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THE APPLICATION OF FERTILIZERS TO ADULT COCONUT PALMS IN RELATION TO THEORETICAL CONCEPTS

By

W. R. N. NATHANAEL,

Director, Coconut Research Institute of Ceylon.

SUMMARY

The problems of experimentation with coconut are widely different from those generally encountered with annual arable crops. The significance of certain diagnostic techniques in the assessment of crop nutritional requirements is discussed. Their use in ascertaining a proper basis for systematic soil replenishment is also considered.

Experiments have shown that coconut production in most coconut soils of Ceylon are limited by deficiencies of nitrogen, phosphorus and potassium. It has also been found that significant increases in production could be achieved by proper fertilizer usage. In accordance with these findings the C.R.I. quantitative recommendations for fertilizer application to adult coconut palms have been progressively increased over the years.

Using reliable plant analysis data the theoretical basis for the application of fertilizers to adult coconut palms is discussed. The usefulness of such factual information as a guiding factor in fertilizer practice is elucidated. In this context, the significance of certain management practices and the importance of using soil and plant diagnostic techniques in complementary roles is emphasized.

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INTRODUCTION

A judgment of the mineral needs of a crop is a problem perennial in agriculture. Though the mineral elements that are basically essential for nutrition remain the same for all crops, their quantitative requirements vary a great deal from crop to crop, depending not only on whether they are annuals, biennials or perennials but also on their morphological features and the agronomic environment governing their growth.

The theoretical basis for fertilizing a crop is relatively simple. In general, all that would appear necessary is to add as fertilizer only that amount (F) of material which would be required to make up the difference between the nutrient required by the crop (R), and that supplied by the soil medium (s). In the form of an equation it could be expressed as follows :—

$$F = R - s.$$

This implies that crop performance could be improved, if we are in a position to estimate *firstly* the amount of a particular nutrient required by the plant for unrestricted growth (R), and *secondly* the amount that is actually supplied by the soil (s). The difference, if any, would represent the quantity (F) that would have to be applied as a fertilizer.

In spite of the apparent simplicity of these basic principles, the problems confronting the crop nutritionist are by no means simple, because they are bound up with all three of the components in the equation. In order to ensure the optimum growth of his crop, he has to determine not only the actual requirements of his crop for each of the essential mineral nutrients in turn, but also the extent (in quantitative terms) to which they are all available in the soil. Even when these have been established, the differences would not reflect accurately the respective fertilizer dosages, because what is applied to the soil is for various reasons never assimilated in full by the plant.

TABLE — I

Estimates of the Annual Removal of Major Plant Nutrients from the Soil by the Coconut Palm

1	2	3	4				
No	Authority	Basis	Nutrients (pounds per acre)				
			N	P_2O_5	K_2O	CaO	MgO
1	Pillai (1919)[1]	2,000 nuts/acre per annum	18	5	38	—	—
2	Jacob & Coyle (1927)[2]	From one acre/annum	57	26	85	—	—
3	Copeland (1931)[3]	2,800 nuts/acre per annum	82	37	122	—	—
4	Georgi & Teik (1932)[4]	Soil rich in plant nutrients	66	27	123	15.7	28.6
5	Eckstein *et al* (1937)[5]	Annual removal per acre	81	36	117	—	—
6	Patel (1938)[6]	Recommendation for annual addition per acre	24	12	60	—	—
7	Carvalho (1947)[7]	156 mature palms per hectare (2.5 acres)	104	36	126	—	—
8	Cooke (1950)[8]	60 palms per acre with 50 nuts/palm/annum	52	16	48	26.0	40.0
	OVERALL AVERAGE FROM EIGHT ESTIMATES		60	24	90	20.8	34.3

COPELAND'S ESTIMATE (Recalculated)

BASIS	NITROGEN		PHOSPHORUS		POTASSIUM		CALCIUM	MAGNESIUM
	As sulphate of Ammonia (20.6% N)	as N	As Saphos Phosphate (27.5% P_2O_5)	as P_2O_5	As Muriate of Potash 60% K_2O	as K_2O	As CaO	As MgO
Pounds per acre per annum	398	82	135	37	203	122	20.8	34.3
Pounds per palm per annum (64 palms/acre)	6.2	1.3	2.1	0.58	3.2	1.9	0.32	0.54

Estimates of the annual removal of plant nutrients by the coconut palm have been made by various workers and the available information is charted in TABLE — I. The fact that the figures are very variable is not surprising because they have been reported from widely dispersed geographic regions, and also because we know that a host of factors, including age of plantation, soil type, variety of palm, soil fertility status, soil management practices and the climatic environment affect the uptake of nutrients. Copeland's estimate, based on an annual production figure of 2,800 nuts per acre, is generally reckoned to be the one that approximates the average mineral requirements of adult coconut palms in regular bearing. In general, the data underline the fact that the coconut palm could rapidly deplete a soil of the essential mineral nutrients owing to its relatively heavy demands. A further fact is that the quantitative sequential order of importance of the major mineral nutrients for the adult coconut palm is as follows :—

Potassium ——> Nitrogen ——> Phosphorus $\rightleftarrows$ Magnesium ——> Calcium.

COCONUT CULTURE

The coconut palm is grown in Ceylon under a variety of climatic and edaphic conditions. It is an extreme type of perennial, and is unique in that once it starts flowering, the productive phase lasts not only throughout the year but all through its economic life, which may average seventy years. Depending on the environment and cultural regime this phase commences between the fifth and tenth years of growth, and in the regular bearers of the tall (*typica*) variety, a cluster of fruits is generally produced every month throughout the year. The palm can therefore be reckoned a true perennial as regards both its growth and yield characteristics.

It is well known that few cultivated plants compare with the coconut in its unique adaptability to different soil and climatic conditions. In the dry zone it remains a *Xerophyte*. Under wet and water-logged conditions it is a *mesophyte*, and under saline conditions on the littoral it is a *halophyte* (*NOTE*. *Xerophyte* is a plant growing in desert or physiologically dry soil. *Mesophyte* is a plant thriving in temperate climate under wet conditions. *Halophyte* is a plant capable of thriving on salt impregnated soils).

The capacity of a soil to supply plant nutrients deteriorates steadily on continued cultivation. For well over a century there has been mono-cultivation on Ceylon's coconut lands, and it is significant that at least in the case of 70 per cent of the properties (principally small-holdings) little or nothing has been put back into the soil. In general practice, the majority of owners remove (besides the harvested coconuts) everything possible from the land, including, pasture grass, leaves, butt-ends of fronds, husks and other plant residues. Further, during replanting, stem is also removed for timber. The removal of these plant products implies the progressive depletion of the nutrients available to the crop with consequent soil impoverishment. On a great many plantations there is no sustained programme of replenishment to compensate for these losses. It is imperative therefore that the continuous commercial cultivation of a perennial crop, without any rotation, requires that the supply of plant nutrients in the soil should be maintained. When this is not done, an obvious decline in yields is only a logical sequel, which under extreme conditions culminates in a derangement of the metabolism of the plant resulting in physiological decease.

From what has been adumbrated above, it should be clear that the main problem for any plant nutritionist working on a crop like coconut, is not only to assess its nutritional requirements but also to establish a proper basis for systematic soil replenishment. Before considering these aspects, perhaps it would be appropriate to know something about the techniques that are generally employed in such studies.

