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

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The common coconut has always played the part of a poor relation to the oil palm. In the best growing conditions (yields of 3 tons of copra per ha), the traditional varieties provide 2 tons/ oil/ha against 5-6 tons for the oil palm. Furthermore, not only do the plantations give a relatively small yield, but they have the major disadvantage of not being very precocious.

By virtue of its geographical distribution, covering the whole of the intertropical zone of the globe, the coconut interests a large section of the world population, for whom it represents the sole source of fats. In the course of the last 10 years, while the world population increased by 25 p. 100 and total consumption of animal and vegetable fats rose by more than 35 p. 100, the share of copra in this consumption declined appreciably. It is to be expected that in the years to come demand will increase with population growth, and it is to be hoped that there will be an improvement in the living standards of the least favoured classes in the developing countries in the tropical regions.

The coconut has an important part to play.

Whilst research with a view to improving the productivity of this oil plant started more than 60 years ago (the first improvement station saw the light of day in 1916 at Pilicode, in India), it is only in the last couple of decades that considerable progress has been made.

Today, the results obtained show that the coconut is a tree with a future. Thanks to the use of modern growing techniques, it has become an oil plant whose per ha production is approaching that of oil palm (4-5 tons, the same hectare producing only 2 tons of groundnut oil or 0.5 tons of soya oil). In addition, it is frequently grown on very poor soils, where it will not compete with oil palm. Finally, its climatic requirements are not so strict as the latter ; in particular, moderate to heavy water deficits its yield less than those of the oil plam [1].

This improvement in yields results from the application of a whole series of modern techniques without which no high yields will ever be obtained. Mineral nutrition is one of them.

And yet fertilization of the coconut is still not current practice. The Philippines, with more than 2.7 million ha, only fertilize about 30 000 ; in India, a few tens of thousands out of the 1.2 million ha of coconut groves receive mineral manuring. The same applies in all the other countries where the coconut is grown, with a few exceptions like the Ivory Coast.

The wide extension of high-yielding Darwf × Tall hybrids could revolutionize coconut growing everywhere, but the absence of fertilization will stop them expressing their full potential, all the more so in that such high production is inevitably accompanied by a corresponding increase in the uptake of mineral elements from the soil.

I. — THE ENVIRONMENT

1. — Geographical distribution of the coconut.

The tree most widely grown in the world, the coconut is found in the whole intertropical zone, where its climatic needs are satisfied. Considered as an important source of liquid for consumption by man, the nut has played a great part in the dispersal of the tree, and this is why it is found in very marginal zones where poor rainfall (Cap Verde Islands) or low temperatures (New Caledonia) severely limit its production ; but in these regions it is no longer of any economic interest.

In spite of the development plans launched in Africa and America, the coconut is still mainly an Asiatic and Oceanian crop. The Philippines, India, Indonesia, Sri Lanka and Malaysia alone account for nearly 7 million ha, or 90 p. 100 of the area planted to coconut in the world.

The coconut's climatic needs are very similar to those of oil palm. The observation of the conditions in which coconut growing develops around the world and the early results of experiments undertaken in the most marginal regions make it possible to define these requirements. The coconut grows well when the rainfall is as regular as possible, the ideal being 150 mm per month, or 5 mm per day, an amount equal to that of the monthly evapotranspiration and equivalent to an annual rainfall of 1 800-2 000 mm. However, this palm can also develop normally with less rain where the water deficit is compensated by the soil moisture reserve or by a high water table. On the other hand, it must be mentioned that the coconut fears excess moisture.

Temperature also limits the extension of the coconut ; 27 °C is considered the optimum. Below 15 °C the life of the plant is perturbed and its physiology influenced. If low temperatures are frequent (Loyalty Islands), the nuts fall and the developing fruit suffer deformations which considerably reduce copra yield.

As the coconut is grown in sunny regions, it was accepted that 2 000 hours of sunshine annually were necessary. But in certain areas which have no more than 1 800 hours (New Hebrides), coconuts give excellent yields when the soil conditions are good.

2. — Soils of the Producer Regions.

Because of its great adaptability, the coconut is found on the most varied soils, and these fall into six main types :

Sandy coastal soils.

