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A Survey of the nutritional status of West Virginia apple orchards

S. Singha

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A Survey of the Nutritional Status of West Virginia Apple Orchards

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Agricultural and Forestry Experiment Station
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S. Singha, T. L. Auxt, S. H. Blizzard and E. C. Townsend

Introduction

Increases in the costs of inputs and labor make it imperative for fruit growers to maximize production efficiency. Proper tree nutrition is important from the standpoint of both optimizing fruit yield and improving fruit quality. In a survey of apple orchards in West Virginia in 1950 (Thompson et al., 1952), information was obtained on soil and leaf macronutrient levels. Since then, however, no information has been obtained on the nutrient status of West Virginia apple orchards. Besides obtaining updated information on macronutrient levels, it was also of interest to determine micronutrient levels. Manganese toxicity has been reported in apple orchards around the state (Berg et al., 1958; Schubert and Orton, 1955); the extent of such toxicity in the primary production areas needs to be established.

The lack of nutrient information frequently results in uneconomical fertilizer applications. The current survey was conducted with the objectives of determining the nutrient status of apple orchards and aiding growers in modifying their fertilizer programs to avoid unnecessary fertilizer applications or to rectify deficiency/toxicity problems where they exist.

Experimental Procedures

Regions, Soils and Cultivars Selected

This study was designed to survey the major regions, soils and cultivars of the West Virginia apple industry. This industry is concentrated in the Eastern Panhandle of the state. Orchards are planted on two general types of soils: those formed from limestone and those formed from shale. Approximately half of the fruit produced in the state is sold to fresh markets, and the rest is processed. Leading cultivars, listed in order by production, are York, Golden Delicious, Red Delicious, Rome, and Stayman. The majority of the trees of these cultivars are on standard rootstocks.

Twenty orchards in Jefferson, Berkeley and Hampshire counties were sampled. Jefferson and Berkeley are located in the topographical region known as the "Great Limestone Valley." The orchards there are planted on deep limestone soils with a high water-holding capacity. Hampshire County is located on the Appalachian Plateau. The soils there for the most part are formed from shale and are more shallow than the valley soils. Several orchards in this county are planted on cherty soils. Through weathering of limestone, the highly resistant chert is left as residual fragments on and in these soils. Red Delicious (Starkrimson Bisbee strain), Golden Delicious, Rome, and York trees, all on standard rootstocks and between 15-25 years of age, were sampled.

Soil and Leaf Sampling Technique

Soil and leaf samples were collected from July 29 through July 31, 1980. Fourteen orchard blocks of each cultivar were sampled (Appendix Tables 1-4). The general locations of the orchards surveyed are given in Figure 1. Four replicate leaf samples and two replicate soil samples were gathered per block, for a total of 224 leaf samples and 112 soil samples. Each leaf sample contained ten leaves, removed from the mid-region of current season's shoot growth, from each of ten trees. Shoots were randomly selected from all sides of each tree at a height of three to six feet. Soil samples were obtained, from a depth of six to eight inches, under the same trees from which leaf samples were collected.

Nutrient Analyses

Leaf samples were washed, dried at 45° C in a forced air oven and ground in a Wiley Mill equipped with a 20-mesh stainless steel sieve. The samples were analyzed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and boron (B) at the Department of Pomology, Cornell University, Ithaca, New York. Nitrogen was extracted with perchloric and sulfuric acid and determined with an ammonia specific electrode. The other nutrients were extracted by a dry-ashing technique using nitric acid and analyzed with an inductively coupled argon plasma spectrograph.

Soil samples were air-dried and sieved through a 20-mesh screen. Calcium, Mg, K, P, pH and lime requirement were determined at the West Virginia University Soil Testing Laboratory (Ghazi et al., 1978).

Figure 1. Location of apple orchards where leaf and soil samples were collected.

