MINERAL FERTILIZERS AND TROPICAL OIL PLANTS. RESEARCHES IN CROP PHYSIOLOGY

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The relationships between the plant and the surrounding medium, which determine the success or failure of a crop, are of extraordinary complexity.

In this far-reaching problem we will limit ourselves to a single question : What is the economic interest of mineral fertilizers for tropical oil crops ?

The answer is not simple. In effect, it is not enough that mineral fertilizing should increase yields, but it must also benefit the grower. In addition, it will be advisable to adapt fertilizing to the changes in soils and crops, to ensure the maintenance of yield increases.

In Africa we have not at our disposal the enormous accumulation of experience on this question gained over the last 100 years in the temperate zones. The problems raised by the crop, the soil, the climate, are still comparatively new.

The question is further complicated from the economic point of view by poorly developed underlying conditions which raise the cost of transport of fertilizers, and by crop yields which are often barely average.

However, increasing yield becomes more and more imperative owing to increasing population and to the simultaneous necessity for maintaining in soils, by suitable fallowing, at least a minimum potential of productivity.

Mineral fertilizers rightly form one of the important factors for obtaining immediate results because of their rapid action. Thus crop research on use of mineral fertilizers in Africa is justifiably placed in the front rank.

The urgency and complexity of the problem compel the research worker to use the most modern acquisitions of crop science. He cannot be satisfied with gradual accumulation of empirical results. Above all, he must try to understand how the results have been obtained on a given point in order to be able to generalize more rapidly.

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Crop research, especially in Africa, must therefore become more and more '*crop physiology*' that is, an *agronomical science* studying the physiological behaviour of the plant in relation to the action of the external medium.

This means that where mineral fertilizers are concerned it will not be sufficient to record their effect on yields, but their action on the physiology and especially on mineral nutrition of the crop will have to be studied. It will be necessary to follow that nutrition through different stages of development :- it would be advisable to study the action of external factors (light, temperature, water, sunshine) on mineral nutrition.

The main questions connected with application of mineral fertilizers can be summarized thus : Which fertilizers ? How much ? Where ? When ?

We shall review briefly the contribution of crop physiology, and particularly of the technique of foliar diagnosis, to the question of mineral fertilizing of the two principal tropical oil crops of North Africa, ground-nuts and oil palms. We shall confine ourselves to the problem of the major elements, N, P, K, Ca and Mg omitting the important question of minor elements.

1. Ground-nuts

The physiological bases of foliar diagnosis have been described elsewhere (Prevot 1953). They derive from results of fundamental research on relationships between stages of development, metabolism and on accumulation. As the founders of foliar diagnosis, Lagatu and Maume, have shown, it is essential to take samplings from leaves of the same physiological age. A study of growth, development and mineral nutrition has made possible the establishment of these fundamentals for ground-nuts (Prevot 1949).

Thanks to the mutual reinforcement of foliar diagnosis and field trials it has been possible to determine fairly rapidly the 'critical levels' of N, P and K, i.e. the N, P and K contents of the leaves expressed in grams per cent of dry matter, below which application of the element in question is likely to prove economic.

In determining critical levels a comparison is made between yield increases due to application of fertilizer, and leaf levels of the element supplied. An example is given for N in Diagram 1. The main results obtained in this connection are summarized in Table 1, which contains certain results of foliar diagnosis for 1952 (see Annual Reports 1951, and 1952 of I.R.H.O.). These results of two years are in agreement.

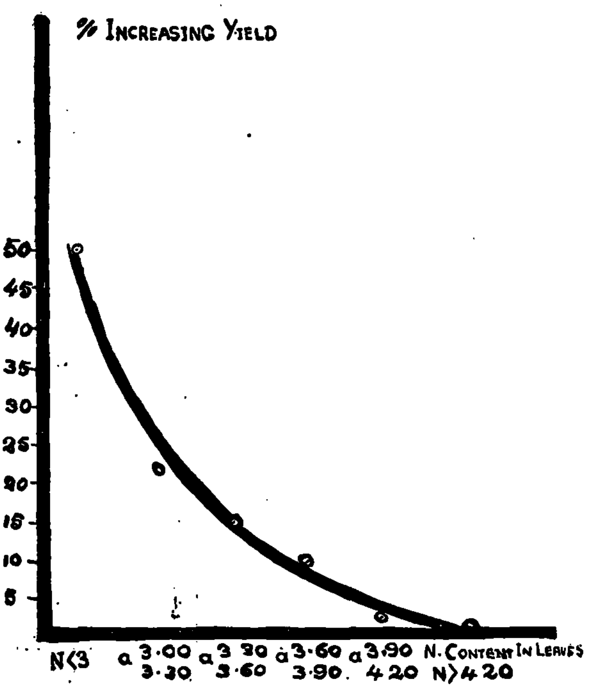

DIAGRAM 1

The response to the application of sulphated ammonia as a function of the ammonia content of the leaves.

