ROOTSTOCK AND VARIETY INFLUENCES IN THE APPLE ON LEAF COMPOSITION, FRUIT COMPOSITION AND STORAGE QUALITY OF THE FRUIT

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ROOTSTOCK AND VARIETY INFLUENCES IN THE APPLE ON LEAF COMPOSITION, FRUIT COMPOSITION AND STORAGE QUALITY OF THE FRUIT

By

Marcel Michel Awad

AN ABSTRACT OF A THESIS

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ABSTRACT

ROOTSTOCK AND VARIETY INFLUENCES IN THE APPLE ON LEAF COMPOSITION, FRUIT COMPOSITION AND STORAGE QUALITY OF THE FRUIT

by Marcel Michel Awad

A study was conducted to evaluate the influence of selected East Malling rootstocks, varieties and other related variables on the leaf and fruit composition of apple trees. The influence of rootstocks and storage treatments on the storage quality of the fruit was evaluated also.

The rootstocks studied were EM I, II, V, VII, XIII and XVI. The varieties grown on these rootstocks were Northern Spy, Red Delicious, Jonathan and McIntosh. Leaf samples were taken five times at two-week intervals in 1959, and once (mid-July) in 1960. Fruit samples were taken at harvest in 1959 and placed in regular and CA storage.

The elements determined in the leaves and fruit were nitrogen, potassium, phosphorus, calcium, magnesium, manganese, iron, copper, boron, zinc, molybdenum and aluminum. Pre-storage observations made on the fruit were soluble solids and flesh firmness in all varieties and ground color in Jonathan and McIntosh only. Fruit of the Northern Spy variety were not available for nutrient composition and storage studies.

At the end of the storage period, flesh firmness and soluble solids determinations were made on all varieties. Storage scald, brown core and

internal breakdown were determined on Red Delicious fruit. Ground color, soft scald, Jonathan spot and russeting were determined on Jonathan fruit. Ground color, storage scald, brown core and mealy breakdown were determined on McIntosh fruit.

Results obtained were as follows:

1. The influence of EM rootstocks on leaf composition was evaluated first in this study. Significant differences between rootstocks in affecting leaf composition were obtained for every element determined with the exception of nitrogen. The significant differences, however, were not large enough to require a change in standard leaf composition values, as used for diagnostic purposes, to account for rootstock differences.

2. The influence of EM rootstocks on fruit composition was evaluated next in this study. Where significant differences between rootstocks were obtained, they were relatively small, with the exception of fruit boron and zinc, which showed a wider composition range as related to rootstocks. In general, the rootstocks which induced the high and the low leaf composition levels also induced the high and the low fruit composition levels.

3. The influence of varieties on leaf composition was determined. Varieties were found to affect, significantly, leaf composition values for all the elements considered. Differences between varieties were particularly wide for leaf potassium. If leaf composition for all elements is considered,

Red Delicious would be a variety with a relatively high nutrient level, Northern Spy and Jonathan would be intermediate and McIntosh would be intermediate to low in this respect.

It is not known whether characteristic high or low levels are related to differences in nutrient requirements or a result of luxury consumption in the case of high levels. The differences obtained between varieties in affecting leaf composition were not large enough to indicate a need for a change in standard leaf composition values as used for diagnostic purposes.

4. The influence of variety on fruit composition was studied. Differences between varieties were significant in this relation for all elements with the exception of molybdenum. The actual differences were small with the exception of Jonathan fruit, which was particularly high in iron, Red Delicious fruit, which was high in boron and McIntosh fruit, which was high in zinc and aluminum. There was a frequent parallelism between high and low nutrient levels in the leaves and in the fruit.

5. The seasonal variation of nutrient elements in leaves was determined. Leaf nitrogen, potassium, phosphorus and boron showed a decline and leaf calcium and aluminum showed an increase from the first to the last sampling date. Leaf magnesium and manganese showed little variation. The other leaf elements considered showed no definite seasonal trends. These seasonal trends were similar to those reported for leaves from trees on seedling rootstocks.

6. The influence of EM rootstocks on storage quality was assessed. Fruit from Red Delicious on EM V showed the lowest incidence of storage scald. Fruit from Jonathan on the vigorous EM XIII and XVI rootstocks showed the lowest incidence of fruit russeting. Rootstocks had little or no influence on the incidence of the other disorders considered.

7. The influence of storage treatments on storage quality was evaluated. Fruit from trees on clonal rootstocks responded to storage treatments in a similar manner to fruit from trees on seedling rootstocks.

8. Highly significant correlations between measurements made on leaves and fruit were determined. Some of the relations obtained were similar to those reported previously for trees on seedling rootstocks. Other correlations are reported here for the first time.

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CONTENTS

	Page
ACKNOWLEDGMENTS	ii
CONTENTS	iii
INTRODUCTION	1
REVIEW OF LITERATURE	2
MATERIALS AND METHODS	19
RESULTS	
Influence of rootstocks on leaf composition	28
Influence of rootstocks on fruit composition	33
Influence of rootstocks on storage measurements	35
Influence of varieties on leaf composition	35
Influence of varieties on fruit composition	42
Influence of seasonal variation on leaf composition	42
Influence of locations on leaf composition, fruit composition and storage measurements	42
Influence of years on leaf composition	46
Miscellaneous interactions	46
Effect of storage treatments on storage measurements on the fruit	49
Correlation studies	54
DISCUSSION	81
SUMMARY	108
LITERATURE CITED	112

INTRODUCTION

The increased use of vegetatively propagated rootstocks in the apple industry has created many new and varied problems for the research worker as well as for the grower. The literature shows numerous reports on the many aspects and problems of stock-scion relations. One of the areas, in which relatively few studies have been conducted, is that of the nutrition of the apple tree as affected by rootstocks, scion varieties and other related variables. It is with this idea in mind that the present investigation was conducted.

Among the vegetatively propagated apple rootstocks are the East Malling series (EM) which are among the best known and the most widely used at the present time. The present study was based on six different rootstocks of the EM series. On each of the six rootstocks were grafted the four varieties which are most widely grown in Michigan.

Since leaf and fruit composition have been one of the most important and useful tools in studying nutrient relations in apple trees, they were used extensively in this study. Finally, the influence of rootstocks on the storage behavior of the apple fruit was studied as another aspect in the evaluation of the EM rootstocks selected for this investigation.

REVIEW OF LITERATURE

Influence of rootstocks on leaf composition.

As early as 1924, Hatton and Grubb (1924) reported that leaves from Bramley's Seedling and Worcester Pearmain apple trees on EM V showed twice as much scorch resulting from potassium deficiency as those from trees on EM I, and that those on EM X showed still less scorch than those on EM I. They classified the EM stocks with respect to scorch susceptibility as follows: EM IX, X, XIII and XVI showing little or no leaf scorch, EM I very little leaf scorch, EM II some leaf scorch, EM VII considerable leaf scorch, and EM V much leaf scorch. This makes EM V extremely susceptible, and EM II and VII distinctly susceptible to potassium deficiency.

Wallace (1931) also found that leaves from Worcester Permain scions on EM V were affected more seriously by scorch than those on EM I. He found that the potassium content in the spur leaves of trees on EM V was about 60 percent of comparable leaves on EM I.

Warne and Wallace (1935) determined the leaf composition of Worcester Pearmain and Lane's Prince Albert trees grown on various EM rootstocks and they reported the following levels based on a percent of the fresh weight:

	Worcester Pearmain	Lane's Prince Albert
Nitrogen	V I II VII	VII V II
Potassium.	I II V VII	I VII II V
Phosphorus	I V VII II	V VII I II
Calcium	V I II VII	II VII V I
Magnesium	II V I VII	II V I VII

They also reported that shoots of varieties on EM II and V, which often bear scorched foliage, were low in potassium even under conditions of favorable potassium supply.

Kane (1939) reported that trees on EM IX had shown less scorch than those on EM I and V. Also Cox's Orange leaves scorched less on EM IX than on EM XII. He concluded that EM IX was the least susceptible of the four rootstocks to scorch, EM XII was intermediate, and EM I and V were most susceptible.

Vandha (1955) classified the leaf composition of trees grown on EM rootstocks as follows:

	High	Medium	Low
Potassium.		VII, II, V	IX
Phosphorus:		II, V, VII, IX	
Calcium.	IX	II, V	VII
Magnesium:		II, V, VII, IX	

Hoblyn (1940-41) pointed out that Bramley's Seedling trees on EM V suffered more from potassium deficiency than those on EM I, but with Cox's Orange Pippin and Beauty of Bath trees the relationship was reversed. He also reported that trees on EM I and VII were particularly susceptible to magnesium deficiency, whereas trees on EM II and V were less subject to it.

Roach and Bolas (1945) found that leaves of trees on the vigorous rootstock EM XII contained less calcium, more magnesium, and probably more potassium than those on the dwarfing rootstock EM IX.

Roach (1947) reported that elements contained in leaves of Cox's Orange Pippin on three EM rootstocks can be arranged in a descending order as follows:

(Mg), B, Fe,	XII > V > IX
(Ca), (Sr),	IX > V > XII
(K),	XII > IX > V
Mn,	IX > V, but XII variable.
P,	Variable

For the above elements shown in brackets, the results were less variable. The above results were remarkably consistent with hardly an aberrant one.

Bould <u>et al.</u> (1950) found that trees on EM XII were most seriously

affected by copper deficiency. Comparable trees on EM I and II were found to be less affected.

The East Malling report for 1959 (Anon. 1960) indicated that rootstocks had an effect on mineral composition of apple leaves. Rootstocks significantly affected the composition of apple leaves, though by no means similarly for nitrogen, phosphorus, potassium, calcium, and magnesium, which were the elements determined in the investigation.

Kenworthy (1960) found that rootstocks affected significantly the leaf composition of 11-year-old McIntosh and Cortland trees. Examination of the data shows that rootstocks can be arranged in descending order with respect to leaf composition as follows:

	McIntosh	Cortland
Nitrogen:	(1)	II > V > VII > XII > XIII
Potassium:	XII > XIII > VII > IV > V > II	XII > XIII > VII > II > V
Phosphorus:	(1)	XIII > V > VII > II > XII
Calcium:	XII > XIII > II > VII > V > IV	XII > XIII > II > VII > V
Magnesium:	XII > XIII > II > VII > IV > V	XII > XIII > II > V > VII
Manganese:	(1)	(1)
Iron:	II > XII > XIII > VII > IV > V	II > XIII > V > XII > VII
Copper:	XII > XIII > VII > IV > V > II	XIII > XII > V > VII > II
Boron:	(1)	II > XIII > V > VII > XII
Zinc:	(1)	XII > VII > V > XIII > II

(1) No significant differences between rootstocks.

Influence of rootstocks on fruit composition.

Brown (1926) was the first worker to report the effect of some of the EM rootstocks on the composition of the apple fruit. He found that, on a percent dry weight basis, fruit of the Lane's Prince Albert variety grown on various EM rootstocks could be classified in a decreasing order of nutrient content as follows:

Nitrogen:	II I IX X
Potassium:	II X I IX
Phosphorus:	II X I IX
Calcium:	I X IX II
Magnesium:	II I IX
Iron:	IX II I

(The differences between the rootstocks underscored by the same line were not found to be significant).

Wallace (1930) reported significant effects on the chemical composition of apples due to the influence of rootstocks. He studied fruit of the Worcester Pearmain and Bramley's Seedling varieties on EM I, II, V, IX and XII rootstocks.

Archbold and Widdowson (1932) examined the chemical composition of Bramley's Seedling and Worcester Pearmain apples on four EM rootstocks and they found marked differences in the fruit from the two varieties on EM V as compared with EM IV, VI and X.

