SOIL AND LEAF ANALYSES IN RELATION TO COCONUT YIELD

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INTRODUCTION

Workers are agreed that the best, if expensive, way to estimate crop fertilizer requirements for specific conditions is through the conduct of field trials/experiments. Two cheaper and less time-consuming methods have been developed by agricultural research and extension workers the world over, namely, *soil analysis testing* and *leaf analysis* or *foliar diagnosis.*

In a broad sense, soil analysis is any chemical or physical measurement made on the soil. Common usage of the term has given it a meaning that is at once more restricted and much broader ---- restricted in the sense that it has come to mean rapid analysis to assess the available nutrient status of a soil, and broader in that it includes interpretation, evaluation and fertilizer recommendation based to some extent on the results of chemical analysis but more often on other agricultural and economic considerations as well.

Soil analysis is practiced with some degree of success, but workers are not entirely satisfied with the reliability or usefulness of this method. Usually, this lack of confidence can be traced to expectations that exceed the capability limits of the system.

During the late 40's and the entire 50's, interest in the use of leaf analysis as an index of crop nutrient status grew rapidly. The concept of foliar diagnosis (Prevot and Ollagnier, 1957) led to the great expectation that it could be used as a means of predicting fertilizer requirements of two related crops, oil palm and coconut. This approach was greeted with enthusiasm by agronomists and soil scientists in view of their relatively unsatisfactory attempts to predict crop fertilizer requirements on the basis of soil analysis alone. It was felt that plant analysis must have an advantage over soil analysis since the former method revealed amounts of nutrients absorbed by the plant and interpretation was not dependent on varying concepts of soil nutrient "availability" or "exchange". Hence, on the assumption that nutrient level or concentration within the plant is related to crop growth or yield, leaf analysis was developed into a diagnostic tool.

This paper deals mainly with certain relations of soil properties and leaf nutrient levels with coconut yield as observed in some studies conducted in the country.

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CRITICAL NUTRIENT LEVEL

In foliar diagnosis,[1] the concepts of critical level and nutrient interactions should always be taken into consideration. Critical level or concentration may be understood better by relating element concentration to crop growth or yield as shown in Figure 1.

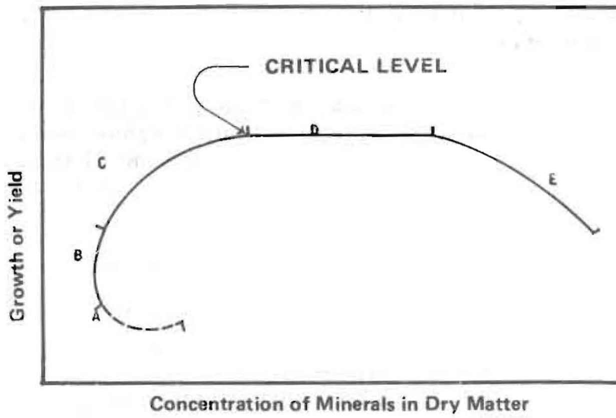

Figure 1. Relation of mineral composition of tissue to growth or yield (after Smith, 1962 and Prevot and Ollagnier, 1957). A & B severe deficiency; C moderate deficiency; D luxury range; E toxic range.

The "critical" level or concentration is shown as the sharply defined transition point between the "deficiency" and "luxury" ranges.

Workers are not agreed on the precise definitions of the terms "critical" level, inter-changeable "sufficiency", or "standard" and "optimum" values, as used by some. For the purpose of this paper, "critical" level may be defined as that concentration of an element in the leaf, expressed as a percentage of its dry matter, below which an addition of the appropriate fertilizer is likely to improve growth and/or yield.

It is well recognized that before leaf composition can be used for diagnostic purposes, any interfering effects on nutrient concentration arising from leaf age and position as well as stage of growth must be minimized. This implies considerable specificity in relation to leaf rank or number sampled and time of sampling, especially for a perennial crop such as coconut where seasonal effects can greatly influence leaf nutrient levels.

