Nutritional Survey of Indiana Apple Orchards Utilizing Foliar Analysis as the Diagnostic Tool[1]

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Foliar analysis has been used in orchard fertility investigations for many years. As leaf analysis methods have been developed for fruit trees and sampling methods standardized, optimum leaf concentration ranges and critical leaf levels have been determined. In recent years fruit orchard surveys, utilizing leaf analysis as the diagnostic tool, have been performed to determine the nutritional status of these orchards, to diagnose nutritional disorders, to determine true nutrient requirements and to aid in developing orchard fertilization programs (1, 2, 4, 5, 7, 8, 9).

Methods and Materials

In 1961 and 1962 a survey was made in Indiana using both foliar analysis and soil tests to evaluate the general nutritional condition of Indiana apple orchards. Twenty orchardists participated in this survey and 40 samples of leaves were collected.

Leaves were collected from the mid-section of current season growth located five to seven feet above ground level. Leaves collected were free of insect, disease and mechanical injury. Only one leaf and petiole was removed from a shoot and only five to eight leaves from any tree. Eight to ten trees were sampled and the leaves composited. Each sample, consisting of 60 to 100 leaves, was placed in a kraft paper bag and forwarded to the Michigan State University Plant Analysis Laboratory. Leaves were analyzed for nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron, copper, boron, zinc and molybdenum.

Soil samples taken from a 6 to 10 inch depth, were collected from leaf-sampled trees. Samples were taken at the tree drip line. Soil

TABLE 1. Standard Leaf Composition Values for Apple Trees and Normal Range in Leaf Composition Values Under Michigan Conditions (6)

Element	Standard	Normal Range
N - %	2.33	1.60 - 2.49
P - %	.23	.155 - .295
K - %	1.53	1.16 - 1.90
Ca - %	1.40	1.06 - 1.70
Mg - %	.41	.31 - .49
Mn - ppm	98	59 - 137
Fe - ppm	220	141 - 302
Cu - ppm	23	6.4 - 40
B - ppm	42	28.6 - 55
Zn - ppm	30	23 - 37

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samples were tested by Purdue Soil Testing Laboratory for pH, available phosphate and available potash.

Results

Kenworthy (6) has proposed standard leaf composition values for common macro- and minor elements of fruit trees. These values are the levels of nutritional content in the foliage associated with good horticultural performance. These values plus a "normal range" in nutritional content for each element for apple are shown in Table 1.

Analyses of the leaf samples revealed variations between samples for each element. The means and ranges for each element and the dis-

TABLE 2. Means and Ranges in Leaf Composition Values for 1961 and 1962 Indiana Leaf Samples and Distribution of Leaf Samples Within Low, Normal or High Range for Nutritional Elements As Proposed by Kenworthy (6)

Element	Mean	Range	Sample Distribution		
			Low	Normal	High
Nitrogen %					
1961	2.03	1.53 - 2.74	1	38	1
1962	2.02	1.44 - 2.46	4	36	0
Phosphorus %					
1961	.184	.128 - .336	10	29	1
1962	.174	.112 - .282	21	19	0
Potassium %					
1961	1.33	.84 - 1.82	7	32	1
1962	1.19	.86 - 1.66	19	21	0
Calcium %					
1961	1.09	.70 - 1.82	21	18	1
1962	1.01	.43 - 1.72	21	18	1
Magnesium %					
1961	.32	.20 - .48	14	26	0
1962	.30	.16 - .40	19	21	0
Manganese ppm					
1961	169	54 - 674	4	32	14
1962	132	26 - 528	4	26	10
Boron ppm					
1961	33.3	26.0 - 42.8	7	33	0
1962	33.5	13.5 - 49.6	9	31	0
Iron ppm					
1961	167	98 - 259	13	27	0
1962	105	50 - 163	35	5	0
Copper ppm					
1962	11.3	6.0 - 16.6	1	39	0
Zinc ppm					
1962	50.1	13 - 140	8	12	20
Molybdenum ppm					
1962	4.7	2.2 - 8.2			

tribution of these samples, either below, within or above the indicated normal range, for respective elements is shown in Table 2.

Leaf potassium content was low in some samples. Likewise 52 percent of the samples were low in calcium. Leaves analyzed in 1961 revealed 35 percent of the sample to be low in magnesium, while 48 percent of the samples collected in 1962 were low in magnesium. Several leaf samples had a low leaf boron content.

Leaf manganese was high in 35 percent of the 1961 samples and in 25 percent of the 1962 leaf samples. Likewise 50 percent of the samples analyzed in 1962 had a high leaf zinc content.

The distribution of pH values for the soil samples is presented in Table 3. Seventy-nine percent of the samples collected in 1961 tested pH 5.5 or lower. Seventy-four percent of the soil samples tested pH 5.5 or less in 1962.

