

Mineral nutrition and fertilization of the coconut around the world ⁽¹⁾

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II. — STUDY OF THE DIFFERENT ELEMENTS (continued)

3. — Potassium.

Potassium is reputed to be of considerable physiological importance, but its role in the formation of yield remains a mystery (Conclusions of the International Potash Institute Congress, Berne, 1978).

It is thought to be important to the plant's metabolism, in accelerating the movements of the stomata (water economy), in activating the enzymes, in the transport of metabolites and in cell division. These points have been little studied for the coconut, or have not yet been.

a) Deficiency symptoms.

For a leaf of rank 14 the critical level is 0.80-1.00 p. 100 of dry matter for Tall varieties. For the new hybrid material, particularly the P-B 121, the level determined by the I. R. H. O. has been raised to 1.40 for the period prior to maximum production.

The first visual symptoms appear on the leaf let as follows :
— rust-coloured spots in two longitudinal bands on either side of the central rib, their diameter ranging from 0.5 to 3-4 mm ;
— slight yellowing of the lamina, more marked towards the tip of the leaflet.

Thereafter, the yellowing gets worse, leaving only a narrow median band still green, thinning down to necrosis. The rusty spots invade the whole leaflet and form large patches of irregular outline.

The visible potassium deficiency is characterized by yellowing of the leaves in the middle of the crown in the early stages and drying up of the lower leaves in the last ones.

The deficiency symptoms are not clearly visible when the levels are between 0.4-0.5 and the critical level.

b) Causes.

The causes are linked mainly to the soils, which rarely possess the large quantities of potassium required by the coconut.

The analyses results given in Table I confirm that numerous coconut plantations in the world suffer from potassium deficiencies:

This is the case of the tertiary and quaternary sands of West Africa, of the coastal sands of Sambava (Madagascar), of the coral soils of the Oceanian atolls, of the exhausted lateritic zones of India, of the sandy soils on the East coast of Sri Lanka, where the K levels are below 0.15 me/100 g.

On the other hand, in Indonesia, the Philippines, Viet Nam, Cambodia and Malaysia there are lands with a high native potassium content, over 0.30 me/100 g, and which cover vast areas. But this initial richness can be heavily compromised by very exhausting food crops, for example cassava.

c) Correction by mineral manuring.

Potassium deficiency is frequent ; it is easy to detect by leaf analysis if the visual symptoms are insufficient to make it absolutely evident.

It is present in the New Hebrides, Madagascar, Mozambique, Jamaica, the Ivory Coast, Togo, Benin, Mexico, in certain parts of Malaysia, in New Guinea, in the Solomon Islands, in Sri Lanka, in India, in Brazil...

Experiments have mainly been done on the traditional Tall material. The arrival of the hybrid coconut, whose abundant production increases uptake [9], has brought the need for bigger potassic manuring. A series of new trials was therefore set up, 19 for the Ivory Coast alone.

The effects of potassium are very marked on the poorer soils such as the tertiary and quaternary sands of the Ivory Coast (Table VIII).

In this respect, when the I. R. H. O. started its experimental programme in 1952 the responses to potassium were immediate and highly conclusive. Its action is manifest in all the production factors : number of inflorescences and bunches/tree, number of flowers/bunch, number of nuts/tree, copra/nut ; and consequently in the quantity of copra produced by the tree in a year. Experiment PB-CC 1 provides interesting information. Without potash, the mean yield for 6 years is 980 kg copra/ha/year ; with the application of 1.5 kg potassium chloride/tree/year, yield rises to 2 100 kg copra/ha/year ; production is **more than double**.

Still within the framework of I. R. H. O. experimentation in the Ivory Coast, trial PB-CC 3 confirms the spectacular action of potassic manuring on yield, and shows that the harm done to the trees by a lack of potassium during immaturity is irremediable. The trees which have received potash manuring from the time of planting always produce more than those which only got it at maturity. The deficit persists, and stabilizes at 15-20 p. 100 [35].

If experiment PB-CC 5 has confirmed high profitability of potassic fertilizer, it has also shown that it should be applied annually, the residual effect of a double rate every two years being less than the annual action of a single rate.

In India, Kunhi Muthiyar et al. [18] consider that the increased yield due to correction of the potash deficiency is essentially due to the increase in the number of nuts and not to the combined increase in the number of nuts and the copra per nut.

