in the research department of the company "Plantations et Huileries du Congo", located in the north of DRC (2°13'N, 22°56' E, 460 m as sea level), now called "Centre de Recherches et d'Expérimentations en Agronomie Tropicale de Yaligimba" (Creaty).

The annual rainfall of this equatorial region is 1,750 mm of water for 110 days of rain and the soil is a 'hygro-kaolinitic ferralsol' [10]. For the experiment, 10 tenera oil palm progenies were planted in the field, in a trial "YAL 67". These 10 progenies were differentiated in term of their parents. Two of these, Y378 and Y379, were sib-crosses and, therefore, characterized by a high rate of consanguinity. The cross Y385 had the same male parent as the two sib-crosses, but was heterozygous like the seven other outcrosses progenies (Y376, Y377, Y380, Y381, Y382, Y383, Y384). More details on the parents of the experimented progenies are given in Table 1.

The experiment materials were planted in randomized complete block design with 8 repetitions and covered 80 experimental plots. Each plot was planted with 10 palms of the same progeny. The planting density was 143 palms per ha. Palms were fertilized by the same manures applied in a circle around the collar, each palm receiving 500 g of KCl, 250 g of kieserite and 250g of rock phosphate. Leguminous cover crops of soil, mainly *Pueraria phaseoloides* L., were well-established during the development of the oil palm trees.

Table 1. Parent details of the ten oil palm progenies studied.

Female palm number	Male parent palm number					
	<i>E37/08</i> [‡] (Bg 271)	<i>E52/24</i> [‡] (Bg 271)	<i>E27/27</i> (Bg 414)	<i>B92/15</i> (Bg 142)	<i>B78/19</i> (Bg 142)	<i>E037/08</i> [‡] (Bg 143)
<i>D47/33</i> (Bg 030)				Y382	Y377	Y380
<i>A86/21</i> (Bg 143)		Y385			Y376	
<i>A137/30</i> (Bg 143)			Y384			
<i>E21/08</i> [‡] (Bg 271)	Y378	Y379				
<i>E11/10</i> (Bg 414)						Y381
<i>E27/27</i> (Bg 414)				Y383		

‡: Palm *E21/08*, *E37/08* and *E52/24* came from the same female and male parent (progeny Bg 271); Bg : Binga, a DRC research station. Palms with the same Bg code came from same parents. () : in brackets is given the code number of parent progeny.

B. Leaf Samples and Chemical Analyses

The foliage samples were collected 30 months after the planting of young palm trees from the nursery to the field. The collection technique involved first the identification of the 9th leaf and then cutting of 6 leaflets on each side of the rachis. A middle portion of 15 cm was taken from each leaflet. Leaflet portions from palms of the same plot were grouped, identified and dried.

The chemical analyses of the tissue samples were carried out in the plant analyses laboratory of the technical advisory department of the company "Brooke Bond Kenya", according to the standard procedures of plant analyses. The mineral contents of four major elements (N, P, K and Mg) were determined. Four essential micro-nutrients (also known as micro elements, minor elements or trace elements) contents of the leaf samples were also measured: manganese (Mn), iron (Fe), zinc (Zn) and copper (Cu).

C. Statistical Analyses of Data

The main statistical analyses were the coefficient of variation (CV), the analysis of variance (ANOVA), the simple correlation coefficient (r calc) and the T-test of Student (t-test). All these functions were calculated using the statistical functions of Microsoft Excel (Windows 10 Professional, V. 1511).

III. RESULTS

A. Experimental Site and Materials

The mean and CV of nutrient contents for the 80 experimental plot samples (10 progenies x 8 repetitions) are summarized in Table 2.

The major nutrient levels were close to or higher the critical levels set by IRHO for the 9th leaf of the oil palm in West Africa ([2], [11]) for the cations (K, Mg). However, for N and P, the values were respectively 7% and 11% below these limits.

The CV of N and P were 7% and 9% respectively, while those of K and Mg were higher, identical and equal to 15%. The ANOVA of the leaf mineral contents revealed that highly significant differences existed between the crosses for all the major nutrients (N, K and Mg), except for P. The N and K contents revealed some important differences between the progenies. The progenies Y378 and Y379 showed significantly lower difference for N compared to the other height crosses (Y376, Y377, Y380, Y381, Y382, Y383, Y384, and Y385). However, no significant difference was found among all these last progenies. The K

results seemed to be opposite to those of N. Thus, the same 2 progenies Y378 and Y379, in addition to Y382, had significantly higher K contents compared to the others while very low levels of K were noted in the other two crosses (Y384 and Y385).