DIAGNOSTIC TECHNIQUES

A plant may be said to be deficient in a certain element when a supply of this element in a suitable form would cause an increase in yield, the effect being specific for the element in question. In the case of an excess, on the other hand, the element would either produce no further yield increase or merely lead to a decrease in yield. In such considerations of mineral status, it may be well to remember that two points are of particular significance for healthy performance —(1) the mineral nutrients must be present in adequate amounts and (2) they must all be present in fairly well-defined proportions.

Plants usually slow down in their normal rate of development and show other signs of disorder whenever one or more of the above factors that contribute to their well-being get out of balance. A range of techniques (affecting the soil and the plant) for the diagnosis of such problems have now been evolved, and those considered relevant to the present context are as follows :—

Method of Field Trials :

Ever since Liebig enunciated his mineral theory of crop nutrition in 1840, the method of field experimentation with chemicals has been applied with increasing importance to various crops for the evaluation of their optimum nutrient requirements. In spite of its limitations, this technique is one of the most direct methods for the determination of the mineral requirements of crops in respect of both yields and quality. A further practical merit of the technique is that wherever favourable results are obtained, the cause and remedy are simultaneously indicated.

Modern statistical designs for field experiments are also very useful in studies on nutrient interactions and induced deficiencies consequent on nutrient imbalance. Since field experiments represent the final test nearest to agricultural practice, it is always to this method that the experimentalist turns in order to judge the validity of his findings from other techniques. Due principally to advances in statistical method, the technique of field experimentation has been revolutionised making this branch of research more or less an exact science.

Method of Soil Analysis

The principle of using soil analysis in relation to problems of plant nutrition was recognised no sooner it was established that plants obtained their mineral requirements from the soil. The immediate object, of soil analysis is of course to determine quantitatively the potential supplies of nutrients in the soil with a view to making good any deficiencies. A further object is to obtain an accurate characterization of soils, for purposes of classification and assessing their suitability for different crops.

In spite of its empirical nature and other shortcomings the diagnostic value of soil analysis is considerable. It is certainly one of the useful tools for ascertaining the conditions in the soil that control the response to fertilizers, and the causes of crop failure when associated with straight soil deficiencies unencumbered by other factors.

Method of Diagnostic Plant Analysis

Though there is an interlocking linkage between the plant and the soil, the nutrient status of the plant can be considered independently of the nutrient status of the soil.

The earlier views, especially of those influenced by the dogmas of traditional agronomy, to the effect that the composition of plants cannot be used as an index of nutrient requirements have now been proved to be untenable. On the contrary, at the present time, the chemical examination of plant tissue for the assessment of (*a*) nutrient needs of plants on the basis of uptake and (*b*) as a guide to fertilizer practice, has reached an active stage in the research programmes of agricultural institutions in many parts of the world. The consensus of opinion at the present time is that this technique is particularly valuable in crop research when it is used with other diagnostic methods in a complementary role.

PROBLEMS OF EXPERIMENTATION WITH COCONUT

Unlike other crops where the integrated unity of the whole plant could be treated as an organism, the coconut palm owing to its morphological features and higher level of organization is in many ways unwieldy for experimental procedure. In spite of these handicaps the palm has certain unique features and offers almost unlimited scope for the application of 'plant diagnostic techniques', provided separate investigations covering distinct phases in the growth cycles of the palm are planned and executed.

As regards field experimentation, with coconut, the associated problems are many, and on the basis of a review that has been made by Salgado[9], they could be summarised as follows:—

(i) Coconuts are planted under estate conditions at not more than 60 to 70 palms per acre. As such, the yield data come from a limited plant population.

(ii) Being open-pollinated and heterozygous, the palms are far from uniform in their genetic compostion and hence in their potential yield capacity. For this reason it is essential to keep yield records on individual palms. (*NOTE. Heterozygous* implies that it bears two dissimilar alternative genetic factors).

(iii) It is rarely possible to get a uniform extent of soil over an area of even 10 to 12 acres. For a comprehensive experiment on coconut as much as 30 acres may be required. The very large Block Variance is therefore a factor that vitiates experimental accuracy.

(iv) Finding a uniform stand of palms on a mature coconut plantation is always a problem. Invariably, there are different age groups resulting from replacements for various reasons.

(v) Even within palms of the same age, it is well known that there are early and late bearers with highly variable productive spans. These features further aggravate the problem of population heterogeneity.

(vi) Since the palms on a coconut plantation are widely spaced, only a relatively small number could be included in a single plot. On the basis of uniformity trials, 18 palms (comprised of 3 rows of six palms each) to the plot have been found to give a minimum standard error. 18 palms represent an area over one-fourth of an acre, and the effects of soil differences within such plots could still be considerable.

(vii) Particularly on sandy soils, the root system of the coconut palm is diffuse and extensive. The provision of an efficient system of "guard rows" is therefore an extra problem in fertilizer trials with coconut.

(viii) Separate records of the yields of individual palms from each plot have to be kept, as sampling of the produce from one whole plot in one harvesting operation (as with cereals) is not possible. The problem is made more difficult by the fact that errors could arise from the intermingling of "fallen nuts" from adjoining plots.

(ix) Premanurial yield records for at least a year are necessary in order to adjust the yields of experimental years.

(x) When the variations in soil and climate are kept in mind, the need for replicating manurial experiments on different coconut soils assumes particular importance. To study the effect of season, it is also necessary to continue field experiments on coconut over a protracted period of time.

From what has been discussed above, it should be evident, that the problems of experimentation with coconut are legion and different from those generally encountered with annual arable crops. In spite of these obstacles, a series of modern field experiments on the manuring and cultivation of coconut have been carried out by the Coconut Research Institute (Ceylon), since 1934. These include experiments on the manuring of young and mature plantations under various environmental conditions laid down on a number of estates in different areas.

CRI FINDINGS AND RECOMMENDATIONS

The fact that fertilizer usage leads to increased yields and reduces costs of production is well recognized in agriculture. With regard to the coconut crop, it has been found that significant increases in production could be realised (within a relatively short period of time) by the proper application of fertilizers, provided that the other basic soil management practices are also maintained at proper levels.

Experiments carried out at the Coconut Research Institute by the Soil Chemist have shown that coconut production in most coconut soils of Ceylon is limited by deficiencies of nitrogen, phosphorus and potassium. In certain areas—particularly in the wet zone, magnesium has also been found to be deficient. Field trials carried out by him in the Chilaw District—which is one of the best coconut growing areas in Ceylon—have shown that without fertilizers annual yields of about 2,500—3,000 nuts per acre per annum could be obtained. Fertilizer application stepped up production to about 5,000 nuts/acre/annum—an increase of about 82 per cent. At Madampe, in an experiment on young palms, plots that did not receive fertilizers from the time of planting yielded 2,400 nuts/acre per annum in their 15th year. Plots treated with 4.5 lbs. per palm per annum(of a mixture containing equal proportions of sulphate of ammonia, saphos phosphate and muriate of potash) gave 4,200 nuts/acre (75% increase), while those plots receiving 9 lbs. per palm of the same mixture gave an annual yield of 5,720 nuts per acre (138 per cent increase). In another experiment on underplanted young palms at Nattandiya unmanured plots gave 2,500 nuts per acre in their 15th year, whereas plots treated with NPK mixture at the rate of 4 lbs. per palm gave 4,200 nuts/acre (68% increase). At Bandirippuwa (Lunuwila), unfertilized plots have given an annual yield of about 2,500 nuts/acre while manuring increased yields to over 5,000 nuts/acre (100% increase). Under comparatively better conditions in Bingiriya, where even without any fertilizer application annual yields were of the order of 4,000 nuts/acre, production was increased to 5,500 nuts per acre (i.e. about 38%) by the application of fertilizers at the rate of 5 lbs. per palm per annum. These experiments have demonstrated that fertilizer application brings about appreciable increases in coconut production even in the better coconut growing districts.