[1] Or soil analysis for that matter.

While waiting for conclusive results from the on-going mineral nutrition studies in the country that would indicate leaf nutrient critical levels under Philippine conditions, those initially suggested by IRHO[2] based on its works in the Ivory Coast, West Africa (Table 1), will be used as reference on this paper.

Table 1. Critical nutrient levels in leaf frond No. 14 (Fremond et al., 1966) in % of dry matter (ppm for Fe and Mn)

N	P	K	Ca	Mg	Cl*	S**	Fe	Mn
1.8-2.0	0.12	0.8-1.0	0.50	0.30	0.5-0.6	0.20	50	60

* Suggested by Ollagnier and Ochs (1971)

** Suggested by Southern (1969)

Many workers in the Philippines and elsewhere believe, of course, that critical levels for coconut may vary according to variety, age and environment of the crop. Nevertheless, the use of the foregoing critical levels which were determined mainly from studies made on the West African Tall palms grown at the Port Bouet coconut station of IRHO at Ivory Coast is deemed acceptable for the following reasons:

a. the palms studied, being of the tall variety, are of a similar classification as those used in the studies reviewed in the paper (Laguna) and likewise extensively planted in the country right now;

b. the soil at Port Bouet is practically sand, i.e., 96% sand with extremely low fertility, thus simulating a sand culture which is the typical approach to a study on mineral nutritional needs of any crop, as it ensures the absence of interference from outside chemical factors and provides for a less complicated basis for critical levels;

c. the values suggested by IRHO are reliable estimates as these were derived from several years of experience and results gathered under said conditions.

To be sure, it initially appears that the suggested critical levels for calcium and magnesium, respectively, are too high to be used as a guide for Philippine conditions (Table 2). Many coconut areas with healthy and high-yielding palms have Ca and Mg leaf levels below the said critical levels (0.50% Ca and 0.30% Mg.) Still, provided it is understood that the IRHO values are used herein merely as reference pending conclusive findings that would establish the comparable figures for local conditions, this approach should be in order as justified by the preceding reasons.

As for the concept of nutrient interaction, this refers to the relationship that obtains in crop nutrition whereby the action of a given element is not independent of that of others. Of very general occurrence, for instance, are the K-Mg and K-Ca antagonisms wherein the heavy fertilization of K tends to reduce the uptake of either Mg or Ca, thus inducing their deficiencies. On the other hand, synergistic effects in the absorption of nutrients by plants are also of interest in crop mineral nutrition. As an example, nitrogen and phosphorous, when applied together so that they enter the root at the same point, are absorbed by plants in greater quantities than when applied singly, that is, when they gain entry into the root at different points. A similar synergistic relationship also exists between nitrate nitrogen and manganese absorption.

Finally, it is recognized that the term critical level may be employed in a biological as well as in an economic sense. Though both are sound concepts, it is only the former that is considered in the present paper. Critical level, defined as the per cent nutrient composition of a reference plant part, i.e., frond 14, below which growth or yield of the palm is limited and response to fertilizers can be expected, without considering the value of the incremental output and the cost of the additional input, is of course used in the biological context.

SOIL PROPERTIES AND LEAF NUTRIENT LEVELS IN RELATION TO PRODUCTION

In this particular section, results of a study conducted on four (4) soils of Luzon utilized for coconut production, each with areas supporting high and low yielding palms (Tables 3 and 4) as evaluated through soil and leaf analyses (Cordova, 1965), are presented.

It may be briefly noted that the PCA-ARB's nationwide "Studies on Coconut Nutrition" using leaf survey and fertilizer trials/demonstration plots, once completed, will probably be more comprehensive and appropriate for presentation. This work involves different agro-climatic set-ups or conditions, and thus shall have wider applicability. For now, however, the results of the study referred to may be utilized.

