Effect of chlorine on the hybrid coconut PB-121 in the Ivory Coast and Indonesia

Growth, tolerance to drought, yield

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An earlier article studied the tolerance to drought of a few coconut hybrids in the conditions of the mid Ivory Coast [1].

This is a region where, in spite of marginal climatic conditions for coconut, it is possible to grow this crop thanks to strict technical norms. The first is to give preference to the hybrid PB-121, which has proved to be the most resistant to juvenile diseases and drought [2].

Another important factor is the maintenance of a good qualitative and quantitative level of mineral nutrition satisfying the plant's requirements for its growth and yield, and also reinforcing its drought resistance.

This, the I.R.H.O. test points in the mid Ivory Coast have been completed by mineral nutrition experiments on PB-121 hybrids.

The aim of this article is to present the most characteristic results obtained to date in these experiments : CC 38 at Gregbeu, near Daloa, 220 km from the sea ; CC 39 at Manzanouan, near Abengourou, 180 km from the sea. They will be compared to those from the lower Ivory Coast in the Abidjan region, on CC 16 at the Marc Delorme Station, 6 km inland, and DA-CC 02 at the R. Michaux Experimental Plantation, 25 km from the sea (Fig. 1).

We will then see how important is the role of chlorine far inland, where the coconuts no longer benefit from **contributions** in the form of sea mist and solid particles deposited by the dominant winds blowing from the sea.

Recent results obtained in Indonesia will be compared to those of the Ivory Coast.

I. — SITE OF THE EXPERIMENTS

Experiments CC 38, CC 39 are planted on soils of ferrallitic character derived from weathering of the granites :

The first is on a plateau with a typical reworked red soil (20.7 p. 100 clay in the topsoil, increasing to 42.3 p. 100, 1 m down) (Table I). Prior to CC 38, the land was occupied by an abandoned coffee plantation invaded by shrubby bush. An analysis of the topsoil shows average organic matter and total N contents (1.84 and 1.70 p. 100 respectively) ;

On the other hand, the second is on a gentle slope about 200 m from the Manzan river, a tributary of the Comoe, where the soil is formed of sandy colluvials with coarse sand predominating (50.4 p. 100 at the surface) (Table I). The soil of CC 39 had been occupied by recent shrubby fallow which did not allow the organic matter stock to be reconstituted, explaining the low levels of organic matter (1.2 p. 100) and N (1.16 p. 100) in the topsoil.

Experiment DA-CC 02 is on a plateau where the very deep clay sands are formed on sedimentary deposits called « tertiary sands ». Experiment PB-CC 16 is South of the lagoons on a low plateau of which the soils compose a very sandy colluvial phase, different from those in the other experiment.

The P levels are low for soils formed over granites (CC 38/39), whereas they are very high for those derived from tertiary sands (DA-CC 02). There is a certain richness in exchangeable cations in the former, but not in the latter.

		CC 38	CC 39	CC 16
Ca^{++}	me/100 g	2.97	2.51	0.36
Mg^{++}	me/100 g	0.74	0.46	0.10
K^{+}	me/100 g	0.33	0.12	0.06

Inland in the Ivory Coast rainfall is lower but better distributed than in the South-East (Table II). The limiting factor is the dry season, which lasts 3 months, with a very low relative humidity provoking intense evaporation. In the South-East the severity of the drought is tempered by the proximity of the sea.

In the sub-soil of CC 39 there is an alluvial-type water table close to the surface in the rainy season (1-2 m deep). It drops steadily down to 3 m in the dry season. To a certain extent this water table compensates the water deficit in the earliest dry months.

In the other experiments, on the contrary, the very deep water table is not reached by the coconut roots.

The dry seasons in 1980/81 and 1981/82 were particularly marked in the inland Ivory Coast, with long periods of Harmattan (a dry wind blowing southwards from the Sahara) during which the temperature fell to 9.5° and the average relative humidity was between 50 and 70 p. 100.