Warne and Wallace (1935) studied the composition of fruit from Worcester Pearmain and Lane's Prince Albert trees on several EM rootstocks. They arranged the rootstocks in decreasing order of magnitude of fruit composition, on a percent fresh weight basis, as follows:

	Worcester Pearmain	Lane's Prince Albert
Nitrogen:	VII XIII II I V	VII XIII V I II
Potassium:	XIII I VII II V	I II XIII VII V
Phosphorus:	V I II VII XIII	XIII V I II VII

(The differences between the rootstocks underscored by the same line were not found to be significant).

Influence of rootstocks on storage quality.

Wallace (1930) gave examples of significant differences in storage quality due to rootstocks under certain environmental conditions. Worcester Pearmain apples from trees on EM IX showed much more internal breakdown than the fruit from trees on EM I, II, V and XII. In the case of Bramley's Seedling, the fruit from trees on EM I exhibited much more brown core and internal breakdown than the fruit from trees on EM V.

Kidd and West (1934) reported marked differences in the case of low temperature breakdown in Bramley's Seedling and on fungal rotting following senescence in the case of Lane's Prince Albert as a result of rootstock effects.

Hoblyn and Bane (1934) found that the fruit from trees on EM I and IX was better colored than the fruit from trees on EM II, V, and XVI.

Horne (1934) reported that Bramley's Seedling trees on EM IV and VI produced apples more resistant to storage rots than trees on EM V and X.

Van Hiele (1946) indicated that, on the whole, his preliminary impression was that EM I, II and XIII had a favorable effect on the keeping quality of fruit and EM IV had a less favorable effect.

Breviglieri (1948) noted that apples kept best from trees worked on seedlings, next best from those on a local variety, and not as well from trees on EM II.

Canadian storage trials (Anon. 1951) of fruit from McIntosh trees grown on EM I, II, IX and XII showed that those trees grown on EM I were very susceptible, and those on EM II were moderately susceptible to brown core. Fruit from trees on EM IX and XII were more liable to fungal rots and fruit from trees on EM XII were very susceptible to senile breakdown.

Investigations in Switzerland (Anon. 1950) indicated that, under their conditions, fruit and storage quality was unaffected by the rootstock with the exception of EM IX, which affected storage quality adversely.

Influence of variety on leaf composition.

There is considerable evidence indicating that varieties do not have identical nutrient requirements. Differences have been observed in numerous occasions among varieties with respect to leaf composition.

Batjer and Magness (1938) reported that leaves from Delicious trees had a higher potassium content than leaves from Jonathan trees.

Collison (1940) found that Delicious leaves had a higher calcium content than McIntosh leaves, and the latter were, in turn, higher than Northern Spy leaves.

Beattie and Ellenwood (1950) showed that Delicious leaves had a higher nitrogen, potassium, magnesium and manganese content than Stayman leaves. The opposite was true for calcium and iron.

Kenworthy (1950) reported leaf content values showing Jonathan to be higher than McIntosh for nitrogen, potassium, calcium, magnesium, and manganese. The opposite was the case for phosphorus, iron, copper and boron. However, the only significant differences occurred in the case of phosphorus, iron and copper.

Thompson et al. (1952) found significant differences between leaf composition values among six varieties of apples of nitrogen, potassium, phosphorus, calcium and magnesium.

Thomas et al. (1953) indicated that Delicious leaves were higher in nitrogen, phosphorus and calcium than Stayman and Rome leaves, whereas Rome leaves were higher in potassium and magnesium than leaves from the other two varieties.

Emmert (1954b) reported that Delicious leaves were higher in nitrogen, phosphorus, potassium and magnesium than McIntosh and Cortland leaves. In the case of calcium there was but little difference between the three varieties already mentioned.

Nour (1959) reported that Delicious leaves had a higher nitrogen, phosphorus, potassium and magnesium content than Jonathan leaves. The opposite was true for calcium, boron, and iron.

Influence of sampling dates on leaf composition.

Wallace (1956) stated that the knowledge of the seasonal cycles of the various nutrients in the leaves is an essential point in the development of leaf analysis techniques for diagnostic purposes.

As early as 1910, Ritcher (1910) found that the potassium content of apple leaves on a percentage basis decreased as the season advanced.

Chandler (1936) reported that in 2-year-old Stayman Winesap trees the nitrogen content of leaves, on a percent dry weight basis, decreased throughout the season. The potassium content decreased to a low in mid-June, increased to a high at the end of June, then decreased to a low at the end of July, and then increased thereafter.

Vaidya (1938) found that, on the basis of the percent of the residual dry matter, the calcium content in leaves showed a decrease in July, after which it increased steadily during the following months. The potassium content of leaves increased during the period of rapid growth, reached a peak in September and then decreased rapidly. Leaf phosphorus was very high in new leaves and decreased to a minimum at the time of leaf fall. Magnesium, iron, manganese and aluminum showed no definite seasonal cycles.

Reuther and Boynton (1939) found a seasonal decrease in leaf potassium from July to October.

Boynton et al. (1944) reported that as the season advanced from July to October leaf calcium increased, leaf potassium decreased, and leaf phosphorus decreased in June, then showed little variation.

Boynton and Compton (1945) found that on a dry weight basis, leaf potassium and leaf nitrogen decreased and leaf magnesium increased slightly as the season advanced.

Cain and Boynton (1948) reported marked decreases in leaf potassium and phosphorus and an increase in calcium, magnesium and total bases (Ca+Mg+K) as the growing season advanced.

Rogers et al. (1953) found that as the season advanced, there was a decrease in leaf nitrogen, potassium and phosphorus and an increase in leaf calcium and no pronounced trend in leaf magnesium.

Thomas et al. (1953) took four leaf samples from Delicious and Rome trees from mid-June to mid-August and they found a decrease in leaf

nitrogen, an increase in leaf calcium, and little variation in leaf potassium, phosphorus and magnesium during the sampling period.

Emmert (1954a) also found that there was a decrease in leaf phosphorus and potassium and an increase in leaf calcium as the season advanced.

Mason's report (1958) indicated that leaves from the middle of the current season's growth of EM VII growing in the stoolbed, leaf nitrogen and leaf phosphorus decreased as the season advanced. Leaf calcium and leaf iron increased steadily from May to November. Leaf potassium increased to a high in mid July, decreased to a low at the end of August, increased again to a high in October, and then decreased steadily. Leaf magnesium increased until mid August then decreased steadily. Leaf manganese increased slightly until mid August then showed little variation. Mason remarked that until mid August, which was the time of cessation of growth, there was a relatively orderly change in the concentration of elements, but after mid August the ageing effect on leaf composition was not orderly in nature.

Mason and Whitfield (1960) studied the seasonal changes of elements in the leaves of the clone EM IX used as a scion grown on the clones EM IX and XVI used as rootstocks. They found that in the EM IX/XVI combination, leaf nitrogen decreased as the season advanced, leaf phosphorus decreased until May, then showed little variation, leaf potassium decreased

until June then increased until September, then decreased rapidly. Leaf magnesium increased until May, showed little change until August and then decreased. Leaf calcium showed a continuous increase throughout the season. When the EM IX IX combination was studied, leaf calcium showed the same variation pattern of the previous combination, but leaf potassium decreased until June, increased in July, decreased in August, increased in September and then decreased throughout the remainder of the season.

<u>Significant correlations between various determinations made on apple leaves and fruit.</u>

Warne and Wallace (1935) were among the first to report a negative correlation between leaf potassium and leaf calcium. The varieties under study were Worcester Pearmain and Lane's Prince Albert grown on various EM rootstocks. Vaidya (1938) reported similar findings.

Boynton and Compton (1945) reported that in McIntosh there was an inverse relation between leaf potassium and leaf magnesium and a positive relation between leaf nitrogen and leaf magnesium.

Cain (1953a) studied the effect of nitrogen fertilizers on foliage composition and found that nitrogen fertilizers caused an increase in leaf nitrogen, calcium and magnesium and a decrease in leaf potassium and phosphorus, regardless of potassium fertilizer levels. Also, potassium fertilizers resulted in a decrease in leaf magnesium.

Hill (1953) reported that increased concentrations of foliage nitrogen were accompanied by decreased concentrations of phosphorus and potassium, and increased concentrations of magnesium.

Eaves and Kelsal (1954) determined the chemical composition of Cortland leaves and they found the following correlations in untreated plots:

a) Positive correlations between P and Ca, N and K, N and Mg.

b) Negative correlations between K and Mg, N and P, P and Mg, Ca and Mg

Wilkinson (1958) reported a positive relation between fruit potassium and magnesium.

Kenworthy and Harris (1960) determined the chemical composition of McIntosh and Red Delicious fruit and found the following highly significant correlations between elements

1) When Michigan apples were considered there were positive correlations between N and K, P and Mg, P and Mn, Mg and Mn.

2) When McIntosh apples from four states were considered there were positive correlations between P and Ca, Ca and Mg, Mg and Mn.

3) When Red Delicious apples from four states were considered, there were positive correlations between P and Mg, P and B, Ca and Mn, Mg and Mn, and negative correlations between

P and Cu, Mg and Cu, Mn and Cu.

4) When both varieties from four states were considered, there were positive correlations between P and Ca, P and Mg, P and B, Ca and Mg, Ca and Mn, Ca and Fe, Mg and Mn, and negative correlations between N and B, Mn and Cu.

Smock and Boynton (1944) conducted a two-year study of four McIntosh orchards and a one-year study in a fifth orchard, and they pointed out the following trends.

a) Increased applications of nitrogen fertilizer decreased the firmness of the fruit at harvest time, but did not seem to stimulate increased rates of softening during storage.

b) Increased applications of nitrogen fertilizer seemed to result in the retardation of the normal development of yellow ground color.

c) There was not always a direct correlation between the amount of nitrogen applied and the effect on firmness or ground color, but there was almost always an inverse correlation between leaf nitrogen and fruit firmness and ground color.

d) There was no marked effect of differential nitrogen treatments on soluble solids in the fruit, but where there were significant differences, soluble solids were reduced by the higher nitrogen levels.

e) There was an indication that the amount of brown core found after storage increased in some orchards with higher leaf nitrogen levels, but there was not always a direct correlation with the amount of fertilizer applied to the tree.

f) In four of the five orchards there was no effect of differential nitrogen treatments on the incidence of storage scald, but in the fifth orchard there was a strong suggestion that the larger nitrogen applications reduced the incidence of scald.

Overley and Overholser (1932) reported an experiment in which the fruit coming from plots receiving potassium fertilizer alone, had the highest average flesh firmness and produced the smallest and the most highly colored fruit. They also reported that the fruit having a low average flesh firmness came from trees on plots receiving nitrogen alone or in combination with other elements and produced the largest and the lowest colored apples.

Hill et al. (1950) and Hill and Heeney (1952) studied the relation of foliage nitrogen, potassium, phosphorus and magnesium to the keeping quality of the apples in 30 McIntosh orchards during three consecutive years. They found that quality of McIntosh apples was reduced if the nitrogen level exceeded 2.1 percent of the dry matter of the leaves in mid-July. A highly significant negative correlation existed between foliage nitrogen and fruit quality. Potassium was found to have a definite but lesser effect than nitrogen on storage quality and they considered that if the potassium levels in the foliage in mid-July fall below 1.7 percent of the dry weight, the storage quality would be impaired. A smaller positive correlation between foliage potassium and fruit quality was determined. The investigators also found no relation between foliage phosphorus and storage quality.