More striking responses to fertilizer application have been obtained by the Soil Chemist in the poorer coconut growing districts of the wet zone which cover an area of about 350,000 acres, representing about 30 per cent of the Island's coconut acreage. Field experiments at Veyangoda and Ahangama showed that in these areas without manuring, annual yields were as low as 600-800 nuts/acre. Application of N.P.K. coconut fertilizer mixtures at the rate of 3.5 lbs. per palm per annum increased the annual production to 2,500 nuts per annum (over 250%). In a trial at Pannipitiya the annual yield of 1,600 nuts per acre without fertilizers was increased to 2,336 nuts per acre (46% increase) by the application of 5 lbs. of N.P.K. mixture. The additional application of 2 lbs. of magnesium fertilizer—in the form of magnesium sulphate or ground dolomite—was observed to further increase yields to 3,622 nuts/acre per annum (i.e. 126% over the original). The above results are all expressed diagrammatically in FIGURE—1. On the basis of the research data obtained from these and earlier experiments, the CRI has been making various recommendations over the years pertinent to fertilizer usage on different soil types. The full details pertaining to the progressive changes in these recommendations are charted in TABLES—2 to 4, and the quantitative aspects of these (expressed in terms of the actual nutrients involved), are summarised in TABLE—5. The salient features are further illustrated diagrammatically in FIGURE—2.

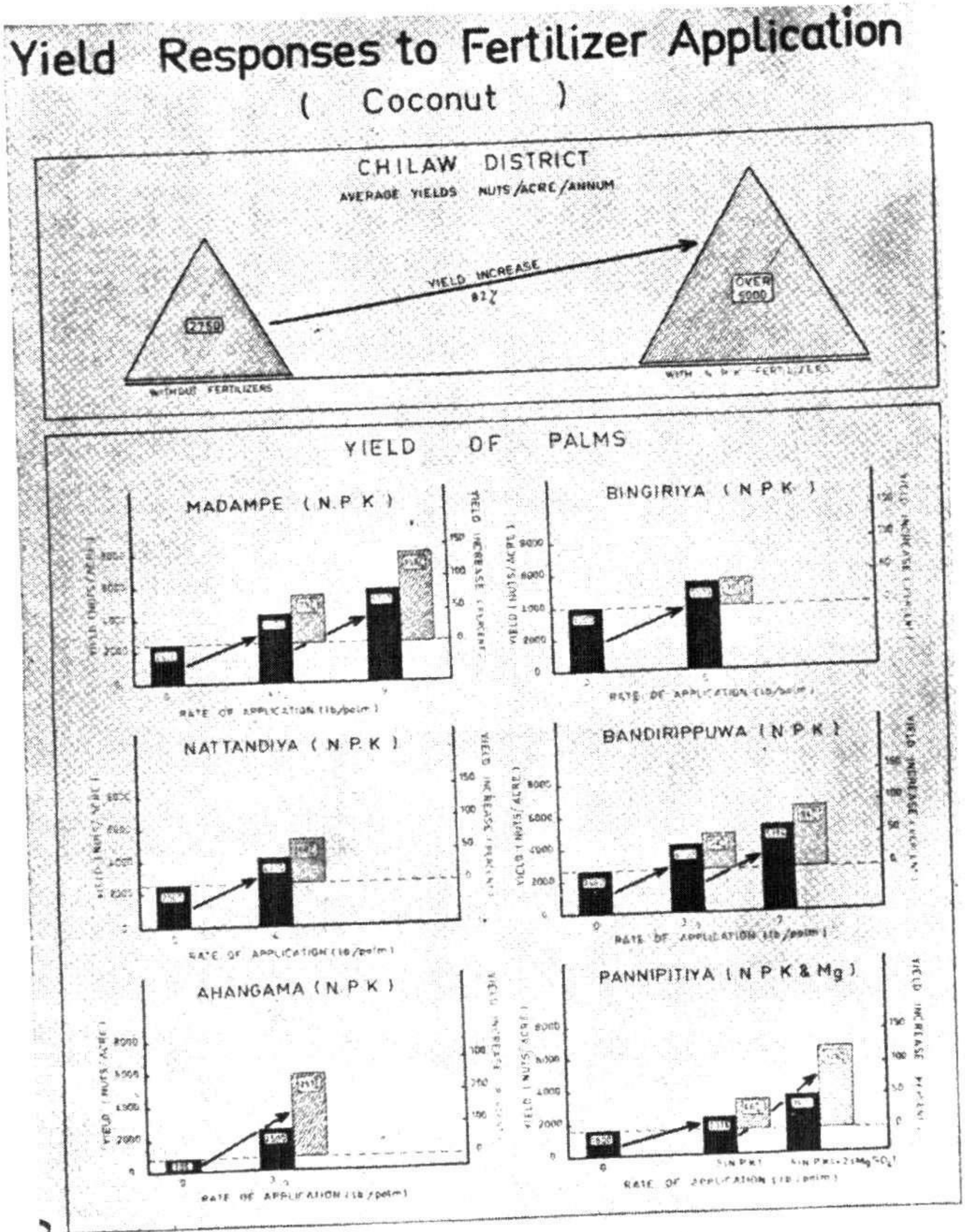

FIGURE 1—Responses to Fertilizers (Adult Palms).

TABLE — 2

PROGRESSIVE CHANGES IN CRI RECOMMENDATIONS FOR THE APPLICATION OF ARTIFICIAL FERTILIZERS TO ADULT COCONUT PALMS

1. FERTILIZERS RECOMMENDED PRIOR TO 1963

(A) For Estates which have NOT been Manured for a long Period.

	Weights of Ingredients (in pounds)				*% Nutrient in Mixture*			*Weight of Nutrient Dosage recommended per palm (in pounds)*					
	Sulphate of Ammonia (20.6%N)	*Saphos Phosphate (29.5%P2 P₂O₅*	*Muriate of Potash (50%K₂O)*	*Total*	*N*	*P_2O_5*	*K_2O*	*Biennial Application*			*Annual Application*		
								N	*P_2O_5*	*K_2O*	*N*	*P_2O_5*	*K_2O*
White Cinnamon Sands and Coarse Marine Sands	3.5	3.0	3.0	9.5	7.6	9.3	15.8	0.72	0.88	1.50	0.36	0.44	0.75
Loams and Sandy Loams	3.0	2.5	2.5	8.0	7.7	9.2	15.6	0.62	0.74	1.25	0.31	0.37	0.62
Clay Soils	3.0	2.5	2.0	7.5	8.2	9.8	13.3	0.62	0.74	1.00	0.31	0.37	0.50
Laterites (Cabooks)	3.5	3.0	3.0	9.5	7.6	9.3	15.8	0.72	0.88	1.50	0.36	0.44	0.75
Lateritic Gravel (Hal-borella) ...	3.0	3.0	3.0	9.0	6.9	9.8	16.7	0.62	0.88	1.50	0.31	0.44	0.75
Calculated General Average	3.2	2.8	2.7	8.7	7.6	9.5	15.4	0.66	0.82	1.35	0.33	0.41	0.67
RANGE	3.0 to 3.5	2.5 to 3.0	2.0 to 3.0	7.5 to 9.5	6.9 to 8.2	9.2 to 9.8	13.3 to 16.7	0.62 to 0.72	0.74 to 0.88	1.00 to 1.50	0.31 to 0.36	0.37 to 0.44	0.50 to 0.75

(B) For Estates which have been Regularly Manured.