By contrast, in the South during the dry season the relative humidity remains high because the sea is close ; the Harmattan only hits the coast for short periods in January and February.

II. — EXPERIMENTAL DESIGN

The four experiments are of the factorial type :

CC 38 :
- 3^2 replicated twice = 18 plots studying P and K at 3 levels ;
- with complementary study of Mg by splitting of the plots ;
- a 0 level for P, K and Mg.

Started in 1979.

CC 39 :
- 2^4 studying N, P, K, Mg at 2 levels = 16 plots in 2 blocks ;
- a 0 level for each element (with or without).

Started in 1977.

CC 16 :
- 3^3 = 27 plots in 3 blocks studying P, K and Mg at 3 levels ;
- with complementary study of N by splitting of the plots ;
- a 0 level for each element.

Started in 1970.

DA-CC 02 :
- 3 × 3 × 2 replicated twice = 36 plots in 2 replications of 3 blocks, studying K and Na at 3 levels and Cl at 2 ;
- a 0 level for K and Cl (Cl^- being replaced by SO_4^{--}) ;
- uniform application of N, P and Mg.

Planted in 1975.

The fertilizers used are :

N = urea at 46 p. 100 N,
P = tricalcium phosphate at 35 p. 100 P_2O_5,
K = potassium chloride at 60 p. 100 K_2O,
or potassium sulphate at 50 p. 100 K_2O,
Mg = kieserite at 25 p. 100 MgO,
or magnesium chloride at 12 p. 100 MgO,
Na = sodium chloride at 39 p. 100 Na,
or sodium sulphate at 14 p. 100 Na.

They were applied from planting at rates increasing with age.

The four experiments received a *Pueraria javanica* cover which developed well on the primary soils (CC 38 and CC 39), with greater difficulty on the poorer tertiary sands.

Maintenance was always done by hand, and consisted in selective weeding and slashing of the cover, the circles round the palms being kept clear.

III. — RESULTS IN THE MID IVORY COAST

1. — Growth. Girth.

Measurements taken at 26 months for CC 39 and 36 months for CC 38 show that only the potassium chloride applications produce a significant effect, with a positive K-Mg interaction.

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CC 38					CC 39		
Girth at 36 months (cm)					Girth at 26 months (cm)		
(—) 91.4					(—) 99.1		
P1 92.1					N1 99.9		
P2 93.8					(—) 100.6		
					P1 98.4		

K-Mg interaction (CC 38)

	(—)	KCl 1	KCl 2	Mean
-)	50	106	109	88
Mg	66	106	118	97*
Mean	58	106**	114**	

K-Mg interaction (CC 39)

	(—)	KCl	Mean
(—)	96	106	101
Mg	79	118	98
Mean	87	112**	

— Precocity of flowering.

he positive effect of KCl on growth is repeated on precocity of ering. Interaction with Kieserite is also positive.

CC 39 — p. 100 trees flowering at 44 months

		(—)	KCl	Mean
-) = 41.4	(—)	36	54	45
= 50.0	Mg	14	73	46
-) = 44.5				
= 46.9	Mean	25	66**	

— Tolerance to drought.

ring the earliest rainy seasons, attacks of *Pestalozzia palma-* were noted in CC 39, on the tips of the leaflets of trees recei- no KCl.

the course of the 1980/81 and 1981/82 dry seasons, there en more drying of the same trees, which induced us to com- the number of living leaves in each treatment at different of the year (Table III).

e trees getting KCl emerged from the last two dry seasons many more living leaves (Fig. 2, 3), mainly reflecting lesser g of the foliage during the dry season.

us, KCl appears to be an essential fertilizer in mid Ivory conditions, since in addition to its favourable effect on th and development it reinforces the resistance of the trees to funguses and **drought.**

— Interpretation of the results.