Table 4 shows the distribution of available potash values for the

TABLE 3. Distribution of Soil pH Values for Indiana Orchard Soil Samples

	Number of Samples	
pH Range	1961	1962
4.5 - 5.0	12	13
5.1 - 5.5	19	15
5.6 - 6.0	4	6
6.1 - 6.5	3	3
6.6 +	1	1

TABLE 4. Distribution of Available Potash Values in Indiana Orchard Soil Samples

	Number of Samples	
Potash - lbs/A	1961	1962
0 - 100 (very low)	3	5
101 - 180 (low)	22	22
181 - 250 (medium)	6	6
251 - 375 (high)	5	5
376 + (very high)	4	—

soil samples. Sixty-two percent of the soil samples had a soil test below the medium level in 1961 and 72 percent tested similarly in 1962.

The distribution of available phosphate values for the soil samples are illustrated in Table 5. The sample distribution was similar both years with slightly over 50 percent of the samples testing less than 100 pounds available phosphate per acre.

TABLE 5. Distribution of Available Phosphate Values in Indiana Orchard Soil Samples

Phosphate - lbs/A	Number of Samples 1961	1962
0 - 40 (very low)	10	12
41 - 100 (low)	11	9
101 - 180 (medium)	7	8
181 - 300 (high)	6	6
301 + (very high)	5	3

Discussion of Results

An increase in leaf nitrogen content would be desirable in several orchards. Excessive nitrogen usage in Indiana orchards was not revealed in this survey. Leaf analysis indicate no critical shortage of nitrogen to occur. Most growers are making annual applications of nitrogen which contributes to the favorable status of this nutrient element.

Some sampled orchards would benefit from applications of potash. The percentage of leaf samples low in potassium was much greater in 1962. This could be a result of slightly earlier leaf sampling, especially since the growing season began slightly later than in 1961. The summer growing season was drier in 1962 and Hibbard and Nour (3) found lower leaf potassium levels when trees were grown under moisture stress. A majority of the soil samples also indicated applications of potassium should be beneficial to the trees.

Leaf calcium levels were similar both years and results indicate a majority of orchards should benefit from lime applications. Less than 13 percent of the soil samples tested pH 6.0 or above. Indiana orchardists are advised to maintain orchard soil pH above 6.0. Ammonium fertilizers and sulfur sprays probably contribute to the acid soil conditions.

The low leaf magnesium levels probably can be related to soil pH. Dolomitic limestone applications would correct magnesium shortage and calcium need. Applications of potassium to orchards where leaf analysis suggested a need, without correcting the magnesium needs could result in severe magnesium deficiency.

Excess levels of leaf manganese were present in 25 percent of the samples. Low soil pH and applications of certain fungicides in disease control programs would produce this condition.

Leaf boron levels were rather satisfactory. Applications of boron would be beneficial in a few sites and these sites were generally located on light soil.

The high leaf zinc levels are probably related to fungicidal programs utilized by orchardists.

Summary

Forty leaf samples were collected in 20 orchards in 1961 and again in 1962 and analyzed for nutrient element content. Soil samples were also collected.

Leaf analysis were compared with nutrient values proposed by Kenworthy for apples. Nitrogen levels were fairly satisfactory for most orchards. Some orchards required applications of potash. Fifty percent of the leaf samples were low in calcium. Likewise a shortage of magnesium was indicated in 35 percent of the leaf samples. About 20 percent of the samples indicate a need for boron.

High leaf manganese levels were observed in about 25 percent of the samples. Leaf zinc values were high in 50 percent of the samples collected in 1962.

Literature Cited

1. Beattie, James M. and C. W. Ellenwood. 1950. A Survey of the Nutrient Status of Ohio Apple Trees. Proc. Amer. Soc. Hort. Sci. **55**:47-50.
2. Emmert, F. H. 1955. Foliar Analysis Results From 40 Connecticut Orchards. Conn. Agr. Exp. Sta. Bul. 317:18 pp.
3. Hibbard, A. D. and Mohsen Nour. 1959. Leaf Content of Phosphorus and Potassium Under Moisture Stress. Proc. Amer. Soc. Hort. Sci. **73**:33-39.
4. Hill, H. 1952. Foliar Analysis as a Means of Determining Orchard Fertilizer Requirements. Rept. 13th International Hort. Congress pp. 1-15.
5. Kenworthy, A. L. 1953. Nutritional Condition of Michigan Orchards: A Survey of Soil Analyses and Leaf Compositions. Mich. Agr. Exp. Sta. Tech. Bul. 237:30 pp.
6. ————. 1961. Interpreting the Balance of Nutrient-Elements in Leaves of Fruit Trees. Amer. Inst. Biological Sci. Pub. No. 8:28-43.
7. Thompson, A. H., R. S. Marsh and O. E. Schubert. 1952. A Leaf Analysis Survey of Apple Orchards in West Virginia. W. Va. Agr. Exp. Sta. Bul. 356. 11 pp.
8. Walker, D. R. and D. D. Mason. 1960. Nutritional Status of Apple Orchards in North Carolina. Proc. Amer. Soc. Hort. Sci. **75**:22-31.
9. Walrath, E. K. and Rodger C. Smith. 1952. Survey of Forty Apple Orchards. Proc. Amer. Soc. Hort. Sci. **60**:22-32.