TABLE I

	Response obtained in K.G. . . . per Hectare	%	*Amount of N. of plots without N.*	*Amount of P. of plots without P.*	*Amount of K. of plots without K.*	*Rate of application and types of mineral manures*
						N P
LOUGA	N + 289**	+ 78	3.01		0.801	N 75 kg. sulphate of ammonia
	P present					
	de N + 181*	+ 47		0.139		P 50 kg. calcium phosphate
						N + P + K
TIVAOUANE	N + 142**	+ 14				N 40 kg. sulphate of ammonia
	P + 131**	+ 13	3.20	0.167		P 60 kg. calcium phosphate
	K + 77*	+ 7			0.799	K 20 kg. muriate of potash
						K N
THIES*	K + 545**	+ 67	3.34	0.360		N 50 kg. sulphate of ammonia
	N present					
	de K + 387**	+ 33			0.458	K 75 kg. muriate of potash
						P + N
DAROU*	P + 217*	+ 9		0.142		
	N + 169	+ 7	3.40			N 50 kg. sulphate of ammonia
	K + 82				1.26	P 75 kg. calcium phosphate
SEFA	P + 462**	+ 30	4.13	0.168	1.81	P 50 kg. calcium phosphate
						P + N + K
BAMBEY . . .	P + 364**	+ 14		0.196		P 75 kg. calcium phosphate
	N + 132**	+ 5	3.99			N 37 kg. sulphate of ammonia
	K + 82*	+ 3			0.591	K 37 kg. muriate of potash
Critical Values			4%	0.225%	1%	

Critical levels can be fixed provisionally as follows, where Nc, Pc and Kc denote those for N, P and K respectively:

$$Nc = 4\%$$
$$Pc = 0.225\%$$
$$Kc = 1\%$$

Pc varies according to the nitrogen content of the leaf:

N 3%, Pc = 0.175%
3% N 4%, Pc = 0.200%
N 4%, Pc = 0.225%

[c.f. Ann. Rept., I.R.H.O., 1952, p. 74].

It is true that these norms might be more precisely defined in the future by introducing corrective coefficients for climatic and varietal factors. This would make possible the comparison of results of different years and in different districts.

Hitherto we have been able to establish interesting correlations between rainfall, levels of nitrogen and phosphorus nutrition of the leaf and response to nitrogen and phosphate fertilizing.

We have put together the results of four years very different from the point of view of rainfall; from 280 mm. between sowing and flowering in 1949 to 620 mm. in 1950 (the 1950 results taken from work by S. Bouyer, L. Collot and M. Mara).

As sowing is done as soon as the rainfall reaches a total of 20 mm. it is usual to connect percentage content of elements with amounts of rainfall between sowing and sampling. Diagram 2 shows that the higher the rainfall the lower the leaf contents of N and P. These low levels probably result from two factors: a dilution of the elements in the soil and a dilution in the leaf due to increased growth. Lundegardh arrived at similar conclusions in Sweden for cereals.

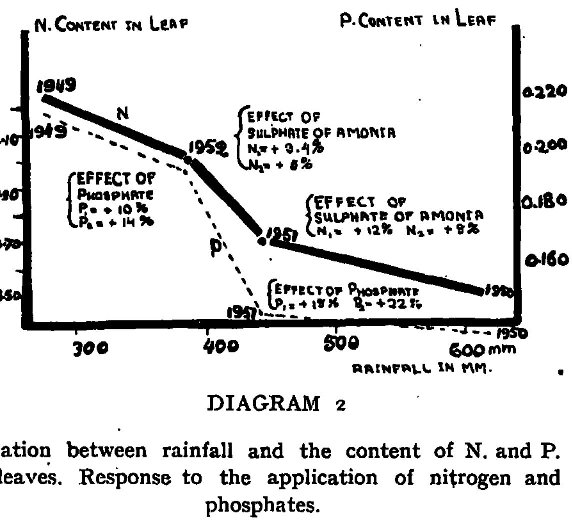

DIAGRAM 2

Relation between rainfall and the content of N. and P. in leaves. Response to the application of nitrogen and phosphates.

Fertilizer trials carried out in 1951 and 1952 show a different response according to the year: nitrogen and phosphorus gave better results in the very wet year 1951 than in 1952. This different intensity of yield response dependent on rainfall is in good agreement with the general tend of responses obtained in the leaf to application of N and P fertilizers; the lower the level of N or P in the leaf the higher the response to application of N or P.

Thus we now have at our disposal arapid means of estimating the type of mineral fertilizer adapted to a specific region. Foliar analysis shows whether N, P or K should predominate in the fertilizing. Thus the researches of I.R.H.O. in Senegal in 1951 and 1952 make possible the suggestion of various fertilizer procedures for Senegal (see Table 1 and fig. 1).