In the Quezon plantation, soils of the high yielding area contain about 4 1/2 times as much available phosphorus, a higher amount of organic matter and a more favorable pH, compared to the low-yield area. In the latter area, trees have reduced crowns as well as short and yellowing fronds. Based on leaf nutrient levels, it appears that the trees in this area are deficient in nitrogen (1.47%) which is the likely cause of 'yellowing' and the low yield.

In the Alimodian clay loam, both high and low-yielding areas are characterized by excessive calcium and low available phosphorus; the latter condition probably induced the former. High yielding palms seem to be limited to areas with deep soil, while the stunted and 'yellowing', low-yielding palms are confined to shallow areas (less than 1 meter deep). From leaf analyses, palms in both areas are likely deficient in phosphorus; this may be attributed to excessive Ca resulting in the fixation of native P in the insoluble forms dicalcium phosphate dihydrate and hydroxyapatite, both of which are unavailable for immediate plant use.

[2] Institut de Recherches pour les Huiles et Oleagineux, France.

Table 2. Leaf nutritional status of some high-yielding coconut areas in the Philippines*

Location/Condition	Estimated Yield nut/tree/yr)	Nutrient Levels (% of DM)						
		N	P	K	Ca	Mg	Cl	S
Tiaong, Quezon/inland flat (alluvial) **	96	1.73	0.14	1.12	0.23	0.18	-	-
Bago-Oshiro, Davao City/ inland-upland	85	1.84	0.15	1.75	0.34	0.22	0.23	0.21
San Pablo City (Laguna) inland-flat ***	102	1.95	0.22	1.44	0.28	0.22	-	-
San Ramon, Zamboanga City/ coastal-flat	82	2.01	0.15	1.01	0.52	0.29	0.53	0.19
Tayabas, Quezon/inland-flat	65	1.78	0.12	1.32	0.24	0.25	0.75	0.18
Biliran, Leyte/coastal-upland	70	1.90	0.11	1.07	0.30	0.25	0.83	0.21
Padada, Davao Sur/inland-flat	65	1.97	0.15	1.23	0.48	0.23	0.82	0.19
Malita Davao Sur/coastal-flat	70	1.79	0.16	1.01	0.31	0.24	0.67	0.19
Sta. Cruz, Davao Sur/ coastal-flat	100	1.79	0.15	0.89	0.42	0.26	0.41	-
Lasang, Davao City/ coastal-flat	95	1.74	0.16	1.48	0.31	0.33	0.76	-
Mati, Davao Oriental coastal-flat	75	1.83	0.14	1.08	0.35	0.31	0.81	-
Critical Levels (%) as Suggested		1.8-2.0	0.12	0.8 1.0	0.50	0.30	0.50	0.20

*From PCA Leaf Survey Progress Report, 1975.
**A.S. Cordova (1965), M.S. thesis (unpublished). UPLB.
***H.R. Von Uexkull (1971)- Manuring of Coconuts, Cocoa, Coconut Conference, Kuala Lumpur

For the Guinobatan sandy loam, soils of the highly-yielding area are characterized by higher amounts of available phosphorus and exchangeable potassium. On the other hand, low-yielding palms have reduced trunk diameters and crowns, and short and yellowing fronds. By soil and leaf analyses, these palms appear to be deficient in nitrogen (1.32%) and in phosphorus (0.084%).

High and low-yielding palms grown under the Castilla clay appear to be deficient in nitrogen and phosphorus based from soil and leaf analyses.

LEAF NUTRIENT LEVELS IN RELATION TO YIELD

Leaf nitrogen and yield

Suspected nitrogen deficiency of palms exhibiting 'general yellowing' at Cagayan de Oro (Misamis Oriental) was verified by leaf analysis (von Uexkull, 1971). The effect of nitrogen was particularly impressive; undoubtedly this is the consequence of the extremely low leaf nitrogen of the unfertilized palms (Table 5).