	Sulphate of Ammonia	*Saphos Phosphate*	*Muriate of Potash*	*Total*	*N*	*P_2O_5*	*K_2O*	*Biennial N*	*Biennial P_2O_5*	*Biennial K_2O*	*Annual N*	*Annual P_2O_5*	*Annual K_2O*
White Cinnamon Sands and Coarse Marine Sands	3.0	2.5	2.5	8.0	7.7	9.2	15.6	0.62	0.74	1.25	0.31	0.37	0.62
Loams and Sandy Loams	2.5	2.0	2.0	6.5	7.9	9.1	15.4	0.52	0.59	1.00	0.26	0.30	0.50
Clay Soils	2.5	2.0	1.5	6.0	8.6	9.8	12.5	0.52	0.59	0.75	0.26	0.30	0.38
Laterites (Cabooks)	3.0	2.5	2.5	8.0	7.7	9.2	15.6	0.62	0.74	1.25	0.31	0.37	0.62
Lateritic Gravel (Hal-borella) ...	2.5	2.5	2.5	7.5	6.9	9.8	16.7	0.52	0.74	1.25	0.26	0.37	0.62
Calculated General Average	2.7	2.3	2.2	7.2	7.8	9.4	15.2	0.56	0.68	1.10	0.28	0.34	0.55
RANGE	2.5 to 3.0	2.0 to 2.5	1.5 to 2.5	6.0 to 8.0	6.9 to 8.6	9.1 to 9.8	12.5 to 16.7	0.52 to 0.62	0.59 to 0.74	0.75 to 1.25	0.26 to 0.31	0.30 to 0.37	0.38 to 0.62

TABLE 3

II. FERTILIZER MIXTURES RECOMMENDED IN AUGUST, 1963

(A) Composition of Mixtures

MIXTURE	*Ingredients (Parts by Weight)*				*% Nutrient in Mixture*		
	Sulphate of Ammonia (20.6% N)	*Saphos Phosphate (28.5% P_2O_5)*	*Muriate of Potash (50% K_2O)*	*Total*	*N*	*P_2O_5*	*K_2O*
A (Soil Fertility—Good)	1.0	1.0	1.0	3.0	6.9	9.5	16.7
B (Soil Fertility—FAIR)	5.0	4.0	5.0	14.0	7.4	8.1	17.9
C (Soil Fertility—POOR)	5.0	5.0	6.0	16.0	6.4	8.9	18.8
Cal. General Aver.	—	—	—	—	6.9	8.9	17.9
RANGE	1.0 to 5.0	1.0 to 5.0	1.0 to 6.0	3 to 16	6.4 to 7.4	8.1 to 9.5	16.7 to 18.8

(B) **Rates of Application**

(Pounds per palm per annum)

SOIL TYPE	C.R.I. Mixture	lbs. mixture/ palm per annum	Weight of Nutrient in dosage recommended (lbs.)		
			N	P_2O_5	K_2O
1. Laterite and lateritic gravels of Southern and Western Province	C	8	0.51	0.71	1.50
2. Lateritic loams of Southern and Western Province	B	8	0.59	0.65	1.43
3. Lateritic gravels and lateritic loams of North Western Province	B	7	0.52	0.57	1.25
4. Cinnamon sands of Negombo and Madampe districts and coastal marine sands of Puttalam and Eastern Province ...	C	8	0.51	0.71	1.50
5. Deep non-lateritic alluvial reddish brown loams and sandy loams of Chilaw/Puttalam districts	A	6	0.41	0.57	1.00
6. Limestone derived chocolate loam soils of Kurunegala/Matale districts and Northern Province	A	6	0.41	0.57	1.00
7. Estuarine clay soils	A	4	0.28	0.38	0.67
Calculated General Average		—	0.46	0.59	1.19
RANGE		4 to 8	0.28 to 0.59	0.38 to 0.71	0.67 to 1.50

TABLE — 4

iii. FERTILIZER MIXTURES RECOMMENDED IN JANUARY, 1967

(A) Composition of Mixtures

MIXTURE	*Ingredients (Parts by weight)*				*% Nutrient in Mixture*		
	Sulphate of Ammonia (20.6% N)	*Saphos Phosphate 27·5 % P_2O_5*	*Muriate of Potash (60 % K_2O)*	*Total*	*N*	*P_2O_5*	K_2O
A ...	4.0	2.0	2.0	8.0	10.3	6.9	15.0
B ...	4.5	2.0	2.5	9.0	10.3	6.1	16.7
C ...	5.0	2.0	3.0	10.0	10.3	5.5	18.0
Calculated Gen. average	4.5	2.0	2.5	9.0	10.3	6.1	16.7
RANGE ...	4.0 to 5.0	2.0	2.0 to 3.0	8.0 to 10.0	10.3	5.5 to 6.9	15.0 to 18.0

(B) Rates of Application

(Pounds per palm per annum)

Soil Type	C.R.I. Mixture	Lbs. mixture/palm/annum	Weight of nutrient in dosage Recommended (lbs)		
			N	P_2O_5	K_2O
1. Lateritic loams and lateritic gravels (boralu series, or cabook soils) of the wet zone in the Southern, Western, Central and Sabaragamuwa provinces (districts of Colombo, Kalutara, Galle, Matara, Kandy, Matale South, Ratnapura, Kegalle) ...	C	10	1.03	0.55	1.80
2. Lateritic loams and lateritic gravels of the intermediate rainfall zone in the North Western province (districts of Chilaw, Puttalam, Kurunegala)	B	9	0.93	0.55	1.50
3. Cinnamon sand soils of Chilaw, Negombo districts, coastal marine sands and lagoon sandy deposits of Puttalam, Chilaw, Negombo, Batticaloa, Mannar and Jaffna districts, and the sandy soils of the Southern and Western coastal belts	C	10	1.03	0.55	1.80
4. Deep reddish brown loam, sandy loams, and clay soils of the districts of Chilaw, Puttalam, Hambantota, Mannar, Anuradhapura, Vavuniya, Mullaitivu, Dambulla, and Melsiripura in the intermediate and dry zones	A	8	0.82	0.55	1.20
5. Limestone derived chocolate brown loamy soils of Matale, Nalanda, Dambulla, and Jaffna district	A	8	0.82	0.55	1.20
6. Deep alluvial loams in valleys and flood plains of rivers and estuarine and lagoon clay soils	A	8	0.82	0.55	1.20
Calculated General Average		9	0.93	0.55	1.50
RANGE		8 to 10	0.82 to 1.03	0.55	1.20 to 1.80

TABLE — 5

PROGRESSIVE CHANGES IN CRI RECOMMENDATIONS FOR THE APPLICATION OF ARTIFICIAL FERTILIZERS TO ADULT COCONUT PALMS

Weight of Nutrient Dosages recommended per palm per annum (Pounds)

SOIL FERTILITY	*PRIOR TO 1963*			*1963*			*1967*		
	N	P_2O_5	K_2O	*N*	P_2O_5	K_2O	*N*	P_2O_5	K_2O
GOOD ...	0.26	0.30	0.38	0.37	0.51	0.89	0.82	0.55	1.20
FAIR ...	0.28	0.34	0.50	0.56	0.61	1.34	0.93	0.55	1.50
POOR ...	0.31	0.37	0.62	0.51	0.71	1.50	1.03	0.55	1.80
GENERAL AVERAGE ...	0.28	0.34	0.55	0.46	0.59	1.19	0.93	0.55	1.50