Similar observations have been made in the New Hebrides by the I. R. H. O. ; on coral soil the increased production brought about by potassium manuring is due to the larger number of nuts only.

Sunbak [32] in Papua-New Guinea obtained a yield increase by potassium application, but was not able to show that it affected the number of nuts and the copra per nut simultaneously. However, it does seem that in the experimentation undertaken the richness of the soils in exchangeable K is relatively high (0.26 me/100 g) and that the major effect is obtained by sulphur applications ; moreover, the author states that potassium sulphate proved better than the chloride.

There are therefore cases where potassium deficiency shown up by leaf analysis is difficult to correct by mineral manuring. This has been observed in the New Hebrides in trial NH-CC 8 on rich clay plateau soils (K = 1.04 me/100 g between 0 and 20 cm down, and 0.64 me/100 g between 20 and 40 cm), where in spite of relatively low K levels (0.582 p. 100 dry matter) the application of potassium fertilizer has no action on the K levels and yields. Here is a case where the soils have a low power of fixation (illites).

On coral soil in Polynesia, two years elapse after the first fertilizer dressing before it starts to take effect on the yield of mature trees, even though the leaf levels rose very quickly.

On more developed coral soils, as in experiment NH-CC 6 in the New Hebrides, it is again the potassic deficiency which is the limiting factor for production, and the application of potassium chloride is accompanied by an increase in the K contents and in the copra per tree.

Foale [42], in the Solomon Islands, also working on Tall material, obtained spectacular effects with potassium. In replanting, increasing annual rates of K significantly increased the height of immature trees ; by 10 years old production was 60 p. 100 higher for the manured trees. In another experiment, potassium has tripled the yield of the control plots. Foale, who made great use of leaf analysis as a means of studying deficiencies, says that following the setting up of two new trials he found that

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the fertilizers applied remained without action on the levels and yields, the various element contents being close to the critical level.

We can thus conclude that for soils of volcanic origin with a high exchangeable K content, coconut nutrition reaches values close to the critical level; potassic manuring then has no action on the leaf K levels and on the development of the plant or the yield.

When the deficiency in another element is corrected, the increased production which results from this may eventually induce a potassium deficiency, since the latter is the element with the biggest uptake. This phenomenon is patent in Mozambique, where correction of nitrogen deficiency raises yields and provokes the fall of the P levels. The same thing happens in the Polynesian atolls, where better maintenance and the correction of iron and manganese deficiencies make potassium applications necessary.

We saw in Table VI that better nitrogen nutrition improves the growth of young plants but leads to the dilution of potassium.

Coomans [14] has shown that potassium levels are strongly influenced by production. This remark is all the more important in that the hybrid material is likely to produce four to six times as much as the Tall coconut.

Fertilizer experiments on hybrids are few and relatively recent. Trial PB-CC 16 is the oldest on hybrids of Malayan Yellow Dwarf × West African Tall and Equatorial Guinea Green Dwarf × WAT, and it started in 1970. The effect of potassium made itself felt right from the start, significantly increasing girth.

This element also has a spectacular effect on the number of inflorescences emitted by the tree; K applications triple them. The beneficial action of potash fertilizer is intensified in yield by its action on the number of nuts and the copra per nut, the total copra being more than doubled.

The I. R. H. O. studies have very clearly demonstrated the highly significant correlation between K levels and copra production per tree. However, the study of potassium cannot be dissociated from that of the other cations, as there are close relationships between them [11]. We will see this in the chapter dealing with the relationships with other elements.

The figure 3 shows how yield progressed in the K0 and K3 plots from 1955 to 1968 in experiment PB-CC 1; the annual rainfall and the cumulative annual water deficit are represented for year n — 1.

The yields of plots K0 and K3 follow the same trend; those of the K3 plots are always higher than those of the K0 (effect of potassium).

Between 1955 and 1961, there were only two water deficits over 200 mm, one of 340 mm and the other of 590 mm. During this period yield does indeed depend on rainfall and the water deficit, but the mean yield remains relatively constant.

On the other hand, from 1962 on yield fell progressively and in function of high water deficits, some over 380 mm (5 were between 380 and 590 mm, 2 less than 200 mm). Each time the deficit was at a minimum, production rose — 1963/1964 and 1965/1966.

The liaison « last year's rainfall/yield » is good. The rainfall and production curves are similar; increased rainfall leads to increased production the following year. However, this is not always so when the water deficit is over 400 mm and the annual rainfall close to optimum (1 800-2 000 mm), but this is explained by the fact that the soil water reserves are insufficient during the dry season, e. g. the K0 plots in 1962/1963.