Results and Discussion

Soil and Leaf Analyses Compared by Soil Type

It is well established that leaf analysis is the best tool available for determining the nutrient status of fruit trees (Kenworthy, 1973; Childers, 1966). Combined with good records of past fertilizer applications and tree performance, leaf analysis can be used to determine when an economic response can be expected from

additional fertilizer applications. Soil analysis is not a reliable indicator of fertilizer needs for several reasons. These include problems with obtaining soil samples which are representative of the extensive feeding area of tree roots and the weak correlation between nutrients extracted from the soil and those absorbed by trees. Soil analysis is, however, of value because it provides information on soil pH and lime requirement and indicates the relative availability of nutrients to tree roots. Liming is an important part of an orchard fertility program since nutrient availability is greatly influenced by soil pH. In acidic soils, macronutrient availability to trees may be reduced while micronutrient availability is generally enhanced.

Results of soil analyses (Table 1) show that the limestone soils, as expected, had a higher pH than the shale soils. The pH of shale soils, restricted primarily to Hampshire County, ranged from 4.3 to 6.3 (Appendix Tables 1-4). The lime requirement of these soils was greater than that for the limestone soils. Since the availability of most micronutrients is greatly enhanced under acidic conditions, higher uptake and possible toxicity may result. Manganese toxicity, which is expressed as internal bark necrosis, is a major concern where Red Delicious (the most susceptible cultivar) is grown. This disorder can be alleviated by increasing soil pH by the use of lime or other acid-neutralizing materials (Auxt, 1981; Schubert and Orton, 1955). Due to the inherent variations in buffering capacity between the limestone and shale soils, liming recommendations should be closely followed. Shale soils, as a rule, have a lower buffering capacity and require smaller quantities of lime to achieve equivalent adjustments in pH.

The soil analyses indicate that, compared to shale soils, the limestone soils had higher levels of all macronutrients analyzed (Table 1). However, results from leaf analyses of trees growing on

Table 1.
Soil analyses summarized by soil type.

Soil Type	No. of Samples	pH	LR* (tons/acre)	Nutrient Element (lbs./acre)			
				P	K	Ca	Mg
Limestone	78	6.5	0.8	53.2	148.4	2298.0	205.0
Shale	34	5.3	2.1	24.3	105.2	1024.7	85.8
LSD 5%		0.2	0.2	8.3	17.2	269.1	42.9

*Lime required to adjust pH to 6.6.

these two soils (Table 2) show small or no differences in the levels of these macronutrients. Soil and leaf macronutrient concentrations did not show a strong correlation (Table 5). This illustrates the point made earlier that leaf analysis is a better indicator of the nutritional status of fruit trees than soil analysis. With the exception of Mn, the differences between the two soils in the leaf micronutrient concentrations were also minimal (Table 2). Levels of Mn in trees grown on shale soils were significantly higher than for trees on limestone soils. This was primarily due to the enhanced Mn uptake in the acidic shale soils. According to statistical analyses, variations in leaf nutrient concentrations (Appendix Tables 1-4) were more closely related to differences in orchard management practices than to differences between soils.

Table 2.
Leaf analyses summarized by soil type.

Soil Type	No. of Samples	Nutrient Element									
		N	P	K	Ca	Mg	Fe	Mn	Cu	B	Zn
		[%]					(ppm)				
Limestone	156	2.24	0.15	1.24	1.38	0.34	54.9	91.9	7.7	33.3	63.9
Shale	68	2.21	0.17	1.24	1.30	0.30	52.5	109.5	6.2	31.5	45.0
LSD 5%		NS*	0.01	NS	NS	0.03	NS	16.6	NS	NS	NS

*Not significant.

Leaf Analyses Compared by Cultivar

Leaf nutrient concentrations show major variations within the same cultivar in different orchards (Appendix Tables 1-4). These differences among orchards were generally significant and could be explained on the basis of management practices used by growers.

Leaf nutrient concentrations are summarized by cultivar in Table 3, and the percentage of orchard blocks deficient or above standard range are given in Table 4. Individual nutrient elements are discussed below.