Highly significant differences were also revealed between the crosses for the Mg content. These differences noted concerned only the crosses Y384 and Y385. These two crosses, which had the lowest K content, were also characterized by the highest Mg contents, significantly different from all the other progenies.

The leaf micronutrient levels were higher than those set up by IRHO. The ANOVA concluded on no significant difference between the 10 progenies for all the micronutrients. The CV of these trace elements were as follows: 24% for Mn, 35% for Zn and Cu, and 44% for Fe. These CV were higher than those of major elements, as the minor elements are usually present and useful at very low levels. Details of nutrient contents are also given in Table 2.

B. Mineral Contents of Inbreeding Progenies compared to the heterozygous crosses

The progeny Y378 (female palm *E21/08* x male palm *E37/08*) and Y379 (female palm *E21/08* x male palm *E52/24*) have same female and close male parents. In fact, the 3 crossed palms (female *E21/08* and male *E37/08* and *E52/24*) came from the same parents and could be considered as "brother and sister".

Table 2. Nutrient contents of oil palm leaves per progeny.

Progeny Code	N %	P %	K %	Mg %	Mn Ppm	Fe ppm	Zn Ppm	Cu ppm
Y376	2.60	0.16	1.21	0.24	636	114	20	7
Y377	2.51	0.16	1.31	0.23	556	88	18	8
Y378 [‡]	2.30	0.15	1.34	0.21	492	115	16	7
Y379 [‡]	2.34	0.16	1.48	0.23	442	91	20	7
Y380	2.59	0.16	1.25	0.24	529	93	24	8
Y381	2.57	0.16	1.20	0.24	550	98	22	8
Y382	2.63	0.16	1.39	0.24	528	89	22	8
Y383	2.49	0.16	1.31	0.25	564	116	19	9
Y384	2.58	0.16	1.01	0.28	590	98	17	8
Y385	2.53	0.17	1.09	0.28	555	123	16	7
Mean	2.51	0.16	1.26	0.24	544	103	19	8
Fcalc. [£]	4.22***	1.16	9.06***	3.21**	1.05	0.97	0.89	0.84
LSD 5%	0.15	n.s.	0.14	0.03	n.s.	n.s.	n.s.	n.s.
CV%	7	9	15	15	24	44	35	33
Ref. [§]	2.70	0.18	1.25	0.23	69	82	15	6



Table 3. Comparison of leaf nutrient contents of sib-crosses and out-crosses progenies in oil palm

Major elements	Anions (A)		Cations (C)		(A/C)
	N %	P %	K %	Mg %	
Sib-crosses (2)					
- Mean	2.32	0.15	1.41	0.22	1.52
- CV% of 16 plots	7	8	12	15	
Outcrosses (8)					
- Mean	2.56	0.16	1.21	0.25	1.83
- CV% of 64 plots	7	8	14	14	
Sib-cross/ Outcross %	91	94	117	88	83
T-test (P) [¥]	1.6-E05	0.011	2.4E-04	1.9E-03	
Microelements	Mn ppm	Fe ppm	Zn ppm	Cu ppm	Total Micro nutrients
Sib-crosses (2)					
- Mean	467	103	18	7	595
- CV% of 16 plots	17	61	37	31	
Out-crosses (8)					
- Mean	565	102	20	8	695
- CV% of 64 plots	23	38	36	28	
Sib-cross/Outcross %	83	101	90	88	86
T-test (P) [¥]	4.1E-04	0.193	0.178	0.483	

¥ P: calculated probability value, with number of degree of freedom of 79

These parentally close palms that were crossed therefore gave progenies with high inbreeding rate. Mean results of these two sib-crosses were compared with the average of the other height outcrosses progenies and data given in Table 3. The levels of N and Mg of sib-crosses respectively represented only 91% and 88% of the mean levels of the outcrosses. On the other hand, the sib-crosses level of K was higher by 17% compared to heterozygous progenies mean. However, the progeny Y385, with the male parent identical to the sib-crosses, showed nutrient content close to the other outcrosses.

The t-test of Student revealed significant differences between the two groups for the macro-nutrients. However, the differences were no significant for the trace elements, except for Mn.

The ratio of the sum of the concentrations of the anions (N, P) to that of cations (K, Mg), abbreviated as “A/C”, was 1.52 for sib-crosses, but higher and around 1.83 for outcrosses. Regarding the micronutrient composition, the leaf content of sib-crosses averaged only 83% to 90% of outcrosses, except in the case of Fe.

C. Study of correlations between nutrient contents

The correlations between different nutrients, calculated on the basis of the individual results of the 80 experimental plots, are detailed in Table 4.

