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SUMMARY

A leaf analyses survey was made in 1950 as the first part of a general apple nutrition project undertaken by the West Virginia University Agricultural Experiment Station. Nitrogen, phosphorus, potassium, calcium, and magnesium determinations were made on 209 leaf samples collected from orchards growing in limestone, shale, and chert soils. In a few orchards the levels of nitrogen, potassium, and magnesium in the leaves were below the generally accepted critical levels; however, no serious deficiencies existed. The survey supports the continued recommendation of nitrogen only as a fertilizer for apple orchards in West Virginia.

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Introduction

Since the need for annual applications of nitrogen to apple trees in est Virginia was first demonstrated in 1920 (1), the use of nitrogen ertilizers has been a standard commercial practice throughout the tate. There has been much variation, however, in the attention given his matter by apple growers. Many growers have applied adequate mounts of nitrogen to insure maximum growth and yield. Others have ot maintained necessary levels of nitrogen in their apple orchards, nd yields of fruit have been smaller. Although most apple growers f the State recognize the need for nitrogen, the majority have used nly the minimum amount necessary for satisfactory yields.

The West Virginia University Agricultural Experiment Station has ecommended use of nitrogen fertilizers in apple orchards for about hirty years. During this period some work has been done with other lements known to be necessary for plant growth. So far no evidence as been obtained to show a need for any element other than nitrogen n the orchard fertilizer application, with the exception of boron in a ew scattered orchards.

Recent work (4,5,9,11,12) has indicated that deficiencies of po- assium and magnesium are present in orchards from New England own the Atlantic seaboard to Maryland. Although most of these de- iciencies have been encountered in peach orchards that have been ultivated for many years, several instances of low potassium and low agnesium have been found in apple orchards. These discoveries ave been made by means of chemical analyses of leaves taken from he various orchards studied. Leaf analysis as a method for the diag- osis of mineral deficiencies is becoming widely used in the United tates. By itself it often is not conclusive evidence of the tree's utritional status. Leaf analysis, however, offers a possibility of ob- aining first-hand information on the approximate nutrient status f fruit trees. In this way it is not necessary to resort to expensive nd time-consuming orchard fertilizer experiments. Such experiments sually are impossible on a State-wide basis.

Leaf analyses are now widely regarded as essential forerunner of any fertilizer experiment on apple trees. Frequently in the pas negative results have been obtained from sound fertilizer experiments Leaf analyses would have eliminated many blocks of trees from con sideration as a site for some of these experiments simply because th element or elements in question were already present in the trees i sufficient amounts.

Leaf analyses, then, for experimental purposes afford an ine pensive and rapid means of determining the mineral nutrient status of given orchard. This method also makes it possible to survey rathe quickly many apple orchards in a given area for the purpose of de termining if deficiencies exist as well as the extent to which suc deficiencies occur.

THE SURVEY

An apple nutrition project was started in 1950 at the West Virgini University Agricultural Experiment Station since deficiencies of po tassium and magnesium are known to exist in near-by areas. Also certain information concerning the nutritional status of apple tree would be invaluable in the event deficiencies were found. A survey was planned to determine the nutrient status of West Virginia appl orchards as measured by leaf analyses. For this purpose, sample of leaves were collected from seventy-one orchards in the State be tween July 11 and August 11, 1950. Five median leaves on curren season's growth were taken from each of three trees for a sample. Th leaves were oven dried and ground in a Wiley mill. With the exceptio of the University orchard at Morgantown, the orchards sampled wer located in Hampshire, Morgan, Berkeley, and Jefferson counties. Th varieties sampled included York, Stayman, Delicious, Rome, Grimes and Golden Delicious. The 209 samples collected were analyzed i the laboratory of the University Experiment Farm at Kearneysville i the winter of 1950-51. Analyses were made according to methods out lined by Lindner (10). Determinations were made to include the nitro gen, phosphorus, potassium, calcium, and magnesium content of eac sample.

The apple orchards in the Eastern Panhandle of West Virginia ar growing on three general soil classes: limestone, shale, and chert When the leaf analyses were summarized according to these three soi classes, certain interesting trends were noted. As can be seen i Table 1, it was found that the nitrogen content of leaves was lowes in trees growing in limestone soils.