Finally, after a dry period, yield increases to a greater extent in the plots which are manured (Table IX).

In conclusion, there is a good relationship between yield, rainfall and water deficit. A drop in production follows decreased rainfall, and the worse the water deficit and the more accentuated the nutrient imbalance, the bigger the reduction in yield. Good mineral nutrition gives the coconut a better chance of getting through the driest season, and there is a considerable yield gain compared to unfertilized trees.

Let us mention here a highly significant positive relationship found in trial PB-CC 3 on Tall material, between mean annual production for the last 11 years and growth at an early age expressed in girth (cm) at 57 months or the number of leaves emitted in 67 months from planting. The coefficients of correlation below:

- mean annual production in number of nuts/tree and girth at 57 months (Fig. 4) $r = 0.77^{***}$
- number of leaves emitted in 67 months (Fig. 5) $r = 0.60^{***}$
- mean annual production of copra/tree and girth at 57 months (Fig. 6) $r = 0.75^{***}$
- number of leaves emitted at 67 months (Fig. 7) $r = 0.54^{***}$

show that the improvement of growth in the early years results in increased production.

Where there is a deficiency, therefore, mineral manuring is indispensable right from the beginning.

d) Relationships with other elements.

The study of potassium has shown the antagonisms between

K-Ca, K-Mg and K-Na. Nevertheless, the K-Mg liaison is much closer than that of the other two couples.

It was in 1955 that the I. R. H. O. proved that there was a general relationship between K and Mg. The application of high potassium chloride rates can induce a severe magnesium deficiency. The table which follows is drawn from a trial dating back to 1955; the massive application of potassium provokes an outstanding drop in the three cations, Ca Mg and Na.

Applications per tree in 1955	Levels in February 1957					
	N	P	K	Ca	Mg	Na
Control (PB-CC 1)	1.80	0.091	0.20	0.495	0.567	0.166
5 kg KCl	1.75	0.097	0.98	0.507	0.188	0.294
10 kg KCl	1.74	0.094	1.38	0.401	0.159	0.234
15 kg KCl	1.74	0.097	1.55	0.392	0.125	0.181

In 1961 it was thought that there was a synergism for low K levels and an antagonism for the highest ones.

In 1970 Brunin [43], working on Tall material, noted that for K levels between 0.7 and 1.2 the application of high rates of Mg fertilizer significantly reduced K. However, the same author concludes, after observing other experiments, that while there is a very good relationship between leaf Mg and yield ($r = 0.616^{***}$), the extra production which can be expected from magnesium manuring when Mg is below the critical level will only be obtained once the potassic deficiency is corrected.

Coomans [44] in 1977 notes the heavy magnesium deficiency induced in hybrids by potassic fertilization. Magnesian manuring, on the contrary, has no effect on the leaf potassium levels. The action of potassium is preponderant, and the effect of magnesium only manifests itself in the presence of K.

In 1978 the I. R. H. O. pursued the study of the K-Mg interaction on the hybrid P-B 121 in experiment PB-CC 16. The results obtained are all the more credible in that the observations cover four years of production.

Cumulative production in copra/tree from December 1974 to July 1978

	Mg0	Mg1	Mg2	Main effect of K p. 100	
K0	33.0	32.6	32.9	32.8	100
K1	66.6	77.4	75.0	73.0 **	223
K2	41.0	88.1	88.7	72.6 **	221
Main effect of Mg p. 100	46.9	66.0 **	65.5 **	100	141
	100	141	139		

Unlike potassium, which acts both on the number of nuts and the copra/nut, magnesium acts only on the number of nuts and has no effect on the copra/nut.

The study of the relationships between nutrient levels and annual production of copra/tree has shown the predominating action of potassium ($r = 0.72^{**}$, campaign 1976-77) and the absence of a correlation between the Mg levels and yield; it is only at the level of K constant that the partial correlation Mg contents/yield becomes significant ($r = 0.52^{***}$). This result confirms those of Brunin and Coomans, as it is only when the potassic deficiency is corrected (level above 1 p. 100 K) that the magnesian manuring has a positive action on production.

In the conditions of soil fertility in the Ivory Coast, the work done by the I. R. H. O. has made it possible to predict the maximum yield of the hybrid P-B 121 taking into account the combined effect of potassium chloride and kieserite.

