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Seasonal Trends in Nutrient Composition of Hass Avocado Leaves[1]

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Leaf analysis is successfully used as a diagnostic aid for many crops once adequate background, information on sampling, chemical analysis, and. reference levels has been established. Although limited, the published data on avocados suggests the feasibility of leaf analysis provided the above mentioned background information is obtained. Embleton *et al.* (6) and. Labanauskas *et al.* (10) provide information on sampling date and season pertaining to the Fuerte avocado. These observations were confined to a Fuerte avocado grove located in San Diego County.

The present report presents details on the importance of leaf age, season, petiole versus leaf blade, and. leaf position, of Hass avocado trees grown outdoors under controlled sand culture conditions and, for comparative purposes, Hass avocado trees in an adjacent field. The comparison between sand culture trees and field trees permits a more confident evaluation of leaf composition in relation to some of the above factors. During the experiment, the sand culture trees as well as the field trees have been under controlled, uniform treatments.

MATERIALS AND METHODS

Ten sand culture units were constructed in such a manner that they were fully automatic with each/unit containing approximately 1 ton of silica sand. The individual solution reservoirs contained 500 liters. Solutions were regularly renewed on a schedule such that the substrate nutrition was essentially constant for the trees receiving the "complete nutrient" treatment.

Commercially propagated Hass avocados on Mexican rootstocks were bare rooted and planted in the sand cultures during the Spring of 1956. The trees were maintained on a complete nutrient solution until November, 1958, at which time differential Mg treatments were imposed on. 6 trees, leaving 4 trees remaining on complete nutrient solution for the following 2 years. Additional details dealing specifically with Mg will be presented later.

For comparative purposes, 2 Hass avocado trees were selected from an orchard adjacent to the tanks, and. included, in the present studies. Richards *et al.* (15) may be referred, to for specific management details of the field trees.

During 1959 and 1960, leaf samples were collected every 60 days from each of the sand culture trees and field trees. Forty leaves (blade and petiole) per tree were

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collected from nonfruiting branches. Primarily, the spring cycle and early summer leaves were sampled. The leaf samples were washed in ivory soap. Ordinarily, the blade alone was analysed, but one study involved comparison of composition of the blade to its petiole (40 blades vs. 40 petioles per tree). Chemical analyses were carried out for Ca, Mg, K, P, N, S, B, Cu, Fe, Mn, and Zn using procedures previously described (3). Coefficients of variation were calculated for each nutrient in case of the sand culture trees.

Nutrients soluble in HAc were also examined. Extraction with *2%* HAc was investigated for Ca, Mg, K, P, NO_3-N, and several of the micronutrients. Separate leaf samples were extracted using different quantities of ground leaf material per 50 ml. of 2% HAc. The procedure was similar to that ordinarily used for analysis of "soluble nutrients" in vegetable plants.