Table 1. Leaf analyses of apple orchards summarized according to soil classes.

Soil Class	No. of Samples	Mineral content as per cent of dry weight				
		nitrogen	phosphorus	potassium	calcium	magnesium
Limestone	115	1.93	.198	1.83	1.32	.294
Shale	72	2.11	.190	1.68	1.17	.302
Chert	17	2.12	.198	1.53	1.19	.268
LSD*		.102		.118	.120	

*Least Significant Difference.

Trees growing in shale and chert soils were higher in leaf nitrogen content, averaging 2.11 and 2.12 per cent respectively, the difference over limestone being significant at the 5 per cent level. The potassium content of leaves was less in the shale and chert orchards than in those orchards growing in limestone soil; the differences were statistically significant. The magnesium level of leaves in orchards growing in limestone and shale was somewhat above that of trees grown in chert soils, possibly a chance result.

No great differences in nitrogen content of leaves were recorded for the different varieties considered (See Table 2). Stayman trees averaged lower in nitrogen than all others, and Delicious, Grimes Golden, Golden Delicious, and York were definitely above the lowest Stayman. York was distinctly lowest, and Stayman and Rome Beauty leaves were intermediate in potassium content. This is in agreement with results of Batjer and Magness (2), who in a national survey of the potassium content of apple leaves, found that York and Jonathan leaves were significantly lower than Delicious leaves, whereas the potassium content of Rome Beauty leaves was intermediate. Grimes, Red Delicious, and Rome as a group are significantly higher in phosphorus content than York, Stayman, and Golden Delicious as a group. Calcium determinations showed that Delicious leaves were significantly lower in calcium than several other varieties, whereas Golden Delicious leaves were significantly higher than Rome, Stayman, and Delicious. Stayman leaves were the lowest in magnesium when compared to the other varieties in this survey. Although the average magnesium content of Stayman leaves was well above the critical level, it will be shown later that several samples of Stayman leaves were found below the critical level.

Many West Virginia apple orchards include blocks of trees that have produced fruit for thirty years or more. Many old trees do not produce as heaviiy as younger trees, and older orchards are generally more expensive to operate than young bearing orchards. In view of

Table 2. Leaf analyses of apple orchards summarized according to variety.

Variety	No. of orchards	Mineral content expressed as per cent of dry weight				
		nitrogen	phosphorus	potassium	calcium	magnesium
York Imperial	54	2.02	.179	1.35	1.33	.283
Delicious	38	2.06	.204	2.04	1.12	.298
Stayman	48	1.91	.175	1.75	1.24	.273
Rome Beauty	25	1.97	.197	1.84	1.21	.312
Grimes Golden	28	2.11	.212	1.95	1.37	.327
Golden Delicious	11	2.04	.175	1.97	1.41	.324
LSD*		.128	.014	.147	.150	.0376

* Least Significant Difference

these facts, it is of interest to consider the mineral content of appl leaves as affected by the age of the trees. In Table 3 the average for trees less than thirty years of age are compared with trees ove thirty years of age. Analyses of Golden Delicious leaves are not in cluded in Table 3 because insufficient samples were available fo comparison.

Table 3. Leaf analyses of apple varieties in West Virginia accordin to tree age.

Variety	No. of orchards	Age of trees* (years)	Mineral content expressed as percent of dry weigh				
			nitrogen	phosphorus	potassium	calcium	magnesiu
York Imperial	13	30–	2.13	.190	1.40	1.19	.312
	41	31+	1.99	.176	1.32	1.37	.276
Delicious	18	30–	2.15	.202	2.09	1.11	.307
	20	31+	1.98	.205	2.00	1.13	.291
Stayman	18	30–	1.96	.168	1.82	1.18	.284
	30	31+	1.88	.179	1.71	1.28	.266
Rome Beauty	13	30–	2.01	.203	1.88	1.16	.309
	12	31+	1.92	.191	1.80	1.27	.314
Grimes Golden	9	30–	2.18	.191	2.05	1.38	.365
		31+	2.08	.222	1.90	1.37	.310

* Based on classification of trees into two groups: 30 years of age or und (30–) and 31 years of age or more (31+).