Fertilization on a well-managed, high-yielding plantation (98-107 nuts/tree/year) in San Pablo City did not significantly improve yield nor affect leaf composition (Uexkull, 1972). Very likely this occurred as nitrogen and other nutrients were found to be above or close to the critical levels, with the leaf nutrient levels of unfertilized palms as follows: 1.95% N; 0.22% P; 1.44% K; 0.28% Ca and 0.22% Mg.

Leaf K and yield

In the Ivory Coast (West Africa), potassium de-

Table 3. Some soil properties and nut yield of coconut grown on 4 selected soils (Cordova, 1965)

Soil Type and Location	Condition of Palms	Estimated Yield* (nuts/tree/yr)	Soil Properties pH	OM (%)	P (ppm)	K (m.e. 100 gram soil)	Ca	Mg	Na
1. Unclassified silt loam soil, Tiaong, Quezon	Low-yielding palms; 'yellowing' leaves; suppressed crown and stunted growth	26	5.5	1.21	13.91	1.30	22.79	8.64	0.38
	High-yielding palms: healthy green, full of bunches	96	6.0	1.49	63.94	2.37	21.52	8.07	0.23
2. Alimodian clay loam, Lupi,	Low-yielding palms; 'yellowing' leaves, suppressed crown and stunted growth	23	5.5	1.81	4.53	0.19	39.55	8.07	0.18
	High-yielding: healthy green	45	6.2	1.72	1.26	0.30	48.67	8.00	0.20
3. Guinobatan sandy loam, Guinobatan	Low-yielding: yellowing, upright fronds and unhealthy growth	22	6.4	1.24	43.91	0.08	4.07	0.45	0.10
Ligao, Albay	High-yielding: healthy, green and full of bunches	55	6.1	1.69	58.99	0.83	1.91	0.85	0.24
4. Castilla clay San Vicente, Sorsogon	Low-yielding: stunted and unhealthy growth	19	4.8	0.77	0.89	0.24	5.59	2.60	0.26
	High-bearing: green and more fruits	39	4.5	1.04	0.97	0.13	3.15	3.20	0.32
Suggested Critical Level			4.5	1.5	10.0	0.45	10.0	2.90	

*By actual nut count from 6 bunches/tree (6 months yield), multiplied by 2 to get annual yield.

ficiency is particularly severe. This is essentially due to the extremely low K status (native K) of the coastal soils grown to coconuts.

The effect of potassium on copra yield and the leaf K of palms at Port Bouet, Ivory Coast, is shown in Table 6. It should be noted that soil organic matter, exchangeable calcium, magnesium and status are very low in the soil of Port Bouet.

The addition of increasing levels of potassium correspondingly increased copra yield and leaf K, the palms responding well to the K application since the soil is highly deficient in this nutrient. In the Philippines, response to K fertilization is uncommon for the reason that most soils of the country are high in K, thus having adequate quantities to supply the needs of the palms.

Leaf chlorine or chloride and yield

As shown in Table 7, the palms grown in an inland elevated area of Davao (reddish-brown Tugbok clay loam) responded well to KCl application.

Without leaf analysis, the response to KCl would be attributed to potassium only, as had always been concluded in the past whenever response to KCl (0-0-60) fertilizer was observed. The leaf analysis data, however, show that the yield response is not correlated with K levels in the leaves. For P, Ca, Mg, the same thing can be said. The P levels are well above the critical level of 0.12% as suggested by I.R.H.O. but Ca and Mg are considerably below the critical levels of 0.50 and 0.30%, respectively. Nevertheless, the very high production in some treatments indicates that the low levels of Ca and Mg have no effect on production. The only element that appears to be

Table 4. Leaf nutritional status and yield of palms grown on four (4) coconut soils (Cordova, 1965)