Weeks et al. (1952) observed that increases in leaf nitrogen in McIntosh trees were associated with depressed fruit color, whereas increases in leaf potassium were associated with increased fruit color. They also reported that high nitrogen trees produced the softest fruit and low nitrogen trees the hardest fruit. Finally they noted that as leaf nitrogen increased, leaf potassium decreased and high inorganic nitrogen treatments caused an increase in leaf nitrogen, magnesium and calcium, and a decrease in leaf potassium and phosphorus.

Collins (1957) reported that as the nitrogen levels in the tree were increased, the color and keeping quality of the fruit decreased. Firmness also decreased as the nitrogen level increased.

Bünemann (1958) made numerous leaf and fruit composition determinations on Jonathan trees and found the following highly significant correlations.

1) A positive correlation between leaf and fruit composition for N, K, P and Mn.

2) Positive correlations between fruit firmness at harvest, after regular storage and after CA (controlled atmosphere) storage.

3) Fruit firmness at harvest was negatively correlated with leaf nitrogen and fruit nitrogen, potassium and magnesium.

4) Fruit firmness after regular storage was negatively correlated with leaf nitrogen and fruit nitrogen and magnesium.

5) Fruit firmness after CA storage was negatively correlated with leaf nitrogen, potassium and magnesium and fruit nitrogen and potassium.

6) Positive correlations between ground color scores at harvest, after regular storage and after CA storage.

7) The soluble solids content of the fruit was positively correlated with the soluble solids content after regular and CA storage and negatively correlated with fruit nitrogen and potassium.

Harding (1936) noted that soluble solids were consistently lower in apples affected with soft scald than in those not affected by the disorder.

Smith (1942) reported that there was a highly significant negative correlation between yellow ground color and the absence of brown core.

MATERIALS AND METHODS

General.

A rootstock-variety orchard located at the Graham Experiment Station, Grand Rapids, Michigan, was used in this study. The orchard layout is presented in Figure 1. The trees were planted in 1952 and were grown under sod culture.[1] In each of the two locations, there were four trees of each variety-rootstock combination. The varieties represented were Northern Spy, Red Delicious, Jonathan and McIntosh. The East Malling rootstocks represented were EM I, II, V, VII, XIII and XVI.[2] There were, therefore, 96 trees in each of the two locations.

Leaf samples were collected from the periphery of the tree. Leaves which were about midway between the base of the current year's shoot and the terminal leaf and free of insect or disease damage were selected. The leaf samples were collected every two weeks during June, July and August, as shown in Table 1. The weather was fair to partly cloudy at all six sampling dates, and the sampling was done between 10:00 a.m., and 5:00 p.m.

The apple leaf samples were washed in a detergent solution then rinsed consecutively in tap water and distilled water. The whole operation required less than one minute per sample. The leaves were then dried in a forced draft oven at 160 F for one week and then ground on a Wiley mill with a 20-mesh

1/ The soil was a Miami loam. pH values ranged 5.3 to 7.4. Soil potassium ranged from 188 to 436 pounds per acre on the basis of the reserve test of Spurway and Lawton (1949). The trees received nitrogen last in 1956.

2/ EM II, V and VII are semi-dwarfing rootstocks, EM I and XIII are vigorous, and EM XVI is a very vigorous rootstock.

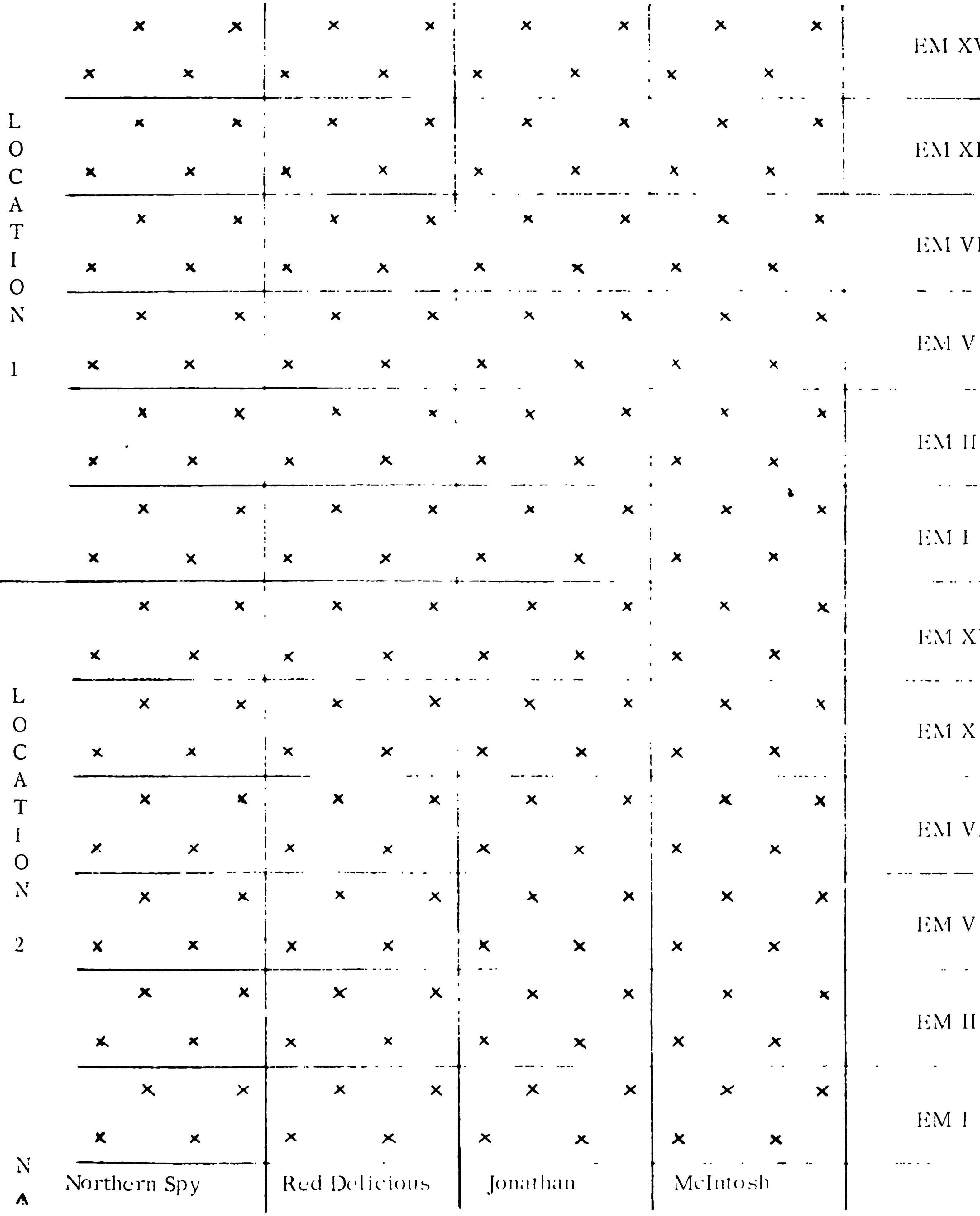

Figure 1. Rootstock-variety orchard located at the Graham Experiment Station in Grand Rapids, Michigan. Trees planted in 1952.

Table 1. Dates and locations of leaf sampling of the variety-rootstock orchard located at the Graham Experiment Station.

Sampling	Date	Location
A	June 30, 1959	1
B	July 14, 1959	1 and 2
C	July 28, 1959	1
D	August 11, 1959	1
E	August 25, 1959	1
F	July 22, 1960	1 and 2

screen. The ground samples were analyzed by the Plant Analysis Laboratory, Department of Horticulture. Nitrogen was determined by the Kjeldahl-Gunning method and potassium by flame photometry. Phosphorus, calcium, magnesium, iron, manganese, copper, boron, zinc, molybdenum and aluminum were analyzed with a "Quantograph" which is a direct-reading photoelectric spectrometer manufactured by the Applied Research Laboratories of Glendale, California.

Mature fruit samples were collected from trees of the Red Delicious, Jonathan and McIntosh varieties. Northern Spy trees were not sampled because of a very light crop.

One bushel and 20 apples were harvested at random from each tree. The 20 apples were used for pre-storage determinations. One half-bushel was placed in regular refrigerated storage rooms at 32° F, and the other half-bushel was placed under controlled atmosphere (CA) conditions. The fruit was placed in the storage rooms on the day of harvest. Red Delicious and

Jonathan fruit placed in CA storage was kept at 32° F and atmospheres of 2.5 percent CO_2 and 3 percent O_2. McIntosh in CA storage was kept at 38° F and atmospheres of 5 percent CO_2 and 3 percent O_2. Table 2 shows the harvest dates, the date of removal of the fruit from storage, and the total duration of the storage period.

Table 2. Harvest dates, dates of removal of fruit from storage and total duration of the storage period for the fruit used in this study.

Variety	Harvest date (1959)	Date of removal from storage (1960)		Days in storage	
		Regular	CA	Regular	CA
Red Delicious (1)	October 1	April 14	May 3	196	215
Jonathan	September 29	April 12	May 3	197	217
McIntosh	September 22	March 30	April 4	191	195

(1) A large part of the crop was knocked down by a very strong wind the day of harvest. In the case of Red Delicious on EM XIII and XVI only fruit for the chemical analyses was collected.

The following tests were run on the lot of 20 apples harvested from every tree.

a) The ground color of the skin was determined on both the McIntosh and the Jonathan fruit with the aid of the Cornell color chart (Smock and Markwardt, 1955) in which color variation between green and yellow are numbered from 5 to 1. Completely red fruit was given a rating of 0. The number of fruits in each color category was recorded and the average color value of the sample was computed.

b) The flesh firmness of the fruit was determined with a Magness-Taylor pressure tester (Magness and Taylor, 1925) using a 7/16-inch diameter plunger which was applied to both the green cheek and the diametrically opposite red cheek of each fruit. An average value was obtained and recorded for each sample.

c) The soluble solids content of the composite sample of juice obtained from the use of the pressure tester was measured with a Zeiss Opton hand refractometer.

d) A wedge was removed from the center slice of each apple and all the wedges from the same sample were composited and used for chemical analysis. Each sample was placed in a cheesecloth bag and dried for one month at 160°F. The dried fruit samples were then ground in a Wiley mill with a 20-mesh screen. The ground samples were then analyzed for the same 12 elements determined in the leaf samples. The same methods of analysis were followed.

At the end of the storage period the following tests were run on each half-bushel sample from both regular and CA storage:

a) Red Delicious: The average flesh firmness and the soluble

solids content of the fruit were determined on 20 fruits. All the fruit was examined for the presence of storage scald, brown core, and internal breakdown and the percentage of affected fruit was determined.

b) Jonathan: All the fruit was examined for the presence of soft scald, Jonathan spot, and russeting, after which 20 fruits were selected at random and the average flesh firmness, the average ground color, the soluble solids content and the percentage of the 20 fruits affected by core browning and internal breakdown was determined. The remaining fruit was held in a room at 75°F for seven days, after which the fruit was again examined for the presence of core browning and internal breakdown and the percentage of affected fruit was determined.

c) McIntosh: All the fruit from both regular and CA storage was examined for the presence of storage scald and the percentage of affected fruit was determined. Twenty fruits were then selected at random and used to determine the average ground color, the average flesh firmness, the soluble solids content of the sample, and the percentage of the 20 fruits affected by brown core and mealy breakdown. The remaining fruit was held in a room at 75°F for seven days after which the fruit was again examined for the presence of storage scald, brown core

and mealy breakdown and the percentage of affected fruit was determined.

Statistical analysis of data.