Nitrogen: Mean N values for Rome and Golden Delicious tended to be slightly lower than those for York and Red Delicious, but these differences were not statistically significant. This is in agreement with an earlier survey of the same region (Thompson et al., 1952). Of the 56 orchard blocks surveyed, only one was below the deficiency level for N, but one-fifth of the blocks had N concentrations above the

Table 3.
Leaf analyses summarized by cultivar.

Cultivar	No. of Samples	Nutrient Element									
		N	P	K	Ca	Mg	Fe	Mn	Cu	B	Zn
		(%)					(ppm)				
York	56	2.26	0.14	0.94	1.42	0.34	58.4	102.1	8.5	34.5	53.0
Rome	56	2.21	0.15	1.17	1.28	0.31	49.8	102.8	6.3	28.0	48.9
Golden											
Delicious	56	2.21	0.16	1.51	1.41	0.32	52.5	87.1	6.6	31.8	70.8
Red											
Delicious	56	2.27	0.17	1.34	1.34	0.35	55.9	97.0	7.5	36.7	59.8
LSD 5%		NS*	NS	0.05	NS	0.01	1.7	NS	0.9	1.2	5.3

*Not significant.

Table 4.
Percentage of orchard blocks which were deficient or above standard range in various nutrients.

Nutrient	Standard Range*	Deficiency Level**	% Deficient	% Above Standard Range
N	2.1 -2.5 %	1.7%	2	20
P	0.12-0.46%	0.08%	0	0
K	1.2 -1.8 %	1.0%	20	0
Ca	1.3 -2.0 %	1.0%	4	0
Mg	0.3 -0.5 %	0.25%	9	0
Fe	50-100 ppm	25 ppm	0	0
Mn	35-100 ppm	35 ppm	0	52
Cu	7- 20 ppm	5 ppm	4	0
B	30-50 ppm	25 ppm	9	2
Zn	25-50 ppm	15 ppm	2	45

*Oberly, G. H. 1980. (Personal communication). These levels should be used as a general guideline only. Minor variations can be expected.

**Level at which fertilizer application would give an economic response.

standard range. Levels as high as 3.41 percent were found. This indicates that excessive rates of N fertilizers are being applied to some orchards. High N levels can result in poor fruit quality and storage behavior (Boynton et al., 1950).

Table 5.

Degree of correlation among levels of various nutrients.

Factors Compared		Correlation Coefficients	
<u>Soil Concentrations</u>		<u>Leaf Concentrations</u>	
K	and	K	0.06
Ca	and	Ca	-0.04
Mg	and	Mg	0.04
pH	and	Mn	-0.23
Mg	and	Cu	-0.37*
<u>Leaf Concentrations</u>			
N and P			0.17
N and K			-0.11
N and Ca			-0.11
K and Mg			-0.24**
Mg and Mn			0.23**
P and Ca			0.20**
P and B			0.53**
Mn and Fe			-0.04
Fe and B			0.42**
Fe and Zn			0.37**

*Significant at the 5% level.

**Significant at the 1% level.

Phosphorus: Phosphorus levels for all cultivars were within the standard range (Appendix Tables 1-4). Differences among cultivars were not significant. The level of P in plants is influenced by a number of factors such as ion interactions, soil moisture and stage of plant growth. There are only a few reports of economic responses following P applications (Taylor and Goubran, 1975).

Potassium: With the exception of York, mean K values were within the standard range. There was a significant difference in K levels among the four cultivars, with Golden Delicious having the highest concentration and York the lowest. Nine York orchards (Appendix Table 4) had a K level below 1.0 percent. Leaf scorch associated with K deficiency was, however, not seen in any of these orchards. Similar low K values were reported in earlier surveys of this cultivar (Thompson et al., 1952; Batjer et al., 1938). The level of N was relatively high in most instances where K was low, indicating that excessive N fertilization was partly responsible for the depressed K

level (Cain and Boynton, 1948). The York blocks with low K were not confined to a particular region or soil.