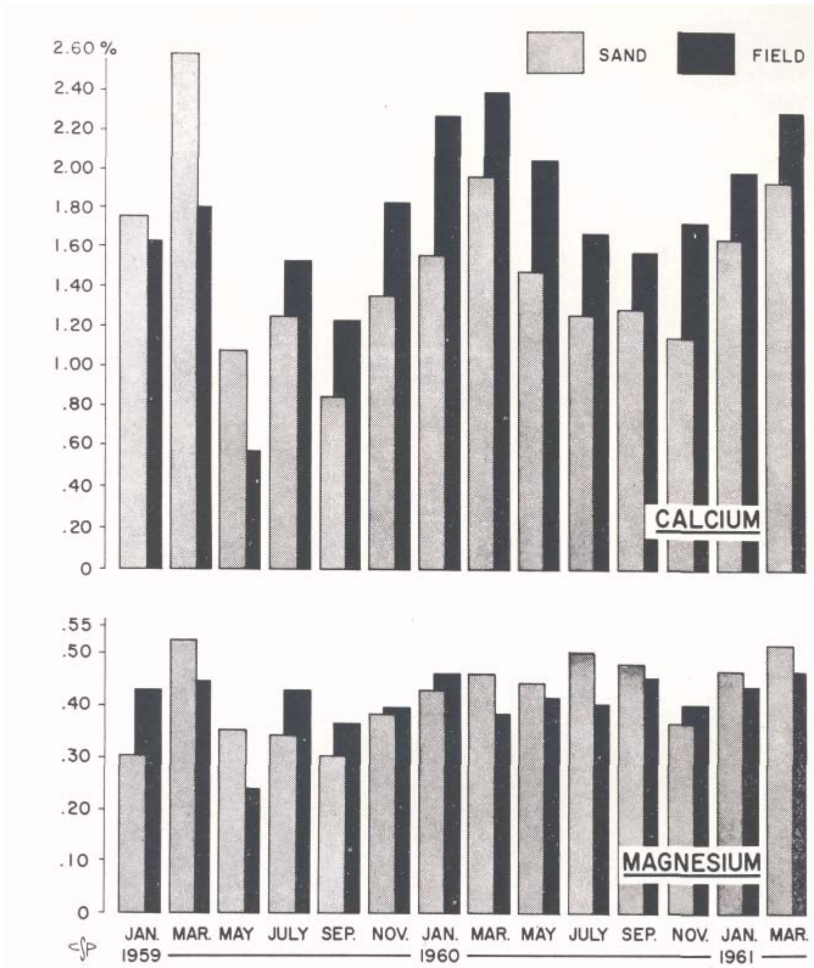

Fig. 1. Relationships between leaf age and content of calcium and magnesium in Hass avocado leaves (primarily spring cycle leaves) collected from sand culture trees and adjacent field trees. Coefficients of variation are 15% and 10% respectively for Ca and Mg.

RESULTS AND DISCUSSION

Variations in nutrients associated with leaf age are presented in 2 general groups: the first, relates to the macroelements; and the second, relates to the microelements. The macroelement data represent, in the case of the sand culture trees, the averaged composition of 4 trees, all of which received a complete nutrient solution for the entire experiment. The field tree data are averages of the 2 trees. For the microelements, an averaged value of all 10 sand culture trees and the 2 field trees was taken since there was no consistent difference between the trees.

Macronutrients

Calcium and magnesium:—An accumulation of leaf Ca was evident only late in the season when the leaf was 6 months or older (Fig. 1). Young spring cycle leaves contained from 0.60 to 1.00% Ca and, by wintertime, these leaves contained up to *2%* Ca or more. The least variation due to leaf age occurred during the summer or early fall months. In the sand culture trees, the coefficient of variation, was 15% for leaf Ca.

Unlike Ca, Mg in the avocado leaf was not greatly influenced by age of leaf. Less deviation in Mg was noted, the coefficient of variation being approximately 10%.