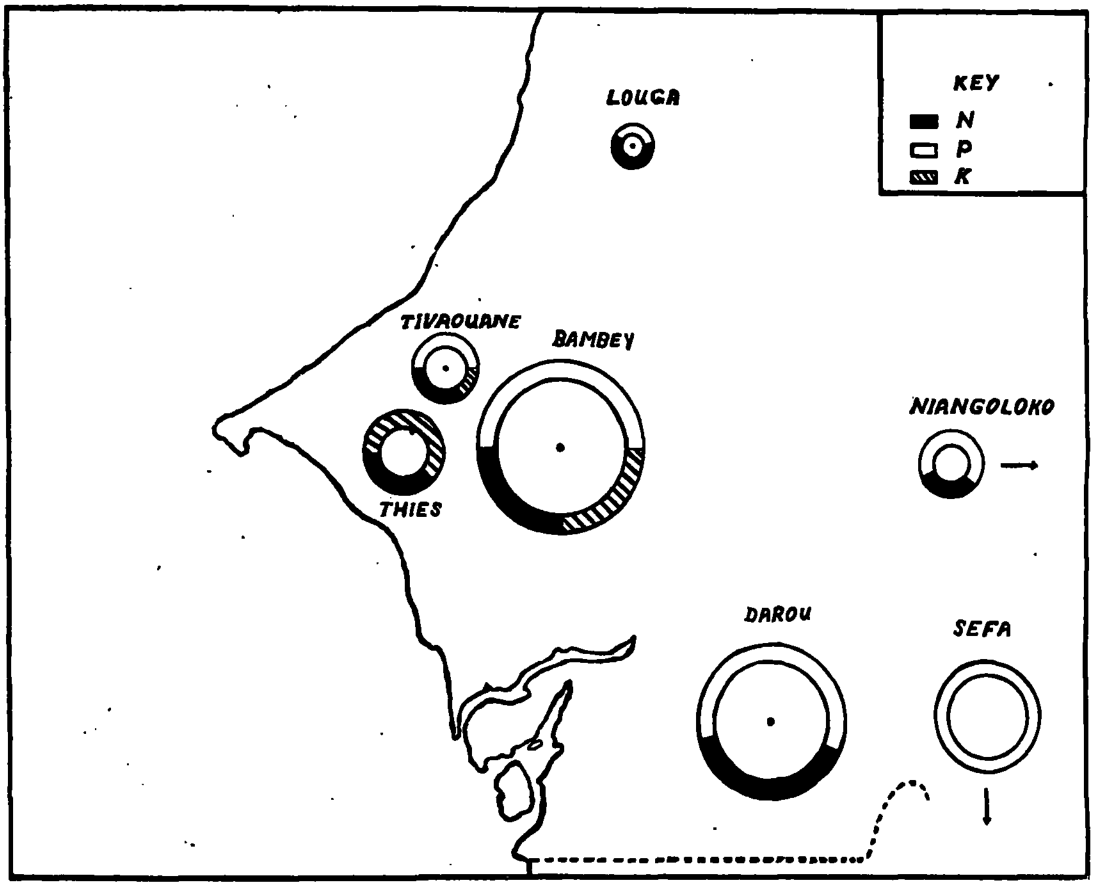

FIG. 1

Map shewing the geographical distribution of the manurial recommendations in Senegal.

Determination of 'principal effects' of fertilizing is essential because the difficulties of economic application of mineral fertilizers to a poor crop prohibit the wasting of a fertilizer whose action would be uncertain.

In collaboration with the Soil Bureau at Dakar and the C.R.A. at Bambey, the I.R.H.O. hopes to produce fairly soon a map of Senegal dealing with mineral nutrition of ground-nuts, facilitating the adaptation of mineral fertilizing to different districts.

The effect of suitable fertilizers on the chemical equilibrium of the plant is well shown by the use of pentagonal diagrams (see fig. 2). In these diagrams the percentages of the different