All statistical analyses were done with the aid of the Michigan State University electronic digital computer (Mystic). For the purpose of the statistical analysis the data for each measurement for each tree was analyzed separately as described in the six different problems as follows:

Problem 1: The data obtained from the results of the leaf analysis from location 1 in 1959 were analyzed statistically. The values obtained from each sample representing a tree were entered separately. The analysis of variance of three main effects, varieties, rootstocks, and sampling dates, and their interactions were determined. The data from four varieties, six rootstocks, and four sampling dates were thus analyzed. The fifth sampling date was omitted from the analysis due to the capacity limitation of the computer. A typical analysis of variance table is given in Table 3.

Differences between treatments were determined by using a minimum required difference (MRD), (Lewis, 1960). The MRD value is obtained by multiplying the standard deviation of the treatment mean by the value in the studentized table (Duncan, 1955) corresponding to degrees of freedom of the error term and the number of averages being

Table 3. Analysis of variance of leaf phosphorus data (Problem 1).

Source	Degrees of Freedom	Mean Square	F value (2)
Varieties	3	.03671	**
Rootstocks	5	.02416	**
Sampling dates	3	.01570	**
V x R (1)	15	.00300	**
V x SD (1)	9	.00217	**
R x SD	15	.00096	
V x R x SD	45	.00091	
Error	288	.00080	

(1) Interactions combined to test main effects.
(2) ** Significant 1% level.
Significant 5% level.

compared. The advantage of this value is that all the means under the same treatment can be compared with the aid of a single value.

Problem 2: The influence of variety, rootstock, location and their interactions on leaf composition was statistically analyzed in this problem. The leaf composition values from both locations 1 and 2 for the July 14, 1959 sampling were used. This sampling date (July 14, 1959) was the one used in the area when collecting leaves for diagnosing purposes.

Problem 3: The influence of variety, rootstock, years and their interactions on leaf composition was determined statistically. This time the values for the two locations were pooled together because the values for the two locations were significantly different in 1959 only

for potassium, magnesium and molybdenum and the actual differences were relatively small. Only the leaf composition data from the July 14, 1959 sampling and the one sampling of 1960 were used.

Problem 4: The influence of variety, rootstock, location and their interactions on fruit composition was analyzed statistically. Only the 1959 data were used.

Problem 5: The influence of rootstock and location on pre-storage and post storage measurements and their interactions within each of the three varieties studied was determined statistically.

Problem 6: Ten correlation problems involving 3, 421 correlations were analyzed statistically. Correlation coefficients were determined for each variety on all rootstocks (three problems), each rootstock on all varieties (six problems), and all observations (one problem). The correlation coefficients were calculated and their significance determined. Only the 1959 data were used.

RESULTS

Influence of rootstocks on leaf composition.

In Tables 4, 5 and 6, the relative influence of the various EM rootstocks on leaf composition is presented. In Table 4, the leaf composition values obtained at each of four sampling dates are considered together. In Table 5, leaf composition values obtained at the main sampling date are evaluated. Finally, in Table 6, the leaf composition values obtained at the main sampling dates of 1959 and 1960 are considered.

Nitrogen: Rootstocks did not have a significant influence on leaf nitrogen.

Potassium: Rootstocks significantly influenced leaf potassium values, as seen in Tables 4, 5 and 6. Whether four sampling dates, the main sampling date of two years were taken into consideration, trees on EM I had the highest leaf potassium values and trees on EM V had the lowest values.

Phosphorus: There were significant differences between rootstocks in affecting leaf phosphorus when four sampling dates or two years were taken into consideration (Tables 4, 6). Leaf phosphorus was highest on trees on EM V and lowest on EM XVI. However, when only the main sampling date was studied, no significant difference was found between rootstocks (Table 5).

Calcium: There were significant differences between rootstocks when the leaf composition data from four sampling dates, one sampling date or two

Table 4. Influence of [illegible] on leaf composition. [illegible] in decreasing order of leaf [illegible]. Differences were not significant between [illegible] underscored by the same line.

[illegible] Dry weight basis.	Highest					Lowest.	LSD 5%	LSD 1%
NITROGEN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NS	NS
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.1?0	.021	.028
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.14	.1?
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.?	16.2
[illegible] p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1?	23
[illegible] p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].4	NS	NS
[illegible] p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.3	5.8
[illegible] p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NS	NS
[illegible] p.p.m.	[illegible]	4.[illegible]	4.[illegible]	[illegible]	4.2	[illegible].7	.6	.7
[illegible] p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NS	NS

1/ Mean values represent [illegible] trees: 4 varieties x 4 sampling dates x [illegible] x 1 year x 4 trees.

Table 5. Influence of EM rootstocks on leaf composition. Rootstocks are arranged in decreasing order of leaf composition(1). Differences were not significant between rootstocks underscored by the same line.

ELEMENT(2) Dry weight basis	ROOTSTOCKS Highest.					Lowest.	LSD 5%	1%
NITROGEN %	[illegible] [illegible]	[illegible] 2.17	[illegible] 2.12	[illegible] 2.11	[illegible] 2.06	[illegible] 2.07	NS	NS
POTASSIUM %	I 1.[illegible]	VII [illegible]	XIII 1.8[illegible]	XVI 1.[illegible]	II 1.7[illegible]	V 1.6[illegible]	.09	.11
PHOSPHORUS %	VII .2[illegible]	V .2[illegible]	XIII .[illegible]	II .[illegible]	I .199	XVI .195	NS	NS
CALCIUM %	XVI 1.16	I 1.16	[illegible] [illegible]	[illegible] [illegible]	XIII [illegible]	II [illegible]	.11	.14
MAGNESIUM %	XVI .3[illegible]	XIII .3[illegible]	II .301	VII .2[illegible]	V .2[illegible]	I .270	.025	.030
MANGANESE p.p.m.	XIII [illegible]	VII [illegible]	I [illegible]	XVI 5[illegible]	V 48.[illegible]	II 43.1	9.0	12.0
IRON p.p.m.	I 27[illegible]	V 27[illegible]	VII [illegible]	II 26[illegible]	XIII 25[illegible]	XVI 234	18	23
COPPER p.p.m.	VII 11.[illegible]	V 11.[illegible]	XIII 10.[illegible]	II 10.4	I 10.3	XVI 10.1	NS	NS
BORON p.p.m.	V 37.7	VII 35.1	I 34.6	XIII 33.2	II 32.0	XVI 29.4	3.9	5.3
MOLYBDENUM p.p.m.	VII 4.7	I 4.7	XVI 4.6	V 4.6	XIII 4.2	II 4.1	NS	NS
ALUMINUM p.p.m.	I 235	XIII 232	II 22[illegible]	VII 225	V 220	XVI 215	NS	NS

(1) Mean values represent 32 trees: 4 varieties x 1 sampling date x 2 locations x 1 year x 4 trees.

(2) Zinc was not included due to analytical difficulties.

Table [illegible]. [illegible] leaf composition [illegible]. Differences are not significant [illegible] same line.

Element [illegible] dry weight basis.	[illegible]					[illegible]	[illegible]	[illegible]
Nitrogen [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Potassium [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Phosphorus [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calcium [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Magnesium [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.035
Iron p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N[illegible]	[illegible]
Copper p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	12.1?	12.[illegible]	[illegible]	[illegible]
Boron p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Molybdenum p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aluminum p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(1) Mean values represent [illegible] trees: 4 varieties x 1 sampling date per year x [illegible] locations x [illegible] years x 4 trees.

(2) Zinc was not included due to analytical difficulties. Manganese was not included as a result of the use of a fungicide containing the element in 19[illegible].

years were taken into consideration (Tables 4, 5 and 6). Trees on EM I and XVI had the highest leaf calcium values, whereas trees on EM II, V and XIII had the lowest values.

Magnesium. Rootstocks significantly affected leaf magnesium values when either four sampling dates, one sampling date or two years were considered. In every case, trees on EM XVI were the highest in leaf magnesium and trees on EM I were the lowest (Tables 4, 5 and 6).

Manganese: There were significant differences between rootstocks in regard to leaf manganese when the data from four sampling dates or one sampling date were analyzed (Tables 4, 5). In every case trees on EM XIII had the highest values, and trees on EM II had the lowest values. The data from the second year could not be used in this study because a manganese containing fungicide was applied prior to leaf sampling.

Iron: Rootstocks affected leaf composition values for iron when the data from four sampling dates (Table 4) and one sampling date (Table 5) were analyzed. However, when the data from two years were considered, no significant difference was found between rootstocks (Table 6). Also, different rootstocks were not consistent in their influence on leaf iron.

Copper: Rootstocks significantly affected leaf copper values only when the data from two years were taken into consideration (Table 6). In every case, trees on EM VII showed the highest leaf copper values.

Boron: There were significant differences between rootstocks with respect to leaf boron when four sampling dates and when only one sampling date were considered (Tables 4, 5). This was not the case when the values from two years were taken into account (Table 6). In every case trees on EM V showed the highest leaf boron values.

Zinc: No significant difference in leaf zinc values was found between the rootstocks when the data from four sampling dates was analyzed (Table 4). The data for zinc were not included in Tables 5 and 6 because of analytical difficulties.

Molybdenum. There were significant differences in leaf molybdenum for the different rootstocks when four sampling dates were taken into account (Table 4). However, in the other two studies, no significant difference was found.

Aluminum: Rootstocks did not affect significantly leaf aluminum values in any of the problems considered (Tables 4, 5 and 6).

Influence of rootstocks on fruit composition.

Rootstocks did have a significant influence on the potassium, copper, boron, zinc and aluminum composition of the fruit (Table 7). Rootstocks, however, did not have a significant effect on the amounts of nitrogen, phosphorus, calcium, magnesium, manganese, iron and molybdenum, in the fruit.

Table 7. Influence of [illegible] rootstocks on fruit composition. Rootstocks are arranged in decreasing order of fruit composition(1). Differences were not significant between rootstocks underscored by the same line.

ELEMENT Dry weight basis	ROOTSTOCKS Highest.					Lowest.	LSD 5%	1%
NITROGEN %	XVI .[illegible]	V .[illegible]	VII .21[illegible]	I .218	II .217	XIII .213	NS	NS
POTASSIUM %	XVI [illegible]	XIII [illegible]	I [illegible]	VII .873	V [illegible]	II [illegible]	.058	.077
PHOSPHORUS %	XIII [illegible]	V [illegible]	VII [illegible]	I .1[illegible]4	XVI .1[illegible]	II .1[illegible]4	NS	NS
CALCIUM %	[illegible] .1[illegible]	I .1[illegible]	XIII .13[illegible]	I .1[illegible]	II .1[illegible]	VII .119	NS	NS
MAGNESIUM %	XVI .097	VII .097	XIII .096	V .095	II .095	I .095	NS	NS
MANGANESE p.p.m.	I 12.[illegible]	XIII 12.9	II 12.3	VII 11.[illegible]	V 11.9	XVI 11.6	NS	NS
IRON p.p.m.	XIII [illegible]	VII 94.[illegible]	V 90.[illegible]	XVI 85.6	I 81.8	II 79.5	NS	NS
COPPER p.p.m.	VII 10.[illegible]	V 8.8	XVI 8.[illegible]	XIII 7.[illegible]	I 7.6	II 7.[illegible]	1.1	1.4
BORON p.p.m.	V 70.6	XIII [illegible]	I 51.0	VII 44.5	II 43.4	XVI 41.0	10.1	13.4
ZINC p.p.m.	XVI 33.3	XIII 21.8	VII 18.1	V 18.[illegible]	I 16.8	II 15.6	11.0	15.0
MOLYBDENUM p.p.m.	I 1.4	II 1.3	V 1.3	XIII 1.3	VII 1.3	XVI 1.1	NS	NS
ALUMINUM p.p.m.	VII 25.2	XIII 24.7	II 24.6	V 23.4	I 22.0	XVI 21.1	2.9	3.8

(1) Mean values represent 24 trees: 3 varieties x 1 sampling date x 2 locations x 4 trees.