Application of Artificial Fertilizers

(C R I Recommendations)

ADULT PALMS

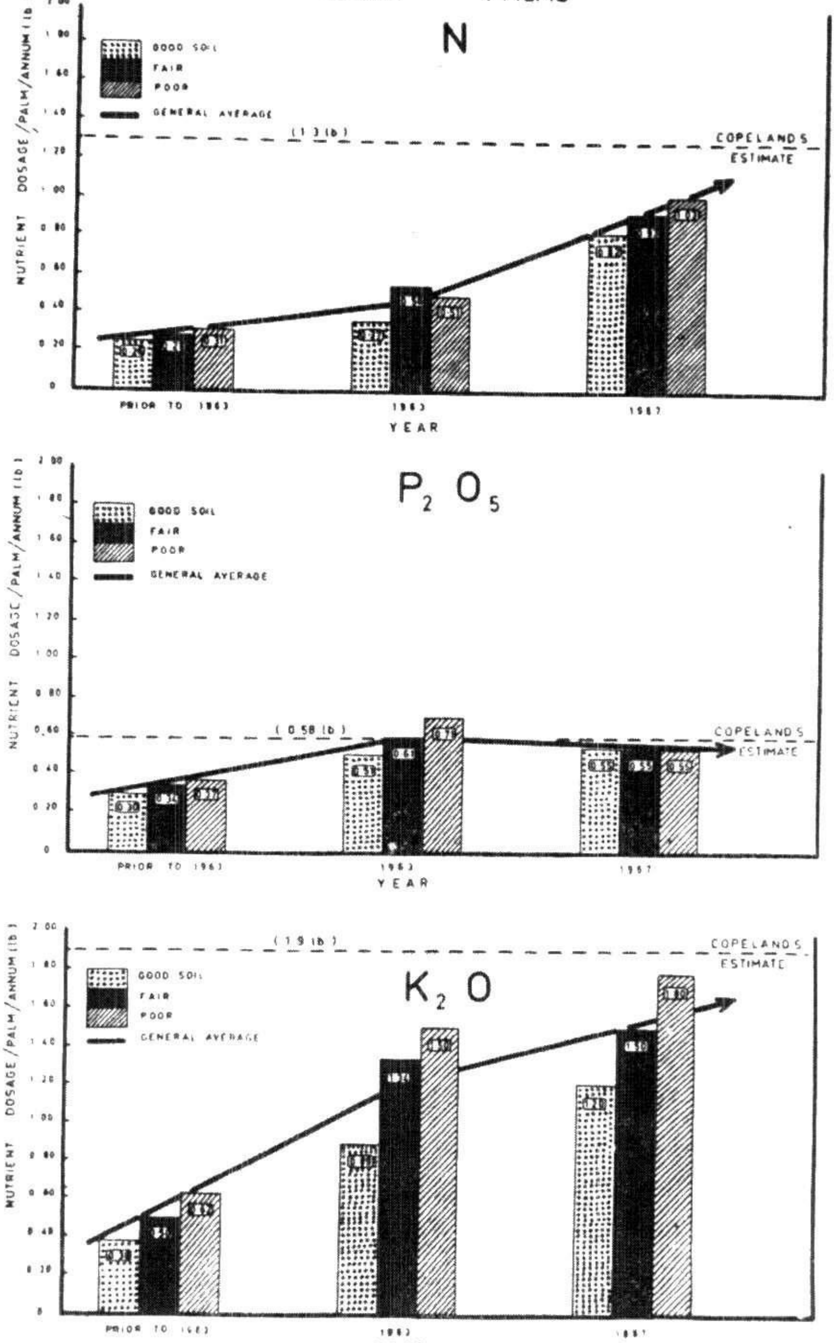

FIGURE 2—C.R.I. Fertilizer Recommendations

QUANTITATIVE CONSIDERATIONS

It should be clear from what has been illustrated above, that the CRI quantitative recommendations for fertilizer application to adult coconut palms have been progressively increased over the years. In this context, it is interesting to note that the most recent of these, tends to equal the estimates of nutrient uptake made by Copeland on theoretical and fundamenta considerations for more or less average plantations yielding 2,800 nuts/acre/annum. This does not however imply by any means that responses to still higher levels of fertilizer application are no longer possible. Much to the contrary, it should be pointed out that Copeland's estimates (based on plant analysis data) refer to the actual quantities (R) of the respective nutrients that are assimilated and utilised annually by a single average adult coconut palm. This means that they represent quantitatively the absolute essentials for the normal growth and performance of such a palm. As regards the correct fertilizer dosage (F) to be applied, we can say on practical considerations alone that it would have to be higher than (R) if the soil fertility status is to be maintained *without impoverishment*. This fact would be appreciated when it is recognised that (depending on prevailing conditions), varying amounts of applied nutrients always get lost through processes of soil fixation, leaching, release to the atmosphere or physical wash-off. In poorly cultivated soils they could also remain unassimilated outside the zone of root activity. For the present discussion we could denote the total quantitative losses collectively associated with all these factors by—(I). Then, for proper fertilizer regime under field conditions where the nutrient status of the soil *is not to be depleted*, the nutrients applied to the soil (F) would have to be higher than (R) by the amount (I). In the form of an equation it could be expressed as follows :—

$$F \doteq R + I.$$

One of the objects of using in complementary roles the diagnostic techniques that have been described earlier, is to establish (I) for different sets of conditions. In this connection, a collateral problem for the agronomist or soil scientist would be the adoption of appropriate management practices (relating to factors such as fertilizer placement and application frequency to minimise (I) quantitatively. Under rigidly controlled conditions, such as in some pot culture experiments, it may be possible to eliminate losses contingent on (I) almost completely. Under such conditions of course the equation would become $F = R$.

In a nut-shell, the overall position could be summarised as follows :—

(i) It has been established in general that Ceylon's coconut soils are deficient in the major mineral nutrients. Mono-cultivation for decades without systematic replenishment with mineral nutrients would probably account for this. It is legitimate to infer that judicious fertilizer usage is a *sine qua non*.

(ii) Theoretically, the annual dosage of a particular nutrient to be applied would be represented by the equation $F = R - s$,

Where F = Annual nutrient dosage to be applied to the soil.

R = Annual quantity of the nutrient actually required by the crop.

s = Quantity of nutrient actually drawn annually from the soil.

(iii) It has been pointed out that the fertility status of Ceylon's Coconut soils should not be permitted to suffer further depletion. This means that (s) which would normally be taken out of the soil would also have to be supplied in the form of added fertilizer. The equation should therefore become $F = R - o$.

(iv) Under practical conditions in the field, the annual addition to the soil of a quantity (F) of the nutrient, equal to the actual requirements (R) of the crop would not suffice because of the collective losses (I) from the soil contingent on a variety of factors that have been mentioned.

(v) The equation giving the correct nutrient dosage (F) to be applied to the soil would thus be expressed as follows :—

$$F = R + I$$

If the fertilizer regime is to be efficient, then the crop nutritionist would have to adopt appropriate management practices to minimise quantitatively the wasteful losses associated with (I). It should be appropriate to mention that whilst the magnitude of (I) would be appreciable on poor unfertilized soils, it would progressively diminish with continued treatment. On well managed lands that are regularly and systematically fertilized however, it could be assumed that (I) would be relatively low and more or less stable.

The value of plant analysis as a reliable guide to fertilizer practice has already been emphasised. TABLE—6 gives data obtained by the writer on the chemical composition of the component parts of the mature coconut. On the basis of this information, the nutrients lost annually to the soil in the nuts removed from a single palm have been computed for yields ranging from 500 to 6000 nuts/acre per annum in TABLE—7. The results are illustrated graphically in FIGURE—3.