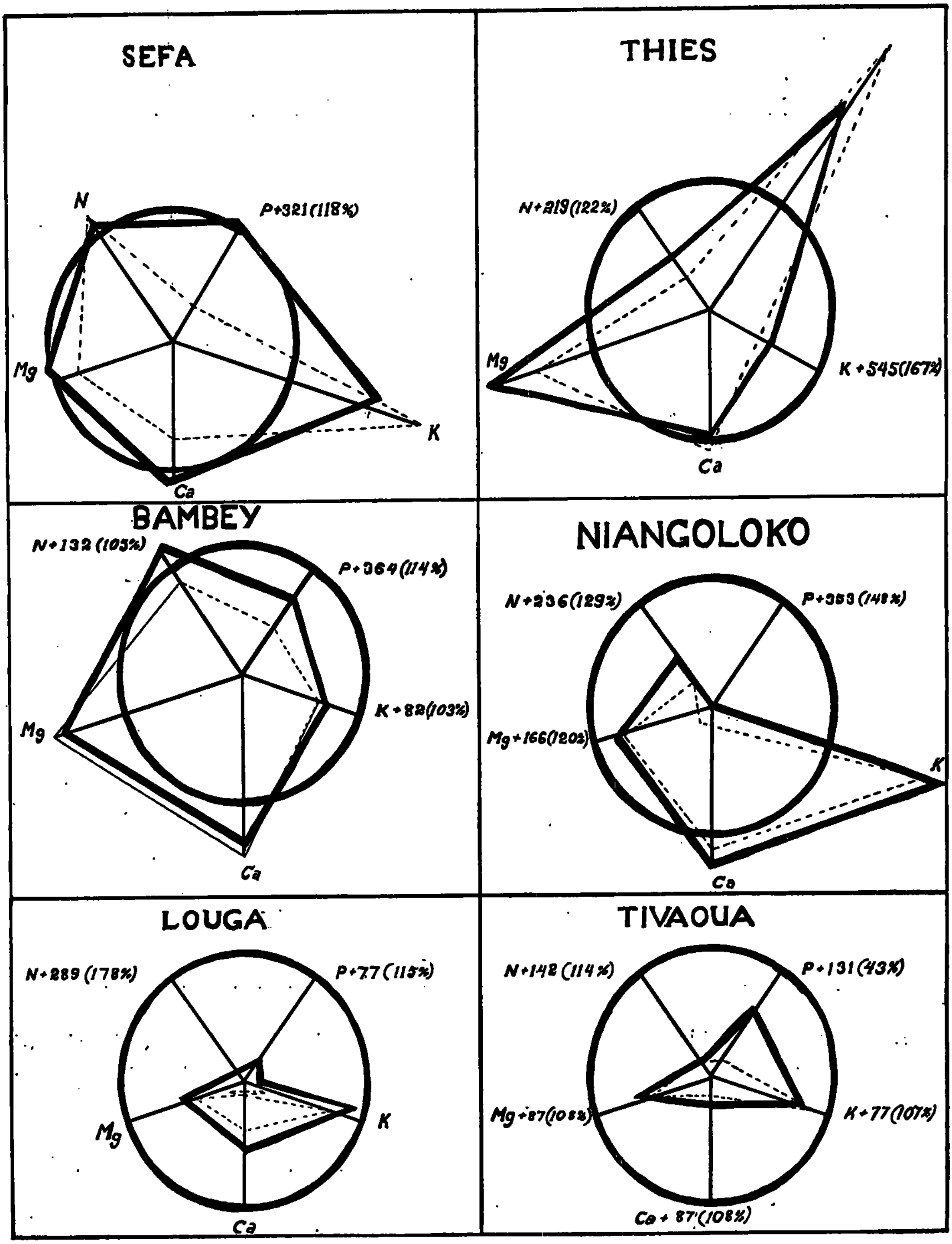

FIG. 2

Diagram shewing the effect of manuring on the chemical equilibrium of the palm.

elements are plotted on radii with the following scales from centre to circumference:

N from 3	to 4%
P from 0.15	to 0.25%
K from 0	to 1%
Ca from 1	to 2%
Mg from 0	to 1%

Thus the critical levels of N, P and K are plotted on the circle of reference but Ca and Mg are given arbitrary values, since we have not yet determined the critical levels for these two elements. Percentages before treatment are in black, those after treatment in red. Opposite each element the yield increase due to fertilizing is indicated.

It will be noted that:

(1) the pentagon is smaller the greater the exhaustion of the soils (Louga, Tivaouane);

(2) beneficial treatment improves not only yields but the chemical balance of the plant, which tends to approach the circle of reference.

The economic success of fertilizing depends not only on the formula but on the quantity to be used. In this respect too, foliar diagnosis gives a precise response. The field trials of the C.R.A. at Bambey showed that it was uneconomic to exceed an application of 150 kg/ha. Our 1952 experiments confirm this result and show that the maximum yield increases were obtained at and above 100 kg/ha with the formula 3.5-26.5-3 (see Diagram 3).

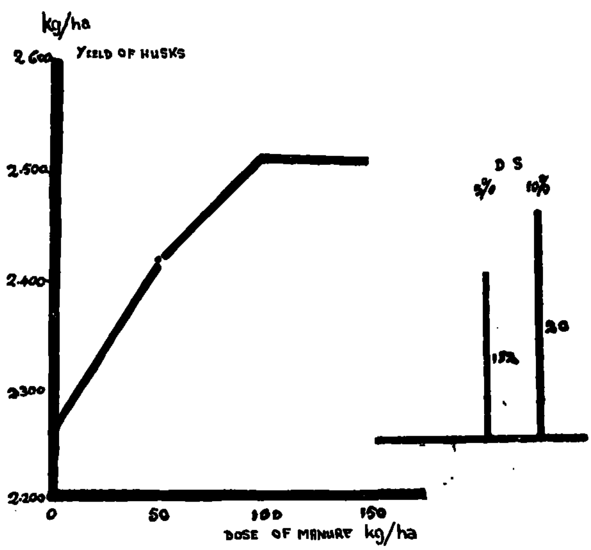

DIAGRAM 3

Bambey—Influence of dose of manure on the yield of husks.

We see that tricalcium phosphate increased neither yields nor per cent of P in the leaf. Bicalcium phosphate and super, however, increased both. But although a supplementary amount (P_2) of bicalcium phosphate did not increase leaf P beyond the percentage attained with P_1, a supplementary application of superphosphate markedly increased leaf P without having any effect on yield. This is readily explained by the fact that the extra superphosphate raised the P content of the leaf well above the critical level. Thus we here have a clear case of 'LUXURY CONSUMPTION' as far as yield of pods is concerned. Experience shows that there is no point in exceeding an application of 75 kg of bicalcium phosphate per ha.