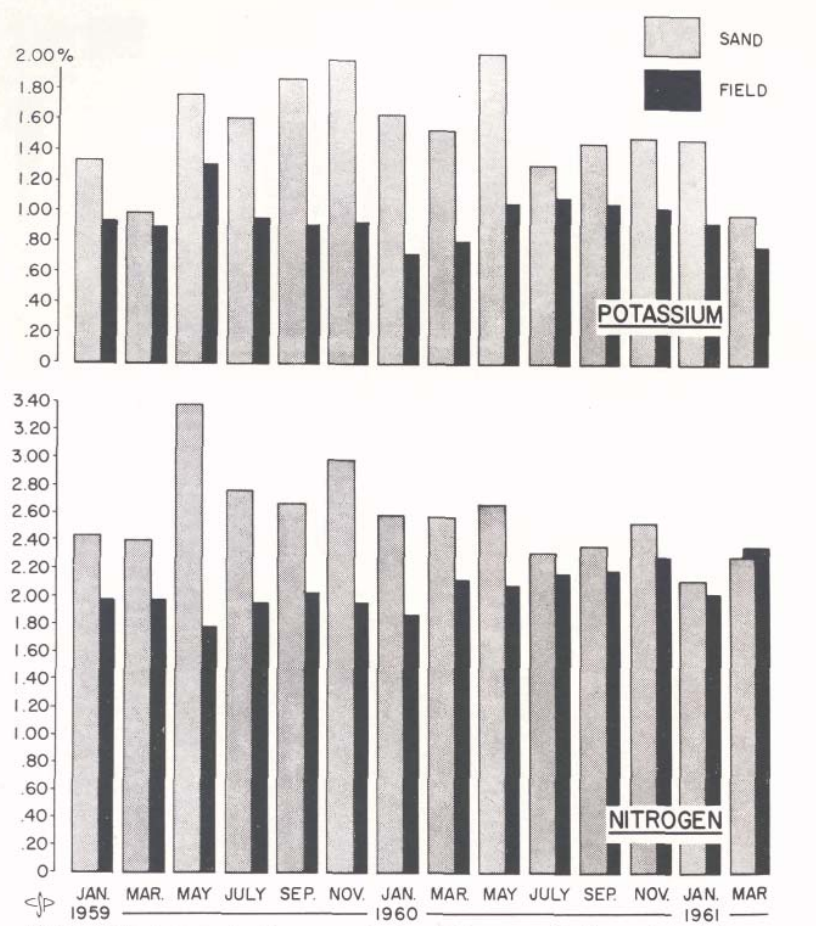

Fig. 2. Potassium and nitrogen contents of Hass avocado leaves in relation to leaf age and season. Coefficients of variation are 14% and 6%, respectively, for K and N.

Potassium and nitrogen:—The leaves from field trees showed a slight decrease in K as they became older (Fig. 2). Leaves collected in the spring contained approximately 1% K, whereas those collected during the winter contained 0.70-.80% K. The sand culture showed, in general, less of a seasonal trend but possibly in the same direction, older leaves having less K.

Nitrogen analyses showed little seasonal effects. However, both the sand culture and the field trees were abundantly supplied with N. Under a restricted N program, leaf N would be expected to reflect stronger seasonal influences with less N being found in old leaves.

Phosphorus and sulphur:—No distinct trend is indicated for P or S other than higher values for young leaves. With leaf age, P gradually dropped to approximately 0.15-0.20% P (Fig. 3). Sulphur exhibited a similar pattern.

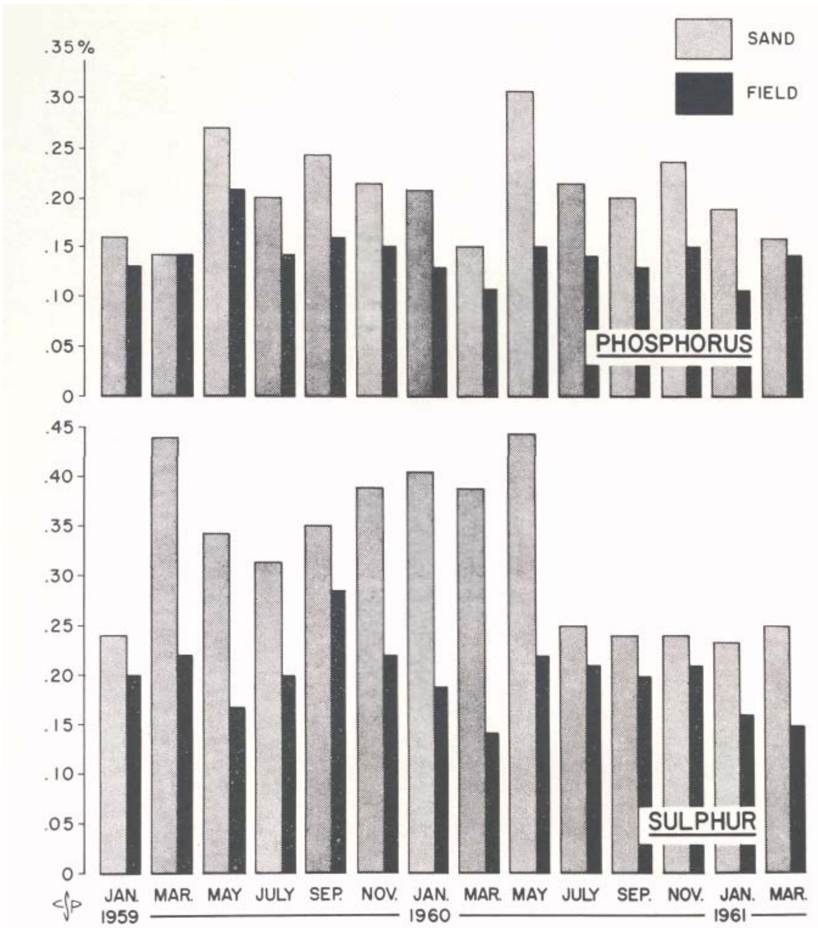

Fig. 3. Phosphorus and sulphur contents of Hass avocado leaves in relation to leaf age and season. Coefficients of variation are 7% and 21%, respectively, for P and S.