ause of the increased knowledge of chlorine flowing from servations of Ollagnier and Ochs [1971], and in view of the ce from the sea of CC 38 and CC 39, the results of the trials studied in function of both K and Cl.

the hybrid coconut, PB-121, the critical K level is 100 d.m. for leaf 14. Whilst the critical Cl level has not yet defined exactly, 0.5 p. 100 d.m. for leaf 14 is esteemed close imum. A level below 0.100 indicates a severe deficiency.

leaf analysis results from CC 39 (Table IV) clearly show a g **Cl deficiency**, whereas the K levels are close to the critical

the end of the 1980/81 dry season, the number of green lea- more closely related to the Cl level than to that of K :

els — number of living leaves (Cl constant) r = 0,420,
els — number of living leaves (K constant) r = 0.893**.

July 1981, the superphosphate treatment was replaced by m chloride so as to study Cl by itself ; the KCl was replaced assium sulphate.

en the 1981/82 dry season ended, out of the 8 plots recei- no KCl, there was a marked improvement in the performance 4 plots which got a sodium chloride dressing 8 months pre- ly.

CC 39 — Number of living leaves at the end of the dry season (on the 8 KCl 0 plots)

	March 1981	March 1982
Without NaCl	10.2 (100)	12.5 (122)
With NaCl	9.3 (100)	14.8 (159)

The co-variance analysis shows that the effect of Cl is highly significant.

Leaf analysis of CC 38 also show a severe Cl deficiency.

CC 38 — Leaf analysis, January 1982 (Rank 14)

	K (p. 100)	Cl (p. 100)
(—)	1.263	0.109
KCl 1	2.113	0.673
KCl 2	2.339	0.915

On the outcome of the 1981/82 dry season, the number of living leaves depends more on the Cl levels than on the K ones :

K levels — number of living leaves (Cl constant) r = + 0.113,
Cl levels — number of living leaves (K constant) r = + 0.511**.

The fact that Cl is essential is confirmed once again in the mid Ivory Coast ; it is not only indispensable to growth and development, but also to **drought resistance.**

Burghardt [4], in a synthesis published in 1962, studied the roles of the Cl^- and SO_4^{--} ions in cultivated plants. He notes that Cl is antagonistic to sulphur, and also reports that Schmalfuss has shown in pot culture that the Cl^- ion increases water absorption and reduces transpiration by stepping up osmotic pressure within the cells. This is due to the accumulation of starch through a change in the starch-sugar ratio. By weighing, an improvement is noted in the weight of dry matter produced per unit of water, whereas the SO_4^{--} ion has the opposite effect.

5. — Effect of Cl on health.

Drought resistance seems to go hand in hand with resistance to leaf diseases of fungal origin. It has already been noted that *Pestalozzia palmarum* were worst in the K0 treatments of CC 39.

The same observation was made in 1979 in a mineral nutrition experiment at the Daloa test point. Here it was a question of *Helminthosporium* attacks, the intensity of which **increased** in proportion to **Urea** applications but **dropped** as **KCl** dressings rose.

Treatments	LA (Rank 1) K (p. 100)	Cl (p. 100)	Helmintho. index
(—)	2.941	1.009	0.07
N1	2.626	0.865	0.42
N2	2.641	0.807	1.04
(—)	1.827	0.323	0.80
KCl 1	3.081	1.111	0.26
KCl 2	3.299	1.246	0.43

The favourable effect of Cl on the health of the coconuts, as well as the unfavourable one of N, were observed by Fremond [1976] in a 3^3 factorial experiment in the nursery conducted in the Philippines. *Pestalozzia* attacks were marked 0-5 according to the degree of necrosis.

	N0	N1	N2	
Cl 0	2.28	3.11	3.44	2.94
Cl 1	1.05	1.44	2.33	1.94
Cl 2	1.39	2.22	2.44	2.02
	1.57	2.59	2.74	

One of the authors of this article noted heavy *Pestallozia* attacks in the Menado region (North Sulawesi), accompanied by Cl levels close to 0.06 p. 100.