Calcium: Average Ca concentrations did not vary significantly among cultivars. Nineteen of the 56 blocks surveyed had Ca levels below the standard range, with two blocks containing a Ca concentration under 1 percent. Calcium levels higher than 1.9 percent are needed to prevent disorders such as cork spot (Shear, 1972). Leaf Ca concentrations ranged from 0.94 to 1.61 percent in Red Delicious blocks and from 1.18 to 1.68 percent in York blocks. On cultivars such as these where Ca-related problems are prevalent, supplementary Ca applications would be beneficial.

Magnesium: Significant differences existed in Mg levels among the four cultivars. York and Red Delicious contained higher Mg levels than Golden Delicious and Rome. Nine percent of the blocks surveyed were below the deficiency level, the majority of these being Rome growing on shale soils. However, no deficiency symptoms were observed in any of these trees. Low foliar Mg may be due to inadequate N fertilization, excessive K fertilization or actual deficiency of the nutrient (Thompson et al., 1952).

Micronutrients: Significant differences existed among cultivars in the foliar concentrations of all micronutrients except Mn. Iron and Cu concentrations were highest in York and lowest in Rome, with levels in Red and Golden Delicious being intermediate. Boron was significantly higher in Red Delicious and York and lower in Golden Delicious and Rome. This is probably a reflection of the recommended usage of soluble B sprays on cultivars which are susceptible to corking problems (Hogmire et al., 1981). Zinc was significantly higher (LSD 1 percent) in Golden Delicious than in other cultivars, reflecting differences in spray programs. Although the differences among cultivars in Mn concentrations were not significant, large variations existed among orchards and soils.

Iron and Cu levels were adequate in most orchards. Boron, however, was marginally low in five orchard blocks. Trees at these locations would benefit from applications of soluble B sprays. Further decline in B levels could result in misshapen fruit or bunched and distorted leaf growth. There also is growing evidence that B is important in fruit set (Childers, 1978). Both Zn and Mn were present in excessive quantities in approximately half the leaf samples. High Zn levels can be attributed to surface contamination by Zn-containing pesticides. Pesticide-induced variations in micronutrient levels in leaf samples have been previously reported (Singh et al., 1974). Many of the principal orchard soils in West Virginia are manganiferous in nature (Berg et al., 1958). Where either acidic or low oxygen conditions exist

in these soils, excessive quantities of Mn are likely to be absorbed by fruit trees.

Interrelationships Among Nutrient Concentrations

The concentration of any nutrient should be considered in relation to the concentration of other nutrients (Kenworthy, 1979). An example of the importance of balanced fertility levels is the relationship between N and K that was mentioned earlier. The K level in leaves is depressed by the addition of excessive quantities of N fertilizers. The degree of association between concentrations of the various nutrients was determined by correlation coefficients (Table 5). The only significant correlation between soil and leaf nutrient concentrations was an inverse relationship between the Mg level in the soil and the Cu level in the leaves. The levels of nutrients in the soil did not correlate with the levels of the same nutrient in the leaves. Increases in soil pH were most strongly associated with decreases in leaf Mn, but this negative correlation was not significant.

When interrelationships between nutrient concentrations in leaves were examined, highly significant positive correlations were obtained between Mg and Mn, P and Ca, P and B, Fe and B, and Fe and Zn. A highly significant negative correlation existed between K and Mg. Correlations between Mg and Mn and K and Mg have been reported earlier (Smith, 1965; Kenworthy, 1953).

Summary and Conclusions

The macronutrient status of apple orchards in West Virginia has not changed appreciably since a 1950 survey (Thompson et al., 1952). Foliar concentrations of most macronutrients were within the standard range in most orchards. The results of this survey indicated that a number of orchardists could reduce usage of nitrogen fertilizers and that in some orchards potassium, calcium or magnesium levels needed to be raised. Even though no visual deficiency symptoms were observed during this survey, previous studies have shown that when a nutrient in the leaves is below the deficiency level, appropriate changes in fertilizer practices will result in improved tree growth and productivity (Kenworthy, 1973; Childers, 1966). Micronutrient analyses of leaf samples indicated that boron sprays would be beneficial in some orchard blocks. Lime applications would be advantageous in a large number of blocks where excessive levels of manganese were present in the leaves. In agreement with surveys conducted in other states, this survey indicated that many growers

could economize in their orchard fertility programs through the use of leaf analysis services.