These are the coastal sands, very poor in organic matter and in colloids, with poor retention capacity but compensated by a very low wilting point, nonetheless occasionally leaving more available water than certain clay soils (I. R. H. O. Annual Report 1976-77) ; they have the advantage of being aerated and well-drained. They are poor in mineral elements and need adequate fertilization. This type of soil occurs in practically all the coconut plantations in West Africa and Madagascar ; they are also found in India, in Malaysia (East Coast), in the Philippines and in many other regions.

Coral soils.

Pebbly or gravelly, more or less poor in organic matter, the coral soils are very rich in limestone. They cover most of the atolls (Polynesia). Their fertility depends on the amount of organic matter and the degree of weathering ; they can be overlaid by a varying thickness of alluvial soils, which makes them very fertile (New Hebrides, Solomon Islands).

Lateritic soils.

Rich in iron and aluminium hydroxides, they result from intense leaching of the silica and the exchangeable bases. They are often short of potassium and phosphorus ; their aptitude for coconut growing depends on the degree to which concretions have formed (water supply).

Alluvial soils.

The fluviogenic soils are often very good for coconut. Their richness obviously depends on the nature of the rocks traversed by the rivers which formed them.

This type of soil is often found in India in the Godaveri delta, in Sri Lanka, in the Philippines and in Mexico (Guerrero).

In Indonesia, the marine alluvions (Selangor series) are favourable to coconut growing.

Volcanic soils.

Often very fertiles, these are found mainly in Indonesia (Sumatra, Java, Bali) and in the Philippines.

Peat soils.

They cover large areas and are frequently uncultivated because of the very special problems which they occasion. A few small coconut groves can be found on them, but they could offer considerable development possibilities for the future on condition that the necessary studies are taken with a view to their improvement (deficiencies in K, Cu, B ; pH very acid).

It will be seen, therefore, that the coconut adapts itself very well to the most varied soils. It is difficult to define the ideal soil exactly, each case being a special one. Generally speaking, the physical support is as important as the chemical richness of the soil, the coconut reacting very well to mineral fertilization, which is a very reasonable financial investment, whereas the modification of the physical qualities sometimes calls for considerable outlay.

If the coconut is often seen growing on even very poor sandy soils, it is because it finds an aerated and properly drained substratum. But it will take to sandy clay or even very clayey soils on condition that the recovery of the stagnation of the water table remains at a fitting level of 0.90 m [1]. In certain regions this minimum depth of healthy soil gives the trees better resistance to gusts of wind. The presence of coarse elements (lateritic gravel) or a compact horizon (coral slab) hinders the development of the

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roots in depth and consequently limits the useful reserves of water and mineral elements.

All textures are suitable for coconut except for extremes such as pure, leached sands and certain very clayey, compact soils.

The coconut is not very demanding as regards the chemical value of the soil, and for this reason the poorest soils are often planted to coconut because they are unfavourable to other crops. Let us say here that the coconut supports a pH of 5-8, although in le most alcaline soils nutrient imbalances provoke iron deficiencies (coral atolls).

In lateritic tropical soils, kaolin clay-bearing and generally desaturated, fertility depends essentially on the organic matter, often localized in the first 20 or 30 cm.

The accepted threshold values are as follows :

	Lowest value considered satisfactory
— C (p. 100)	1
— N (p. 1 000)	1
— C/N	10-12
Absorbant complex (me/100 g)	
— K { with Mg/k > 2.5	0.15-0.20
— Mg {	0.20-0.50
Sum of exchangeable bases (me/100 g)	1
Phosphorus	
— P total (ppm)	400
— P Olsen	25
— P Saunders	100

For soils of alluvial or volcanic origin, with swelling clays of the illite or montmorillonite type and deeper, the reserves in the layers further down can be taken into account, as the tree has a bigger mass of soil at its disposal. A volcanic soil with 0.1 me K down to 0.8 m will be chemically better as regards K than a lateritic one with 0.2 me K in the 0.30 cm horizon only.

Table I gives the physical and chemical characteristics of a few of the soils in which coconut is grown.

3. — Mineral nutrition. Methods of study.

