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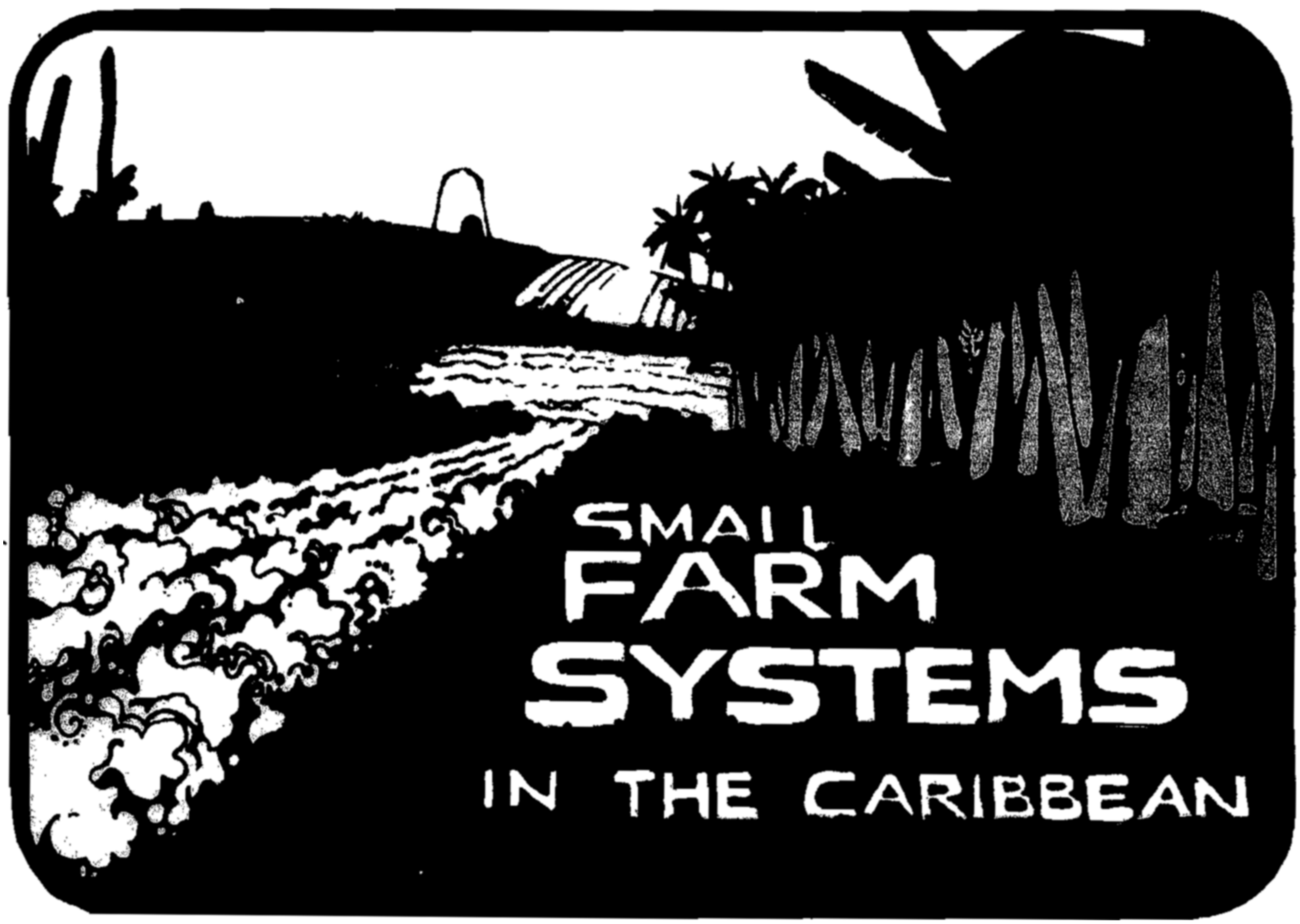

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Foliar Analysis as a Diagnostic Technique in Tropical Horticulture

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A brief history of the development of foliar analysis as a diagnostic technique for horticultural crops is reviewed and discussed. Terminology, together with a basic discussion of the components necessary to operate a successful foliar analysis program for growers, is presented. Some standard values, as they relate to 'normal' growth of selected tropical and subtropical horticultural crops, are listed.

Keywords: foliar analysis, plant analysis, leaf analysis, petiole analysis, diagnostic techniques, plant nutrition, nutrient elements.