Influence of rootstocks on storage measurements.

Red Delicious. Rootstocks influenced significantly the soluble solids content of the fruit and the incidence of storage scald on the fruit (Table 8). However, rootstocks did not affect significantly the flesh firmness of the fruit. No brown core or internal breakdown was found at any time.

Jonathan: Rootstocks had a significant influence on the flesh firmness of the fruit and on the percentage of russeted fruit (Table 9). However, rootstocks did not affect significantly soluble solids, ground color of the fruit, and the incidence of Jonathan spot or soft scald on the fruit. No core browning or internal breakdown was found at any time in the fruit.

McIntosh: Rootstocks had no significant influence on any of the measurements considered (Table 10).

Influence of varieties on leaf composition.

In the case of almost every element, there were significant differences between varieties with respect to leaf composition (Tables 11, 12, and 13). This was true whether four sampling dates, one sampling date, or two years were taken into consideration.

The only exceptions were for copper when the data for four sampling dates were used and for phosphorus, iron, copper and aluminum when the data from two years were taken into account. There was very little or no difference in relative composition between varieties whether the data from

Table [illegible]. Influence of [illegible] rootstocks on pre-storage and post-storage measurements on Red Delicious fruit. Rootstocks are arranged in decreasing order of values for the measurements considered. Differences were not significant between rootstocks underscored by the same line.

Measurement	Rootstock Highest.			Lowest.	LSD 5%	1%
Soluble solids(1)	I [illegible] 14.[illegible]	VII 14.1	V 1[illegible].[illegible]	I 13.[illegible]	.4	.6
Average flesh firmness in lbs.(1)	[illegible]	[illegible]	VI[illegible] 14.[illegible]	I [illegible]	NS	NS
% of fruit affected by storage scald(2)	[illegible]	I [illegible]	VII [illegible]	V 1[illegible]	10.5	13.7

(1) Mean values represent 24 samples: 1 sampling date x 2 locations x 4 trees x 3 observations (At harvest, after regular storage and after CA storage).
(2) Mean values represent 16 samples: 1 sampling date x 2 locations x 4 trees x 2 observations (After regular storage and after CA storage).

Table 9. Influence of [illegible] rootstocks on pre-storage and post-storage measurements on Jonathan fruit. Rootstocks are arranged in decreasing order of values for the measurement considered. Differences were not significant between rootstocks underscored by the same line.

MEASUREMENT	ROOTSTOCKS Highest					Lowest	LSD 5%	1%
% soluble solids (1)	II [illegible]	XIII [illegible]	I [illegible]	V [illegible]	VII [illegible]	XVI 13.3	NS	NS
Average flesh firmness in lbs. (1)	VII [illegible]	II [illegible]	XIII [illegible]	I 13.4	V [illegible]	XVI 13.3	.4	.5
Ground color score (1)	[illegible] 1.1	I 1.1	[illegible]	V .9	XIII [illegible]	VII .7	NS	NS
% of fruit affected by Jonathan spot (2)	[illegible]	VII [illegible]	V [illegible]	XVI 17.1	II [illegible]	XIII [illegible]	NS	NS
% of fruit affected by soft scald (2)	XIII [illegible]	V 2.7	XVI 2.5	I 1.8	II 1.7	VII 1.5	NS	NS
% russeted fruit (2)	VII [illegible]	II [illegible]	I [illegible]	V 14.8	XIII [illegible]	XVI [illegible]	8.2	11.3

(1) Mean values represent 24 samples: 1 sampling date x 2 locations x 4 trees x 3 observations (at harvest, after regular storage and after CA storage).
(2) Mean values represent 16 samples: 1 sampling date x 2 locations x 4 trees x 2 observations (after regular storage and after CA storage).

Table 10. Influence of EM rootstocks on pre-storage and post-storage measurements on McIntosh fruit. Rootstocks are arranged in decreasing order of values for the measurements considered. Differences were not significant between rootstocks underscored by the same line.

MEASUREMENT	ROOTSTOCKS Highest					Lowest.	LSD 5%	LSD 1%
% soluble solids (1)	VII [illegible]	XIII 12.8	II 12.7	V 12.5	XVI 12.5	I 12.[illegible]	NS	NS
Average flesh firmness in lbs. (1)	XIII 11.6	VII 11.5	II 11.3	V 11.1	XVI 11.1	I 11.0	NS	NS
Ground color score (1)	XVI 2.8	I 2.3	V 2.0	II 2.0	VII 2.0	XIII 1.6	NS	NS
% of fruit affected by storage scald (2)	I 24.8	II 24.8	XIII 23.6	XVI 22.9	V 22.1	VII 21.3	NS	NS
% of fruit affected by brown core(2)	I 23.7	V 23.4	II 19.9	XVI 19.7	VII 17.8	XIII 15.2	NS	NS
% of fruit affected by mealy breakdown(2)	VII 11.9	II 9.5	XVI 9.1	XIII 8.2	I 8.1	V 7.2	NS	NS

(1) Mean values represent 24 samples: 1 sampling date x 2 locations x 4 trees x 3 observations (At harvest, after regular storage and after CA storage).
(2) Mean values represent 32 samples: 1 sampling date x 2 locations x 4 trees x 4 observations (After regular and CA storage plus 7 days at 75º F after both regular and CA storage).

Table 11. Mineral composition of apple leaves as affected by varieties grown on six MM rootstocks. Varieties are arranged in decreasing order of leaf composition(1). Differences were not significant between varieties underscored by the same line.

ELEMENT Dry weight basis.	VARIETIES Highest			Lowest	LSD 5%	1%
NITROGEN %	DEL [illegible]	JON 2.0[illegible]	SPY 2.0[illegible]	MC 1.96	.06	.09
POTASSIUM %	SPY 1.81	DEL 1.78	MC 1.46	JON 1.44	.09	.13
PHOSPHORUS %	SPY [illegible]	DEL .221	JON .201	MC .18[illegible]	.017	.022
CALCIUM %	JON 1.13	MC 1.07	DEL 1.01	SPY [illegible]	.11	.15
MAGNESIUM %	DEL [illegible]	JON .309	MC .302	SPY .301	.016	.021
MANGANESE p.p.m.	MC 5[illegible].4	DEL 53.[illegible]	SPY 46.6	JON [illegible]	9.3	12.6
IRON p.p.m.	JON [illegible]	MC 227	DEL 220	SPY 217	14	18
COPPER p.p.m.	JON [illegible]	DEL 9.1	SPY 9.[illegible]	MC 8.[illegible]	NS	NS
BORON p.p.m.	DEL [illegible]	JON [illegible]	SPY [illegible]	MC 29.2	3.4	4.6
ZINC p.p.m.	JON 2[illegible].3	SPY 26.1	DEL 25.6	MC 25.[illegible]	2.6	3.4
MOLYBDENUM p.p.m.	JON 4.[illegible]	MC 4.4	DEL 4.3	SPY 3.9	.4	.6
ALUMINUM p.p.m.	JON 263	MC 251	SPY 225	DEL 223	21	28

(1) Mean values represent 96 trees: 6 rootstocks x 4 sampling dates x 1 location x 1 year x 4 trees.

Table 12. Mineral composition of apple leaves as affected by varieties grown on six EM rootstocks. Varieties are arranged in decreasing order of leaf composition(1). Differences were not significant between varieties underscored by the same line.

ELEMENT(2) Dry weight basis.	VARIETIES Highest.			Lowest.	MRD 5%	1%
NITROGEN %	DEL 2.24	JON 2.15	SPY 2.06	MC [illegible]	.10	.14
POTASSIUM %	SPY 2.07	DEL 2.01	MC 1.65	JON 1.5[illegible]	.07	.09
PHOSPHORUS %	DEL .24[illegible]	SPY .22[illegible]	JON .207	MC .188	.020	.041
CALCIUM %	JON 1.0[illegible]	MC 1.0[illegible]	DEL 1.00	SPY 0.9[illegible]	.08	.11
MAGNESIUM %	DEL .3[illegible]4	MC .3[illegible]4	JON .303	SPY [illegible]	.018	.024
MANGANESE p.p.m.	MC 56.2	DEL 55.2	SPY 48.1	JON 4[illegible].4	7.0	9.5
IRON p.p.m.	JON 312	MC 252	DEL 251	SPY 233	14	18
COPPER p.p.m.	JON 11.5	DEL 10.9	SPY 10.5	MC 10.1	.6	.7
BORON p.p.m.	DEL 38.8	JON 33.0	MC 31.9	SPY 31.1	3.1	4.2
MOLYBDENUM p.p.m.	JON 4.8	DEL 4.4	MC 4.4	SPY 4.2	.5	.7
ALUMINUM p.p.m.	JON 257	MC 234	DEL 209	SPY 201	20	26

(1) Mean values represent 48 trees : 6 rootstocks x 1 sampling date x 2 locations x 1 year x 4 trees.
(2) Zinc was not included due to analytical difficulties.

Table 13. Mineral composition of apple leaves as affected by varieties grown on six EM rootstocks. Varieties are arranged in decreasing order of leaf composition. Differences were not significant between varieties underscored by the same line.

ELEMENT(2) Dry weight basis.	VARIETIES Highest.			Lowest.	MRD 5%	1%
NITROGEN %	DEL 2.31	JON 2.23	MC 2.17	SPY 2.10	.10	.13
POTASSIUM %	SPY 1.83	DEL 1.83	MC 1.40	JON 1.39	.06	.08
PHOSPHORUS %	DEL .237	SPY .222	MC .203	JON .197	NS	NS
CALCIUM %	JON 1.09	MC 1.05	DEL 0.95	SPY 0.92	.09	.13
MAGNESIUM %	DEL .324	SPY .301	JON .288	MC .275	.020	.02
IRON p.p.m.	JON 270	DEL 245	SPY 229	MC 228	NS	NS
COPPER p.p.m.	JON 13.1	DEL 12.6	MC 12.4	SPY 12.2	NS	NS
BORON p.p.m.	DEL 38.1	MC 30.4	JON 30.2	SPY 29.7	6.3	9.3
MOLYBDENUM p.p.m.	JON 4.7	MC 4.6	SPY 4.1	DEL 4.1	.5	.7
ALUMINUM p.p.m.	JON 359	MC 329	SPY 252	DEL 245	NS	NS

(1) Mean values represent 96 trees: 6 rootstocks x 1 sampling date per year x 2 locations x 2 years x 4 trees.
(2) Zinc was not included due to analytical difficulties. Manganese was not included as a result of the use of a fungicide containing the element in 1960.

four sampling dates, one sampling date, or two years were considered.

Influence of varieties on fruit composition.

For every element, with the exception of molybdenum, there were significant differences between varieties with respect to fruit composition (Table 14). No data for Northern Spy were available because of inadequate fruiting.

Influence of seasonal variation on leaf composition.

There was a continuous decrease in the leaf content of nitrogen, potassium, phosphorus and boron from the first to the last sampling date (Table 15). There was a continuous increase in calcium and aluminum from the first to the last sampling date. Magnesium, manganese, iron, copper, zinc and molybdenum showed an irregular pattern of variation from the first to the last sampling date.

Influence of locations on.

(1) Leaf composition: When the two locations were taken into consideration, it was found that there were significant differences between locations for potassium, magnesium and molybdenum (Table 16). There were no significant differences for the other elements studied.