Soil Type and Location	Condition of Palms	Estimated Yield*	Leaf Nutrient Level (%) of DM, Frond 14					
			N	P	K	Ca	Mg	Na
1. Unclassified silt loam soil, Tiaong	Low-yielding palms: 'yellowing' leaves suppressed crown and stunted growth	26	1.47	0.118	1.21	0.19	0.15	0.06
	High-yielding palms: healthy green, full of bunches	96	1.73	0.137	1.15	0.23	0.18	0.05
2. Alimodian clay loam, Lupi Camarines Sur	Low-yielding palms: 'yellowing' leaves, suppressed crown and stunted growth	23	1.25	0.100	0.74	0.29	0.28	0.29
	High-yielding: healthy green	45	1.60	0.084	0.39	0.40	0.24	0.40
3. Guinobatan sandy loam, Guinobatan, Albay	Low-yielding: yellowing, upright fronds and unhealthy growth	22	1.32	0.084	1.04	0.17	0.23	0.19
	High-yielding: healthy green and full of bunches	55	1.80	0.118	1.64	0.16	0.22	0.07
4. Castilla clay, San Vicente, Castilla, Sorsogon	Low-yielding: stunted and unhealthy growth	19	1.45	0.076	1.28	0.16	0.27	0.16
	High bearing: green and more fruits	39	1.42	0.079	1.30	0.16	0.27	0.14
Critical Level			1.8-2.0	0.12	0.8-1.0	0.50	0.30	—

*By actual nut count from 6 bunches/tree (6 months yield), multiplied by 2 to get annual yield.

significantly correlated with production of bearing palm is chlorine.

Another clear relationship between leaf chlorine and yield is presented in Table 8.

The results strongly indicate that the effect of KCl on bearing palms is manifested more in terms of copra yield rather than nut production. Leaf analysis revealed that the likely limiting nutrient is chlorine and not potassium. While no significant variations in leaf nutrient levels of N, P, K, Ca, Mg and S were noted, the chlorine levels were significantly increased with the addition of all KCl rates except at the lowest level. Therefore, it appears probable that the improvement in copra yield is due mainly to the correction of chlorine or chloride deficiency from KCl application, as evidenced by the high soil K and leaf K of the minus-KCl palms.

Leaf nutritional status and yield of inland and coastal coconuts

Two of the soil series utilized for coconut in Davao are the San Manuel (coastal soil) and Tugbok clay loam (inland soil). San Manuel soil is of alluvial origin and commonly found along rivers or streams and near coastlines in Davao, while Tugbok soil is a reddish-brown residual soil formed from igneous rocks.

Leaf analysis (Table 9) of samples collected from coconut areas grown in these two soils in Davao indicated that

Table 5. Effect of fertilization on leaf nutrient content and yield of palms in Cagayan de Oro (from Von Uexkull, 1971)

Treatment	Yield (nut/tree)	Leaf Nutrient Levels (%), Frond 11 N	P	K	Ca	Mg	Na
Before fertilizer application;	0	1.07	0.14	1.27	0.14	0.47	0.04
Two years after fertilizer application;							
Control	1.0	1.04	0.13	1.23	0.13	0.45	0.03
K	5.4	1.09	0.12	1.50	0.13	0.45	0.04
NK	18.3	1.34	0.15	1.50	0.12	0.37	0.06
NPK	16.4	1.29	0.15	1.41	0.13	0.38	0.04

Soil: alluvial sandy loam.

Table 6. Effect of K fertilization on yield and leaf nutrient levels (from Fremond et al., 1966)

KCl Rate (kg/tree)	Accumulated Copra Years, 1955-63 (kg/tree)	Leaf K, % of DM
0	7.33	0.168
0.5	11.88	0.380
1.0	13.18	0.545
1.5	15.78	0.800

Soil analysis: 2% clay; 2.3% silt; 95.7% sand; pH 5.7;.36% OM; 0.038% N; 0.29% P_2O_5 0.18 m.e. Ca; 0.20 m.e. Mg and 0.01 m.e. K/100 g soil.