In 1958, Nathanael [3] distinguished three approaches to the study of the coconut's mineral nutrition :

— the first method is to define the needs of the plant with the aid of agronomical experiments and by successive approximations. Coconut growing does not lend itself very well to this operation which, because of the low planting density (between 150 and 180 trees/ha), entails heavy expenditure on planting and management without solving all the problems for all that ;

— analysis of the soil is the second method recommended. It does not take account of the plant's reactions and the interpretation remains tricky ;

— the third method interrogates the plant directly by means of chemical analysis of the coconut water and the leaves (foliar diagnosis). Analysis of the coconut water is said to have enabled Salgado [4] to study the effect of potassic fertilization on yields. Experiments made in the Ivory Coast proved that there was indeed an analogy between leaf analysis and analysis of the coconut water, the latter giving a good reflection of the considerable action of potassic fertilizer on yields. However, by reducing the number of trees sampled, analysis of the water is subject to much larger variations than leaf analysis, so that it requires much bigger sampling than the latter and gives less precise information on the action of manurings.

It is for these reasons that the analysis of coconut water did not take over from leaf analysis.

More recently, Ollagnier, Ochs and Martin [5], in a paper of oil palm manuring around the world, described two possible methods for studying the mineral nutrition of that oil plant :

— the first deals with the balance of nutrient element uptake, with all the practical difficulties and imprecisions that implies ;

— the second is based on experiments in the field, and analysis of the plant makes it possible to define the level of deficiency or surplus of the nutrient elements. It is much more accurate than the first method and, given the present level of research, gives a good picture of the effect of manuring on vegetative development and yield.

We will deal one by one with the last two methods, the ones which have been most used by researchers, whilst giving more importance to the second.

a) Uptake of nutrient elements.

Numerous studies have been undertaken to determine the quantity of nutrients taken up by the coconut. Frémond et al. [7] recall the results obtained by Jacob and Coyle in 1927, Eckstein in 1937 and Pillai and Davis in 1963 [6] (Table II).

Expressed in absolute values, the differences between the authors appear to be large. However, it is interesting to note that there is a certain similitude between the figures of Eckstein and those of Copeland.

Unlike the other researchers, Ouvrier and Ochs worked on hybrid material. Line 6 of Table 2 gives the nutrient uptake for all the bunches in an annual production of 6.7 t copra/ha, whilst line 7 shows the uptake for the palm (trunk and foliage as well as yield). The difference between the two is the annual immobilization in the trunk and foliage.

For its trunk and leaves the coconut consumes more calcium (61 kg against 9 kg for yield), magnesium (24 kg to 15 for yield), sodium (34 kg to 20 kg) and sulphur (21 kg to 9 kg). For chlorine the uptake is practically equal : 125 kg for yield and 124 kg for the production of stem and leaf.

The biggest removal in the nut harvest is potassium, with 193 kg. The estimate of chlorine taken up for yield is 125 kg, which makes it the second most import element, coming before nitrogen, which amounts to 108 kg. All the other elements account for 10 to 20 kg.

Ouvrier, to make a comparison with Copeland's estimates, worked out the uptake of a variety of hybrid producing 1.5 t of copra/ha/year. The figures are given in line 5 and compared to those in line 4. There is a similarity between removals by the Tall variety and those of the Dwarf × Tall hybrid.

For the same yield, there is no difference in uptake between hybrid or Tall coconuts.

b) Diagnosis of mineral deficiencies.

As for the oil palm [5], foliar diagnosis proves the easiest and most accurate way of studying mineral nutrition.

Indeed, when the agronomists took an interest in fertilization in a tropical zone, they ran up against numerous problems. In particular, the comparison of soil analyses in a temperate or tropical environment led to mistaken interpretations. The experience accumulated in a temperate climate could not be transposed to a tropical one. The diagnosis of nutrition by soil analysis came up against the microheterogeneity of this environment and the difficulty of appraising assimilability. To these purely agricultural considerations were added preoccupations of an economic nature, Tropical soils generally appear poorer than those of the temperate regions, and the plants grown in the former were originally considered low yielders, so that it was not possible to promote fertilization of tropical crops without having a simple analysis method giving quick resultsand the interpretation of which could enable the information drawn from experimentation to be generalized to a certain extent.

This is why the I. R. H. O. returned to the work of Chapman and Gray [10] on foliar diagnosis, applying it to tropical oil plants (groundnut, oil palm and coconut) [11].

For the coconut, following leaf analysis results in 1952 it appeared that the potassium levels were probably low in Ivory Coast ; a first fertilizer trial was set up. After potash manuring had been given for three years running, leaf analysis showed that the K level had risen from 0.165 p. 100 to 0.492 p. 100 of dry matter and that, at the same time, the number of nuts/tree had increased from 58 to 89. As far as the coconut was concerned this was the first demonstration of the advantage of foliar diagnosis in determining deficiencies.