Foliar analysis has been an active research procedure since the late 1930's. Some of the early comprehensive studies of importance to us today were conducted on horticultural crops such as citrus, apples, grapes, peach, tomato, and potato and others. The goal of these studies, then, as well as now, was to develop a method whereby the nutritional status of the plant can be accurately determined. As we have gained knowledge and experience, developed equipment and techniques, fertilizer programs based upon foliar analysis have been devised which resulted in increased production and quality. Early researchers such as T. Wallace (Great Britain), P. Prevot (France), W. Reuther (USA), H.F. Clements (USA), A. Kenworthy (USA), M. Maume (France), C. Bould (Great Britain), G.T. Nightingale (USA) have given us much insighr into this procedure and deserve credit as the pioneers in the field. The definition of foliar analysis, as used here, includes the terms tissue analysis, leaf analysis, petiole analysis, and plant analysis, somewhat interchangeably. Although it is possible to use rapid tissue tests, the procedure is declining in popularity and is nor developed or discussed further in this presentation.

Modern Methods and Equipment

During this early period, chemical analysis procedures were time-consuming, tedious and sources of considerable error. Today, although the equipment is relatively expensive, much progress has been made and it is possible to run accurate and rapid analyses of many elements on a wide range of tissues. However, accurate chemical analysis of a tissue is only one part of the diagnostic technique we call foliar analysis. Sampling procedures, including collection, preparation and interpretation of the data are still vital components and the ultimate success of the technique generally depends on how accurately they are handled. Depending upon the tissue and time of sampling, leaf age and condition, drying and grinding procedures, etc., considerable variability can be introduced and are major sources of error.

Regardless of the difficulties of past and present research, much of the progress and development of current information on nutrition of horticultural crops can be attributed to the use of foliar analysis. For example, before the general use of foliar analysis many fertilizer experiments were conducted to determine the effectiveness of a given type and rate of fertilizer on yield and quality of a crop. Yet because there was no 'common denominator,' or means of judging the relative nutrient status of the plant, much of the reference value was lost for anything but localized conditions. On the other hand, through the use of foliar analysis, the relationship between nutrient content of a specific tissue, yield and quality has been utilized. This has been sufficiently reliable from year to year and from one soil type or cultural condition to another, that standards for many crops have been developed. Conducting field fertilizer experiments today without using foliar analysis is, in this author's opinion, almost inexcusable. For the commercial fruit producer, failure to take advantage of such an important tool is an invitation to failure. Thus, within the scope of this discussion, some of the fundamental procedures will be discussed whereby both researchers and growers can avail themselves of this technique.

Definition of Terms

Nutritional studies of individual elements indicate that deficiencies or excesses can limit growth. However, it soon becomes obvious to the researcher that the concentration of one element within a plant cannot be changed very much without influencing another to a degree that growth may be affected. The term used for this is called nutritional interaction. Some of these interactions become very dominant on certain crops. For example, the relationship between potassium and magnesium on grapes is very obvious in any studies with either element. In recent years, studies on nutrient interactions have led to the development of procedures such as the DRIS system (Diagnosis and Recommendation Integrated System).

A definition of terms for all the nutrient elements as used in this discussion can be defined as follows:

Deficient: Plants are in the deficient range if they show visible leaf symptoms or distinctive decreases in yield and quality can result.

Low: Plants are in the low range if the amount of an element present in the plant is inadequate to produce optimum yield or quality.

Sufficient: Plants are in this range if it is doubtful that further additions or reductions of the element will result in a desirable increase of growth, yield, or quality. Somewhere within this range is the absolute optimum, which together with the combination of the other elements present, will produce the most desirable production.

High: Plants are in this range if the level of the element present in the plant is higher than necessary to produce optimum yield, growth or quality. This amount may indicate unfavorable quality relationships or an imbalance of other nutrients.

Excess: A plant contains an excess amount of an element if visible leaf symptoms are present or definite reductions in yield, vigor, or quality resulr.

General Use of Foliar Analysis for Tropical and Subtropical Crops

My main goal today is to discuss the feasibility of using foliar analysis to diagnose nutritional problems of tropical crops. However, I have conducted only a minor portion of my research under a tropical environment. Therefore, my knowledge of many of your conditions is very limited. Hopefully, a discussion of foliar analysis fundamentals, regardless of the crops used, will be of value to you.

Extensive nutritional studies have been conducted on several important tropical and subtropical crops such as bananas, pineapple, citrus, oil palm and sugarcane. A review of the literature appears to indicate that foliar analysis data is available. However, there are many additional horticultural crops of lesser importance that have received only minor attention. Assuming that your institution wanted to set up a diagnostic service program as soon as possible, how easy would it be to develop a database for some of these crops? Personal experience, as well as a review of the literature on foliar analysis, shows that at least two procedures can be effectively used:

1. Conduct a routine foliar analysis survey of the crops under consideration.
2. Conduct some field experiments either concurrent with or following the survey.