Copeland's data give the gross annual nutrient losses to the soil consequent on the production of all the component plant parts of an average palm during the course of a year. The writer's data give corresponding values for the production of nuts alone. For comparison, the latter expressed as percentages of the former for the different nutrients is given in TABLE 8.

The data relating to nuts show that as far as relative magnitudes are concerned the nutrients appear in the following order :—

Potassium ——> Nitrogen ——> Phosphorus ——> Magnesium ——> Calcium.

It is interesting to note that this order is the same in Copeland's data for the gross uptake of nutrients by the palm.

In order to enhance the usefulness of the foregoing discussion, TABLE—9 has been prepared by combining the author's data with those of Copeland. The calculated values summarised therein show the gross annual nutrient losses to the soil consequent on the production of all the component parts produced by an average palm during the course of a year, for yields ranging from 500 to 6000 nuts/acre. The assumption has of course been made that Copeland's assessment of losses to the soil consequent on the production of plant products (other than nuts) is constant throughout the productive range 500 to 6,000. This is not strictly correct but in the absence of relevant factual information it is deemed to be reasonably satisfactory for the present purpose.

Nutrients Lost Annually to the Soil in the Nuts Removed From a Single Palm (Pounds)

(Planting Density — 64 palms/acre)

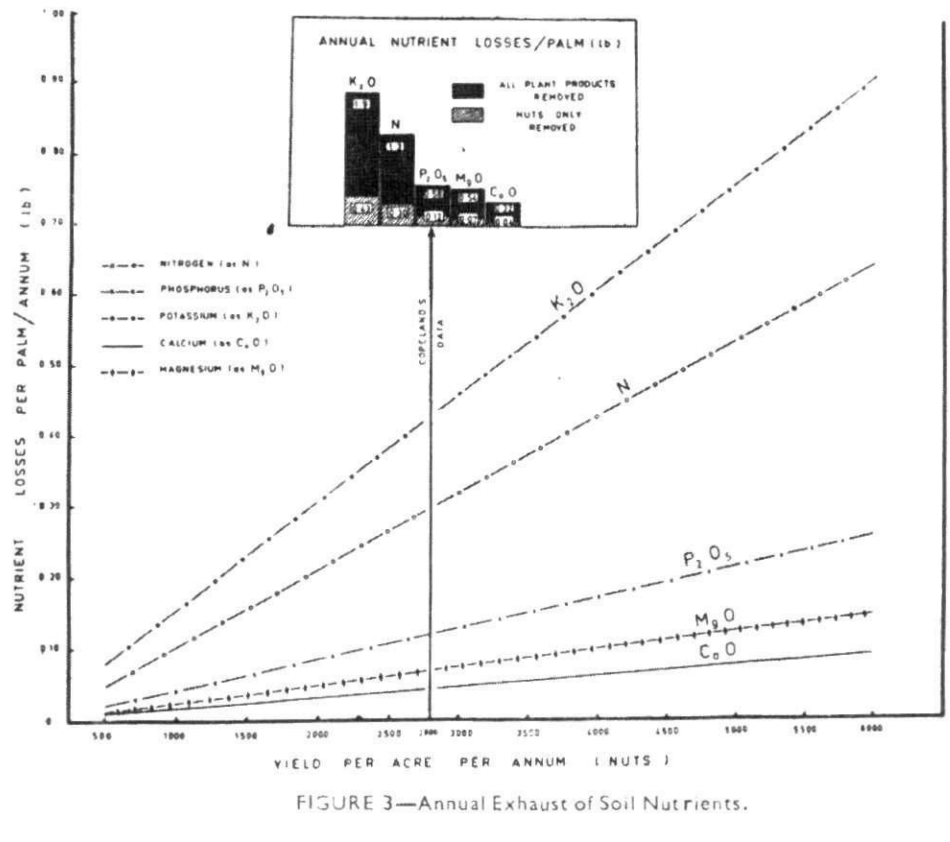

FIGURE 3—Annual Exhaust of Soil Nutrients.

TABLE — 6

Distribution of Dry Matter, Mineral Matter and Macronutrients in the Components of the Mature Coconut (Grammes per Drupe)

1	2	3	4	5	6	7	8
Drupe Component	*Dry Matter*	*Mineral Matter (Ash)*	*Nitrogen as N*	*Phosphorus as P_2O_5*	*Potassium as K_2O*	*Calcium as CaO*	*Magnesium as MgO*
Husk ...	298.3	15.00	0.69	0.29	2.80	0.31	0.25
Shell ...	127.7	1.30	0.13	0.05	0.31	0.05	0.03
Kernel ...	184.0	4.08	2.28	0.87	1.15	0.04	0.38
Nut Water ...	6.3	0.62	0.02	0.01	0.19	0.02	0.02
Total (per drupe) ...	616.3	21.00	3.12	1.22	4.45	0.42	0.68
*Total (Per 43.75 drupes in Gram.) ...	26,963.1	918.8	136.5	53.4	194.7	18.4	29.8
*Total (per 43.75 drupes in pounds.) ...	59.4	2.03	0.30	0.12	0.43	0.04	0.07

(***NOTE.**—A yield of 43.75 nuts per palm per annum is equivalent to 2,800 nuts per acre per annum when the planting density is 64 palms to the acre. The computation has been made on this basis for purposes of comparison with Copeland's data—*vide* Table I).

TABLE — 7

NUTRIENTS LOST ANNUALLY TO THE SOIL IN THE NUTS REMOVED FROM A SINGLE PALM (Pounds)

(Planting Density — 64 palms/acre)

Yield/Annum		*NITROGEN as N*	*PHOSPHORUS as P_2O_5*	*POTASSIUM as K_2O*	*CALCIUM as CaO*	*MAGNESIUM as MgO*
Per acre	*Per Palm @ 64 palms per acre*					
500	7.81	0.05	0.02	0.08	0.01	0.01
1000	15.62	0.11	0.04	0.15	0.01	0.02
1500	23.44	0.16	0.06	0.23	0.02	0.04
2000	31.25	0.21	0.09	0.31	0.03	0.05
2500	39.06	0.27	0.11	0.38	0.04	0.06
2800	43.75	0.30	0.12	0.43	0.04	0.07
3000	46.88	0.32	0.13	0.46	0.04	0.07
3500	54.69	0.37	0.15	0.54	0.05	0.09
4000	62.50	0.43	0.17	0.61	0.06	0.10
4500	70.31	0.48	0.19	0.69	0.06	0.11
5000	78.12	0.54	0.21	0.77	0.07	0.12
5500	85.94	0.59	0.24	0.84	0.08	0.14
6000	93.75	0.64	0.26	0.92	0.09	0.15

TABLE 8

Comparison of Annual Soil Nutrient Losses consequent on the production of nuts and all other products by a single palm during the course of a year.

NUTRIENT	*Total in All Plant Products produced annually (pounds)*	*Nutrients in Nuts Removed*		*Nutrients in all Products (other than nuts) produced annually*	
		Pounds	*As % of Total*	*Pounds*	*As % of Total*
Potassium (as K_2O)	1.9	0.43	22.6	1.47	77.4
Nitrogen (as N)	1.3	0.30	23.1	1.00	76.9
Phosphorus (as P_2O_5)	0.58	0.12	20.7	0.46	79.3
Magnesium (as MgO)	0.54	0.07	13.0	0.47	87.0
Calcium (as CaO)	0.32	0.04	12.5	0.28	87.5

Basis of Computation

Planting Density — 64 palms/acre.