The method consists in measuring the concentration of nutrients in the leaves and comparing them to critical values, themselves defined as the level of a nutrient below which application of the appropriate fertilizer has every chance of provoking a profitable increase in yield.

These critical levels have been worked out by comparing the many resnlts of field experiments. In its last Annual Report (1976-1977), the I. R. H. O. determines such levels on the basis of the graphic relationships between fertilizer rates, yield responses and leaf contents. However, the action of one element is not always independent of the others, and interactions had to be taken into account.

The arrival of the hybrid coconut meant that new fertilizer trials had to be set up. If the general trend of liaisons between elements could appear more or less identical in both Talls and hybrids, it was not certain that the level of production expected from the hybrids would not alter the mineral balances of the tree. For example, the remarkable effect of the combined action of potassic and magnesian manuring on the hybrid has been amply demonstrated by now, whereas it is insignificant on the traditional planting material. Although the study is not yet definitive, it is also recognized that the nutrient levels are not the same in the Tall varieties as in the Dwarfs ; within the Dwarf varieties there are also far from negligible differences which need to be defined. Finally, research has concluded that mineral manuring is of the greatest interest in immaturity ; the corresponding critical levels are determined in function of responses in vegetative development (height, number of leaves, girth, vigour index) obtained in experimentation.

The critical levels worked out for the West African Tall variety are as follows :

$$N = 1.8\text{-}2.0 \qquad K = 0.8\text{-}1.0$$
$$P = 0.120 \qquad Mg = 0.24.$$

They probably apply, by and large, to most of the Tall varieties. Table III gives the critical levels proposed for the hybrid

P-B 121 (Malayan Yelow Dwarf × West African Tall) according to the earliest results of experiments set up in the Ivory Coast in 1970.

The critical level of K in the peak production period has not yet been determined experimentally ; certain indications suggest that this level will be lower than that in immaturity, and approaching the critical level for Tall material. The critical level of magnesium is likely to evolve in correlation.

As regards the critical levels of N and P, these will also be determined experimentally when the trials most recently set up on soils deficient in nitrogen and phosphorus start bearing ; the levels given in Table III are not definitive and can be considered rather as optimum values from the physiological view point.

It is found that the nitrogen levels increase slightly with age, whereas those of phosphorus and potassium fall ; the Mg levels vary little.

Comparing the Tall varieties and the hybrid P-B 121, the phosphorus contents are identical, nitrogen and potassium are higher in the hybrid ; on the other hand, the P-B 121 seems to be satisfied with a lower Mg content, at least before it reaches maximum production.

The critical levels for Ca and Na have not been worked out, as no response to these two elements has yet been obtained in the experimental network.

For chlorine, Ollagnier, Ochs and Daniel [12] *have shown that the coconut responds well to chlorated manuring when the initial levels are very low ; 0.3 p. 100 is a threshold below which yield responses to Cl applications are certain, 0.5 p. 100 probably being the optimum value.*

It will be seen that leaf analysis is a good means of studying mineral nutrition. It is the foundation stone of the work undertaken by the I. R. H. O., and many other scientific bodies in the world have now adopted it for coconut. However, the experiment network on Talls, whose production is mediocre, is still much more developed than that on hybrid material.

In effect, while the agronomists were applying themselves to finding the best-balanced manuring for getting the biggest yields out of the Talls, thus providing a short-term answer to the preoccupations of the planters, the geneticists were attempting the long-term improvement of this variety by mass selection then hybridization between varieties geographically distant.

Because of the big increase in yield recorded on hybrids, the fertilizer rates recommended for traditional varieties became insufficient. New experiments were therefore started in different parts of the world, as the big development projects will consecrate most of their areas to this new material.

For the traditional varieties, a certain number of fairly old experiments were chosen ; on the contrary, the trials on hybrids are recent, but the older ones have led to interesting conclusions as to the future. Table IV gives the plans of the main experiments mentioned.

II. — STUDY OF NUTRITION ELEMENT BY ELEMENT

1. — Nitrogen.

In plant physiology nitrogen is indispensable as a constituent of the amino-acids [13], *proteins and nucleic acids. A shortage of nitrogen makes itself felt throughout the coconut's physiology and provokes a big drop in yield.*

a) Deficiency symptoms.