Through the first procedure, general levels can be established, such as those presented in Table 1. If this information is combined with visual symptoms, growth ratings, quality evaluations and indications of general plant condition, then much usable data can be obtained quite rapidly. Some of the obvious errors created by this procedure are that if soils do not provide an adequate cross-section of nutritional conditions, *i.e.*, mostly deficient or excessive amounts of certain elements (copper, boron, zinc, etc.) are present, then adequate nutritional levels cannot be sampled.

However, in most areas there is an adequate range of conditions, and foliar nutrient levels can readily be related to yield and quality. Visual deficiency or excess symptoms can also help indicate minimum levels.

Once approximate levels have been established by the survey data, then field experiments should be conducted. Plantings thought to be low or deficient in certain nutrients can be utilized as effective experimental sites and corrective measures applied. The results of your survey data can thus be verified and refined.

Without any previous history on a crop, what can be learned from a foliar analysis? One of the very desirable associations that can be used effectively is to compare plants growing in a satisfactory vigorous condition with plants not growing well or those that exhibit visual symptoms and those that do not. Some of the pitfalls to be avoided here are: (1) do not take samples from obviously diseased or physically injured plants; and (2) avoid plants with known herbicide or chemical damage. Under either condition, nutrient concentrations will be obtained that are meaningless because the primary cause of poor growth, etc., is not due to nutrition, but to the injured or diseased condition. Drought, salinity, poor drainage, and saturated soil conditions also offer pitfalls that will lead to false interpretations of the foliar analysis data.

Thus, even though little or nothing is known about the required nutrient level of a crop, if comparisons are made using healthy plants as your base, then some fundamental deductions can be made. It has been the author's experience that within reasonable limits somewhat typical levels of nitrogen, phosphorus, potassium and other nutrients can be expected in the average leaf or petiole of a plant (Table 1). There are notable exceptions to this, but they become readily apparent with normal sampling procedures for a given crop.

TABLE 1. Foliar nutrient levels associated with dry weight of some fruit crops.

	%					ppm				
Crop	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn
Mango (M. indica)	1.4/2.0	.14/2.0	.7/1.1	1.8/2.6	.25/.35	30/150	70/120	35/100	5/15	25/50
Guava (P. guajava)	1.5/2.4	.15/3.0	.7/1.1	1.8/2.6	.25/.40	40/150	50/120	35/100	5/15	25/50
Litchi (L. chinensis)	1.9/2.6	.14/2.0	1.0/1.5	2.0/3.0	.30/.55	30/150	50/130	35/100	5/15	20/50
Fig (F.carica)	1.8/2.0	.12/.18	1.0/1.5	3.0/5.5	.40/.70	25/50	50/120	35/100	5/15	25/50
Orange (C.sinensis)	2.0/2.6	.12/.18	1.2/1.7	3.0/5.5	.26/.60	25/50	50/120	35/100	5/10	25/50
Mandarin (C.reticulta)	2.8/3.0	.15/.26	.9/1.3	3.0/5.5	.26/.60	25/50	50/120	30/100	5/10	25/50
Grapefruit (C.paradisi)	1.5/2.2	.15/.26	.6/1.5	3.0/5.5	.26/.60	25/50	50/120	35/100	5/10	25/50

Three basic criteria should be combined when establishing a foliar analysis procedure. They include: (1) a sample taken from a leaf, petiole, or other easily identified tissue; (2) the position on the plant should be equally easy to identify (first fully mature leaf on current season's growth or mid-shoot leaf on the spring flush of growth, etc.; (3) the tissue (leaf or petiole) should be in an 'active' position on the plant (a leaf well exposed to ambient sunlight on a fruiting shoot, etc.); (4) the time of sampling should be a well-defined phenological period (mid-season or at a specified number of days following bloom, veraison, etc.).

Relative Importance of Nutrient Elements

As a general rule the element of greatest concern in nutrition studies is obviously nitrogen because it relates so strongly to yield and quality. Most of our cultivated crops require additions of nitrogen in one form or another in order to produce satisfactory yield. Legumes are the major exception. The second element of major concern would probably be potassium, especially in our higher rainfall soils. Phosphorus, although very necessary for plant growth, is generally not of major concern for fruit crops, although for vegetables it frequently is in second position in general fertilizer recommendations. Around the world, deficiencies or excesses of minor elements such as boron, zinc, and copper play an important role in developing adequate yield and quality.