Micronutrients

Boron:—The data for both the sand culture and field trees exhibited a distinct seasonal influence with very low levels of B being found in old leaves sampled in early spring (Fig. 4). Samples collected in May and July were appreciably higher in B. The deviation in B levels was approximately 20%.

Copper and zinc:—No distinct trend was indicated by the Cu and Zn data in relation to leaf age other than perhaps the youngest leaves (collected in May) contained higher concentrations of Cu and Zn than leaves sampled during the late winter (Fig. 5).

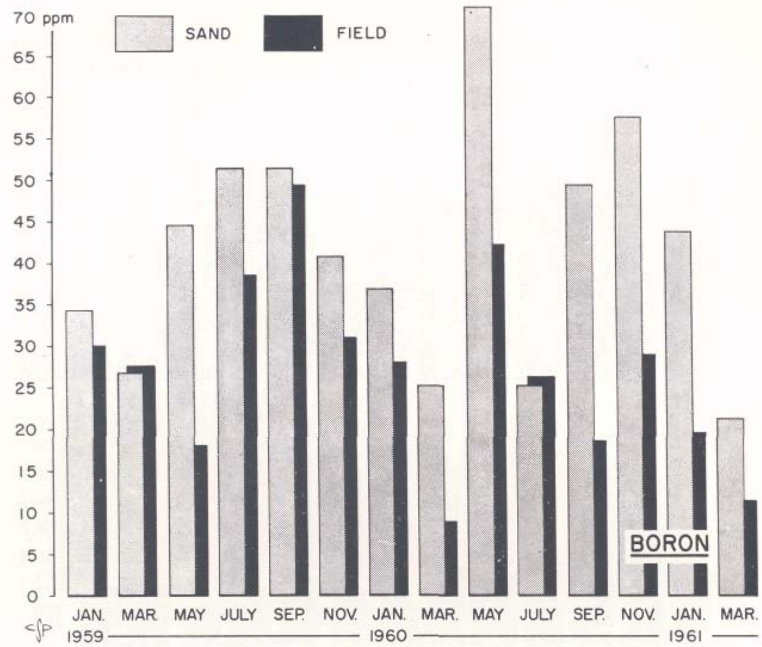

Fig. 4. Boron content of Hass avocado leaves in relation to leaf age and season. Coefficient of variation is 20%.

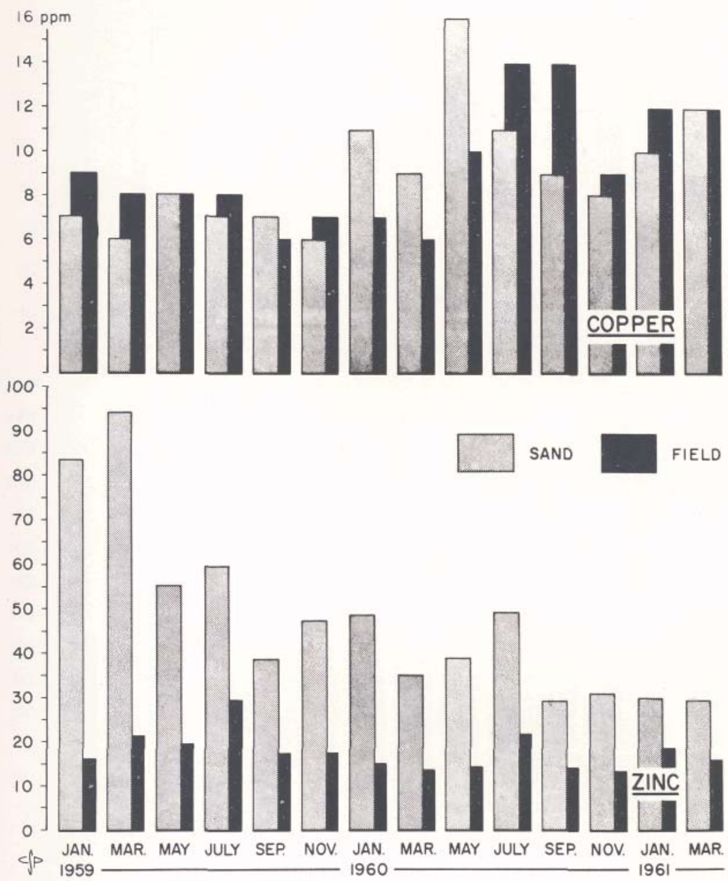

Fig. 5. Copper and zinc contents of Hass avocado leaves in relation to leaf age and season. Coefficients of variation are 31% and 24% respectively for Cu and Zn.