The critical level of N in a leaf of rank 14 can be fixed at 1.80-2.00 p. 100 of dry matter for Tall varieties, and 2.2 p. 100 for the hybrid P-B 121. Below this value N nutrition is not assured, which leads to anomalies exteriorized by deficiency symptoms.

In the first stage, there is slight and continuous yellowing of all the foliage ; the tree no longer has the frank green colour characteristic of a good nutrient balance.

In a more advanced state, the young fronds are pale green, giving the leaflets a dull appearance ; the severely discoloured old leaves may become a uniform golden yellow. Many bunches abort, and the number of female flowers per inflorescence is small (rarely more than one spadix branch).

In the last stage of deficiency the coconut seems affected by a sort dwarfing ; as it grows, the stem narrows gradually to a « pencil point », the leaves in the crown are few and short.

b) Causes.

The causes of nitrogen deficiency in the coconut are now well known, and are of three sorts :

— low rainfall (State of Guerrero, Mexico, Benin, Mozambique) or one which is badly distributed, influences the N levels by reducing the nitrification time and the length of activity of the absorbant root system ;

— soil conditions unfavourable to the mineralization of organic matter ; this is the case of the coral soils of the Polynesian atolls, the coral lands of the New Hebrides, or white sands leached by a very high water table ; the same thing can happen in rich soils (Philippines, Indonesia) ;

— faulty maintenance encouraging the spread of grasses, especially Imperator, all big consumers of nitrogen.

A nitrogen deficiency is fairly common ; it can also result from exhaustion of the soil by many years of cropping (India, Philippines), but when the nitrogen nutrition is found to be deficient, it is a good idea to find out what exactly is the main cause.

Coomans [14] *in particular has shown that N nutrition depends directly on rainfall. On the Marc-Delorme Station in the Ivory Coast there is a significant negative correlation (r = — 0.57 **) between N levels and the cumulative water deficit for the previous three months (Fig. 1). The same relationship has been found in the Malgassy Republic (r = — 0.48 **) on the Ankivanja Research Station.*

c) Correction by mineral manuring.

The I. R. H. O. achieved the best correction of nitrogen deficiency in Mozambique [15], *with yield increased by 30-40 p. 100 according to the years. In a first factorial 2^3 experiment studying N, K and Mg (MP-CC 1), fertilizer applications had no effect on levels, and the action of N on the number of nuts was not very marked (Table V). As the nitrogen deficiency was evident, a new trial was set up to compare various treatments with legume covers, hoed in or not, with and without fertilizer. The legume cover gave good results, acting on the number of leaves and their colouring.*

However, the legume is often deteriorated by factors which are difficult to control (nematodes, cartepillars, shade), consequently fertilizer applications were started again, but taking the date of spreading into account. Experiment MB-CC 4 showed that spreading at the start of the rainy season was best (the number of nuts per tree/year increased by more than 40 p. 100). This result is closely linked to the activity of the superficial root system, destruction of which during the dry season considerably slows down absorption (symptoms of nitrogen deficiency are frequently noted at the end of the dry season when leaf analysis revealed no signs of them a few weeks earlier). The rainy season stimulates a new growth of the leaf mass, and it is at this moment that the mineral elements must be provided, to keep up with this growth and facilitate absorption of the nitrogen.

Ramanandan and Pillai [16] *find the same thing in India when they compare treatments, cultivated or not, with and without manuring, through the seasons. The variations are not significantly different, but the authors do not indicate whether they decided to take their leaf samples at the beginning or the end of the rainy season.*

It was also with the object of pinpointing the best time to apply manuring that the I. R. H. O. set up trial PB-CC 18 on Yellow Dwarf hybrid material ; it compares the effects of two rates of urea, of potassium chloride and of kieserite applied before or after the rainy season, split or not. The nitrogenous fertilizer had a significant effect on the number of nuts per tree/year and the copra per tree, although the copra/nut was significantly depressed.

