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NUTRITION STUDIES WITH MATURE AVOCADO TREES IN SANDCULTURE: A PROGRESS REPORT

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The following discussion is developed from information presented by the author at the Annual Meeting of the California Avocado Society, Santa Paula, California on June 3, 1961. The paper centers upon principal results of the long-term sandculture studies carried out at Riverside which will be of value in evaluating leaf analysis data. The first sections summarize the magnesium studies and the remaining sections develop background information that will be helpful to those contemplating a leaf analysis program.

MAGNESIUM DEFICIENCY

The original 10 sandculture units were installed in 1956 with the trees (Hass var. x Mexican root) being planted that spring. After several years of standard uniform growth conditions, the experiment was modified to bring forth symptoms associated with Mg deficiency, and later, to explore several corrective procedures for the deficiency of Mg. Effective November, 1961, the above trees, deficient to varying extents in Mg, have been under close observation regarding Mg nutrition levels for three complete years. Aside from many leaf analyses, numerous photographs have been obtained covering different expressions of deficiency, and to a limited degree, some production characteristics have been noted, also. A preliminary report summarizing the sandculture facility as well as gross aspects of Mg deficiency has been published (2). The more technical aspects of the experiment will be available (1) in the near future for the interested reader.

At present, the above experiment is being terminated in preparation for new experiments dealing with other phases of avocado nutrition. Ten more sandculture units are currently under construction and will be available shortly for use along with the original 10 units.

LEAF SAMPLING TECHNIQUES

During the course of the present studies, considerable detail has been devoted to background information pertinent to a realistic leaf sampling program. Visual symptoms alone are not sufficient for safe diagnosis of an excess or deficiency of nutrient elements. In many instances, lea! analysis must be performed prior to making an appraisal in nutrition. Also, the degree of nutrition cannot be readily evaluated except through leaf analysis in many cases. For example, consider the nitrogen-fruit production relationship that Embleton et al. (4) have established for the Fuerte variety. They are able to follow the tree's N-level by leaf analysis and recommend an appropriate N-fertilizer program accordingly. Yet by visual symptoms alone, such would be impossible. The frequent examples of Fe deficiency, Zn deficiency, excess salt, are other examples where leaf analysis may be of real value in determining the disorder. In the case of the Mg studies, many photographs are available, but the crucial test still remains to be the chemical analysis of the leaf. The above approach requires, however, considerable background information before it can be used confidently. Fortunately, the sandculture experiment has been available for studying many of the factors important to a realistic leaf analysis program. In addition to the sandculture trees, two trees located nearby in the field have been included For comparative purposes since they were of the same variety. Results of this study which has been carried out over the past three years serves as the basis for the present paper.

Seasonal Effects (Age of Leaf)

Discounting economics, several important questions confront the grower contemplating a leaf sampling program. When and how to sample surely are real issues. However, the answer may be conditioned upon the elements in question, and in general, the purpose or the question the grower has in mind regarding tree nutrition. A leaf analysis program designed for N-control is entirely different from the approach used for "troubleshooting" a suspected disorder. Certain principles must be recognized in both approaches, however.

For example, the age of the leaf sampled is vital, especially where comparisons are to be made. The sandcultures were ideal for evaluation of leaf age since the trees' nutrition was maintained under very rigorous control. In practice, 20 most recently matured leaves were collected from each tree every two months for two complete years. The leaf samples *ere* essentially spring-cycle leaves, so in effect a time function was at hand. The leaves were separated from the petioles and usually only the leaf blades were analyzed for nutrient elements: Ca, Mg, K, P, S, N, B, Cu, Fe, Mn. and Zn. Table 1 contains a partial summary of the leaf analysis data as influenced by leaf age. Included arc the coefficient of variations, which indicate the reasonable limits of variations to be expected. For example, the Ca data show a pronounced age effect—the older the leaf, the higher the Ca level in general. Also, the coefficient of variation is approximately 15%. Magnesium varies little in relation to leaf age. Also, its C.V. is quite low—10%. No distinct trend is apparent in the P and K data other than the May leaf (youngest leaf) may be higher in P and K. Nitrogen and S data are not given in the table as no pronounced age effect was noted. These trends are in general agreement with the observations made by Embleton et al. (5) with Fuertes at Agua Tibia. Regarding the macroelements (Ca, Mg, K, P, S, N) Ca would be expected to accumulate in the leaf with leaf age. Perhaps P and K would be high in new tissue, then gradually decline. Nitrogen levels would be expected to be relatively constant over a July to January period, when the spring-cycle leaf is taken.