In each of the five varieties presented in Table 3, the older tree contained less nitrogen in the leaves than the younger trees. Althou

he differences are not great, the trend is consistent. This is lue largely to the frequent practice of increasing the nitrogen ıpplication with increased age and size of trees up to about twenty- ive or thirty years, after which nitrogen fertilization is held to fairly :onstant amounts regardless of the size or bearing capacity of the rees. The potassium and magnesium levels in the leaves also were ;enerally lower in the older trees than in the younger ones. Calcium, n the other hand, was higher in older trees with the single exception f the Grimes Golden samples. These showed no difference. No con- istent trends were noted in the phosphorus content of apple leaves f young trees compared to older trees.

All averages shown in Tables 1, 2, and 3 are well above the gener- lly accepted critical levels for each mineral element. Six orchards, owever, contained trees that were low in potassium, and another six rchards included trees that were low in magnesium. The low po- assium samples were taken from trees growing in all three soil lasses, and the low magnesium leaves all came from trees in the henandoah Valley growing in limestone soils. Detailed information n these twelve samples is presented in Table 4.

The critical level of potassium in apple leaves, according to Batjer nd Magness (2), is about 1.0 per cent for York, and about 1.5 per cent r Delicious and Rome. Below these levels leaves are regarded as eficient in potassium and deficiency symptoms may appear. All amples in this survey below these levels are listed in the low po- ıssium group in Table 4. Four samples of York leaves, one of De- cious, and one of Rome showed less than the critical level of po- ssium. In no case was any of the typical leaf scorch symptom of po- ıssium deficiency found on trees from which these samples were ken. The nitrogen levels of these low potassium leaves were rela- vely high, as can be seen in Table 4. Tree vigor was fair to good in l of the orchards from which these samples were taken, though the ees varied in age from thirty-five to fifty years.

Samples of four varieties, Stayman, York, Grimes, and Delicious, ere found to be low in magnesium (See Table 4). All of these samples ere taken from orchards in Berkeley and Jefferson counties; the age the trees varied from thirty to forty-five years. Only three of these mples were taken from trees exhibiting good vigor. All others came m trees showing fair to poor vigor. The nitrogen levels in these es were all relatively low. Only one sample, No. 139, was as high 2.0 per cent in nitrogen. The magnesium content varied from 0.118 0.195 per cent. Considering 0.200 per cent as the critical level magnesium below which a deficiency exists, it can be seen from the

Table 4. Survey samples found to be low in potassium or in magnesium.

Laboratory Sample No.	Variety	Soil Type	Vigor	1950 Crop	Tree age (years)	Mineral content expressed as per cent of dry weight		
						Nitrogen	Potassium	Magnesium
LOW POTASSIUM GROUP								
32	York	shale	good	mod.	41	2.42	.980	--
48	York	shale	good	heavy	42	2.03	.935	--
147	York	limestone	fair	heavy	50	1.93	.675	--
164	York	limestone	good	heavy	37	1.96	.790	--
45	Delicious	shale	fair	light	40	2.20	1.290	--
73	Rome	chert	good	heavy	35	2.32	1.170	--
LOW MAGNESIUM GROUP								
117	Staymar	limestone	poor	mod.	45	1.67	--	.195
133	Stayman	limestone	poor	mod.	45	1.83	--	.168
134	York	limestone	poor	heavy	45	1.82	--	.148
138	Stayman	limestone	good	heavy	35	1.68	--	.155
139	York	limestone	good	heavy	35	2.03	--	.165
156	York	limestone	fair	heavy	40	1.90	--	.151
158	Grimes	limestone	fair	heavy	35	1.94	--	.165
171	Stayman	limestone	good	mod.	45	1.80	--	.155
172	York	limestone	poor	light	45	1.22	--	.118
175	Delicious	limestone	poor	heavy	30	1.64	--	.128
176	Stayman	limestone	fair	mod.	35	1.87	--	.161
177	York	limestone	poor	light	40	1.49	--	.138

igures in Table 4 that some of the samples were critically low in mag-
esium. However, no clear cut deficiency symptoms appeared on the
oliage of the trees from which these samples were taken.