(2) Fruit composition: There were significant differences between locations with respect to the fruit content of nitrogen, calcium, magnesium, copper, boron, zinc and molybdenum (Table 16).

Table 14. Mineral composition of apple fruit as affected by varieties. Varieties are arranged in decreasing order of fruit composition (1). Differences were not significant between varieties underscored by the same line.

ELEMENT Dry weight basis	VARIETIES Highest.		Lowest.	LSD 5%	LSD 1%
NITROGEN %	[illegible]	[illegible]	[illegible]	.022	.029
POTASSIUM %	[illegible]	[illegible]	[illegible]	.039	.052
PHOSPHORUS %	[illegible]	.167	[illegible]	.018	.025
CALCIUM %	[illegible]	[illegible]	[illegible]	.012	.016
MAGNESIUM %	[illegible]	[illegible]	[illegible]	.002	.003
MANGANESE p.p.m.	[illegible]	12.4	[illegible]	.7	.8
IRON p.p.m.	[illegible]	[illegible]	[illegible]	[illegible]	16.7
COPPER p.p.m.	[illegible]	7.9	7.9	.7	.9
BORON p.p.m.	[illegible]	[illegible]	44.[illegible]	6.7	9.0
ZINC p.p.m.	[illegible]	[illegible]	[illegible]	7.3	10.0
MOLYBDENUM p.p.m.	1.4	1.4	1.4	NS	NS
ALUMINUM p.p.m.	[illegible]	[illegible]	19.8	1.9	[illegible]

(1) Mean values represent 48 trees: 6 rootstocks x 2 locations x 4 trees.

Table 15. Mineral composition of apple leaves as affected by sampling dates. Sampling dates are arranged in decreasing order of leaf composition(1). Differences were not significant between sampling dates underscored by the same line.

ELEMENT Dry weight basis.	SAMPLING DATES Highest.			Lowest.	LSD 5%	1%
NITROGEN %	A 2.17	B 2.11	[illegible] 1.[illegible]	[illegible] 1.[illegible]7	.06	.09
POTASSIUM %	A [illegible]	B 1.78	[illegible] 1.5[illegible]	[illegible]	[illegible]	.05
PHOSPHORUS %	[illegible]	B .217	[illegible] .202	A [illegible]	[illegible]7	[illegible]
CALCIUM %	[illegible]	[illegible] 1.1[illegible]	B 1.01	[illegible]	[illegible]	[illegible]
MAGNESIUM %	[illegible]	B .31[illegible]	[illegible] .31[illegible]	A [illegible]		NS
MANGANESE p.p.m.	52.7	52.1	51.7	4[illegible]	NS	NS
IRON p.p.m.	B 261	[illegible] 234	A 22[illegible]	[illegible] 212	14	18
COPPER p.p.m.	B 10.4	A 9.2	C 8.4	D 7.9	.4	.5
BORON p.p.m.	A 38.1	B 33.9	C 28.8	D 27.8	3.[illegible]	4.6
ZINC p.p.m.	A [illegible]2.1	D [illegible]6.1	C 24.4	B [illegible]	6.[illegible]	9.0
MOLYBDENUM p.p.m.	B 4.8	D 4.7	C 4.3	A 3.4	.4	.6
ALUMINUM p.p.m.	D 267	[illegible] 242	B 228	A [illegible]26	21	28

(1) Mean values represent 96 trees: 4 varieties x 6 rootstocks x 1 location x 4 trees.
Sampling A made on June 30, 1959.
" B " " July 14, 1959.
" C " " July 28, 1959.
" D " " August 11, 1959.

Table 16. Mineral composition of apple leaves and apple fruit as affected by locations. Differences were not significant between locations underscored by the same line.

ELEMENT (1) Dry weight basis	APPLE LEAVES(2) High.	APPLE LEAVES(2) Low.	APPLE FRUIT(3) High.	APPLE FRUIT(3) Low.
NITROGEN %	2 2.15	1 2.1[illegible]	2 .231	1 .213
POTASSIUM %	2 1.6[illegible]	1 1.[illegible]	2 .873	1 .857
PHOSPHORUS %	1 .217	2 .21[illegible]	2 .177	1 .165
CALCIUM %	2 1.04	1 1.01	2 .138	1 .124
MAGNESIUM %	1 .3[illegible]8	2 .303	2 .097	1 .095
MANGANESE p.p.m.	1 52.7	2 49.3	2 12.3	1 11.9
IRON p.p.m.	2 26[illegible]	1 [illegible]61	2 93.6	1 88.8
COPPER p.p.m.	2 11.[illegible]	1 10.5	2 8.9	1 7.7
BORON p.p.m.	1 32.8	2 32.6	2 53.2	1 47.9
ZINC p.p.m.			2 25.8	1 15.4
MOLYBDENUM p.p.m.	1 4.8	2 4.2	1 1.4	2 1.1
ALUMINUM p.p.m.	1 228	2 225	2 24.2	1 22.8

(1) Leaf zinc was not included due to analytical difficulties.
(2) Mean values represent 96 trees : 4 varieties x 6 rootstocks x 4 trees.
(3) Mean values represent 72 trees : 3 varieties x 6 rootstocks x 4 trees.

(3) Storage measurements: The only significant difference between locations occurred for flesh firmness in Red Delicious (Table 17).

Influence of years on leaf composition.

There were significant differences between years for leaf nitrogen, potassium, copper, boron and aluminum (Table 18). No significant differences were found for the other elements considered.

Miscellaneous interactions.

Rootstock x Variety interaction for leaf composition: When the data from four sampling dates were considered, this interaction was significant for all 12 elements under study. When the main sampling date was considered, the rootstock x variety interaction was significant for nitrogen, calcium, magnesium, manganese, boron, molybdenum and aluminum, but was not significant for potassium, phosphorus, iron and copper. When the data from two years was taken into consideration, the interaction was significant for nitrogen, potassium, calcium, magnesium and molybdenum, but was not significant for phosphorus, iron, copper, boron and aluminum.

Rootstock x Variety interaction for fruit composition: The rootstock x variety interaction was significant for nitrogen, phosphorus, magnesium, manganese, iron, copper, boron, zinc and aluminum, but was not significant for potassium, calcium and molybdenum.

Table 17. Influence of locations on pre-storage and post-storage measurements on Red Delicious, Jonathan and McIntosh fruit. Differences were not significant between locations underscored by the same line.

MEASUREMENT	RED DELICIOUS High.	RED DELICIOUS Low.	JONATHAN High.	JONATHAN Low.	McINTOSH High.	McINTOSH Low.
% soluble solids (1)	1 13.9	2 13.9	1 13.8	2 13.6	1 12.6	2 12.5
Average flesh firmness in lbs. (1)	1 14.2	2 13.8	1 13.6	2 13.4	1 11.4	2 11.2
Ground color score (1)			2 1.0	1 0.9	1 2.1	2 2.0
% of fruit affected by storage scald(2)	1 32.0	2 26.1			1 23.7	2 22.5
% of fruit affected by Jonathan spot(3)			1 19.8	2 18.4		
% of fruit affected by soft scald(4)			1 2.3	2 2.1		
% russeted fruit(4)			1 16.3	2 14.5		
% of fruit affected by brown core (2)					2 21.6	1 18.3
% of fruit affected by mealy breakdown(2)					2 10.0	1 8.6

(1) Mean values represent 48 samples for Red Delicious and 72 samples for Jonathan and McIntosh.
(2) Mean values represent 32 samples for Red Delicious and 96 samples for McIntosh.
(3) Mean values represent 48 samples.
(4) Mean values represent 72 samples.

Table 15. Mineral composition of apple leavea as affected by years. Differences were not significant between years underscored by the same line (1).

ELEMENT(2) Dry weight basis	YEARS High.	Low.
NITROGEN %	1960 2.27	1959 2.13
POTASSIUM %	1959 1.82	1960 1.43
PHOSPHORUS %	1960 .217	1959 .215
CALCIUM %	1959 1.03	1960 .97
MAGNESIUM %	1959 .299	1960 .296
IRON p.p.m.	1959 262	1960 223
COPPER p.p.m.	1960 14.3	1959 10.8
BORON p.p.m.	1960 34.5	1959 29.6
MOLYBDENUM p.p.m.	1959 4.5	1960 4.2
ALUMINUM p.p.m.	1960 367	1959 226

(1) Mean values represent 192 trees: 4 varieties x 6 rootstocks x 8 trees.
(2) Zinc was not included due to analytical difficulties. Manganese was not included as a result of the use of a fungicide containing the element in 1960.

Rootstock x Sampling dates: This interaction was significant for leaf calcium, iron, copper, boron, zinc, molybdenum and aluminum.

Rootstocks x Locations. This interaction was significant for leaf nitrogen, phosphorus, calcium, magnesium, manganese, copper, boron and molybdenum, and for fruit iron, boron zinc and molybdenum.

Rootstocks x Years: This interaction was significant for leaf phosphorus, calcium, magnesium, iron, boron and molybdenum.

Varieties x Sampling dates: This interaction was significant for leaf phosphorus, calcium, magnesium, iron, copper, boron, zinc and aluminum.

Varieties x Locations: This interaction was significant for leaf phosphorus and calcium and for fruit boron.

Varieties x Years: This interaction was significant for leaf nitrogen, phosphorus, calcium, magnesium, iron, boron, molybdenum and aluminum.

Effect of storage treatments on storage measurements on the fruit.

Red Delicious: (Table 19)

(1) Soluble solids: There was a significant increase in the percent soluble solids of the fruit during both regular and CA storage. No significant differences between regular and CA storage were found.

(2) Flesh firmness: The flesh firmness of the fruit was highest at harvest, then declined during storage. The decline was more pronounced in CA storage than in regular storage.

Table 19. Influence of the time of observation on pre-storage and post-storage measurements on Red Delicious and Jonathan fruit. Differences were not significant between observations underscored by the same line.

MEASUREMENT	OBSERVATIONS(1) Highest.		Lowest.	LSD 5%	LSD 1%
RED DELICIOUS(2)					
% soluble solids	AR 14.5	ACA 14.4	AH 12.8	.4	.5
Average flesh firmness in lbs.	AH 16.4	AR 15.2	ACA 14.6	.4	.5
% of fruit affected by storage scald	AR 32.4	ACA 25.8		NS	NS
JONATHAN (3)					
% soluble solids	AH 13.9	AR 13.6	ACA 13.6	.2	.3
Average flesh firmness in lbs.	AH 16.7	ACA 12.4	AR 11.5	.3	.4
Ground color score	AH 1.6	ACA .7	AR .5	.2	.3
% of fruit affected by Jonathan spot	AR 37.5	ACA .7		4.6	6.3
% of fruit affected by soft scald	AR 2.8	ACA 1.6		1.1	1.5
% russeted fruit	ACA 17.1	AR 13.7		NS	NS

(1) AH: Measurement made at harvest.
AR: Measurement made after regular storage.
ACA: Measurement made after CA storage.
(2) Mean values represent 32 samples: 4 rootstocks x 2 locations x 4 trees.
(3) Mean values represent 48 samples: 6 rootstocks x 2 locations x 4 trees.

(3) Storage scald: There was no significant differences between regular and CA storage in preventing storage scald.

Jonathan: (Table 19)

(1) Soluble solids: There was a significant decrease in the percent soluble solids content of the fruit during both regular and CA storage. No differences were found, however, between regular and CA storage in their effects on the soluble solids content of the fruit.

(2) Flesh firmness: There was a significant decrease in flesh firmness during storage. The decrease was more pronounced with regular storage than with CA storage.