Table 1. Relationship between leaf age and mineral content of macronutrients for Hass avocado leaf blades.

Leaf Collected	MEAN LEAF CONTENT %Ca	%Mg	%K	%P
May	1.08	0.35	1.75	0.27
July	1.22	0.34	1.60	0.20
September	1.25	0.30	1.86	0.24
November	1.35	0.38	1.99	0.22
January	1.54	0.42	1.62	0.21
March	1.95	0.46	1.53	0.21
May	1.47	0.44	2.03	0.31
July	1.24	0.50	1.28	0.22
Coefficient of variation	15%	10%	16%	8%

In the case of the micronutrients, and incidentally the published data are limited to one paper (7), B, Mn, and Fe exhibited marked influences due to leaf age. Table 2 contains a summary of the data. The variation in content is greater, being approximately 25%. Boron is very interesting in that the data show that as the leaf ages, the B level drops. For example, a mature spring-cycle leaf collected during the late summer contains approximately 50 ppm B, yet if sampled just prior to the spring flush, values half as large are noted. The field trees show this even more so, normal values of 30-50 ppm B are frequently found throughout the year except prior to the spring flush at which time the leaves contain 8-10 ppm B. Such extremely low values would suggest at first thought, a deficiency. However, the tree apparently behaves this way-— that is, prior to abscission, B may move out of the leaf. For diagnostic purposes, leaves should be collected during the fall. Both Fe and Mn accumulate with age. In the case of a possible Fe deficiency, the age factor should be recognized. Manganese deficiency has not been identified in the field in California avocados. Since there is a strong tendency for Mn to accumulate as the leaf ages, the stipulation made for Fe likewise ¡s necessary for considerations of Mn.

Table 2. Relationship between leaf age and mineral content of micronutrients for Hass avocado leaf blades.

Leaf Collected	MEAN LEAF CONTENT ppm B	ppm Cu	ppm Fe	ppm Mn	ppm Zn
May	44	8	44	40	55
July	51	7	41	45	59
September	51	7	64	55	38
November	41	6	68	86	47
January	37	11	63	124	48
March	25	9	77	130	35
May	71	16	61	83	39
July	49	11	49	67	49
Coefficient of variation	20%	31%	24%	36%	18%

The above data are consistent with the findings of Labanauskas et al. (7) and Embleton et al. (5) derived from studies of a Fuerte grove at Agua Tibia. Recognizing the extremes in variation possible from leaf aging, a recommendation follows that the spring-cycle leaf should be collected during the July-January period since the least variation would be expected then. Samples collected at other times could still be examined provided that the examiner recognized season effects on nutrient level.

Tissue to Sample

Considerations of the appropriate tissue to sample for chemical analysis are often quite involved but usually the leaf blade and/or the petiole are selected. Embleton et al. (4) developed their N-standards for Fuerte avocados on the basis, that the entire leaf is analyzed (blade plus petiole). Earlier, Fullmer (6) sampled only the petiole. The present author has considered unless otherwise noted, the leaf blade; for example, in the iron-chelate studies (3) and more recently, in the Mg studies (2). Fortunately, as for Mg, either the blade or petiole may be sampled and analyzed because both tissues contain essentially the same levels of Mg.

Table 3. Relationship of composition of leaf to composition of petiole.