Variations in leaf nutrient values could be attributed more to differences in orchard management practices than to differences in soil types or cultivars. There was very little correlation between soil and leaf nutrient levels. Although significant differences existed in the levels of soil nutrients between limestone and shale soils, the differences in leaf nutrient levels among trees growing on these soils were minimal. Significant differences were observed among cultivars in the foliar concentrations of a number of nutrients. These variations were probably due to differences in cultural practices and market intentions rather than differences in plant requirements, per se (Cahoon, 1965).

Information gained from this survey is being used in planning nutrition studies and in improving the program for making fertilizer recommendations to fruit growers.

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Appendix

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Table 1.
Leaf and Soil Analyses for Red Delicious
Orchards Surveyed.

Orchard Code*	Soil Class	Soil Analysis**						Leaf Analysis†									
		LR		P	K	Ca	Mg	N	P	K	Ca	Mg	Fe	Mn	Cu	B	Zn
		pH (T/A)		(lbs/A)				(%)						(ppm)			
A	Limestone	6.9	0	43	199	1570	178	2.05	0.19	1.26	1.24	0.42	59.2	88.6	7.9	30.6	40.7
B	Limestone	6.5	1.0	41	216	1755	97	1.93	0.17	1.36	1.36	0.37	65.5	75.1	8.7	54.5	205.0
E	Limestone	6.0	1.8	23	36	1570	74	1.89	0.13	1.80	0.94	0.27	48.8	112.3	7.3	36.9	37.7
F	Limestone	7.1	0	108	42	3745	125	2.03	0.21	1.13	1.60	0.39	46.7	144.8	8.0	34.8	71.5
G	Limestone	6.6	0	43	229	1680	244	2.93	0.17	1.13	1.61	0.42	59.0	52.1	8.5	38.4	81.1
J	Limestone	6.7	0	39	189	2190	162	2.37	0.14	1.39	1.44	0.40	63.0	94.2	8.0	32.7	40.4
K	Limestone	6.1	1.4	55	204	1630	74	2.27	0.14	1.21	1.32	0.24	48.5	134.0	7.3	30.2	44.1
M	Limestone	7.3	0	48	63	2270	63	2.47	0.15	1.14	1.44	0.37	67.7	45.8	7.2	32.8	58.9
N	Limestone	6.4	1.0	44	208	1535	105	2.63	0.16	1.47	1.33	0.29	50.5	129.0	7.8	41.6	52.2
O	Limestone	6.0	1.6	124	163	4980	537	2.25	0.23	1.33	1.41	0.35	52.4	47.3	6.5	44.6	31.1
P	Shale	5.5	1.6	13	127	835	120	2.58	0.23	1.29	1.49	0.35	52.3	143.8	7.1	34.7	51.5
Q	Shale	4.7	3.6	27	163	495	111	2.30	0.19	1.44	1.27	0.40	54.4	148.5	7.7	32.0	23.6
R	Shale	5.6	1.6	14	157	800	87	2.14	0.17	1.40	1.30	0.34	57.6	87.4	6.5	40.8	57.5
T	Shale	5.2	2.0	16	67	695	25	1.96	0.15	1.43	1.06	0.33	57.6	55.7	6.6	29.3	42.4

*For orchard locations, refer to Figure 1.

**Means of 2 replicates.

†Means of 4 replicates.

Table 2.
Leaf and Soil Analyses for Golden Delicious
Orchards Surveyed.