Critical levels of 1.4 for K and 0.20 for Mg correspond to this maximum yield.

e) Evolution of the critical level.

The critical level for potassium has been revised several times as experimentation progresses.

The interpretation of trial PB-CC 1 led to the critical level being fixed at close to 0.45 p. 100, taking into account the best yields obtained at the time with Tall material on sandy soils of mediocre fertility. In 1962, following the latest results from the same experiment, the critical level was raised to 0.8-1.0 p. 100 of dry matter.

In other regions, several researchers undertook to define critical levels and to compare them with those of the I. R. H. O. Kanapathy [39] finds a good concordance between the I. H. R. O's levels and the observations made in Malaysia both on Dwarf and Tall varieties. In the Philippines Magat [33] does not contest the critical level for K, but has reserves about those for Ca and Mg

initially defined by the I. R. H. O. as 0.50 and 0.30 respectively, which cannot be applied to all situations.

For magnesium, Magal's observation agrees with the latest I. R. H. O. publications, which give a critical level of 0.20-0.24, determined according to the results of experiment PB-CC 16.

4. — Calcium.

Calcium is not a very mobile element; it plays a part in the formation of cell walls (insolubilization of pectic acids), in the elasticity of the cells in course of elongation and in enzymatic actions.

The visual symptoms of calcium deficiency were observed in 1979 with Ca levels below 0.100 in experiment DA-CC3 in the Ivory Coast which studied the effects of an N, K and Mg mineral manuring on Malayan Yellow Dwarf. The tips of the leaflets become yellow — yellow — orange ring — shaped spots spread on the leaflets. They become necrotic then brown. The leaf dries up. The symptoms can affect the middle leaves before the oldest.

The critical level of 0.50 which was retained was never determined by experimentation; it is more the level of balance observed when the other cations, potassium and magnesium, are close to their optimum (critical) level. Very much lower values do not seem to have any consequences for yield. Thus, an experiment carried out on Dwarfs in Malaysia (United Plantations Berhad), where the levels were about 0.3, gave no results.

Magal [33] had already found the same thing in 1975, and considered that levels of 0.33-0.35 were acceptable.

In experiment PB-CC 23 on Talls in the Ivory Coast, the application of Ca in the form of calcium carbonate — 50 p. 100 CaO for four consecutive years never modified the Ca levels in the leaves (variations were less than 2 p. 100), and had no influence on yield.

Table X, which gives the Ca contents in the different experiments studied, indicates levels of 0.20-0.40 for adult trees, 0.50 being reached on coral soils. In the early years, the levels can be below 0.20 [Coomans, 44] and show the characteristic symptoms of deficiency for the lowest levels.

The calcium contents are appreciably increased by nitrogenous or phosphated fertilizers. Potassium manuring tends rather to depress the levels.

To conclude, a Ca level of 0.30-0.40 p. 100 dry matter in leaf rank 14 is satisfactory, and no improvement in development or yield can be expected from calcic fertilizer applications.

5. — Magnesium.

Magnesium enters into the physiology of the plant as a constituent of chlorophyll.

The critical level of leaf 14 is 0.24 for Talls. For the hybrids, the level has not yet been fixed definitively for the peak yield period; experimentation has enabled a critical value of 0.20 to be fixed for the first years of fruiting.

a) Deficiency symptoms.

The visual symptoms are characterized by yellowing of the leaflets on the oldest leaves, going from the tips towards the rachis of the leaf. This discoloration is worse on the parts exposed to the sun, the shaded parts remaining greener.

When the deficiency is fairly severe, the leaflet is almost devoid of pigmentation, but the parts nearest the rachis remain green.

When the deficiency gets worse, there is necrosis of the tips of the leaflets, which take on a characteristic red-brown hue, whilst translucent spots can be seen on the yellowed leaflets.

When the Mg levels are marginal in the field, it is not rare to see visual magnesium deficiency symptoms on the border rows, the foliage exposed to the sun exteriorizing the deficiency more clearly. This phenomenon is more pronounced on Red and Yellow Dwarf than on hybrids or Talls.

Recent observations made in experiment PB-CC 16 in the Ivory Coast show that there is a good relationship between the Mg levels in leaf 14 and the number of green leaves in the crown, once the potassium deficiency is corrected. In the case of the hybrid P-B 121, when the Mg contents are below 0.110, there are fewer than 12 green leaves; from 0.110-0.170, there are 13-20 leaves, and for Mg values above 0.170, more than 30.

b) Causes.