Table 7. Effect of NPK on yield and leaf nutrient levels 5 years after initial fertilization (from Mendoza and Prudente, 1972)

Treatment	Annual Yield		Leaf Level (%), Frond 14					
	Nut/tree	Copra/tree	N	P	K	Ca	Mg	Cl
0	88.9	11.87	1.67	0.16	1.23	0.34	0.14	0.036
N	111.2	15.72	1.67	0.18	1.28	0.34	0.16	0.035
$NKCl_1$	102.7	20.37	1.70	0.16	1.10	0.35	0.14	0.098
$NKCl_2$	135.0	29.50	1.81	0.17	1.32	0.33	0.13	0.196
NP	109.3	12.81	1.77	0.16	1.09	0.36	0.14	0.041
$NPKCl_1$	127.0	22.74	1.81	0.17	1.08	0.32	0.13	0.115
$NPKCl_2$	113.7	24.50	1.75	0.17	1.17	0.32	0.15	0.233

Soil Type: Tugbok clay loam: reddish-brown residual soil (latosol) formed from igneous rocks, predominantly andesite, gently sloping topography; good external and internal drainage.

Soil chemical analysis: pH 6.5; 1.5% OM; 19 ppm P; 500 ppm K

Table 8. Effect of KCl on production and leaf nutrient (from Magat et al., 1975)

Treatment	Accumulated Yield		Leaf Level (%), Frond 14						
	Nut/tree	Copra/tree (kg)	N	P	K	Ca	Mg	Cl	S
$NKCl_0$	156.3	28.2	1.88	0.16	1.43	0.38	0.21	0.03	0.19
$NKCl_1$	197.3	34.5	1.94	0.16	1.45	0.40	0.22	0.10	0.20
$NKCl_2$	211.8*	44.1**	2.06	0.15	1.37	0.41	0.20	0.23**	0.21
$NKCl_3$	222.9*	47.9**	1.98	0.16	1.23	0.37	0.19	0.37**	0.18
$NKCl_4$	182.9	55.2**	1.99	0.16	1.45	0.40	0.19	0.49**	0.21
HSD .05	49.3	7.05	NS	NS	NS	NS	NS	0.108	NS
01	NS	10.47	NS	NS	NS	NS	NS	0.146	NS
CV (%)	12.5	4.9	6.7	6.5	14.9	13.9	12.4	15.4	7.4

*Significant
**Highly Significant
NS-Not Significant

Soil type: Tugbok clay loam (37% sand, 33% silt, 30% clay) gently sloping topography; well-drained.
Soil chemical analysis: pH 6.7; 1.22% OM; 12 ppm P; 320 ppm K; 270 ppm Cl; 11.3 m.e. Ca/100 g; 5.1 m.e. Mg/100 g.

Table 9. Average leaf nutrient levels and nut production of coastal and inland coconuts

Factor	Inland Tugbok Soil (10 sample areas)	Coastal San Manuel Soil (20 sample areas)
Leaf Nutrient: (% of DM, frond 14)		
N	1.68	1.73
P	0.15	0.15
K	1.53	1.25
Ca	0.33	0.35
Mg	0.21	0.29
Na	0.056	0.064
Cl	0.11	0.72
Average distance from coastline (km)	13.5	1.8
Average yield (nut/tree/yield)	37.8	77.5

only the leaf chlorine varied highly, with the inland Tugbok soil far below (severely deficient) the critical level. For both soils, the levels of P and K are above the critical levels, while N is below the critical level of 1.8%, thus probably deficient.

The very low nut yield (37.8/tree/year) of trees grown in the inland Tugbok soil compared to the yield in coastal/alluvial San Manuel soil (77.5 nuts/tree/year) can be probably attributed to low levels of leaf chlorine (0.11%) which most likely are within the deficiency range for coconut. This relationship is clearly shown in Figure 2. From these results and those of the other briefly presented studies, it appears that for working purposes, 0.50-0.55% leaf chlorine (leaf no. 14) may be used in the interim as the critical level for bearing palms.