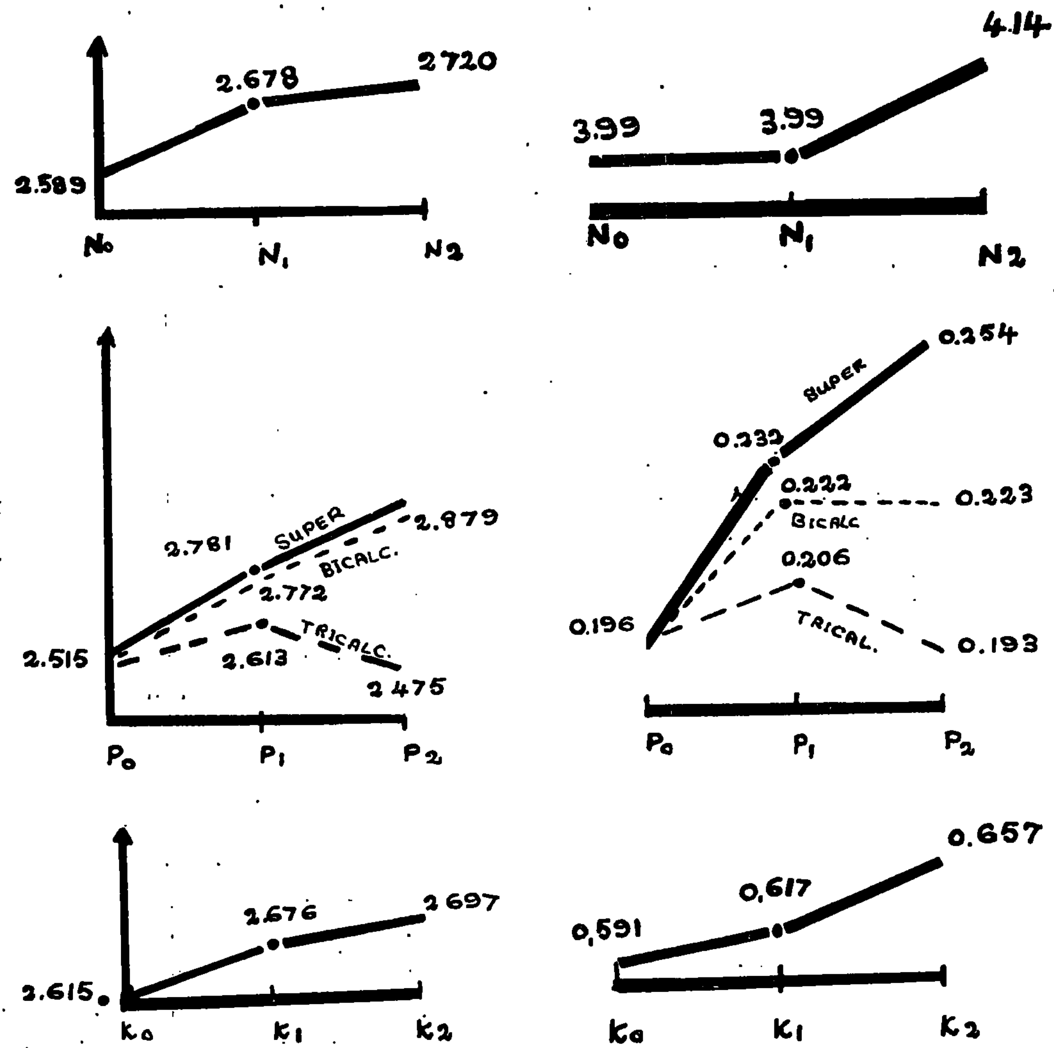

DIAGRAM 4

Influence of N, P, K on the yield of husks (per bunch) and on the N, P, K content at Bambey.

At Sefa we came to the conclusion that if there were a maximum economic gain from applying phosphate at 120 kg/ha there would not be much advantage in using more than 60 kg/ha (Chausson and Ollagnier 1953).

It is good to note that in general the amounts of fertilizer to be applied to ground-nuts on sandy soils in Senegal need not be more than 100 to 150 kg/ha.

The efficiency of fertilizers can be further improved by careful placement. Orgias (1951) studied in Senegal the root system of the ground-nut. The preliminary results will have to be completed by investigations in crop physiology on determination of root-absorption zones and ion-accumulation capacities. There is already an indication of an advantage in placing the

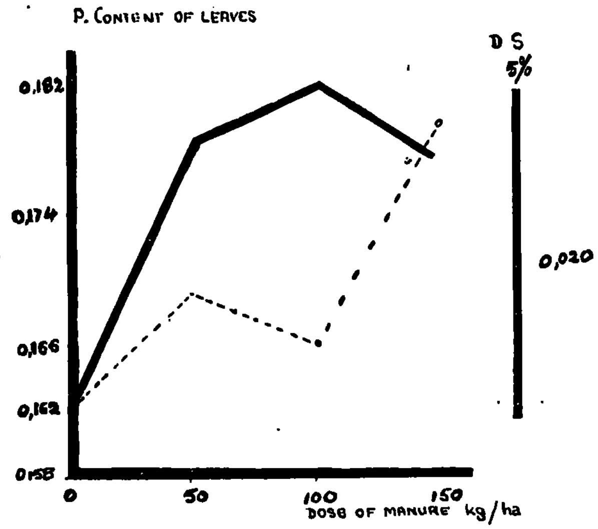

DIAGRAM 5

Comparison of the mode of application of manure on phosphoric acid.