Magnesium deficiency can appear on soils poor in this element, but in the coconut it is frequently provoked by large potassium applications. Furthermore, this sensitivity to induced Mg deficiency is greater in the Dwarf, the Red and Yellow Dwarfs being the most susceptible. It is also found to a lesser degree in the Dwarf × Tall [44].

Before the hybrid coconut appeared, magnesium deficiencies were not often seen, the soils having a sufficient reserve to face to relatively modest production of the Talls and potassic manuring itself being of limited proportions.

However, Mg deficiencies are known on the traditional varieties in the Ivory Coast, Sri Lanka and India, where the Mg levels in leaf 14 can be 0.100 or 0.140.

Magnesian deficiencies are more striking on Dwarf × Tall hybrids, where the high potassium fertilizer rates, indispensable to compensate uptake due to high yields, tend to induce a magnesian deficiency through the antagonism between K and Mg.

Table XI clearly shows this effect of potassic manuring on the Mg levels, which are strongly depressed.

c) Correction by mineral manuring.

The application of magnesian fertilizer, usually kieserite, corrects the deficiency very well. The absorption of Mg leads to re-greening of the foliage, an increase in leaf levels and significant action on growth or production when the potassium shortage has been made up.

The I. R. H. O. has shown that the principal effect of magnesium on yield can be as much as 40 p. 100, but that it is only produced in the presence of potassium chloride.

d) Relationships with other elements.

In the sandy coastal soils, nitrogen fertilizer application often depresses the Mg levels. On the other hand, phosphorus increases leaf magnesium.

The most outstanding action is that of potassium, which always reduced the magnesium levels. Particular care must be taken when drawing up a manuring schedule, as the Mg deficiency induced by heavy potash fertilization can reduce yield by 40 p. 100.

We have already seen in the section on potassium that there is a close liaison between K and Mg levels. Figure 8 expresses the intensity of this liaison very well.

6. — Sodium.

Sodium is not really indispensable, but it is known that it can replace potassium to a certain extent when the latter is in short supply.

It favours the growth of certain plants (O. W. Lunt), and Harmer, on the basis of information available in literature on the matter, classes the coconut amongst the plants which give a moderate response to sodium even when there is plenty of potassium.

The critical level for sodium has not been determined experimentally for lack of trials concerning its application. The level of 0.40 previously retained should be taken as a rough guide, even though coconut groves giving excellent yields have Na levels below 0.100.

Planters in Java, India and Colombia apply sodium chloride; they consider that the sodium favours coconut yield, NaCl dressings having provoked increases in production. There is no scientific proof of this assertion, and it may be thought that as sodium was given in chloride form, it was the chlorine which raised yield (see section on chlorine).

In the Ivory Coast, DA-CC 2, a factorial $3 \times 3 \times 2$ experiment, studies sodium at three levels. While the leaf Na is significantly increased and rises from 0.339 to 0.511** for rank 4, there is no effect on development, girth being 102 cm for treatments receiving no fertilizer and 103 cm for those getting sodium manuring.

Table XII shows the relationships with the other elements applied. Only potassium fertilization has a strongly depressive effect on the sodium levels.

In a study of the irrigation of coconuts with salt water [45], Pomier uses water half as salt as the sea, resulting in the doubling of leaf sodium, which rises from 0.066 for unwatered trees to 0.135 for the irrigated ones, the Mg and Cl levels being raised in parallel.

7. — Chlorine.

Although there are large quantities of chlorine in plant tissue (from 0.05 to more than 1 p. 100), it was considered an element without specific importance until Broyer (1954) showed that it was without doubt an indispensable element for the nutrition of cultivated plants.

No particular work had been done on chlorine in tropical oil plants before its importance was brought to light on oil palm in 1970, thanks to the difficulty encountered in interpreting a fertilizer experiment set up by the I. R. H. O. in Colombia [Ollagnier and Ochs, 46].

It is now possible to show that in recent alluvial or volcanic soils which often have high exchangeable base contents (5-10 me/100, including 0.3-1 potassium), there are the following relationships in the leaves between Ca^{++} , K^+ and Cl^- under the influence of potassium chloride applications (or of chlorides):

— the absorption of Cl brings about the parallel absorption of Ca;

— the absorption of Ca leads to a drop in K from a level much higher than the critical one to values close to it or just a little above.