Development of a Grower Foliar Analysis Program

Ohio has had a grower service program since 1964. During this period many thousands of samples have been sent to the laboratory for analysis and the results returned to the growers with recommendations. Some comments relating to this experience may be appropriate at this time.

Development of a Questionnaire. In most programs, the nutritional specialist for a laboratory takes the sample, analyzes it and completes the service by returning the information to the grower with his recommendations. In Ohio, we have allowed the grower to fill out a questionnaire (Fig. 1), take his own samples, and send them to the laboratory.

With the deveopment of computers, it seems as though much of our information must be in abbreviated form. Thus, the use of the information questionnaire, such as the one shown (Fig. 1), has been reduced to the bare essentials. The original questionnaire developed for fruit crops in Ohio allowed the grower to indicate conditions he saw in his plantings, but not interpret the problem (nutritional or otherwise).

Kits are distributed to all county or district offices and departments. Only when the grower uses the kit and sends in the sample is he charged a fee. Thus, the kits are available in quantity at a number of locations. Instructions for their use are attached. At least 60 units (leaves, petioles, etc.) are requested per sample. This is an attempt to make the grower get a good cross-sectional sample of his planting. Turn-around time in the Ohio program generally takes about 3-5 days. By the time the samples arrive on my desk, five days have generally passed. For sample analyses on which growers rapidly need the information, transmittal of results may be by telephone. It must be recognized that in many cases, especially for tree fruits, samples taken one year may not be used until the appropriate season of the next year. However, with increased speed of analysis the trend has been to get the information back to the grower just as rapidly as possible, and then apply the needed elements during the same season. This should be even more important in the tropics than in temperate regions. Standards for each crop are printed by the computer in the deficient, low, sufficient, high and excess ranges previously indicated (Fig. 2).

The importance of time of sampling, leaf age, and sampling position must be continually emphasized to the grower. Three basic criteria are frequently combined when establishing a research or grower foliar analysis sampling procedure. They include: (1) a sample is taken from recent fully matured leaves (if the petiole is used, it is from this type leaf); (2)the leaf should be exposed to ambient sunlight conditions much of the time and where applicable be on a fruiting shoot; (3) the time of sampling should be about mid-season or a specified number of days following bloom or another well-defined phenological period. The research database developed for such crops is, therefore, tied to these three conditions and all grower samples taken for this purpose should conform to them.

Concurrent Research Programs

In the development of any foliar analysis service program a concurrent research program is also extremely important. Many problems as they are found in grower plantings, need to be incorporated into a research program for solutions. More problems seem to be identified every year by the Ohio grower foliar analysis program than can be resolved. Each year's results provides the researcher with an updated survey as to nutritional conditions for the crops sampled.

An applied nutritional research program can and must provide the following information: (1) recommended nutrient ranges that will reflect differences in growth, yield and product quality; (2) effects of rates of fertilizer application for specific soil types, etc. In this area, it is very necessary to conduct such experiments on grower plantings in order to get reliable data; (3) a criterion for proper sampling procedures that will most efficiently utilize the database developed.

The use of a companion tool, soil analysis, has not been discussed. It is well known that good soil testing methods are also a desirable means of providing the grower with an additional tool for his fertility program. For tree crops, it has been the general feeling that foliar analysis provides a better indicator of what the plant is actually absorbing than does soil analysis. However, in the establishment of any crop, soil testing should be used before planting or concurrent with foliar analysis where a problem is involved. Basic modifications in the fertility and pH of the soil prior to planting can then be made. In Ohio, a combined use of soil and plant analysis has never been mandatory. However, we do offer both programs. Independent analysis and recommendations for both soil and plant analysis is not without its problems; especially when a grower uses both and receives conflicting information. For example: soil test indicates the potassium is low, but the plant analysis indicates it is quite satisfactory (the amount that is in the plant tissue must take precedence over the soil levels, is a position I have always assumed). Discussions in grower meetings, short courses, etc., have been necessary to help the grower recognize that the best fertilizer program includes all the information that he can get his hands on. This includes soil testing, plant analysis, visual observations, previous experience, the research information available on the crop involved, etc. With the justification that they all offer some benefits, as well as some sources for error, we will continue to study and develop such methods to help the growers increase the quality and quantity of their crops.

FIG. 1. Questionnaire used by the Ohio Research Extension Analytical Laboratory (REAL), Wooster, Ohio.