Iron and manganese:—Unlike B and Cu, Fe and Mn accumulated in the leaves as they became older (Fig. 6). Young leaves contained around 30 ppm Fe, and by late winter, similar leaves contained twice as much. Manganese levels increased twofold or more under the same conditions.

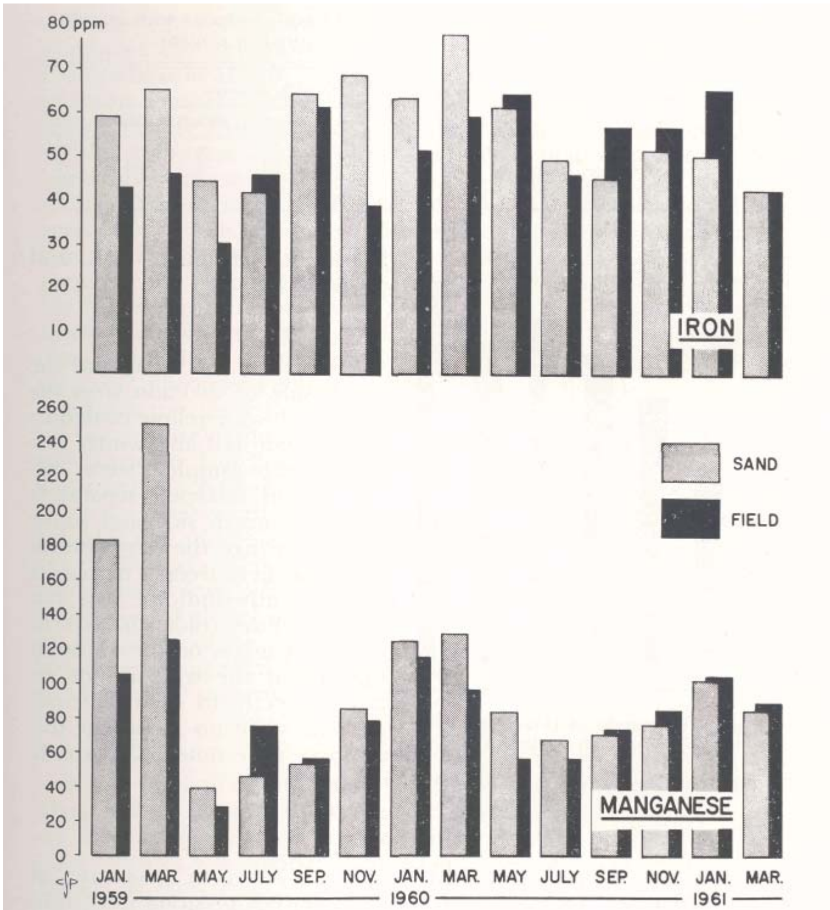

Fig. 6. Iron and manganese contents of Hass avocado leaves in relation to leaf age and season. Coefficients of variation are 18% and 36% respectively for Fe and Mn.

General comments:—Only two publications are available for reference to trends in macro- and micronutrients in leaves of avocados in relation to leaf age. Embleton *et al.* (6) reported on seasonal variations in macronutrient content of leaves collected in a Fuerte avocado grove in southern California, and Labanauskas *et al.* (10) reported on micronutrients in the same orchard. Their results were similar to those reported here. Results of other studies with tree crops show certain consistent similarities. For example, Ca levels increase with leaf age according to reports pertaining to such widely different crops as avocados (6), citrus, (7, 19), apples (5, 16, 8), peaches (1, 12), pears (13), figs (14), and grapes (17). In general, K, P, and N levels decrease with leaf age. The data on Mg are not consistent.

The micronutrient data for tree crops are limited. Bradford and Harding (4), Labanauskas *et al.* (11), and Smith *et al.* (18) conclude that for citrus, B, Fe, and Mn usually increase with leaf age. Variable results for Cu and Zn are reported. McClung and Lott's (12) study with peaches is similar regarding the variations associated with leaf age.