The coconut seems to follow this general trend. For example, the analysis of trials by Magal [1978] is an excellent demonstration of this, especially trials 1, 2, 4 and 5 in the Philippines.

At the beginning of the research, we mainly tried to show that Cl has a specific role, however slender, in the nutrition and yield of oil palm and coconut, and to show that the coconut was not always a « potash-loving crop » when its yields responded to potassium chloride applications. In effect, this point could be of importance from an economic point of view, because if it can be shown that on certain soils rich in potassium the increased yield obtained by KCl applications is due entirely to Cl, then it would be possible to have recourse to inhabitant fertilizers in case of double deficiencies — ammonium chloride for N and Cl deficiencies, magnesium chloride for Mg and Cl ones.

In general, the results of the last ten years have amply confirmed the initial hypotheses, and it can even be said that on the practical plane certain experimental findings in the Philippines are of unquestionable economic import (copra/nut increased by 10-20 p. 100, number of nuts up by 50-100 p. 100).

The mechanism of this action has still to be explained; a joint I. R. H. O./P. C. A. research project is now studying in France whether it occurs at the photosynthesis stage [Arnon, 48].

a) Deficiency symptoms.

According to Von Uexkull [48]: « chlorine deficiency manifests itself in a yellowing and/or orange mottling of the older leaves and with a drying up of the outer edges and tips of the leaflets — a symptom very similar to that of potash deficiency — but this would need further verification ».

The size of the nut is also an indication of Cl deficiency; those on coconuts lacking chlorine are smaller than on trees well provided with this element.

b) Causes.

The amount of chlorine in the soil depends mainly on how much is brought down by the rains; all the Cl assimilable by the plant is contained in solutions in the soil which are constantly renewed by rain. Consequently, the soil content is a function of the quantity in the rainfall. Seawater is a good source of chlorine; seaboard soils are often richer in this element than inland ones.

The annual chlorine contribution, according to Erickson, varies from 5 to several hundred kilos of K per ha [12]. Measurements made by the I. R. H. O. show that the yearly input in the area of experiment PB-CC 16, already mentioned, is about 25 kg; now, the uptake as determined by Ollagnier and Ochs in this same region is 249 kg/Cl/ha for a hybrid coconut plantation producing 6.7 t of copra/year. If uptake is no longer compensated, a Cl deficiency will appear quite soon.

This observation is all the more important in that the hybrids, four to six times as productive as the Talls, also export four to six times as much mineral elements.

c) Correction by mineral manuring.

As early as 1971, Ollagnier and Ochs [46] suspected that chlorine was responsible for yield increases in a factorial experiment, DA-CC 1, in the Ivory Coast, which studied the effects of urea, potassium chloride and kieserite at three rates and sodium chloride at two (split plots), because the increased yields could not be explained by the rise in the Na or K levels, even though a slight effect of K was observed. Figure 9 shows that the number of nuts per tree increases at the same time as the Cl levels.

In 1972 von Uexkull [48] in the Philippines concluded that there was a positive action of chlorine on yield. In a 2⁵ experimental design studying sodium chloride, ammonium sulphate, bicalcic phosphate, potassium chloride and magnesium sulphate, yields are increased to an outstanding extent with potassium chloride; the potassium cannot be held responsible, since the correlation yield-leaf K levels is negative. On the other hand, there is a close correlation between yield and Cl levels. With sodium chloride there is also a positive correlation yield-Cl levels, the sodium levels being depressed (Table XIII).

More complete results were published by Magat et al. [49] in 1975 about an experiment studying increasing rates of potassium chloride. The fertilizer has a positive and significant action on copra/tree, which passes from 28 kg in the control to 55 kg in the treatment receiving 3.33 kg KCl/tree/year, i.e. the yield doubles. Whilst the leaf K levels do not change, remaining stable at 1.7 and 1.8 p. 100 dry matter, thus well above the critical value, the Cl contents increase considerably; the mean for the control plots is 0.074, against 0.534 ** for those getting the highest KCl rate. There is undeniably a very strong correlation between Cl levels and production per tree. Chlorated manuring acts both on the number of nuts and on the copra/nut. According to Magat, and in the conditions of the experiment in the Philippines, the gain in copra/nut was 35 p. 100 in 1975 (159 g for the control against 230 g for the plots getting KCl), and 56 p. 100 in 1976 (159 g for the control compared to 248 on the KCl plots). **This is a very large gain and an altogether remarkable result.**