fertilizer in the surface layers and around the plant. In one of his recent experiments the efficiency of phosphorus absorption was much greater for fertilizer applied as side dressing (5 cm. from the plant and 5 cm. below the surface) than for broadcast application (see Diagram 5).

Summarizing, we begin to see answers to the three main questions; which fertilizers, how much and where to apply them.

It can be definitely stated that in the majority of cases an application of 100 kg of a well suited mixture would be economic.

2. Oil Palms

INVESTIGATIONS ON A PERENNIAL CROP TAKE LONGER THAN ON ANNUAL CROPS. The effects of fertilizers are not apparent until one to one and a half years after application. *Where there is pronounced deficiency three or four years are needed to restore the palms to good condition.* Until the last few years, trials with mineral fertilizers for oil palms have given only negative results in Africa. The first positive results were obtained on the Dabou plantation by the I.R.H.O. They are even sensational, in that at Dabou (Ivory Coast), the annual application of k kg of Kcl per tree was sufficient to triple production (Ferrand, Ollagnier and Boye 1952).

Following on the work of Chapman and Gray in Malaya the I.R.H.O. has systematically used foliar diagnosis since 1951 in all experiments on mineral fertilizing. Comparison of these results with those of G. W. Chapman has enabled us to put forward the following ' Critical levels ' which will be checked by further research. The method used is the same as for groundnuts : comparison between response to fertilizer and leaf content of the elements applied :

$$Nc = 2.75\%$$
$$Pc = 0.15\%$$
$$Kc = 1.10\%$$

Leaf samplings in native groves have established with certainty that the results obtained at the research stations at Pobe in Dahomey and Dabou and La Me in the Ivory Coast (Potassium deficiency in all three cases) could be generalized for the sections of Dahomey and the Ivory Coast covered by the survey.

Naturally at Dabou, for example, the effects of applications of KCl on leaf percentages of N, P, K, Ca and Mg are regularly followed up, and this will permit of modification of fertilizing if there are signs of chemical disbalance in the leaf.

In establishing fertilizer formulas attention must be given to quantities of the various elements in relationto one another, that is, conclusions must be based not only on the absolute levels of the elements (quantitative aspect of nutrition) but also on reciprocal relationships (quantitative aspect of nutrition) and on antagonisms. Our studies show the existence of K-Ca and K-mg antagonisms very clearly and a frequent connection of Ca and Mg. A further point is that the N/P ratio, about 16, is very constant. This reflects the strong connection between the elements N and P (fundamental constituents of protopalasm) on the one hand and the alkalis and alkaline-earth elements on the other.

Table 2 shows contents of N, P, K, Ca and Mg found :

(1) where characteristic yield increases were obtained by applying potassium generally, or magnesium :

(2) where disease occurred accompanied by nutritive disbalance (work done at Sibiti, Etoumbi, work by Hale in Nigeria and British Cameroon).

It can be seen from the table that, generally speaking, K and Ca on the one hand and K and Mg on the other, vary in an inverse manner at the same station. It is very interesting to study the sum K + Ca + Mg, which is relatively constant at about 2. When the initial value is low in cases of potassium deficiency, application of potash raises the value back toward 2%.

For studies of simultaneous variations of K, Ca and Mg trilinear plotting is particularly interesting. (It involves use of the properties of the equilateral triangle, with a constant value of 100 for the sum of the distances from the sides as the value for each element). The results are not affected by too great variations of K + Ca + Mg because the sum is fairly constant.

In diagram 6 the results from Table 2 are represented, corresponding to different treatments applied in the experiments, or to a favourable or unfavourable health condition. The direction of the arrow indicates progress towards higher production or a more healthy state. It is interesting to note that the 'possible' balances of K, Ca and Mg nutrition both before and after establishment of equilibrium are all grouped in a fairly narrow elongated area of which the outline is drawn. Treatments benefiting production as well as crop health limit nutrition to a very restricted section of favourable ratios. The optimum appears to be in the neighbourhood of 58% K, 30% Ca and 12% Mg. Given the high degree of constancy of K + Ca + Mg already mentioned, the optimal percentages correspond to dry-matter contents of :

1. 15 for K
0.600 for Ca
0.240 for Mg

The value 1.15 for K corresponds to that of the proposed critical level. We think it justifiable to propose the optimal values thus derived for Ca and Mg as critical levels.

The Mg level has already been confirmed from samplings at Etoumbi in 1953. The Mg content of unhealthy trees is about 0.026. It rises to 0.266 in healthy trees. Application of Mg sulphate increases leaf Mg and improves health and production. At Dabou, where the Mg content is 0.315-0.320 application of Mg does not increase yield.