Annual yield/palm — 43.75 nuts (equivalent to 2,800 nuts/acre).

TABLE 9

Gross Annual Nutrient losses to the Soil consequent on the Production of all the Component parts produced by an average palm during the course of the year

(PLANTING DENSITY—64 PALMS PER ACRE)

YIELD/ANNUM		*NITROGEN As N*	*PHOSPHORUS As P_2O_5*	*POTASSIUM As K_2O*	*CALCIUM As CaO*	*MAGNESIUM As MgO*
Per Acre	*Per Palm @ 64 palms per acre*					
500	7.81	1.05	0.48	1.55	0.29	0.48
1000	15.62	1.11	0.50	1.62	0.29	0.49
1500	23.44	1.16	0.52	1.70	0.30	0.51
2000	31.25	1.21	0.55	1.78	0.31	0.52
2500	39.06	1.27	0.57	1.85	0.32	0.53
2800	43.75	1.30	0.58	1.90	0.32	0.54
3000	46.88	1.32	0.59	1.93	0.32	0.54
3500	54.69	1.37	0.61	2.01	0.33	0.56
4000	62.50	1.43	0.63	2.08	0.34	0.57
4500	70.31	1.48	0.65	2.16	0.34	0.58
5000	78.12	1.54	0.67	2.24	0.35	0.59
5500	85.94	1.59	0.70	2.31	0.36	0.61
6000	93.75	1.64	0.72	2.39	0.37	0.62

It should be evident now that a complete cessation of fertilizer application to coconut soils would be fraught with adverse consequences. The figures in Tables 7 and 9 serve to indicate what must be put back into the soil to actually compensate for the losses of nutrients consequent on the production of nuts and/or all other palm products over the productive range 500 to 6000 nuts/acre/annum.

It should be appropriate to point out at this stage that the information that has been consolidated above would serve as a useful guide to fertilizer practice in relation to theoretical concepts alone. As regards the economics of fertilizer usage on coconut lands and the application of the Law of Diminishing Returns, the considerations would be quite different, because the evaluation of economic optima is based on maximum profits and not necessarily on maximum yields. Under favourable economic conditions however, the optimum fertilizer dosage would tend towards that which gives maximum yields. This along with other aspects of the economics of fertilzer usage on coconut lands are discussed fully by Abeywardena in a publication [10].

PLACEMENT OF FERTILIZERS

Most green plants are highly specialized organisms possessing various organs which perform special functions. These different organs may be considered to be interdependent, because there is reciprocal exchange between them of materials required for their functions.

In general, we believe that the roots of a plant which penetrate into the soil and ramify among the soil particles, draw in water with its dissolved mineral matter. These are then transported from the roots to all parts of the plant, and the surplus water is eventually transpired as water vapour by the leaves. The roots in turn are understood to obtain their organic nourishment from the leaves. Perhaps in a way, it would be correct to say that the closely related fields of soil chemistry and plant chemistry meet in the root system of a plant.

The coconut palm has a fibrous highly branched root system which is attached to the base of the stem ("bole"). Depending on age and environment, the total number of roots in a single palm has been estimated to range from 2,000 to 7,000. In view of the great height, the weight of the crown, and the heavy nutrient requirements of the palm, these roots are well distributed in the soil in vertical, oblique and horizontal directions. Unlike most other plants, in the coconut palm the absorption of water and mineral nutrients takes place not through root hairs but through a small area located close to the root cap. A further point is that at any one time all the component elements in its root system are not necessarily active because a process of new root formation and renewal is known to take place continuously. It should therefore be evident that in spite of the vast number of roots the "absorptive area" is relatively restricted. These facts logically lead up to the question of correct fertilizer placement, for effective utilization by the palm. In this connection it would be appropriate to remember that only a fraction of the nutrients applied to the soil actually gain entry into a plant.

The diagrams in FIGURES—4 and 5 illustrate eight different types of fertilizer placement which include those that have been tried out experimentally or practised as a matter of routine on coconut plantations. The drawings are self-explanatory, and Nethsinghe 11, using radio isotopic techniques has studied the relative efficiencies of some of these methods. He contends that the efficiency of fertilizer utilization would be governed by two fundamental factors—(1) the extent of active root surface available for absorbing the available nutrients and (2) the increase in activity of the nutrients in the soil solution which is brought about as a result of the fertilizer applied.

These investigations have shown that even on light well drained soils which offer no impediment to the development of an extensive root system, the density of roots with maximum absorptive area is highest in the soil region up to a distance of 5.5 feet from the bole. In conformity with this observation, it has been established that fertilizer application in this entire region at the base of the palm (5.5 feet in radius) leads to 100% more efficient fertilizer utilization by the palm than application in centres of squares or in trenches. It has also been demonstrated that application in full circles is about 40% more efficient than in semi-circles. In view of the fact that Salgado 12, obtained no differences in yields between trench manuring and broadcast application of fertilizers in the entire field area (FIGURE 4, (4) and (5)), it can also be concluded indirectly by inference that the 1967 CRI recommendation (FIGURE 4 (1)), is superior to the method of broadcast application.

FREQUENCY OF FERTILIZER APPLICATION

It is generally accepted that the availability of soil nutrients to a plant is dependent on the concentration of these nutrients in the soil solution. Immediately after the application of fertilizers this concentration would be high but it would tend to fall with time consequent on leaching and absorption phenomena.

In dealing with water soluble fertilizers such as sulphate of ammonia and muriate of potash, obviously the soil nutrient concentrations could be maintained at higher levels by reducing the time interval between successive fertilizer applications. Biennial application of fertilizers has been a traditional feature on coconut plantations. On scientific grounds the practice of annual manuring (using half dosages) would be preferable. In areas where both monsoons