(3) Ground color: There was a significant decrease in the ground color score of the fruit during storage. The decrease was greater with regular storage than with CA storage. (A decrease in ground color score indicates an increase in the yellow ground color of the fruit).

(4) Jonathan spot: There was a very significant decrease in the percent of the fruit affected by this disorder in CA storage as compared to regular storage.

(5) Soft scald: There was a significant decrease in the percent of the fruit affected by soft scald in CA storage as compared to regular storage.

(6) Fruit russeting: There were no differences between regular and

CA storage in the percent of russeted fruit. (Fruit russeting is not a storage disorder).

McIntosh: (Table 20)

(1) Soluble solids: There was a significant increase in the soluble solids content of the fruit during storage. There was no difference between regular and CA storage in this respect.

(2) Flesh firmness: There was a significant decrease in flesh firmness during both regular and CA storage. There was, however, no difference between regular and CA storage in this respect.

(3) Ground color: There were no significant changes in ground color during the storage period.

(4) Storage scald: At the end of the storage period, there were no significant differences between the fruit from regular and CA storage with respect to the incidence of storage scald. However, after seven days at 75° F, the fruit from regular storage was significantly higher in storage scald than fruit from CA storage.

(5) Brown core: The fruit from CA storage was significantly lower in brown core both at the end of the storage period and after seven dats at 75° F.

(6) Mealy breakdown: There was no significant differences between the fruit from regular and CA storage with respect to the incidence

Table 20. Influence of the time of observation on pre-storage and post-storage measurements on McIntosh fruit. Differences were not significant between observations underscored by the same line.

MEASUREMENT	OBSERVATIONS(1) Highest.			Lowest.	MRD 5%	MRD 1%
% soluble solids	ACA 12.7	AR 12.6	AH 12.3		.1	.2
Average flesh firmness in lbs.	AH 14.2	ACA 9.9	AR 9.7		.6	.9
Ground color score	ACA 2.2	AR 2.0	AH 1.9		NS	NS
% of fruit affected by storage scald	AR7 58.9	ACA7 13.2	AR 11.5	ACA 8.9	4.4	5.7
% of fruit affected by brown core	AR7 65.3	AR 12.8	ACA7 1.6	ACA .1	6.5	8.7
% of fruit affected by mealy breakdown	AR7 34.1	ACA7 2.9	AR .1	ACA .1	4.9	6.5

(1) Mean values represent 48 samples: 4 rootstocks x 2 locations x 4 trees.

AH: Measurement made at harvest.
AR: Measurement made after regular storage.
AR7: Measurement made after regular storage plus 7 days at 75º F.
ACA: Measurement made after CA storage.
ACA7: Measurement made after CA storage plus 7 days at 75º F.

of mealy breakdown at the end of the storage period. However, after seven days at 75° F, the fruit from CA storage was significantly lower in mealy breakdown than the fruit from regular storage.

Correlation studies.

Tables 21, 22 and 23 present highly significant correlations between measurements made on each variety grown on various EM rootstocks. Correlations which occurred in two of three varieties were considered in the following paragraphs.

However, when observations were made on only one or two varieties, the occurrence in one variety was considered to be sufficient. The following presentation of correlations is based on these assumptions.

Leaf nitrogen showed a negative correlation with leaf aluminum and a positive correlation with fruit nitrogen for both Red Delicious and McIntosh trees. Leaf nitrogen was correlated negatively with fruit firmness before and after storage in all three varieties. Leaf nitrogen was related negatively with the percent of storage scald when McIntosh fruit from regular storage was held seven days at 75° F. However, the correlation was positive when McIntosh fruit from CA storage was held seven days at 75° F.

Leaf phosphorus showed a positive correlation with fruit phosphorus and with fruit firmness before and after storage of Jonathan and McIntosh fruit.

Leaf calcium and leaf molybdenum were correlated positively in Red

Identification key for measurements shown on the opposite page.

1-Leaf nitrogen.
2- " potassium.
3- " phosphorus.
4- " calcium.
5- " magnesium.
6- " manganese.
7- " iron.
8- " copper.
9- " boron.
10- " molybdenum.
11- " aluminum.
12-Fruit nitrogen.
13- " potassium.
14- " phosphorus.
15- " calcium.
16- " magnesium.
17- " manganese.
18- " iron.
19- " copper.
20- " boron.
21- " molybdenum.
22- " aluminum.
23-Percent soluble solids at harvest.
24- " " " after regular storage.
25- " " " " CA storage.
26-Flesh firmness in lbs. at harvest.
27- " " " " after regular storage.
28- " " " " " CA storage.
29-Percent of fruit affected by storage scald after regular storage.
30-Percent of fruit affected by storage scald after CA storage.

Table 21. Highly significant correlations between measurements made on Red Delicious trees on four EM rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented on the opposite page.

COLUMN A	COLUMN B
1	-11, +12, -26, -28.
2	+19.
3	
4	+10.
5	- 7, - 9, +24, +25.
6	+19, -28.
7	- 5, +11.
8	
9	- 5, +20, -24, -25.
10	+ 4, +30.
11	- 1, + 7, -23.
12	+ 1, -26, -28.
13	
14	
15	+17, +21.
16	-20, +30.
17	+15, +18.
18	+17.
19	+ 2, + 6.
20	+ 9, -16, -30.
21	+15.
22	
23	-11, +24.
24	+ 5, - 9, +23, +25.
25	+ 5, - 9, +24.
26	- 1, -12, +28.
27	+28.
28	- 1, - 6, -12, +26, +27.
29	+30.
30	+10, +16, -20, +29.

(1)Correlation coefficients significant (30 df)
(+) positive at 1% level.
(-) negative at 1% level.

Identification key for measurements shown on the opposite page.

1-Leaf nitrogen.
2- " potassium.
3- " phosphorus.
4- " calcium.
5- " magnesium.
6- " manganese.
7- " iron.
8- " copper.
9- " boron.
10- " molybdenum.
11- " aluminum.
12-Fruit nitrogen.
13- " potassium.
14- " phosphorus.
15- " calcium.
16- " magnesium.
17- " manganese.
18- " iron.
19- " copper.
20- " boron.
21- " molybdenum.
22- " aluminum.
23-Percent soluble solids at harvest.
24- " " " after regular storage.
25- " " " after CA storage.
26-Flesh firmness in lbs. at harvest.
27- " " " " after regular storage.
28- " " " " " CA storage.
29-Ground color score at harvest.
30- " " " after regular storage.
31- " " " " CA storage.
32-Percent of fruit affected by Jonathan spot after regular storage.
33-Percent of fruit affected by Jonathan spot after CA storage.
34-Percent of fruit affected by Soft scald after regular storage
35- " " " " " " " " CA storage.
36-Percent of fruit affected by russeting found after regular storage.
37-Percent of fruit affected by russeting found after CA storage.

Table 22. Highly significant correlations between measurements made on Jonathan trees on six EM rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented on the opposite page.

COLUMN A	COLUMN B
1	-26, -27.
2	- 5, +27.
3	+ 9, +14, +26, +27.
4	
5	- 2, - 9, -24, -36, -37.
6	-15, -19.
7	+11.
8	+22.
9	+ 3, - 5, +14, +19, +20, -29.
10	
11	+ 7.
12	+13, +16, -21, +30.
13	+12, +14, +16.
14	+ 3, + 9, +13, +18, +19, +20.
15	- 6, + 7, +19, +21.
16	+12, +13.
17	+15, +18, +21.
18	+14, +17, -28.
19	- 6, + 9, +14, +15, +22, -29.
20	+ 9, +14.
21	-12, +15, +17, +36.
22	+ 8. + 19.
23	+24, +25, +26, -31, +37.
24	- 5, +23, +25, +26, +27, +28, +36.
25	+23, +24, +26, +28.
26	- 1, + 3, +23, +24, +25, +27.
27	- 1, + 2, + 3, +24, +26, +37.
28	-18, +24, +25.
29	- 9, -19.
30	+12, +31.
31	-23, +30, +34.
32	+36.
33	
34	+31.
35	
36	- 5, +21, +24, +32, +37.
37	- 5, +23, +27, +34.

(1) Correlation coefficients significant (46 df)
(+) positive at 1% level.
(-) negative at 1% level.

Identification key for measurements shown on the opposite page.

1-Leaf nitrogen.
2- " potassium.
3- " phosphorus.
4- " calcium.
5- " magnesium.
6- " manganese.
7- " iron.
8- " copper.
9- " boron.
10- " molybdenum.
11- " aluminum.
12-Fruit nitrogen.
13- " potassium.
14- " phosphorus.
15- " calcium.
16- " magnesium.
17- " manganese.
18- " iron.
19- " copper.
20- " boron.
21- " molybdenum.
22- " aluminum.
23-Percent soluble solids at harvest.
24- " " " after regular storage.
25- " " " " CA storage.
26-Flesh firmness in lbs. at harvest.
27- " " " " after regular storage.
28- " " " " " CA storage.
29-Ground color score at harvest.
30- " " " after regular storage.
31- " " " " CA storage.
32-Percent of fruit affected by storage scald after regular storage.
33-Percent of fruit affected by storage scald after regular storage plus 7 days at 75ºF.
34-Percent of fruit affected by storage scald after CA storage.
35- " " " " " " " " " " plus 7 days at 75º F.
36-Percent of fruit affected by brown core after regular storage
37- " " " " " " " " " " plus 7 days at 75º F;
38-Percent of fruit affected by brown core after CA storage plus 7 days at 75º F.

Table 23. Highly significant correlations between measurements made on McIntosh trees on six EM rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented in the opposite page.

COLUMN A	COLUMN B
1	− 3, −11, +12, −26, −33, +35.
2	− 7, +13.
3	− 1, +11, +14, +24, +25, +26, +28.
4	+ 5, +10, −24, −25, −27, −28, +31, +36, +37.
5	+ 4.
6	
7	− 2, + 8, + 9, +11, +20, −23.
8	+ 7, + 9, +10, +18.
9	+ 7, + 8, +10, +20, +21, −23.
10	+ 4, + 8, + 9.
11	− 1, + 3, + 7.
12	− 1, +16, +17, +18, −24, −25, −26, −28, −33, +36.
13	+ 2, +14, +16, +19.
14	+ 3, +13, +16, +19, +20.
15	+17, +21.
16	+12, +13, +14, +18, +19.
17	+12, +15.
18	+ 8, +12, +16, +19, +22.
19	+12, +13, +14, +16, +18.
20	+ 7, + 9, +14, −26, +36.
21	+ 9, [illegible].
22	+18.
23	− 7, − 9, +24, +25, +26, +28, −36.
24	+ 3, − 4, −12, +23, +25, +26, +27, +28, −30, −31.
25	− 4, −12, +23, +24, +26, +27, +28, −36.
26	− 1, + 3, −12, −20, +23, +24, +25, +28, −30, −36, −37
27	− 4, +24, +25, +28, −30.
28	+ 3, − 4, −12, +23, +24, +25, +26, +27, −30, −31, −36, −37.
29	+31
30	−24, −26, −27, −28.
31	−24, −28, +29.
32	+33.
33	− 1, −12, +32.
34	+35.
35	+ 1, +34.
36	+ 4, +12, +20, −23, −25, −26, +37.
37	+ 4, −26, −28, +36.
38	

(1) Correlation coefficients significant (46 df)
(+) positive at 1% level.
(−) negative at 1% level.

Delicious and McIntosh trees. In McIntosh trees, leaf calcium was correlated positively with the ground color score of the fruit after CA storage, and with the percent brown core in the fruit after regular storage.