MEAN LEAF/PETIOLE COMPOSITION

	No. of trees	Ca	Mg	K	P	N	S	B	Cu	Fe	Mn	Zn
Sampled September												
Sandculture —Complete	4	0.53	0.98	0.83	0.76	2.98	1.40	0.87	1.12	0.96	1.39	0.92
Field Trees	2	0.67	0.79	0.96	1.00	3.12	1.17	0.74	0.83	1.42	2.40	0.72
Sampled January												
Sandculture —Complete	4	0.65	1.03	0.54	0.91	2.20	......	1.16	1.34	1.40	2.22	1.17
Field Trees	2	0.70	1.05	0.79	1.50	2.91	......	1.29	1.80	1.70	4.60	1.36

More specific information is given in Table 3 where comparisons between the composition of the leaf blade and petiole is given and also in relation to leaf age—spring cycle leaves sampled in September and in January. Only the ratio of the leaf blade-composition to that of the petiole is given. Ratios greater than 1.0 simply mean that the blade has the higher nutrient level. The major differences occur for Ca and K which are higher in the petiole (ratios are less than 1.0) and for N and in general, the micronutrient which are higher in the leaf blade. In particular, N and Mn show much larger values in the blade.

The chief merit of such data as given above relates to the demonstrated need for standardizing on a tissue. The choice should be made on the basis of the tissue or tissues used for developing the leaf standard.

In the Mg studies, both the petiole and the leaf blade were evaluated separately. Fortunately, either tissue may be used since they both contain the same amount of Mg.

Soluble Nutrients

Under certain conditions, plant tissue has been analyzed by first extracting the tissue in question with a variety of reagents such as hot water, dilute acids including acetic acid, salt solutions, etc. In particular, such techniques are applied often by workers studying nutrition of vegetable plants and occasionally tree crops. Nutrients so extracted are referred to as "soluble nutrients" and they usually represent some portion of the total nutrient since the extraction does not ordinarily remove all of the nutrient. To obtain specific information on the Hass avocado, leaf samples were analyzed by conventional, reliable means and then separate portions were analyzed by the "soluble nutrient" technique where a small portion of ground leaf sample was extracted with 2% HAc (acetic acid). Results are given in Table 4. Potassium is more or less completely extracted—85-89% recovered; whereas, only 50-60% of the Mg and P is extracted. Very little Ca is removed and no NO^-N is found in the avocado leaves.

Table 4. Recovery of "soluble nutrients" with 2% acetic acid. The zero recovery *of nitrates means that NO_3-N is not accumulated in the avocado leaf.*

Quantity of Leaf extracted with 50 mls. of 2% Acetic Acid	NUTRIENT-RECOVERY				
	Ca	Mg	K	P	NO_3-N
gm.	%	%	%	%	%
0.50	5	63	98	53	0
1.00	4	60	93	51	0
2.00	5	63	95	59	0

Hence the conclusion is drawn that "soluble nutrient" extractions are of little value except for K. Some of Fullmer's data (6) pertain to P and K solubilized in a similar extract.

CONCLUDING REMARKS

Leaf analysis techniques may serve a very useful role in following avocado tree nutrition. Deficiencies as well as excesses of nutrients may be confirmed through leaf analysis. Yet it must be recognized that additional controlled nutrition experiments must be carried out first in order to have appropriate leaf standards. Fairly reliable information now exists for N, Mg, Fe, and Zn. Regarding excesses, data exist for evaluation on a tentative basis, excesses of Na, Cl, and S. The future studies, both in the field and here with sandcultures will permit extension of the above list of nutrients to include all of the possible nutrients important to avocado culture. The combination of closely controlled field experiments as being carried out by Embleton and his associates of the Riverside Department of Horticulture with sandculture— and greenhouse—controlled experiments will result in more reliable background information pertinent to proper utilization of a leaf analysis program.

Where leaf samples are to be collected for chemical analysis, the spring-cycle leaf should be collected when the leaf is *4* to 8 months old (normally late July through

December). The sample must be representative of the plot or group of trees sampled and to achieve this goal, good judgment must be exercised.

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