Orchard Code*	Soil Class	Soil Analysis**						Leaf Analysis†									
		LR		P	K	Ca	Mg	N	P	K	Ca	Mg	Fe	Mn	Cu	B	Zn
		pH (T/A)		(lbs/A)				(%)						(ppm)			
A	Limestone	6.5	0.8	43	123	1580	168	1.93	0.14	1.46	1.25	0.42	50.4	94.4	6.9	24.9	26.9
B	Limestone	6.3	0.8	45	179	2010	94	1.87	0.15	1.56	1.35	0.26	51.3	55.9	6.4	36.8	202.5
E	Limestone	6.1	1.8	28	47	1365	70	1.87	0.13	1.80	1.46	0.28	48.9	97.8	7.6	32.7	37.7
F	Limestone	6.4	0.8	48	137	1780	70	1.90	0.16	1.46	1.55	0.32	46.4	139.8	7.5	27.7	56.2
G	Limestone	7.1	0	73	248	3070	631	2.63	0.15	1.46	1.70	0.32	64.8	47.4	6.7	36.9	128.3
I	Limestone	6.4	1.2	41	302	1970	181	2.69	0.15	1.77	1.50	0.29	46.2	77.3	6.8	30.8	63.7
J	Limestone	6.5	0.6	36	80	1585	200	2.20	0.15	1.36	1.48	0.44	51.6	116.8	8.0	34.1	32.2
M	Limestone	7.3	0	44	35	3005	68	2.25	0.12	1.20	1.29	0.31	69.3	25.5	5.8	27.3	86.0
N	Limestone	6.8	0	69	174	2240	122	2.54	0.15	1.63	1.42	0.28	55.1	103.6	6.3	34.0	83.1
O	Limestone	5.2	2.8	42	152	3290	270	2.27	0.22	1.29	1.68	0.36	49.4	42.2	6.3	33.0	32.3
P	Shale	5.1	2.6	8	108	525	50	2.27	0.17	1.82	1.13	0.28	52.2	77.8	5.9	29.0	76.6
Q	Shale	6.0	1.6	22	137	2400	118	2.48	0.17	1.45	1.37	0.36	48.5	142.0	6.3	31.8	33.6
R	Shale	5.5	1.8	17	81	750	100	1.77	0.14	1.63	1.06	0.27	43.2	95.1	4.8	35.7	104.1
S	Shale	4.3	4.2	116	126	310	20	2.29	0.17	1.23	1.51	0.27	58.0	104.3	6.4	30.7	28.7

*For orchard locations, refer to Figure 1.

**Means of 2 replicates.

†Means of 4 replicates.

Table 3.
Leaf and Soil Analyses for Rome
Orchards Surveyed.

Orchard	Soil	Soil Analysis**						Leaf Analysis†									
		LR		P	K	Ca	Mg	N	P	K	Ca	Mg	Fe	Mn	Cu	B	Zn
		Code*	Class	pH (T/A)	(lbs/A)				(%)				(ppm)				
A	Limestone	6.9	0	116	252	3435	378	1.98	0.15	1.18	1.17	0.41	49.8	105.6	6.2	26.3	38.8
C	Limestone	6.6	0	55	148	2785	147	2.03	0.15	1.14	1.48	0.29	51.1	44.0	6.0	28.6	38.2
D	Limestone	5.8	1.8	31	41	1260	76	2.05	0.15	1.29	1.51	0.33	46.8	149.5	7.2	31.8	101.0
E	Limestone	6.1	1.6	35	146	1205	73	2.05	0.15	1.51	1.12	0.29	50.4	77.1	7.4	27.5	32.9
F	Limestone	6.8	0	90	74	2230	91	2.09	0.17	0.84	1.25	0.33	48.0	133.5	7.3	25.9	51.0
G	Limestone	6.7	0	85	190	2100	179	2.80	0.16	1.48	1.46	0.29	66.6	50.5	7.4	36.1	129.5
H	Limestone	7.2	0	66	239	5160	909	2.01	0.16	1.09	1.59	0.48	48.7	165.5	6.3	29.6	53.0
K	Limestone	6.9	0	69	145	1860	67	2.08	0.13	1.12	1.12	0.24	42.2	122.5	5.9	21.6	39.1
L	Limestone	6.1	1.2	31	131	1585	153	2.65	0.12	0.93	1.06	0.37	45.6	49.4	6.4	24.5	13.2
P	Shale	5.5	1.8	32	190	1255	160	2.31	0.13	1.11	1.02	0.25	41.1	110.3	4.9	24.0	37.3
Q	Shale	5.8	1.2	14	59	1260	39	2.50	0.19	1.08	1.60	0.28	48.4	132.8	6.3	27.2	31.7
R	Shale	6.3	0.8	19	81	1310	257	1.89	0.14	1.46	0.89	0.25	45.6	114.5	5.6	34.2	52.2
S	Shale	4.9	2.4	48	133	795	36	2.24	0.20	1.03	1.36	0.26	55.1	82.2	5.7	25.3	27.3
T	Shale	4.7	2.6	8	53	255	19	2.27	0.17	1.10	1.23	0.25	58.6	101.3	5.7	29.8	40.0