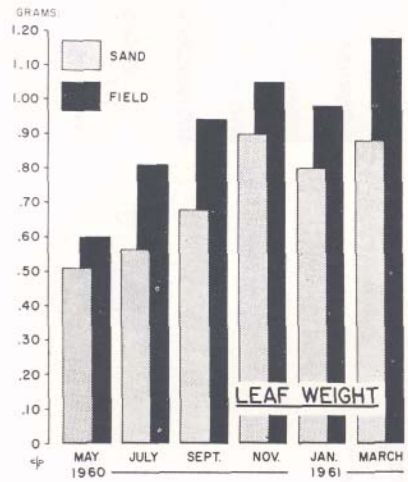

Fig. 7. Dry weight of Hass avocado leaves in relation to leaf age.

Leaf Weights

There was a gradual increase in the weight of spring cycle leaves with leaf age (Fig. 7). Data from the sand culture trees are comparable to those from the field trees except that leaves from the field trees were heavier. The increase of leaf weight with age is similar to that reported by Embleton *et al.* (6) for Fuerte avocado. The petiole accounts for approximately 10% of the leaf weight.

Petiole Versus Leaf Composition

On two occasions, January, 1960 and September, 1960, individual leaf blade and petiole samples (40 leaves) were collected from each of the 10 sand culture trees and the 2 field trees for comparisons of leaf blade composition to petiole composition (Table 1). The leaf blade contained larger amounts of N, Fe, and Mn, and similar or somewhat smaller concentrations of the Ca, K, Mg, B, Cu, and Zn. Fullmer's data (9) showed that as the P or K nutrition status of the avocado was increased, larger amounts were found in the petiole. The choice of tissue for analysis will be determined by considerations of convenience and tissue used for the reference level calibration. The coefficients of variability were approximately the same for either the blade or petiole and, in general, there was a relationship between the composition of blade compared to that of the petiole (Table I).[2]

Soluble Nutrients

Results summarized in Table 2 indicate that 2% HAc extracted 60% of the P, *95%* of the K, 63% of the Mg, and less than *5%* of the Ca—the reference being the total quantities of each element. Further, no NO_3-N was detected. Partial recovery of Fe and Mn was obtained. Thus, the use of *2%* HAc as an extraction solution appears to be limited to K, and possibly P.

Table 1.—Relationship of composition of leaf blade to leaf petiole.

Treatment & statistical indices	Number of trees	Ca Blade	Ca Petiole	Mg Blade	Mg Petiole	K Blade	K Petiole	P Blade	P Petiole	N Blade	N Petiole	B Blade	B Petiole	Cu Blade	Cu Petiole	Fe Blade	Fe Petiole	Mn Blade	Mn Petiole	Zn Blade	Zn Petiole
		%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
SEPTEMBER SAMPLING																					
Sand culture complete	4	1.26	2.15	0.510	0.518	1.50	1.80	0.208	0.210	2.44	0.85	53	61	8.3	8.5	50	53	64	46	31	34
low Mg	6	1.75	3.24	0.089	0.095	2.05	1.75	0.187	0.273	2.51	0.86	54	50	9.0	10.5	42	44	72	44	28	34
Field	2	1.94	2.89	0.450	0.565	1.13	1.18	0.130	0.125	2.28	0.73	28	38	14.0	17.0	57	40	84	35	15	21
JANUARY SAMPLING																					
Sand culture complete	4	1.55	2.40	0.415	0.375	1.61	2.75	0.208	0.210	2.59	1.14	36	31	11.5	9.3	57	40	100	45	41	35
low Mg	6	2.07	3.70	0.078	0.063	2.25	3.53	0.213	0.273	2.74	1.17	37	29	10.2	8.7	65	43	138	47	52	40
Field	2	2.34	3.39	0.410	0.390	0.79	1.00	0.120	0.075	1.96	0.67	23	17	8.5	5.0	51	30	115	25	15	11
Weighted Grand Mean		1.78	3.02	0.268	0.268	1.75	2.26	0.190	0.223	2.50	0.95	42	39	10.0	9.6	53	43	96	43	35	35
r1[a]		—		0.43		—		0.65		0.41		—		0.42		—		0.85		0.81	
r2[a]		0.77		—		—		—		—		—		—		0.20		—		—	
C.V.(%)[a]		14.1	14.0	11.1	6.5	b	b	7.3	11.7	7.1	8.4	b	b	26.6	23.5	23.5	30.4	18.2	20.5	9.9	13.7

[a]r1 calculated on the basis of a common regression.
[a]r2 calculated on the basis of a common regression and common average.
[a]C.V.(%) calculated on same basis as r1.
[b]Where r not given "between slopes" mean square was significant, hence C.V. was not calculated.