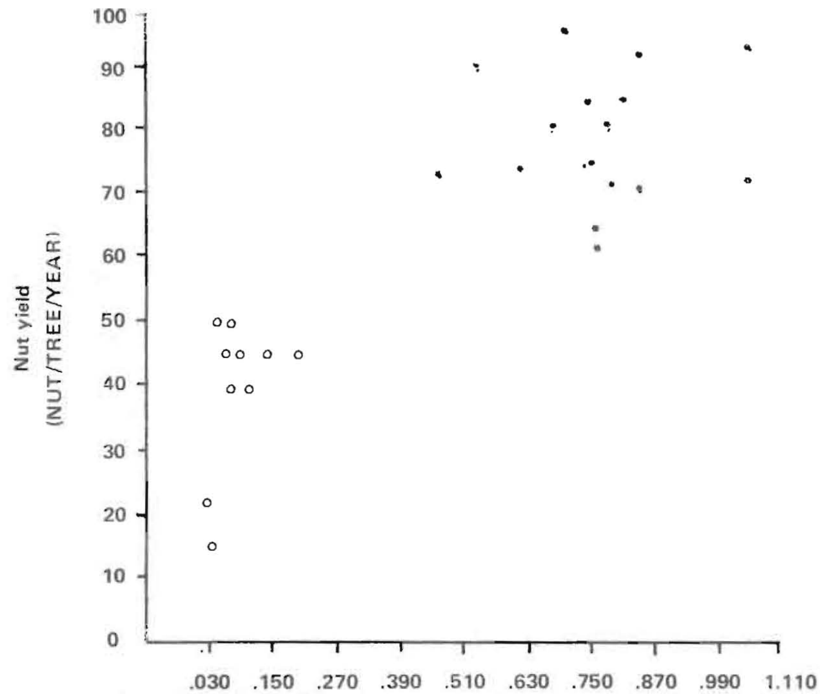

Fig. 2. Relationship of leaf Cl and nut yield

SUMMARY AND CONCLUSIONS

In general, leaf analysis has the capability to diagnose the nutrient status of the crop and, specifically, it can confirm suspected deficiencies, uncover hidden deficiencies, determine toxicities and evaluate the effectiveness of fertilizer treatments.

Although leaf analysis may indicate that one or more elements are abnormally low or high in the leaves, it will not necessarily tell which of the yield-limiting factors (e.g., inadequate or excess water, pests and diseases, imbalance nutrition, improper fertilizer placement, very low or very high pH, over-gazing) is the cause. When leaf analysis is supplemented by soil analysis, a much better insight on the nutritional status of the crop may be obtained.[3]

It appears that foliar diagnosis is an efficient method of detecting nutrient deficiencies if they occur singly. If, however, several deficiencies occur simultaneously, greater interpretative caution is required and other agricultural factors have to be considered. In most cases, field trial or experiment is advisable, especially if the results of soil and leaf analyses, respectively, are inconsistent.

Initially, it appears also that the critical levels suggested by I.R.H.O., especially for Ca and Mg, may not be applicable to a certain extent under Philippine conditions, considering that in some healthy, high-yielding coconut areas, leaf nutrient level concentrations for these elements are below the suggested levels of 0.5 and 0.30 percentages of the leaf dry matter, respectively. Thus, further studies in establishing critical levels for various agro-climatic set-ups should be given serious consideration or encouragement. This must be done if leaf analysis is to be used intensively and extensively in diagnosing nutritional needs and formulating more precise fertilizer recommendations for coconut under specific conditions in the country.

[3]Though not fully dealt within the text, this last point is the direction of the ongoing studies on mineral nutrition by the PCA-ARB and will be the subject of succeeding articles.

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