*For orchard locations, refer to Figure 1.

**Means of 2 replicates.

†Means of 4 replicates.

Table 4.
Leaf and Soil Analyses for York
Orchards Surveyed.

Orchard Code*	Soil Class	Soil Analysis**						Leaf Analysis†									
		LR		P	K	Ca	Mg	N	P	K	Ca	Mg	Fe	Mn	Cu	B	Zn
		pH (T/A)		(lbs/A)				(%)					(ppm)				
A	Limestone	6.4	2	37	105	1740	239	1.89	0.12	1.10	1.18	0.37	53.4	100.7	7.4	27.5	36.4
D	Limestone	5.8	1.7	52	75	1160	102	2.15	0.14	1.10	1.42	0.40	51.9	130.2	8.0	33.1	98.7
E	Limestone	6.4	1.0	35	171	1525	71	1.63	0.14	1.17	1.42	0.32	57.9	101.7	8.0	34.6	55.7
G	Limestone	6.9	0	48	209	2125	191	2.60	0.14	1.00	1.47	0.35	73.2	42.9	8.5	45.3	135.8
H	Limestone	7.3	0	59	115	5570	749	2.10	0.13	0.86	1.57	0.47	67.5	130.8	8.0	31.2	45.0
I	Limestone	6.9	0	57	292	2580	215	2.67	0.14	1.08	1.44	0.30	57.1	64.1	7.8	30.3	38.4
J	Limestone	7.0	0	52	127	2790	500	3.41	0.13	0.78	1.39	0.40	57.4	115.8	24.5	30.4	27.2
M	Limestone	6.5	0.6	29	40	1765	80	2.28	0.13	0.75	1.29	0.31	71.3	44.8	6.9	31.2	74.9
N	Limestone	5.8	1.4	37	165	990	82	2.32	0.14	1.00	1.30	0.30	54.1	144.3	7.6	45.3	36.4
O	Limestone	5.4	2.2	62	70	2935	120	1.84	0.15	0.69	1.43	0.33	53.7	88.6	6.4	42.0	34.0
P	Shale	5.6	1.8	13	93	1530	93	2.39	0.17	1.06	1.47	0.29	57.4	117.0	6.8	34.9	50.1
Q	Shale	4.9	3.0	9	69	840	31	2.42	0.15	0.99	1.68	0.35	51.0	139.3	6.7	29.5	34.1
R	Shale	5.9	1.4	17	56	1090	82	1.82	0.13	0.78	1.27	0.30	51.4	109.3	6.4	37.3	47.3
S	Shale	5.8	1.4	25	93	2275	59	2.13	0.16	0.79	1.54	0.29	60.0	99.9	6.5	30.0	27.5

*For orchard locations, refer to Figure 1.

**Means of 2 replicates.

†Means of 4 replicates.