Leaf Position on Tree

Frequently the foliage on the south side of avocado trees develops a bronze-yellow caste during the late fall and winter seasons. Leaf samples were collected and analyzed separately from the north side and south side of each of the sand culture trees and field trees. The results of the study indicate that the bronze-yellow color characteristic of the leaves on the southern quarter of the trees is not related directly to their nutrient content since no consistent differences were noted. Perhaps N is consistently lower in the south side leaves.

Table 2.—Extraction of nutrients from ground avocado leaves with 2% HAc expressed as percentage of the total nutrient content.

Quantity of leaf extracted	Nutrient recovery						
	Ca	Mg	K	P	NO_3-N	Mn	Fe
gm	%	%	%	%	%	%	%
0.50	5	63	98	53	0	65	12
1.00	4	60	93	51	0	68	14
2.00	5	63	95	59	0	64	10

DISCUSSION

Season variations, illustrated by Figs. 1-7, are in most cases of such magnitude that a satisfactory leaf analysis program must take into account such variations. The feasibility of using a single "critical value" as an index of nutrient status would be conditioned on sampling the identical tissue for which the diagnostic level had been calibrated. Avocados, fortunately, produce a characteristic growth of new leaves in the early spring which can be recognized and sampled, once they have matured. The question of when to sample is perhaps open to debate, depending upon objectives but ordinarily, a sample of the most recently matured spring cycle leaves collected during the late summer or fall months would be appropriate for examination of the macronutrient. Except for Ca, the nutrient level within the leaf is relatively stable during the August to December period. The micronutrients may vary, leaving no alternative but to sample similar tissue. However, seasonal effects must be recognized. For example, Fe in the early summer may be approximately 40 ppm Fe, approaching a level suggested for deficiency (2), yet within a few months the level may double. Boron is another element which varies significantly with leaf age (Fig. 4). Labanauskas *et al.* (10) reported similar trends for a Fuerte avocado grove in southern California. Perhaps an early season and a late season sample (August and December) would be more indicative of the tree's nutritional level provided that appropriate leaf standards were available.

There appear to be no distinct advantages of sampling the blade versus the petiole. There is a proportionality between their respective nutrient levels (Table 1). Either tissue is readily collected and prepared for chemical analysis. The choice should depend upon the tissue that reference levels are specific for. The same reference level cannot ordinarily be used interchangeably for blades or petioles. Magnesium is an exception, possibly K, P, and S could be included, also (see Table 1, the September samples).

Soluble nutrients, that is, those solubilized in 2% HAc or similar extractants are of interest where time is of prime importance and only then for 1 or 2 specific nutrients. Practically all of the K was extracted. No NO_3-N was detected in avocado leaves even though the trees received all of their nitrogen as NO_3-N. Extraction of P, Ca, Mg, Mn, and Fe with HAc would represent only a partial recovery of the leaf's total content (Table 2). Such methods to be applicable where low recoveries are obtained, call for a very careful calibration. Fullmer (9) reports some success for P and K analysis of Fuerte avocados. According to the present study, his K data would represent total K, but soluble P would include only 50-60% of the total P content of the leaf.

SUMMARY

Season variation in macro- and micronutrient composition of Hass avocado leaves was followed by bimonthly sampling and analysis. The composition of bearing trees growing outdoors in large sand cultures was compared to 2 field trees adjacent to the installation. In most cases, the spring flush leaves were sampled. Very similar trends were noted for the sand culture trees and field trees. Calcium, B, Fe, and Mn contents of the Hass avocado leaves vary in relation to leaf age.

Comparison of leaf to petiole nutrient content shows considerable variation, depending upon the element in question. Nitrogen, Fe, and Mn values are distinctly higher in the leaf blade. Calcium is higher in the petiole.

Nutrient extraction with 2% HAc appears to be applicable primarily to K and Na. No NO_3-N was detected in avocado leaves.

Regarding sampling technique, spring cycle leaves from non-fruiting terminals may be collected during the August through December period for leaf analysis. Reference "critical levels" would be more useful if specified for the August leaf, and for the January leaf.

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