Alonzo and Palomar [1980] also report that in the Philippines the application of sea water at the rate of 200-1,000 ml or 20-100 g sea salt to the base of Malayan Red Dwarf coconuts aged 6 months reduces the incidence of *Pestalotiopsis palmarum* on the leaves. The mechanism of this action of Cl is not really known yet.

IV. — ACTION OF Cl IN THE SOUTH-EAST IVORY COAST

Experiment DA-CC 02, of which the results are condensed in Table V, shows :

— an unquestionable effect of K, which practically doubles the number of nuts and slightly increases copra/nut ;

— an equally indubitable effect of Cl, which increases the number of nuts by nearly 50 p. 100 and the copra/nut by about 17 p. 100 (chloride/sulphate comparison). This effect occurs because the leaf Cl levels in the plots without Cl are very low, less than 0.100 on average ;

— an average nil effect of increasing rates of Na on copra/nut, and a non-significant one on number of nuts. This experiment was designed without a 0 level for Na (sulphate or chloride) ; in such conditions, it cannot verify very accurately whether, for the coconut as for certain other plants, Na can replace K to some extent ; this seems unlikely, since the effect of K, either chloride or sulphate, remains very considerable, in the presence of NaCl as well as in that of the sulphate form of sodium.

In other respects, the correlations between K and Cl levels and yield in copra/tree are positive and significative (0.621** and 0.687***), whereas that between Na level and yield is negative (− 0.626**).

In 1978, the partial correlations « Cl and K levels — development » showed that girth was related positively both to K and to Cl :

Cl level — girth (K constant) r = 0.657**,
K level — girth (Cl constant) r = 0.640**.

In experiment CC 16, on the other hand, the native Cl levels are higher, and an examination of the correlations « Cl and K levels — development or yield » shows the preponderant role of K.

CC 16 — Leaf analysis, February 1974 (Rank 9)

Rate	K levels	Cl levels
KCl 0	0.850	0.176
KCl 1	1.608	0.406
KCl 2	1.755	0.531

Correlations « LA levels — precocity of flowering » :

Cl level — p. 100 trees flowering (K constant) r = + 0.412**,
K level — p. 100 trees flowering (Cl constant) r = + 0.736***.

Similarly, the last four seasons' production results also demonstrate the exclusive action of the K^+ ion.

CC 16 — Leaf analysis : Average 1978/79/80/81 (Rank 14)

Rate	K levels	Cl levels
KCl 0	0.482	0.260
KCl 1	1.370**	0.480**
KCl 2	1.646**	0.650**

Correlations « LA levels — production » :

Cl level — production (K constant) r = − 0.153,
K level — production (Cl constant) r = 0.580**.

V. — DISCUSSION

As the coast is approached, Cl becomes of lesser importance.

Taking a theoretical yield of about 4.5 t copra/ha, the quantities of nutrients exported in the nuts (shells, husks and albumen) are in the region of : 76 kg N, 9 kg P, 162 kg K (including 129 in the husks), 9 kg Mg, 111 kg Cl (including 102 in the husks), according to the work of Ouvrier at Port Bouet, Ivory Coast [1982].

These exports or immobilisations are even greater in plantations where the stalks are used in the boilers, and if the quantity of elements contained in the stem is also taken into account.

It is perfectly understandable, therefore, that the Cl balance becomes negative, since the studies by Delmas and Djouka [1983] on the dry and wet chlorine deposits in the Ivory Coast speak of a very large contribution along the coast (nearly 100 kg/ha/year between 1 and 10 km from the sea), diminishing inland. Two hundred km from the seaboard, the deposit is less than 20 kg/ha ; the sharpest drop occurs in the first 50 km.

The comparison of the native Cl levels in leaf analysis and the importance of its role situate its critical level :

CC 16 (LA 1981)
Treatment K0 — Rank 14-K = 0.480 — Cl = 0.260 ;
No effect of Cl on growth and yield of the coconuts.