Table 4. Coefficient of correlation between different mineral element contents

Nutrient ¥	N	P	K	Mg
P	0.51***			
K	-0.20	0.15		
Mg	0.11	0.06	-0.32**	
Mn	0.38**	0.30**	-0.27*	0.16
Fe	0.11	0.14	-0.09	0.05
Zn	0.28**	0.31**	0.28*	0.02
Cu	0.38***	0.21*	0.16	0.06
Nutrient¥	Mn	Fe	Zn	Cu
Fe	0.15			
Zn	-0.03	0.17		
Cu	0.07	0.17	0.25*	

¥ ndf = 78; Coefficient of correlation is significant at 5% (*), -1% (**) or -0.1% (***).

Leaf concentrations of anions (N and P) were significantly correlated while a negative significant correlation was revealed between the two cations, K and Mg.

In the micronutrient results, Mn, Zn, and Cu were significantly correlated with the anions (N and P). However, significant negative correlations were also found between K- Mn, and K- Zn. No significant correlation obtained between the microelements, except Cu-Zn. The Fe contents showed correlation with neither the major elements, nor the other minor elements.

IV. DISCUSSION

The ninth oil palm leaves collected 30 months after planting revealed mineral nutrient contents close to the optimum levels set by I.R.H.O. ([2], [11]), except for N and P which had low values. Therefore, the oil palm trees concerned in this study benefited from acceptable mineral nutrition. According to the CV, the mineral composition of progenies showed low variability for the anions (N, P) and large more variability for the cations (K, Mg). The highest variability was observed for the microelements. Tan and Rajaratnam (quoted by [1]) have also noted on the oil palm that the CV are significantly lowers for the anions compared to the cations.

The highly significant correlation noted between the levels of N and P confirmed the synergy of these two elements in the oil palm, as has been reported by a number of authors ([1], [7], [12], [14]). The well-known antagonism between K and Mg in the oil palm ([1], [13], [14]) was confirmed in this study through the significantly negative correlation of the two cations. In fact, the anions are the



constituents of proteins and nucleic acids, and thus explain their strong synergies. This is not the case for cations and trace elements, which often play the role of catalysts and can be absorbed in greater quantities than necessary, which is known as “luxury uptake”. This explains the observed large variability.

Genetic material was an important factor in the variability, as significant differences between the crosses were highlighted for the concentrations of various mineral elements. The progenies Y378 and Y379 which were differentiated from the others by the lowest levels of N and Mg, and highest K content, were derived from the inbred crosses, having very close female and male parents. In fact, the palm E21/08 used as female and the palm E37/08 or E52/24 as male came from the same parents. The coefficient of inbreeding (F_x), which is equal to the coefficient of relationship between parents, has been calculated according to the steps given by [15]. For the two concerned crosses (Y378 and Y379), the F_x calculated was closed to 0.50. References [1] and [9] found that inbreeding significantly affects several parameters of growth and bunch production in oil palm. Reference [15] has also emphasized the low level of gibberellins acid and disturbance in the meiosis due to the inbreeding depression. However, its effect on the mineral composition of oil palm, which has never been investigated, is revealed in this study. The low content of principal plant nutrient N could explain the depression in the growth and production of inbreeding oil palm. These low levels of N, i.e. below the optimal level, should be corrected with nitrogen fertilizer, in order to avoid compromising the future production of these trees, which may be used as mother palms in seed production programs.

A significant negative correlation found between the levels of N and K, although low, seems surprising and inexplicable in the light of the role played by K in the water economy of plants. However, reference [2] reported that oil palm yield responses to K were better correlated with levels of K in the rachis than with the leaf K content. Nevertheless, it is easier to take leaf samples.

For the micronutrient results, significant positive correlations were obtained between the anions (N and P) and Mn, Zn and Cu while significant negative correlations were found between K-Mn, and K-Zn. Close results were observed by [16], who concluded that K fertilizer in most cases significantly reduced Zn levels in the leaves of young oil palm in Malaysia. In contrast, reference [1] reported that high rates of N and P fertilizers increased the deficiency symptoms of Zn and Cu for the old palms, probably due to the increase in plant demand.

V. CONCLUSION

From this study, it is confirmed that the genetic material exerts a significant influence on the mineral composition of the leaves of young oil palm. Therefore, it is essential to take into account the progenies differences during the field planting and, also later during the leaf samplings in oil palm plantations.

On the other hand, the initial investigations in this study have revealed that the oil palm inbreeding significantly

depressed the leaf levels of N and Mg, but also increased the leaf level of K. However, other works are necessary to confirm these first conclusions.

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