The question of fertilizer placement has been partially elucidated by the detailed researches of Fremond and Orgias (1952) on the root system of the oil palm at La Me (Ivory Coast). Results have been confirmed at Pobe (Dahomey) and Sibiti (Middle Congo). As a preliminary, absorption experiments with coloured solutions (e.g. 1% fuchsin) had shown that roots of the first and second orders lacked the power of absorption. *Only the fine rootlets absorbed the coloured*

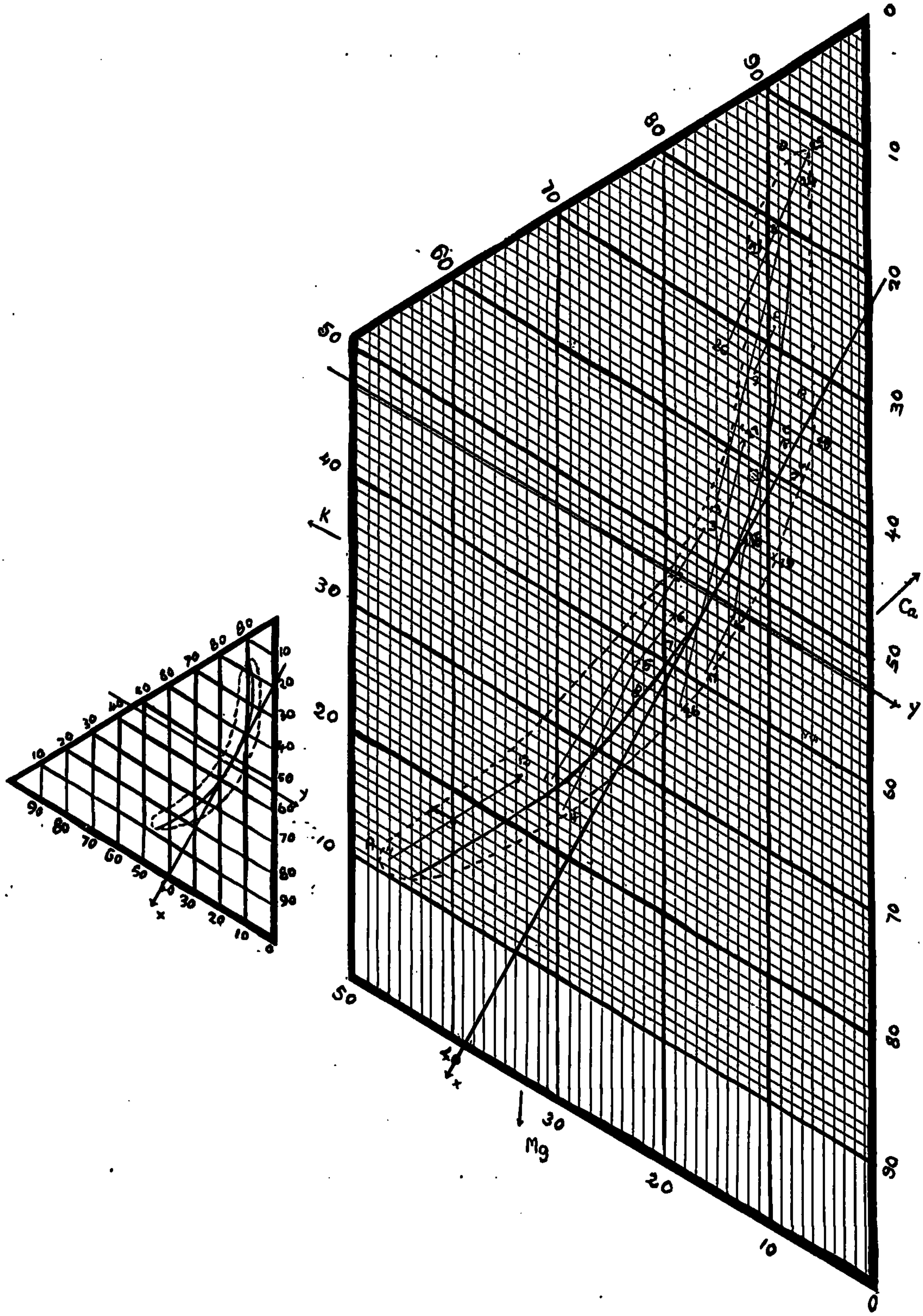

DIAGRAM 6
Trilinear diagram of the nutrition of the palm, K, Ca, and Mg.

solutions. The important active mass of the root system is distributed between 5 and 35 cm below the surface. For eleven-year-old palms the densest zone of absorbing roots is localized in a ring of 2 m internal and 4 m external radius. Therefore fertilizers should be applied at very shallow depth in a ring, the size of which depends on the age of the tree. Naturally, as or ground-nuts, these studies call for completion. The results obtained already illustrate how crop-physiology investigations rapidly lead to applications of a practical nature.

3. Conclusions

The results, too briefly condensed here, on mineral fertilizing of ground-nuts and oil palms, provide an affirmative answer to the question at the beginning of this article: the economic advantage of mineral fertilizing for these oil crops is certain.