In Malaysia a good response to nitrogenous fertilizer was obtained by Khoo Kay Thye et al. [17] *on coastal clays (Kang Kong series) planted to Red Dwarf. The authors noted better vegetative development (length and area of the leaves), an increase in the number of nuts but a drop in the quantity of copra per nut. Even so, the balance is positive, with an increase of 26 p. 100 copra per tree/year.*

Kunhi Muliyar and Nelliat [18] *in India come to the same conclusion as regards the effect of nitrogen on copra/nut. Whilst the nitrogenous fertilizer significantly increases the number of nuts (17 p. 100 in the case of the experiment), it also depresses copra/nut very significantly.*

Treatment	*Copra per nut (g)*
N0	*179*
N1	***165*** **
N2	***162*** **

** *Significant to 1 p. 100.*

Pomier [19, 20] *shows that on coral soil, once the iron and manganese deficiencies are corrected, nitrogen becomes the limiting factor, but that the only means of raising the levels is to plant a legume, as the soil formed of very coarse elements has great difficulty in retining the fertilizers.*

Like the authors quoted above, the I. R. H. O. has often found a depressive action of nitrogen manuring on copra/nut. However, this effect seems to be closely connected to the potassium levels. In fact, for low K contents, ammonium sulphate reduces the number of nuts and the copra/nut, but as soon as the potassic deficiency is corrected, the nitrogen favours the number of nuts whereas the depressive effect on copra/nut persists [21].

For the last few years the I. R. H. O. has been studying the effect of different anionic forms of fertilizer on coconut yield. Treatments where the cations are given in nitrate form have always given the best nut yield.

Form of fertilizer	Levels in frond 14	Yields			
		No. nuts/tree	p. 100	Copra/tree kg	p. 100
KCl	1.873	61.6	(100)	12.6	(100)
K_2SO_4	1.940	67.6	(110)	13.8	(109)
$KCl + MgCl_2$	1.912	63.6	(103)	13.1	(104)
$K_2SO_4 + MgSO_4$	1.940 *	62.1	(101)	12.8	(101)
$KCl + NaCl$	1.928	57.0	(92)	12.7	(101)
$KNO_3 + NaNO_3$	2.047 **	88.5 **	(144)	16.9 **	(134)

Nevertheless, it is on young coconuts that nitrogen manuring has given the most characteristic results, both on Talls and on Dwarfs or hybrids.

In Jamaica, Smith [22], working mainly on Dwarfs, obtains an increase in growth (height) and development (number of leaves) by the application of nitrogenous fertilizer.

More recently, numerous I. R. H. O. experiments in the nursery and young plantings have made it possible to work out manuring schedules in which it is shown that nitrogenous fertilizers have a far from negligible role to play.

On the hybrid between Malayan Yellow Dwarf and West African Tall (P-B 121), it is again the nitrates which have given the finest plants in the nursery. In a trial conducted on quaternary sandy soils in West Africa (Ivory Coast), various measurements taken at 6 months old show that :

— the N contents of the control are low and nitrogenous fertilizer raises the level in the leaves, this increase being greater with urea and ammonitrate than with ammonium sulphate ;

— ammonitrate very significantly increases the number of leaves and of leaflets and the girth ;

— urea only improves foliage development by 4-6 p. 100 ;

— ammonium sulphate increases the number of leaves by only 4 p. 100.

Table VI gives these results ; it will be seen that the best N nutrition, which improves growth, causes the dilution of the K levels in the leaves.

At the age of 12 months, these effects are confirmed :

— ammonitrate increases the weight of the plant by 19 p. 100, but the foliage benefits most from this (+ 51 p. 100 for the leaves and + 37 p. 100 for girth) than the root system (+ 14 p. 100 only) ;

— urea, on the contrary, acts very strongly on root development (+ 56 p. 100), where the root hairs are much denser, the weight increase being due mainly to the larger number of roots and not to their thickness ;

— ammonium sulphate does not change the fresh weight of the plant.

Always on the hybrid P-B 121, and particularly in experiment PB-CC 16, the I. R. H. O. has confirmed the positive and significant action of a nitrogenous manuring on the growth and development of young coconuts ; those receiving such fertilization have a girth significantly greater than that of unmanured plants. By the third year this effect is very much attenuated, and at maturity it is no longer visible.

In replanting, mineral nitrogen can have a spectacular effect on precocity of flowering ; this is the case in experiment PB-CC 31 in the Ivory Coast, where the soil is considerably exhausted and where a dense grass cover persists.

In conclusion, the nitrogen deficiency exists, although it is not very frequent. It has often been studied on Tall material and the researchers have obtained responses to mineral manuring. However, it is indispensable, when faced with a nitrogen deficiency, to find out exactly what is causing it, the most economical practice not necessarily being the use of a nitrogen fertilizer.

