The Relationship of Soils and Fertilizers to the Nutrient Content of Apple Trees[1]

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Introduction

The observation by Liebig in 1840 that "crops on a field diminish or increase in exact proportion to the diminution or increase of the mineral substances conveyed to it" has become the dominant concept in mineral nutrition. It, with modifications to include problems in nutrient availability and balance, has been the basis of chemical tests to establish the nutrient requirements of plants and soils. As an approach to problems in mineral nutrition, this philosophy has been very effective. Crop yields have been markedly increased and visible deficiencies have become rare.

However, as higher levels of fertility become more common, the limitations of this philosophy become more apparent. In fact, the ability to modify or improve the nutrient content of the plant by the application of fertilizer is becoming increasingly problematical. In this respect, some of our recent studies with fruit trees, more specifically with dwarfed apple trees, illustrate some of the areas in which knowledge is inadequate.

Leaf Composition and Tree Performance

For apple, one of the better, as well as more convenient tissues for establishing the nutrient condition of the tree is the foliage. The nutrient content of this tissue reflects the performance of tree sufficiently well to permit the establishment of "Standards" (2). Deviations from these standard values occur as is indicated in Table 1, but the amount of

TABLE 1. Standard leaf composition values for apples with the coefficients of variation and range for normal plants.*

Nutrient	"Standard"	Coefficient of Variation	Range expressed as a Percent of Average or Standard
N	2.33%	9.0	80-120
P	0.23%	43.9	39-236
K	1.53%	29.5	49-162
Ca	1.40%	30.6	56-158
Mg	0.41%	30.6	62-164
Mn	98 ppm	58.1	32-207
Fe	220 ppm	51.7	15-240
Cu	23 ppm	77.0	18-247
B	42 ppm	46.9	27-327

* After Kenworthy, A. L., 1961 (2).

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deviation without changes in tree performance has been found to be remarkably small. This is particularly true considering the wide range in climatic soil and cultural conditions under which apples are grown.

The reliability of these "Standard leaf composition values" varies in practice both with the nutrient and the measure of tree performance. Such a test can be seen in Table 2. This data was obtained in a study

TABLE 2. Simple correlations between the nutrient content of the leaf and apple tree performance (3).

Measures of performance	Leaf Composition N	P	Ca	Mg	K
Tree Height	.28	.03	—.29	—.40	.57
Trunk Circumference	—.01	—.02	—.00	—.25	.36
Trunk Growth	.07	—.12	—.09	—.24	.40
Shoot Growth	.01	—.10	.10	—.24	.08
Number of Shoots	—.63	—.05	.54	.46	—.20
Number of Blossoms	—.55	—.48	.47	.56	—.32
Number of Fruits	—.48	—.40	.39	.44	—.19

Significance: 5% level r = .44
1% level r = .56

involving a group of trees which varied widely in growth and fruiting characteristics, as well as nutrient content. The level of all of the nutrients however, were within the optimum range. Of interest, is the fact that most of the various measures of growth recorded did not correlate well with the level of any single nutrient tested, N, P, K, Ca,

TABLE 3. Multiple correlations between various measures of tree performance and the nutrient content of the leaf expressed as interaction coefficients (1).

Measures of performance	Expression of Nutrient Composition* Linear	Linear and Interaction
	r=	r=
Tree height	.72	.95
Trunk growth	.52	.88
Shoot growth	.41	.78
Number of shoots	.69	.84
Number of blossoms	.77	.96
Number of fruit	.67	.96

* Linear = N + P + K + Ca + Mg
Interaction = NP + NK + NCa + NMg + PK + PCa + KCa + KMg + CaMg

or Mg, yet significant correlations were obtained between most of these nutrients and fruiting (4).

When, however, the total quantity of nutrients (N, P, K, Ca, and Mg) present in the leaves were correlated with tree performance the level of significance was appreciably improved (see Linear expression in Table 3). The level of correlation was further improved when the balance between these five nutrients was considered and expressed as an interaction (1).

Such results emphasize the need for a better understanding of leaf analysis data. Involved is more than simply the quantity of any one nutrient or any single measure of tree performance. The balance between nutrients appears to be, at least, as significant and may correlate better with more different measures of tree performance.