RETURN THIS SHEET IN SMALL ENVELOPE

OHIO PLANT ANALYSIS LABORATORY

Ohio Cooperative Extension Service, The Ohio State University and Ohio Agricultural Research and Development Center, Cooperating

Horticultural Sample No 07547

Name ____ Street, Route ____ City ____, Ohio ____ Zip Code ____ Telephone Number ____

Grower Name (if other than at left) ____ County ____ Your Sample Identification ____

Fill in Blanks and Appropriate Boxes

CROP AND SOIL HISTORY

Date Received

TYPE OF CROP: (1) Fruits (2) Greenhouse Vegetables (3) Outdoor Vegetables (4) Nursery-Deciduous (5) Nursery-Evergreen (6) Flowers

CROP ____ CULTIVAR (Variety) ____

PLANT PART SAMPLED: (1) As Directed ____, (2) If Other, Describe ____

DATE PLANTED:

DATE TRANSPLANTED:

DATE SAMPLED:

Mo Day Year

PREVIOUS CROP: (List) ____

PLANT APPEARANCE: (Check) (1) Normal ____ (2) Abnormal ____, (Describe) ____

PERCENTAGE OF PLANTS AFFECTED (0 to 99%)

HERBICIDE APPLIED CURRENT CROP YEAR: ____

HERBICIDE APPLIED PREVIOUS CROP YEAR: ____

SOIL. (1) Fine or Medium Texture (clay and silt) (2) Coarse Texture (sandy) (3) Organic (muck or peat) (4) Container, Bed, Bench or Pot Mixture

SOIL MOISTURE PRIOR TO SAMPLING (1) Excessive (due to poor drainage) (2) High (due to above average rainfall) (3) Normal (4) Low

CURRENT SOIL TEST DATA

pH

LIME TEST INDEX

CATION EXCHANGE CAPACITY (Meq/100g)

AVAILABLE NUTRIENTS (Lbs./A)

Phosphorus

Potassium

Calcium

ORGANIC MATTER

SOLUBLE SALTS

SOIL TEST BY: 1. O.S.U., 2. Other

DATE TESTED: 19 __ __

SOIL TYPE (MAPPING) NUMBER

FERTILIZER AND/OR LIMESTONE APPLIED

RATE: (1) Lbs./Acre (2) Lbs./Plant (3) Lbs./Cu. Yd (4) Ppm

PREVIOUS (LAST) YEAR OR CROP

Nitrogen (N)

Phosphorus (P_2O_5)

Potassium (K_2O)

Ag Ground Limestone

CURRENT YEAR OR CROP

Nitrogen (N)

Phosphorus (P_2O_5)

Potassium (K_2O)

Ag Ground Limestone

RETURN THIS SHEET IN SMALL ENVELOPE

FIG. 2 The completed results form, with typical recommendations, used by the Research Extension Analytical Laboratory (REAL), Wooster, Ohio.

OHIO PLANT ANALYSIS REPORT

WOOSTER OHIO 44691

COUNTY WAYNE

GROWER ID NO 1502

PLANT SAMPLE NO D 0549

SOIL BAG NO M008686

DATE RECEIVED 07/20/80

DATE PRINTED 07/25/80

N	1.56	XXXXXXXXX
P	00.19	XXXXXXXXXXXXXXXX
K	00.84	XXXX
(%)Ca	01.32	XXXXXXXXXXXXX
Mg	00.43	XXXXXXXXXXXXXXXXXXXXXX

(ppm)Mn	0111	XXXXXXXXXXXXXXX
Fe	0120	XXXXXXXXXXXXXXX
B	0020	XXXXXXXXXX
Cu	0010	XXXXXXXXXXXXXXX
Zn	0040	XXXXXXXXXXXXXXX
S	0048	

[illegible]

CROP & SOIL HISTORY

CROP APPLE
CULTIVAR RED DELICIOUS
PLANT PART AS DIRECTED
PLANTED OR TRANSPLANTED 04/12/69
DATE SAMPLED 07/18/80
PREVIOUS CROP APPLE
PLANT APPEARANCE LIGHT GREEN 80 PCT.
HERBICIDE (CURRENT) SIMAZINE
HERBICIDE (PREVIOUS) SIMAZINE

MR. FRUIT GROWER
RD 1
WOOSTER, OHIO 44691

COUNTY AGRICULTURAL AGENT
428 W. LIBERTY ST.
WOOSTER, OHIO 44691

SPECIALIST'S COPY

SOIL TEST DATA
TYPE FINE/MEDIUM TEXT
MOISTURE NORMAL
PH 5.4
P 2 lbs/A
K 169 lbs/A
CA 1650 lbs/A
OM 2 SALTS 24
BY OSU
YEAR 1980

FERT.&LIME APPL.
RATE, LBS/ACRE
N P K
PREVIOUS CROP
45.0 0 0
LIME 0 lbs.
CURRENT CROP
55.0 0 0
LIME 0 lbs.