DA-CC 02 (LA 1982)
Treatment K0 — Cl 0 — Rank 14 — K = 0.388 — Cl = 0.098 ;
Action of Cl as great as that of K.

CC 39 (LA 1982)
Treatment K0 — Rank 14 — K = 1.105 — Cl = 0.051 ;
Predominant effect of Cl.

CC 38 (LA 1982)
Treatment K0 — Rank 4 — K = 1.263 — Cl = 0.109 ;
Predominant action of Cl.

It was shown by leaf analyses made in 1980 on different leaf ranks that the Cl levels varied little compared to those of K. It can therefore be accepted that for a leaf of rank 14, in Ivory Coast :

— there is no Cl deficiency when the levels are above 0.250 p. 100 d.m.,

— there is a slight deficiency between 0.150 and 0.250,

— there is a serious one below 0.150.

These figures should be modified when all the experiments are in bearing.

Indeed, it is not impossible that 0.250, while sufficient to ensure maximum yield, is too low to give the highest resistance to leaf diseases and drought as well as the greatest copra/nut, in which case the optimum level of 0.500 mentioned previously and based on experiments in different parts of the world would be equally valid for the Ivory Coast.

Fertilizer experiments are now going on in Indonesia on the hybrid PB-121. We can site that at the Bah Lias Estate.

(London Sumatra), of which the first results have been published by Rosenquist [1980].

This experiment has been set up on coconuts planted in 1974 and the 1980 results can be summarized as follows :

	No. of nuts per tree	Copra g/nut	Copra kg/ha	Leaf levels K	Cl
KCl 0	87 (100)	131 (100)	1,764 (100)	1.50	0.12
KCl 1	94 (109)	177 (135)	2,608 (148)		
KCl 2	100 (115)	187 (143)	2,921 (166)	1.60	0.53

The K nutrition level is excellent, and above the Ivory Coast cri-ical value without any K fertilizer.

On the other hand, the Cl levels without chlorine application e very low, and fall in the category of serious deficiency in the ory Coast (less than 0.150).

The considerable effect of KCl on yield, exerted mainly on the umen, **is entirely due to Cl.**

Figures 4 and 8 show the great effect of Cl on the crown : **many** y and broken **leaves** without this element.

Bah Lias Estate is on the coastal plain of North Sumatra where ere is also a dry season early in the year (mean rainfall 968/80 : 1,803 mm, Table II).

The second experiment is at PTP X, South Sumatra, Lampung ovince, and was planted in January 1977. Figure 5 shows that in ovember 1982 there was a great difference in vegetative appea-nce between plots with or without KCl. From Figure 9 it can be en how extensive is the dessication resulting from a Cl ficiency.

In the 1982 LA, rank 14, the K and Cl levels were :

	K	Cl
KCl 0	0.796	0.046
KCl 2	0.819	0.412

It is to be noted that there was an intense drought in Lampung 1982.

Although the K level is below the critical value, the slight diffe-nce in leaf K between the plots with or without KCl is an insuf-ent explanation of the surprising disparity in performance pending on whether or not the palms receive KCl, and which n only be attributed to the Cl deficiency (**very low level, 0.046, the controls**).

The third experiment, at PTP VI, North Sumatra, was planted 1977 at Bangun Purba. The K and Cl levels (rank 14) were :

	K (1982)	Cl (1982)
KCl 0	1.56	0.040
KCl 1	1.65	0.307

The number of nuts/tree is increased by 24 p. 100, copra/nut 47 p. 100 and copra/tree by 79 p. 100.

In other respects, there is a big difference in development bet-een plots with and without KCl. The K level in the controls is ove the critical value ; **their Cl level (0.040) is extremely low.** gures 6 and 7 show a very large effect indeed of Cl on the vege-tive appearance of the trees, their development and yield.