Tree Structure and Nutrient Composition of the Foliage

In contrast to most plants which are propagated from seed, apple trees can be rather complex structures involving two or more separate individuals grafted together. Such a method of constructing trees allows the use of materials which impart greater disease, insect, drought or cold resistance to the tree as well as modifying its habit of growth and fruiting. The top or foliage bearing portion of the tree is referred to as the *scion* and the root portion as the *rootstock.*

If a rather extensive portion of plant material is employed as a portion of the trunk, comprising a major portion of that trunk, it is referred to as a *bodystock.* If not, it is designated an *interstock.* Interstocks may be as long as 6 to 8 inches or as short as ½ inch depending upon its function.

While such a method of constructing a tree serves many useful purposes, it confounds the problem of correlating the nutrient composition of the foliage with soil tests and fertilizer response. Trees which vary in the number of graft components as well as in the variety of plant

TABLE 4. Influence of rootstock, interstock and bodystock on the nutrient content of the scion variety Jonathan, 1958 (5).

Interstock	Bodystock	Rootstock	Nutrient content of the foliage* Percent dry weight				
			N	P	K	Ca	Mg
		Western	2.64	.21	1.41	1.32	.41
		EM VII	—.32	—.04	—.04	—.46	—.11
		EM II	.36	—.03	.24	—.29	—.06
		EM I	.54	.00	—.09	—.12	.05
		EM XIII	—.06	.01	.15	.13	.02
	Virginia	Western	—.73	—.05	.08	.03	.16
	Hibernal	Western	.14	.05	—.04	—.16	.03
Clark	Virginia	Western	—.66	.02	—.22	—.34	.04
Clark	Hibernal	Western	—.19	.06	.16	—.04	—.10
L.S.D.	5%		.31	.04	.13	.19	.04
	1%		.46	.07	.16	.28	.07

* Expressed as differences from the standard, Jonathan/Western

material used as one of the components, can be associated with distinctly different leaf composition values (5). As is shown in Table 4, such differences can be seen with trees of the same scion variety, growing in the same orchard and therefore under similar soils and management. While differences between rootstocks might have been anticipated from studies in nutrient uptake, such would not explain the influence of the bodystock and interstock. Also of interest in this data is the fact that the direction or amount of change in nutrient composition is not typical of a given plant material. For example, Clark, as an interstock, was associated with depressing the influence of Virginia bodystocks on leaf N but was associated with the opposite effect with Hibernal. The influence of Clark on leaf K also varied, being associated with increasing leaf K in one combination and decreasing it in another.

The importance of stock-scion relations in mineral nutrition is further emphasized by the results of another study. This investigation attempted to relate changes in nutrient composition of the scion foliage with changes in plant materials used as rootstocks and interstocks (4). Under consideration also was the interaction of plant materials suggesting the influence of the physical presence of the graft union as well as various degrees of congeniality between plant materials.

According to the analysis of variance, changes in the variety employed as the scion resulted in greater variations in nutrient content than changes made in the other plant parts (Table 5). Changes in

TABLE 5. Relative influence of the scion, interstock and rootstock on the nutrient content of the scion foliage as indicated by the significance of the analysis of variance (4).

Source of Variance	Nutrient				
	N	P	K	Ca	Mg
Rootstock	ns	ns	*	ns	*
Interstock	**	**	**	*	**
Scion	**	**	**	**	**
Interaction of:					
Rootstock and Interstock	*	ns	ns	ns	ns
Rootstock and Scion	ns	ns	ns	ns	ns
Interstock and Scion	**	**	*	ns	**
Rootstock, Interstock and Scion	**	*	**	ns	ns

ns no significant correlation
* correlation significant at the 5% level
** correlation significant at the 1% level

rootstock caused the least amount of variation while the interstock was intermediate in its influence but more nearly resembling the amount of variation caused by the scion than by the rootstock. Any interactions which might have been present involving the rootstock were not associated with changes in nutrient content. However, the interaction of the interstock and scion varieties resulted in several highly significant variations.

The results of these experiments indicate that the role of each of the various portions of the plant in mineral nutrition is not fully understood. It suggests that their activity is more complex and more vital than is commonly depicted. The dominant influence of the stem and foliage bearing portions of the plant is particularly noteworthy and deserves further study.

Nutrient Supply and Composition of the Foliage

The use of foliar analyses to determine the nutrient requirement of the tree assumes that the nutrient content of the foliage is a true reflection of nutrient supply. It also assumes that modifying this supply, as with the addition of fertilizer, will result in a corresponding change in nutrient content of the tree.