SIGNIFICANCE OF THE SURVEY

This survey, although not all inclusive, was reasonably repre-
entative of the orchards of West Virginia. It included six major varie-
ies, the three major soil classes upon which orchards are grown, and
cross section of orchards varying from vigorous, well-managed, high-
roducing blocks to marginal ones in the major apple region of the
tate. The analyses made indicate that generally the orchards of West
irginia are receiving adequate nutrition. Most of the trees sampled
owed levels of nitrogen, phosphorus, calcium, potassium, and mag-
esium well above the critical levels of these elements. A few indi-
dual orchards in addition to those in the low magnesium group
f Table 4) had varying degrees of nitrogen deficiency. No phosphorus
ficiency was found, and only six low magnesium and six low po-
ssium samples were found in the 209 samples collected. It is ap-
rent, therefore, that the general recommendation of nitrogen only for
e apple orchards of West Virginia remains sound.

It is evident, however, that instances of low potassium and low
agnesium levels in apple trees do exist in the State. This should
t be interpreted as a signal for widespread use of these elements in
e orchard fertilization program. The frequency of these deficiencies
the survey reported here was small, and the orchards were scattered
oughout the Eastern Panhandle, rather than being concentrated in
y particular region or on any particular soil type. Furthermore, the
istence of an actual deficiency is only suggested by this survey. It
mains to be determined whether or not the orchards in question will
pond to applications of potassium or of magnesium.

Recent research has demonstrated that no single element can be
sidered by itself, but must be regarded in terms of its position with
erence to the levels of other elements present. For example, it is
wn that the addition of large quantities of nitrogen fertilizers to
le trees will depress the potassium level in the leaves (6,8). It is
nterest to note that in all the orchards that showed low potassium,
nitrogen in the leaves was at an average or higher than average
el. Furthermore, no visual symptoms of potassium deficiency could
ound in any of these orchards.

Similarly, the low magnesium levels (reported in Table 4) may or
not be indications of a simple magnesium deficiency. The levels

of other elements are known to have a marked influence on the level of magnesium in apple leaf tissue. Conclusive evidence has recently been obtained to show that under certain conditions applications of potassium fertilizers can induce a magnesium deficiency in the apple orchard (7), and that the appearance of a magnesium deficiency is usually closely associated with a high potassium level in the trees. Also, it has been found that the magnesium level of apple leaves increases when the nitrogen level is increased (3,8).

In this survey, every low magnesium sample came from trees that had an optimum—though not high—level of potassium, but generally a low level of nitrogen. In the orchard where the lowest magnesium level was found (sample No. 172, Table 4), analyses showed that the leaves contained only 0.118 per cent magnesium and only 1.22 per cent nitrogen. In the fall of 1950 the operator applied nitrogen in this orchard for the first time in several years. This application, which consisted of five pounds of nitrate of soda per tree, was followed by two spray applications of urea each at five pounds per 100 gallons in the spring of 1951. Another sampling was made in this orchard on August 10, 1951. Analyses of these samples (Table 5) showed an increase in the nitrogen level of the leaves from 1.22 per cent to 1.93 per cent a year later. It is of interest to note that the magnesium level also was considerably higher in 1951. These trees in 1951 contained 0.210 per cent magnesium in the leaves, or approximately the amount regarded as the critical level below which deficiency symptoms are likely to appear. This illustrates that the low magnesium levels found in the survey may indicate actual magnesium deficiencies, or they may in some cases be simply a reflection of insufficient nitrogen fertilization in the orchard.

The information obtained in these analyses will be used in planning further nutrition work to determine the nature of the deficiencies found, and the most economical means of dealing with them.

Table 5. Effect of nitrogen applications on the levels of nitrogen and magnesium in apple leaf tissue (York variety).

Sample number	Year*	Mineral content of leaves expressed as per cent of dry weight	
		Nitrogen	Magnesium
172	1950	1.22	.118
—	1951	1.93	.210

*These trees were fertilized with 5 pounds per tree of nitrate of soda in the fall of 1950; two sprays of urea each at 5 pounds per 100 gallons were applied in the spring of 1951.

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