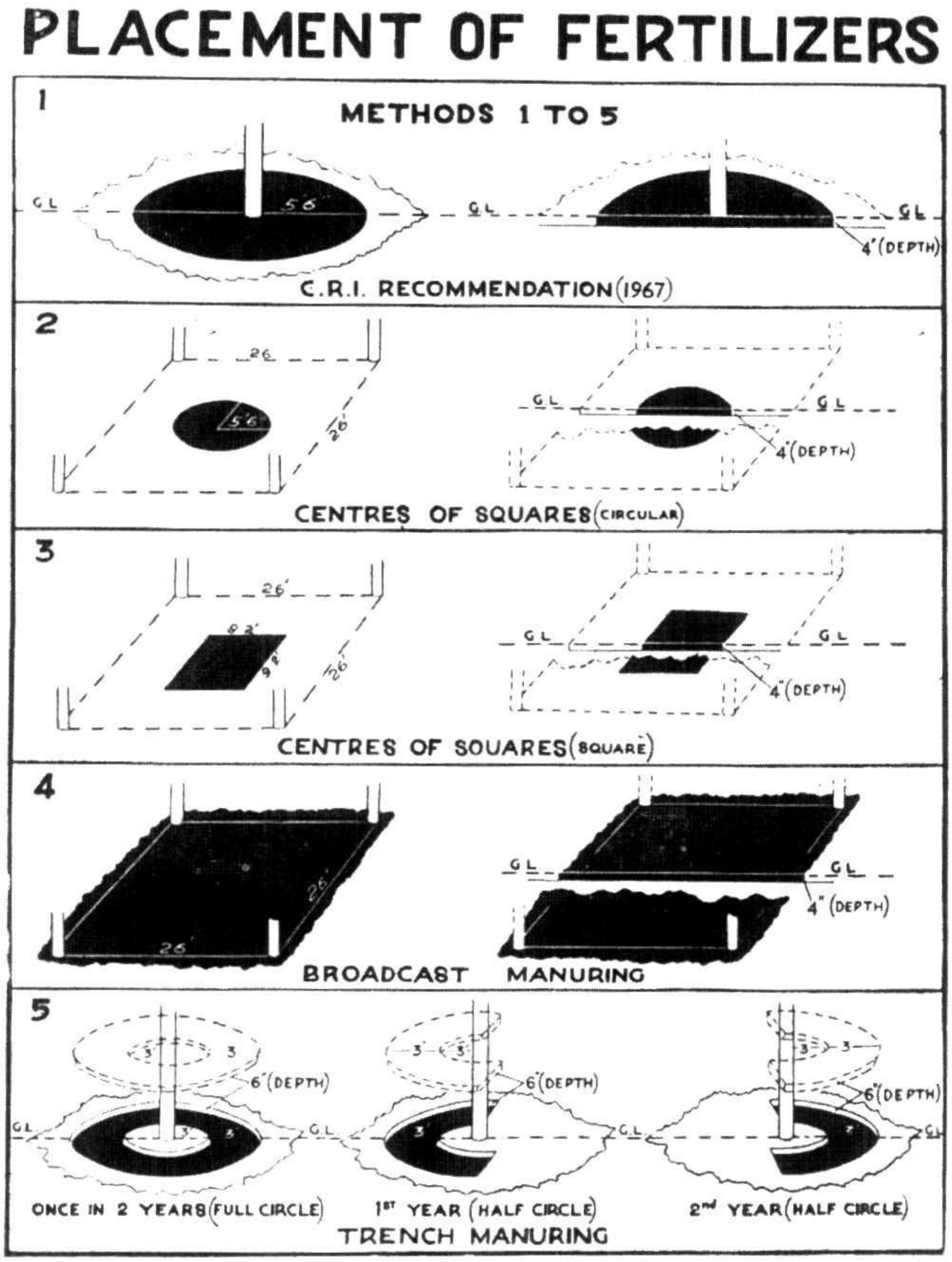

FIGURE 4—Placement of Fertilizers (1 - 5).

PLACEMENT OF FERTILIZERS

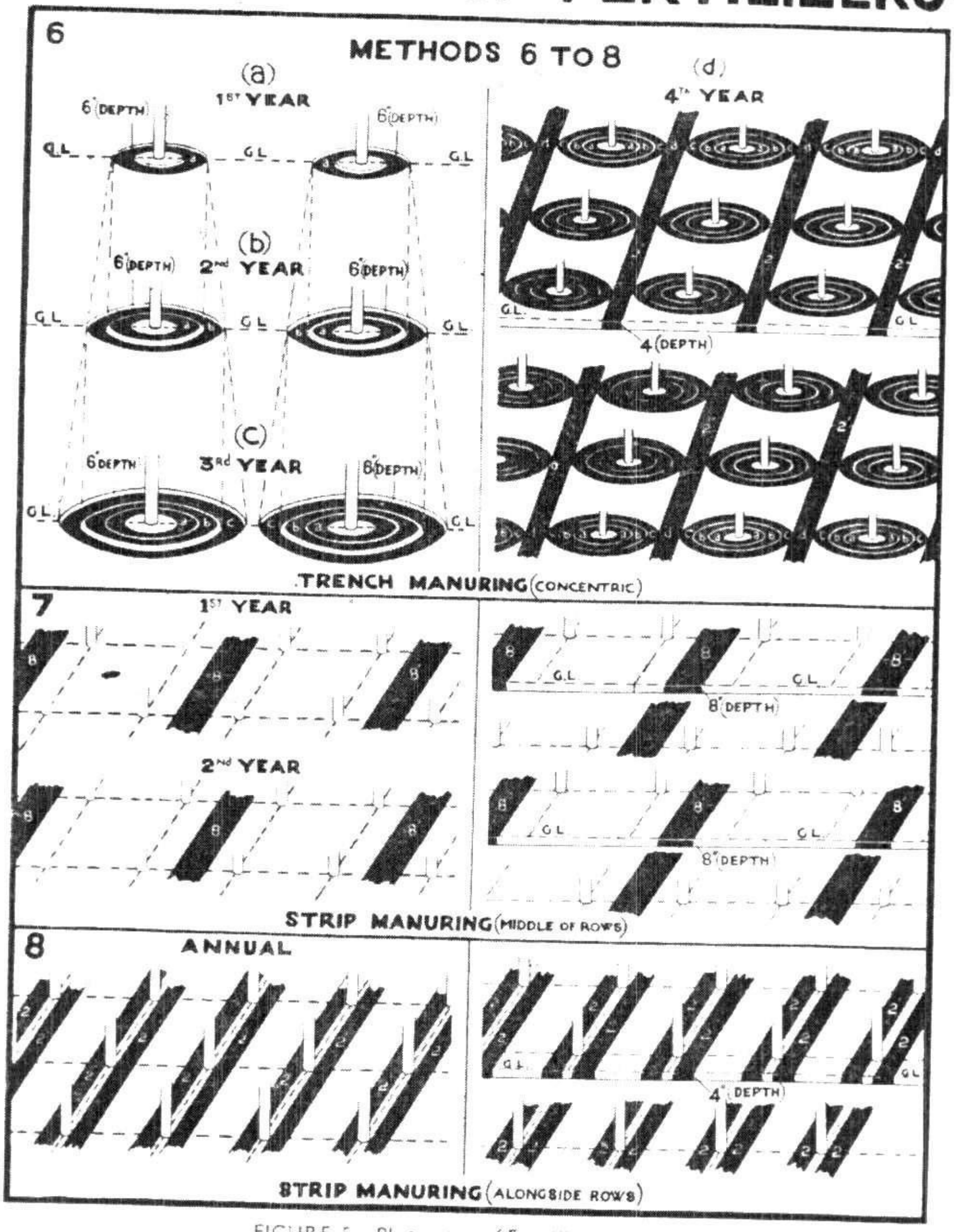

FIGURE 5—Placement of Fertilizers (6 - 8).

prevail and particularly on coarse sandy soils bi-annual application of fertilizers in split doses during each monsoon would doubtless increase the efficiency of fertilizer utilization by coconut palms still further. The current C.R.I. recommendations have been made in accordance with these principles.

CONCLUSION

The fact that fertilizer usage promotes plant growth, leads to increased yields of food crops and reduces costs of production is well recognized in agriculture. It should however be remembered that our knowledge of fertilizer practice is by no means complete and its use is always subject to the Law of Diminishing Returns.

One of the main problems in crop production is the supply of those essential nutrients that are deficient (or absent in the soil), not only in the correct form but also in adequate quantities to ensure optimum performance. The determination of the nature and amount of a particular nutrient needed would be based not only on the actual nutrient requirements of the crop in question but also on the availability and amount present in the soil. In spite of the fact that certain basic principles associated with these problems need re-statement from time to time, it is now well recognised that Plant and Soil analysis techniques used in complementary roles are indispensable tools for assessing the nutrient status of soils and determining correct fertilizer practice.

An endeavour has been made within the compass of this article to pinpoint the significance of certain diagnostic techniques in assessing the nutrient requirements of the adult coconut palm. In spite of the fact that the need for more fundamental research and experiments by practical men is recognised, it is hoped that the quantitative information that has been consolidated will enable a better understanding of underlying-principles and serve as a useful guide to fertilizer practice in coconut agronomy.

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