The results obtained in the Ivory Coast are also verified in donesia, where it proves that there are severe Cl deficiencies in th North and South Sumatra, the consequences of which can be bstantial, especially in dry years.

Chlorine has a certain number of non-specific functions in ants. It raises osmotic pressure in the cells, with a resulting crease in hydration of the tissues because this ion is hydrophilous engel, Kirby, 1978].

The coconut is a plant of halophytic tendency with good tole-nce to common salt in the soil. Plants of this type usually need high concentrations of electrolytes in their cells to grow and equi-librate their water balance.

In this context, the manifestations of Cl deficiency seen on coconuts in the Ivory Coast and Indonesia can be interpreted as the inability of the plant to maintain its water potential at suffi-ciently low values because of the deficiency in monovalent anions.

Studies of stoma opening are going on in the Ivory Coast and Indonesia, using the isopropyl alcohol method. The basic hypo-thesis is that in deficient coconuts stoma opening should be less durable, both during the dry season and during the day. It appears to be verified in Indonesia, where the phenomenon has been studied in a fertilizer experiment in the Medan region (Ban-gun Purba, PTP VI) in North Sumatra ; the same tendencies appear in this trial as in the preceding ones : serious Cl deficiency and high K nutrition in the controls without KCl.

After a drought period in February 1983 (0 mm), average stoma opening is 3.7-6.8 without KCl, against 4.8-7.0 with it (0 = com-pletely closed stomata, 12 = stomata fully open).

CONCLUSION

Four I.R.H.O. experiments in the lower and middle Ivory Coast at various distances from the ocean have improved know-ledge of the **essential aspect** of Cl in coconut nutrition.

On the basis of the results obtained, a critical level of 0.250 p. 100 d.m. in leaf 14 can be proposed.

When the levels are below 0.100 (a very severe Cl deficiency), growth and development slow down and there is a drop in yield (DA CC 02, 25 km from the ocean). Identical observations as to growth and development are made in experiments CC 38 and CC 39, 180 and 220 km inland, and there is every reason to think that the same will occur for yield (observations are going on in CC 39).

It is also found that in this situation there is **less drought resis-tance and greater sensitivity to fungus diseases.**

Obviously, in these extreme cases distance from the coast is determinant, since Cl is transported in aerosol form by the domi-nant winds which, in the Ivory Coast, blow from the S.W. and therefore from the sea.

Thus, in the inland Ivory Coast KCl would seem to be the most advantageous fertilizer, as it provides not only potassium of which there is a medium deficiency, but above all chlorine, which together with water is the prime limiting factor.

In Indonesia, where the programme for the extension and rege-neration of the coconut plantations with the hybrid PB-121 is very substantial, it is very important to make a more thorough study of Cl deficiency for several reasons :

— it is problably more acute in precocious and fast-growing material such as Dwarf × Tall hybrids than in Indonesian Talls ;

— traditionally coconut was grown on the coastal fringes where there are large dry Cl deposits. Diversification policies often lead to its being planted further inland where deposits are smaller, which explains why deficiencies can occur with an inten-sity hitherto unknown. It would be interesting to know the Cl deposit balance in different situations ;

— it would be worth-while proving the essential role of Cl in coconut nutrition from a physiological standpoint, since some years ago **physiologists** were still casting doubt on the function of this element in plants grown in the open air [Corley, 1976]. In fact, since there are soils and situations in North and South Suma-tra which are deficient in Cl but not in K, it is essential to avoid any confusion about the nature of the deficiency, K or Cl, and if it is the latter, to use sodium chloride which can be produced abundatly in the various salt works around the Archipelago rather than import potassium chloride, so costly in foreign currency.

In the Ivory Coast and in Indonesia, Cl deficiency results in a reduction in the number of nuts/tree, and even more in copra/nut, and this has been amply demonstrated in the Philippi-nes as well [Palomar, Magat, Habana, 1980].