The development plans often reason in function of a more precocious and higher yielding hybrid material. Results on this type of material suggest that in certain cases nitrogen manuring is an excellent motor for the growth and development of young plants. Leaf analysis is a very good working tool for finding out possible deficiencies.

d) Relations with other elements.

There are close relationships between the nitrogen levels and those of other elements.

In particular, we saw in the previous chapter that in the Ivory Coast the action of nitrogenous fertilizer can be subordinate to the potassic nutrition. However, Ollagnier and Ochs [23], in the study of the NK interaction which they undertook on tropical oil plants, conclude that the absence of a clear interaction (defined with N and K, which separately increase yields, and the association NK, which gives bigger yields than N + K) may be the consequence of the small number of N deficiencies and the very slight action of potash on N metabolism ; they also consider that the use of more productive planting material will have a considerable influence on nitrogen requirements and will bring marked interactions to light.

The hybrid P-B 121 does indeed seem to be a bigger nutrient consumer than its Tall parent, but this is normal in view of its precocity and yield ; but for the moment there is no evident interaction between nitrogen and potassium in the Ivory Coast.

In the rest of the world, experimentation on Dwarf × Tall hybrids is still too recent to provide an answer about the NK interaction, but it is certainly in the zones of severe nitrogen deficiency that this interaction could be brought out.

Finally, the close liaison between N and P must be mentioned.

2. — Phosphorus.

Phosphorus uptake is small (15-18 kg), one-tenth of the uptake of potassium or chlorine. Nevertheless, phosphorus is important because it enters into the regeneration of adenosin triphosphoric acid and in the constitution of the phosphoro-proteins. It is usually abundant in the young organs ; the study of P levels is function of leaf rank [24] shows higher contents in the youngest leaves (0.160 p. 100 for a leaf of rank 4).

The critical level for a leaf of rank 14 is 0.120 p. 100 dry matter.

a) Deficiency symptoms.

Phosphorus deficiency is rare in coconut.

There are no particularly characteristic visual sumptoms, apart from slowing down of growth and shortening of the fronds.

b) Causes.

The quaternary coastal sands of the Ivory Coast and of West Africa in general, on which a response to phosphated manuring has been recorded, have a native content of 25 ppm total phosphorus. The tertiary sands are better off, with contents ranging from 120 to as much as 500-600 ppm. Above 120 ppm, leaf analysis of P gives levels over 0.120 p. 100, and phosphated manuring does not increase yield.

The liparitic latosols of North Sumatra on which there are big responses to P on oil palm should also prove deficient for the coconut ; their total P content is between 100 and 300 ppm.

Because of the close N-P liaison, nitrogen-deficient nutrition can lead to a fall in the phosphorus levels.

The application of potassic manuring very often provokes a drop in leaf phosphorus.

c) Correction by mineral manuring.

Only a few examples of the favourable action of phosphated fertilization are known, in Madagascar, India, Sri Lanka and the Ivory Coast. In the last three countries, it is only after several years' manuring that phosphorus increases the nut yield to any significant extent. Phosphorus does not take immediate effect, as the coconut's requirement is small [25] and in many cases it is necessary to wait until the soil is exhausted before the action of the mineral manuring becomes evident.

It was after 26 years of fertilizer applications that phosphorus had a significant effect on yield in one experiment in Sri Lanka. In experiment PB-CC 3 in the Ivory Coast [27], the I. R. H. O. only had to wait 12 years ! (Table VII).

In their monograph, Menon and Pandalai [28], although they speak of the probable favourable action of phosphorus in association with potassium on the quality of production, do not mention any work which has proved the advantages of phosphated manuring. But it must be said that when they were writing, the experimenters were using compound NPK fertilizers, and it was impossible to dissociate the action of any one element.

It is only recently that experiments have made it possible to situate the phosphorus deficiency and eventually the profitability of manuring. The application of phosphated fertilization is very often accompanied by a significant increase in the leaf P levels.

In the I. R. H. O. experiment mentioned above, potassium applications increase the phosphorus contents very significantly. The effect on production is through the increased number of female flowers.