Many questions will have to be further developed: fertilizer ratios adapted to different regions, the type of fertilizer to use, time and method of application, connexions with climatology. Other questions so far are hardly entered upon: relationships between organic matter and mineral fertilizing, bacterial life in the soil, trace elements, accumulating capacity of the root system, etc. However, up to the present the investigations of the I.R.H.O., like those of the C.R.A. at Bambey, have been able to demonstrate the economic advantage of applying various fertilizer mixtures to ground-nuts in Senegal. They have made it possible to prescribe certain types of fertilizer suited to different regions.

For oil palms the economic advantage of applying potassium chloride is evident in the Ivory Coast and our results allow its advocation for Dahomey.

The results have been well supported and have allowed of rapid application, because the studies combine the agricultural and physiological sides of the question. Crop physiology will continue to provide, we hope, solutions to some of the problems posed by the growing of tropical oil crops.

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TABLE II

	Territory	Station	Treatment	N	P	K	Ca	Mg	Report N/P	K + Ca + Mg	K%	Ca%	Mg%	Increase
1	IVORY COAST	DABOU	without potash	3.00	0.184	0.460	0.760	0.535	16.3	1.755	26.2	43.3	30.5	
2			potash since 1949	3.16	0.189	0.920	0.656	0.382	16.7	1.958	47.0	33.5	19.5	+ 100
3			potash since 1946	3.06	0.179	1.04	0.638	0.323	17.1	2.001	52.0	31.9	16.1	a 200%
26		LA ME	without potash	3.17	0.168	0.57	0.691	0.287	18.9	1.550	36.8	44.7	18.5	
27			with potash	3.19	0.181	1.25	0.543	6.257	17.6	2.050	61.0	26.5	12.5	+ 28%
4	DAHOMEY	POBE	without potash	2.53	0.167	0.565	0.868	0.607	15.1	2.040	27.5	42.5	29.8	
5			1 kg. KCl since 1948	2.61	0.170	0.784	0.791	0.481	15.4	2.056	38.1	38.5	23.4	+ 28%
6			2 kg. since 1948	2.58	0.163	0.917	0.770	0.401	15.8	2.088	43.9	36.9	19.2	+ 25%
7	MALAISIE according to G. W. CHAPMAN		without potash	2.58	(1) (3.19)	(7.64)	(12.8)	(5.01)		(25.45)	30.0	50.3	19.7	
8			with potash	2.73	(3.30)	(14.7)	(11.1)	(4.39)		(30.19)	48.7	36.8	14.5	+ 64%
11	NIGERIA according to J. B. HALE (feuille mediane)	N'KWELE	diseased			0.174	0.643	0.690		1.507	11.5	42.7	45.8	
12			healthy			0.373	0.593	0.492		1.458	25.6	40.7	33.7	
13		N'DIAN	chlorotic			1.26	0.479	0.138		1.877	67.1	25.5	7.3	
14			healthy			0.838	1.10	0.114		2.052	40.8	53.6	5.5	
15	CAMEROONS BRITISH	COWAN ESTATE	healthy			1.17	0.743	0.264		2.177	53.7	34.1	12.1	
16			lemon frond			1.02	0.843	0.282		2.145	47.6	39.3	13.1	
17			bronzing			0.809	0.843	0.318		1.970	41.1	42.8	16.1	
18	SUMATRA	BANGUN BANDAR	low production	2.37	0.163	1.18	0.543	0.165	14.5	1.888	62.4	28.7	8.7	
19			high production	2.39	0.160	0.93	0.644	0.157	14.9	1.731	53.7	37.2	9.1	
9	A.E.F.	SIBITI (1951)	healthy	2.80	0.162	1.38	0.457	0.230	17.3	2.067	66.7	22.1	11.1	
10			diseased	2.53	0.158	1.54	0.412	0.202	16.0	2.154	71.6	19.2	9.4	
20		SIBITI (1952)	healthy	3.07	0.149	1.56	0.436	0.324	20.6	2.320	67.2	18.8	14.6	
21			chloroticyellowishgreen	2.44	0.123	1.81	0.324	0.242	19.8	2.376	76.2	13.6	10.2	
22			chlorotic yellowish	2.10	0.113	1.88	0.292	0.226	18.6	2.398	78.4	12.2	9.4	
		SIBITI (1953)	healthy	3.01	0.203	1.29	0.686	0.326	14.8	2.302	56.0	29.8	14.2	
23			chloroticyellowishgreen	2.55	0.172	1.80	0.184	0.153	14.8	2.137	84.2	8.6	7.2	
24			chlorotic yellowish	2.39	0.177	2.05	0.170	0.152	13.5	2.372	86.4	7.2	6.4	
25														
28		ETOUMBI	NPK without magnesium	2.95	0.189	1.21	0.562	0.114	15.6	1.89	64.0	29.7	6.0	
29			NPK with magnesium	2.98	0.197	(1.13)	0.577	0.135	15.1	1.84	61.4	31.4	7.3	