This beneficial effect of chlorine on yield is found again in the growth and development of the young plants. In the New Hebrides, in a 4 × 4 × 2 type experiment on young coconuts planted on clay volcanic soil and studying ammonium sulphate, potassium chloride and bicalcic phosphate, Daniel and Manziol [40] examined the possible relationships between K and Cl

levels and the vigour index, defined by a formula expressing the volume of the plant by means of the girth, the two perpendicular diameters of the projection of the foliage on the soil and the height from the ground to the tip of the highest leaf. The results prove that there is a significant correlation between the Cl levels and the vigour of the plant of $r = 0.390^*$ at 2 years and $r = 0.408^*$ at 3 years; no correlation between K levels and the vigour of the plant was shown. In other respects, the leaf analysis results show that potassium nutrition is satisfactory with more or less constant levels for the four treatments, whilst the Cl contents are significantly increased in proportion to the KCl rates applied (Fig. 10).

Ollagnier et al. [12] describe the effect of chlorine on young coconuts in the nursery. In a 3³ factorial experiment studying nitrogen, potassium and magnesium, the plots were split into chloride and sulphate. Leaf analysis revealed a slight but significant rise in the phosphorus levels (0.141 against 0.145 * in the chlorine/sulphur comparison), which are good; the differences are much greater for chlorine, of which the contents pass from 0.785 with sulphate to 1.181 ** with chloride. The N, K, Ca, Mg and S levels do not change. Growth measurements confirm the positive action of chlorides compared to sulphates. Table XIV summarizes the results.

In experiment DA-CC 2 at Dabou, Ivory Coast, a 3 × 3 × 2 factorial design compares the effect of chlorides and sulphates of potassium and sodium on Yellow Dwarf × West African Tall hybrids; the chloride forms have the advantage, and stimulate better development than the sulphates.

	K0	K1	K2
K levels in 1977.....	0.437	1.408 **	1.897 **
Girth in 1977 (cm)	59.7	64.3 *	68.1 **

While the above figures show that in 1977 there was an effect of potash fertilizer on girth, those below indicate that chlorine, the levels of which are significantly depressed in the presence of sulphate, also has a significant effect on girth:

	Cl levels in p. 100 dry matter		Girth (cm)	
	Chlorides	Sulphates	Chlorides	Sulphates
February 1976	0.538	0.196 **	42.3	39.8
February 1977	0.743	0.101 **	66.9	61.2 **

In Indonesia (North Sumatra), leaf analyses revealed severe Cl deficiencies on liparitic soils, very easily corrected by the application of potassium chloride. The evolution of the K and Cl levels in the presence of potassium chloride is given below:

	Leaf contents in p. 100 dry matter			
	K	(p. 100)	Cl	(p. 100)
K0	1.55	(100)	0.063	(100)
K1	1.59	(103)	0.290	(460)
K2	1.61	(104)	0.686	(686)

It will be seen that potassium chloride has no action on the K levels, which are above the critical value. On the other hand, the very low Cl contents are considerably raised by the chloride. In Indonesia again, levels below 0.100 have been recorded near Menado (North Sulawesi).

Again, in experiment PNP X, Exp 1 in Indonesia, it is chlorine which is the factor limiting growth.

In the Philippines, it is the chloride forms which favour development, all the growth characters being correlated to the Cl levels (PH-CC 6).

In the Ivory Coast, a Cl deficiency has just been detected in experiment PB-CC 39, planted on sandy-clay alluvial soil.

Chlorine deficiencies have undoubtedly been exposed by different authors, and this element is very easily absorbed by the coconut; it acts on growth and yield, and in certain situations the latter can be doubled. For Ollagnier, Ochs and Daniel [12], chlorine should therefore be included in the major elements, all the more so in that the values can reach 0.5 p. 100 of dry matter.

In the framework of a leaf analysis enquiry carried out in the Philippines from 1974 to 1976, the samples for which were analysed in the I. R. H. O. laboratories, the table below gives the percentage of samples deficient in the element considered compared to the 295 analysed.

Element	p. 100 samples deficient
Nitrogen	84
Chlorine	52
Magnesium	43
Potassium	13
Phosphorus	0.1

Nitrogen is the most frequent deficiency with 84 p. 100 of the samples below the critical level. It is interesting to note that chlorine comes second with 52 p. 100.

In this enquiry the Mg levels were strongly influenced by the high potassium contents. There were few P and K deficiencies.