*Originally the critical level was fixed at 0.100 p. 100 of dry matter. Results obtained in Sri Lanka and the Ivory Coast give significant P/yield correlations (r = 0.499 ** in Sri Lanka and 0.495 ** in the Ivory Coast) for P levels below 0.130. In view of this the critical level was raised to 0.120 p. 100 dry matter.*

Amongst the P deficiencies, special mention must be made of those in Madagascar on coastal sands in the North-East, very poor in this element. Research done on young coconuts has shown that phosphorus is the prime limiting factor for development, and that phosphate applications increase girth by 30 p. 100. Correlatively, the correction of the P deficiency improves overall nutrition and minimizes the imbalance of the N/S ratio, likewise reducing any nutrient disorders which might occur.

In this exceptional case, attentive surveillance of the nutrition is necessary.

At maturity, nitrogenous manuring usually raises the leaf P levels. The opposite happens with potassic or magnesian fertilization.

During immaturity, N applications have practically no effect on the P levels, except in one situation in the Philippines on Red Dwarf (BK-CC 6), where P is significantly depressed. There can be wide variations when there potassic fertilizer has been applied ; in the Philippines the P levels rise considerably, whilst they are stationary in Indonesia, Oceania and Mozambique and drop very significantly in the Ivory Coast.

d) Relations with other elements.

The importance of the relationship between N and P levels has been demonstrated on groundnut, olive trees, oil palm and numerous other plants. This notion holds good for all field crops and particularly for coconut.

However, it is surprising to find that with this oil plant, while there is this correlation and it is highly significant for the old leaves, it does not occur in the youngest. This amply justifies the I. R. H. O's decision to use an old leaf of rank 14 as the standard foliar diagnosis leaf.

*In experiments PB-CC 16, where nitrogenous manuring had an effect on growth in immaturity, and PB-CC 31, in which the nitrogen deficiency is fairly severe, the N-P interaction is highly significant (Fig. 2). In PB-CC 16, the liaison is just as strong in the plots getting no nitrogenous fertilizer (r = 0.89 **) as in those getting urea (r = 0.776 ***).*

*The regression curve for the N-P interaction in experiment PB-CC 31 (r = 0.794 ***) does not lie close to those of PB-CC 16, the slope being very different, so that it is not yet possible to propose, as for oil palm, a linear N-P relationship which would make it possible to define the limits of surplus or deficiency zones for N and P.*

We have already noted the liaison between P and K in the previous chapter.

To be continued (*)

(*) The 2nd and 3rd parts of this article will be published in the December 1979 and January 1980 numbers of *Oléagineux* respectively.

Congrès, Salons, Expositions

— 1980 —

Salon International de la Machine Agricole — 2-9 mars 1980, Paris (France).

Les visiteurs originaires des pays tropicaux qui viendront étudier du 2 au 9 mars 1980, au Salon international de la Machine agricole à Paris, les matériels de toute nature, originaires de 30 pays, y trouveront diverses manifestations techniques plus particulièrement organisées à leur intention par le C. E. E. M. A. T.

Mercredi 5 mars (9 h 30-17 h 30) : Journée « *Séchage et stockage* » des céréales (riz, maïs, mil, sorgho), des haricots et de l'arachide, du café, du cacao et du manioc.

Jeudi 6 mars (9 h 00-17 h 30) : Exposés, visites et discussions sur le « *Travail du sol avec les outils à dents et sur les applications possibles en pays chauds* ».

Vendredi 7 mars (9 h 00-12 h 00) : Colloque à propos de « *Quelques exemples de mécanisation dans les récents complexes sucriers africains* ».

Pour tous renseignements, s'adresser au Salon International de la Machine Agricole, 24, rue du Pont, 92522 Neuilly sur Seine, Cedex (France).

European-American Commodities Conference — 3-4 mars 1980, Hilton International, Londres (Gde Bretagne).

Ce congrès est organisé par la New York University, School of Continuing Education, Division of Career and Professional Development. Son objectif est de procéder à une analyse critique des marchés des produits aux Etats-Unis et en Europe, pouvant servir de guide aux industriels, acheteurs, organismes financiers.

Pour tous renseignements, s'adresser à : Commodities Conference, c/o Conference Associates, 34 Stanford Road, London W8 5PZ (Great Britain).

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International Conference on natural fibres : their processing, utilization and marketing with particular reference to developing countries — 10-14 mars 1980, Church House, Westminter, Londres (Gde Bretagne).

Cette conférence, organisée par le Tropical Products Institute, de Londres, concerne le traitement, les utilisations et la commer-