In this respect, several studies which have attempted to correlate nutrient supply with nutrient content are of interest. Because of the question of differences in availability of nutrients to different rootstocks, a comparison was made between the K content of the soil and that of the foliage of twelve stock-scion combination (3). Soil samples were taken at the outer edge or drip line of the trees and a composite made between the 4 to 24 inch depths. As shown in Table 6, little

TABLE 6. Relationship between the availability of K in the soil and the K content in the foliage of various stock-scion combinations (3).

	Ratio Leaf K (%) to Available Soil K (me)			
Scion Variety	Western	EM II	EM VII	Mean
Golden Delicious	1.34	1.54	1.38	1.42
Delicious	1.38	1.97	1.55	1.63
Jonathan	1.28	1.44	1.19	1.30
Rome	.88	1.86	1.30	1.48
	1.23	1.70	1.37	

relationship was noted between soil and leaf K although the soils tested, ranged from medium to high in available K. Further, differences between scion varieties were almost as great as between rootstocks.

A similar lack of association between nutrient supply and nutrient content of the foliage was noted in a long term fertilizer trial (3). Four scion varieties placed in combination with three different rootstocks were fertilized differentially with N, NP, NPK, N-K and N-KMg over a four year period as shown in Table 7. Leaf samples taken from these combinations and treatment were not significantly different in any of the nutrients tested nor was there any great variation between trees.

In still another experiment, differences in the availability of nutrients to the root were eliminated by growing trees in sand culture (1). The six rootstocks used were all grafted to the same scion variety to facilitate comparison. A modified Hoagland's nutrient solution was supplied to trees at ⅓rd, 1 and 3x standard strengths. As shown in Table 8, while there was a tendency for the nutrient content of the

TABLE 7. Influence of four years of fertilizer treatment upon the nutrient content of scion foliage (3).*

Treatment	Rootstock	Nutrient Content Percent Dry Weight				
		N-	P	E	Ca	Mg
N—	EM II	2.6	.22	1.4	1.2	.40
	EM VII	2.6	.21	1.4	1.2	.39
	Western	2.7	.22	1.4	1.3	.40
NP—	EM II	2.7	.21	1.5	1.1	.39
	EM VII	2.6	.22	1.4	1.2	.42
	Western	2.9	.23	1.3	1.2	.38
NPK	EM II	2.7	.22	1.6	1.1	.37
	EM VII	2.6	.23	1.5	1.2	.38
	Western	2.8	.24	1.5	1.3	.39
N-K	EM II	2.5	.23	1.6	1.2	.38
	EM VII	2.6	.22	1.6	1.2	.38
	Western	2.9	.23	1.4	1.2	.40
N-KMg	EM II	2.7	.22	1.6	1.1	.37
	EM VII	2.5	.22	1.6	1.2	.39
	Western	2.8	.23	1.5	1.2	.37
	CV	3.5%	.74%	2.4%	1.2%	.67%

* Mean of Delicious, Golden Delicious, Jonathan and Rome varieties. Annual rate of fertilization per tree: N-0.51 lb., P-2.5 lb., K-0.9 lb., Mg-0.5 lb.

TABLE 8. Influence of nutrient solution concentration on the nutrient content of Delicious foliage expressed as the difference in per cent dry weight (1).

Rootstock	Difference in Nutrient Content*				
	N	P	K	Ca	Mg
EM XI	.59	.03	.82	—.23	—.06
MM 106	.17	.02	.95	.19	.02
EM II	.35	.02	.48	—.27	—.04
EM I	.00	—.04	.89	—.04	—.08
EM XIII	.43	.01	.40	.04	.04
Western	.25	—.02	.88	.07	.08
Mean	.30	.00	.73	—.04	—.01

* Difference between trees grown in 1/3rd and 3x standard Hoagland's nutrient solution.

foliage to be higher in the more concentrated nutrient solution, only N and K were significantly increased. Considering the fact that one solution was nine times as concentrated as the other, such changes must be considered remarkably small. Further, the response varied with each of the nutrients thereby creating in the leaves an entirely different condition of balance between nutrients.

Discussion and Conclusions

The results of this series of studies indicate that at near optimum levels of nutrition, tree performance is not necessarily related to the quantity of N, P, K, Ca or Mg in the foliage. Only when all five of these major nutrients were considered and expressed empirically to reflect the balance between them were the correlations with tree performance highly significant. Similarly, when trees were constructed employing different combinations of rootstock, bodystock, interstocks, and scions, each combination was found to develop leaf composition values which were dissimilar and unrelated to either nutrient availability or supply.

It can also be suggested from these results that soil and plant analyses are of primary use in establishing mineral deficiencies. At higher levels of fertility, their value is establishing nutrient requirements is limited.

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