To conclude, a Cl deficiency is quite frequent in the Philippines, and it is also found in the Ivory Coast, Indonesia and in certain parts of Oceania. Since Ollagnier and Ochs discovered its importance in oil palm nutrition, new observations have been going on and make it possible to circumscribe the deficient zones better. Systematic analysis of Cl in leaf samples will make it easier to detect areas lacking this element.

The Cl levels are very effectively raised by chlorides, and if the chlorine deficiency was not discovered straight away at Dabou, it was because potassium was considered to be the limiting factor, and the KCl applied made up part of the Cl shortage. This shows the importance of the form of fertilizer and the need to determine the deficiencies accurately by leaf analysis. When there is a double deficiency in chlorine and nitrogen, ammonium chloride is doubtless the form most apt to correct both simultaneously. Nevertheless, it is only by field experiments which allow for all these factors that the value of the fertilizer recommended can be confirmed.

In this respect, Magal [54], in a series of ten demonstration plots installed in the Philippines, obtains diverse responses to the manurings applied. From these ten plots, we have chosen six which appear to us to be of particular interest, even if the conclusions cannot have the strict value of an experiment which can be exploited statistically.

The data and results are given in Tables XV and XVI.

Plots 1 and 2 both suffer from a severe nitrogen deficiency; the Cl deficiency is evident for plot 2, it is less pronounced or nonexistent (it all depends on the critical level, not yet defined by experiment) in plot 1. The contents of all the other elements are good. Yields at the start were fairly similar. There is no great difference between the plantations (planting 9×8 m in square, age 18-20 years, yield 35-40 nuts/tree), the rainfall and the soils (clay alluviums with 48-60 p. 100 clay). Plot 2 received almost twice as much ammonium chloride at plot 1 at

each application. The ammonium chloride raises the N levels appreciably in both plots, as well as the chlorine levels, the effect in plot 2 being more striking because of the native poverty in Cl. In both cases the copra/nut is increased by 18-19 p. 100; the number of nuts augments by 32 p. 100 in plot 1 against 13 p. 100 in plot 2 and the copra/tree increases by 56 p. 100 in plot 1 and 34 p. 100 in plot 2. Although the N deficiency is severe, everything happens as if chlorine were the prime limiting factor.

Plot 6 seems to confirm this analysis. The N and Cl deficiencies in the field are severe. The application of ammonium sulphate corrects the nitrogen deficiency notably without acting on the Cl levels, and increases copra/tree by 48 p. 100 (29.8 kg with ammonium sulphate against 20.1 kg for the control). The effect is more spectacular with ammonium chloride, which raises the N and Cl levels simultaneously and procures a gain of 11 p. 100 copra/tree (an effect of dilution for K is noted). What would have happened with another chloride which would have raised the Cl levels only?

In this same plot, the action of sodium chloride has not yet made itself felt as it has only been applied recently. The case is different in plots 4 and 5. The N deficiency is larger in plot 5 than in plot 4; it is the other way round for the Cl deficiency. The action of the association ammonium sulphate-sodium chloride is altogether remarkable, and the worse the N deficiency the more marked the effect: the copra/tree increases by 307 p. 100 in plot 5 against 86 p. 100 in plot 4. With the application of ammonium sulphate alone plot 6 only gives 48 p. 100 more copra/tree. However, the action of ammonium chloride is not negligible for all that, since there is an increase of 62 and 274 p. 100 in the copra/nut for plots 4 and 5 respectively. There is therefore a certain equivalence between the effects of ammonium chloride on the one hand and the association ammonium sulphate-sodium chloride on the other.

The peculiarity of plot 3 lies in its fourfold deficiency in nitrogen, potassium, chlorine and sulphur. Potassium chloride associated with ammonium sulphate raises all the deficient elements close to or even above the critical levels; copra/tree increases by 49 p. 100. The effect of ammonium chloride, which only acts on the Cl and N levels, only results in an increase of 35 p. 100, potassium and sulphur probably becoming limiting factors.

Overall, Magal's study shows that leaf analysis is a very fine tool. After defining a certain number of deficiencies in function of the critical levels, application of the appropriate fertilizers gives a yield gain of 30, 50, 100 and... 300 p. 100!

d) Relationships with the other elements.

The studies are too recent to give the relationships with the other elements with any accuracy.

To be continued (*)

(*) The IIIrd part of this communication will be published in the January 1980 number of *Oléagineux*.



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