Leaf magnesium showed a negative correlation with leaf boron in both Red Delicious and Jonathan trees. Leaf magnesium was correlated positively with the soluble solids content of the fruit after storage in Red Delicious. However, a negative correlation was determined between leaf magnesium and the percent soluble solids of the fruit in Jonathan. Finally, a negative correlation between leaf magnesium and fruit russeting was found in Jonathan after storage.

Leaf manganese was correlated positively with fruit copper in Red Delicious, but negatively correlated with fruit copper in Jonathan.

Leaf iron was correlated positively with leaf aluminum in all three varieties.

Leaf boron showed a positive correlation with fruit boron in all three varieties. Leaf boron was correlated negatively with the percent soluble solids of the fruit in Red Delicious and McIntosh. Finally, leaf boron was correlated negatively with the ground color scores of Jonathan fruit.

Leaf molybdenum was correlated positively with the percent storage scald found after CA storage in Red Delicious.

Fruit nitrogen was correlated positively with fruit magnesium in both Jonathan and McIntosh. Fruit nitrogen was correlated negatively with the firmness of the fruit at harvest and after storage in Red Delicious and McIntosh.

Finally, there was a positive correlation between fruit nitrogen and the ground color score of Jonathan fruit, a negative correlation between fruit nitrogen and the percent of storage scald in McIntosh in fruit held for seven days at 75° F after regular storage, and a positive correlation between fruit nitrogen and the percent of McIntosh fruit affected by brown core after regular storage.

Fruit potassium showed a positive correlation with fruit phosphorus and magnesium in both Jonathan and McIntosh.

Fruit phosphorus was correlated positively with fruit copper and boron in both Jonathan and McIntosh.

Fruit calcium showed a positive correlation with fruit manganese and molybdenum in all three varieties.

Fruit magnesium was correlated positively with the percent of storage scald found after CA storage in Red Delicious.

Fruit manganese showed a positive correlation with fruit iron in both Red Delicious and Jonathan.

Fruit boron and the percent of McIntosh fruit affected by brown core after regular storage were correlated positively.

Fruit copper was correlated negatively with the ground color scores of Jonathan fruit at harvest.

Fruit molybdenum showed a positive correlation with fruit russeting found after regular storage in Jonathan.

The percent of soluble solids of the fruit at harvest showed a positive correlation with the soluble solids content of the fruit after storage in all three varieties. The soluble solids content of the fruit also showed a positive correlation with the firmness of the fruit at harvest and after storage in both Jonathan and McIntosh. Finally, there was a negative correlation between the soluble solids content and the ground color scores of CA-stored Jonathan fruit, a positive correlation between the soluble solids content of the fruit and the percent russeted fruit in CA-stored Jonathan fruit, and a negative correlation between the soluble solids content of the fruit and the percent of brown core in regular stored McIntosh fruit.

The percent soluble solids content of the fruit after regular storage was correlated positively with the following measurements: (1) the percent soluble solids of the fruit after CA storage in all three varieties; (2) the flesh firmness of the fruit at harvest and after storage in Jonathan and McIntosh; (3) the percent russeted fruit after regular storage in Jonathan. The percent soluble solids content of McIntosh fruit was correlated negatively with the ground color scores of the fruit.

The percent soluble solids of the fruit after CA storage was correlated positively with the flesh firmness of the fruit at harvest and after storage in Jonathan and McIntosh. A negative correlation was found between the soluble solids content of the fruit and the percent brown core in McIntosh.

The flesh firmness of the fruit at harvest was correlated positively with the flesh firmness of the fruit after storage in all three varieties, and correlated negatively with the ground color score of the fruit after regular storage and with the percent brown core in McIntosh fruit after regular storage.

The flesh firmness of the fruit after regular storage showed a positive correlation with the flesh firmness of the fruit after CA storage in Delicious and McIntosh, a positive correlation with the percent russeted fruit in Jonathan after CA storage, and a negative correlation with the ground color score of McIntosh fruit after regular storage.

The flesh firmness of the fruit after CA storage showed a negative correlation with the ground color scores of McIntosh fruit after storage and with the incidence of brown core in McIntosh fruit after storage.

The percent of fruit affected by storage scald after regular storage was correlated positively with the percent of fruit affected by the same disorder after CA storage in Red Delicious.

In Jonathan fruit there were positive correlations between: (1) the ground color score of the fruit after regular storage and the ground color score of the fruit after CA storage; (2) the ground color scores of the fruit after CA storage and the percent of the fruit affected by soft scald after regular storage; (3) the percent of the fruit affected by Jonathan spot and the percent of the fruit affected by russeting after regular storage and the percent of the fruit affected by the same disorder after CA storage.

In McIntosh fruit there were positive correlations between: (1) the ground color scores of the fruit at harvest and the ground color scores of the fruit after CA storage; (2) the percent of the fruit affected by storage scald after regular storage and the percent of the fruit affected by the same disorder after seven days at 75° F; (3) the percent of the fruit affected by storage scald after CA storage and the percent of the fruit affected by the same disorder after seven days at 75° F; (4) the percent of the fruit affected by brown core after regular storage and the percent of the fruit affected by the same disorder after seven days at 75° F.

Tables 24, 25, 26, 27, 28 and 29 present all highly significant correlations between determinations made on each of the six EM rootstocks on which the three varieties were grown. The only correlations presented in the following paragraphs were those which occurred in three or more rootstocks out of the possible six rootstocks considered.

Leaf potassium was correlated positively with: (1) leaf potassium in EM I, II, XIII and XVI; (2) leaf boron in EM I, II, V and XIII; (3) fruit phosphorus in EM II, XIII and XVI. Leaf potassium was correlated negatively with: (1) leaf aluminum in EM II, VII and XVI; (2) fruit magnesium in EM I, II, VII, XIII and XVI; (3) fruit iron in EM V, VII, XIII and XVI.

Leaf phosphorus was correlated positively with fruit phosphorus in EM II, XIII and XVI, and correlated negatively with fruit magnesium in EM I, II, VII and XVI.

Identification key for measurements shown on the opposite page.

1-Leaf	nitrogen.
2- "	potassium.
3- "	phosphorus.
4- "	calcium.
5- "	magnesium.
6- "	manganese.
7- "	iron.
8- "	copper.
9- "	boron.
10- "	molybdenum.
11- "	aluminum.
12-Fruit	nitrogen.
13- "	potassium.
14- "	phosphorus.
15- "	calcium.
16- "	magnesium.
17- "	manganese.
18- "	iron.
19- "	copper.
20- "	boron.
21- "	molybdenum.
22- "	aluminum.

Table 24. Highly significant correlations between measurements made on Red Delicious , Jonathan and McIntosh trees on E.M. I rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented on the opposite page

COLUMN A	COLUMN B
1	-11, +12.
2	+ 3, + 9, +13, -16 , +20.
3	+ 2, - 6, + 9, -16, +20.
4	
5	+ 9, -11, -16.
6	- 3, -15.
7	+11, +18.
8	
9	+ 2, + 3, + 5, -16 , +20.
10	
11	- 1, - 5, + 7.
12	+ 1.
13	+ 2, +14, +20.
14	+13, +20.
15	- 6.
16	- 2, - 3, - 5, - 9, -20.
17	+18
18	+ 7, +17.
19	
20	+ 2, + 3, + 9, +13, +14, -16.
21	
22	

(1) Correlation coefficients significant (22 df)

(+) positive at 1% level.

(-) negative at 1% level.

Identification key for measurements shown on the opposite page.

1-Leaf nitrogen.
2- " potassium.
3- " phosphorus.
4- " calcium.
5- " magnesium.
6- " manganese.
7- " iron.
8- " copper.
9- " boron.
10- " molybdenum.
11- " aluminum.
12-Fruit nitrogen.
13- " potassium.
14- " phosphorus.
15- " calcium.
16- " magnesium.
17- " manganese.
18- " iron.
19- " copper.
20- " boron.
21- " molybdenum.
22- " aluminum.

Table 25. Highly significant correlations between measurements made on Red Delicious, Jonathan and McIntosh trees on EM II rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented on the opposite page.

COLUMN A	COLUMN B
1	+ 9, +12, +20.
2	+ 3, + 9, -11, +13, +14, -16.
3	+ 2, + 5, +14, -16.
4	+10.
5	+ 3, -11.
6	
7	+11, +16, +18.
8	+12, +18, +20.
9	+ 1, + 2, +14, +20.
10	+ 4.
11	- 2, - 5, + 7, -14, +16.
12	+ 1, + 8.
13	+ 2, +14.
14	+ 2, + 3, + 9, -11, +13.
15	+17, +21.
16	- 2, - 3, + 7, +11.
17	+15.
18	+ 7, + 8.
19	+22.
20	+ 1, + 8, + 9.
21	+15.
22	+19.

(1) Correlation coefficients significant (22 df)
(+) positive at 1% level.
(-) negative at 1% level.

Identification key for measurements shown on the opposite page.

1-Leaf	nitrogen.
2- "	potassium.
3- "	phosphorus.
4- "	calcium.
5- "	magnesium.
6- "	manganese.
7- "	iron.
8- "	copper.
9- "	boron.
10- "	molybdenum.
11- "	aluminum.
12-Fruit	nitrogen.
13- "	potassium.
14- "	phosphorus.
15- "	calcium.
16- "	magnesium.
17- "	manganese.
18- "	iron.
19- "	copper.
20- "	boron.
21- "	molybdenum.
22- "	aluminum.

Table 26. Highly significant correlations between measurements made on Red Delicious, Jonathan and McIntosh trees on EM V rootstocks. The measurements in column A are correlated with the measurements in column B as indicated(1). The key to the numbers is the same for both columns and is presented on the opposite page.

COLUMN A	COLUMN B
1	
2	+ 9, -18.
3	
4	+16, +22.
5	- 7, -18.
6	
7	- 5, +18.
8	
9	+ 2, -18, +20.
10	
11	+16.
12	+16, +17, +18, +19.
13	+14.
14	+13.
15	+17.
16	+ 4, +11, +12, +17, +18, +19, +22.
17	+12, +15, +16, +18, +19.
18	- 2, - 5, + 7, - 9, +12, +16, +17, +19.
19	+12, +16, +17, +18.
20	+ 9.
21	
22	

(1) Correlation coefficients significant (22 df)

(+) positive at 1% level.

(-) negative at 1% level.

Identification key for measurements shown on the opposite page.

1-	Leaf	nitrogen.
2-	"	potassium.
3-	"	phosphorus.
4-	"	calcium.
5-	"	magnesium.
6-	"	manganese.
7-	"	iron.
8-	"	copper.
9-	"	boron.
10-	"	molybdenum.
11-	"	aluminum.
12-	Fruit	nitrogen.
13-	"	potassium.
14-	"	phosphorus.
15-	"	calcium.
16-	"	magnesium.
17-	"	manganese.
18-	"	iron.
19-	"	copper.
20-	"	boron.
21-	"	molybdenum.
22-	"	aluminum.

Table 27. Highly significant correlations between measurements made on Red Delicious, Jonathan and McIntosh trees on EM VII rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented on the opposite page.

COLUMN A	COLUMN B
1	+ 2, + 6, -11, -18.
2	+ 1, + 6, -10, -11, -16, -18.
3	+ 5, -16, -22.
4	
5	+ 3, -15, -17, -18, -20.
6	+ 1, + 2, - 7, -11, -15, -17, -18.
7	- 6, +11, -19.
8	
9	-16, -19.
10	- 2.
11	- 1, - 2, - 6, + 7.
12	
13	+14, +19.
14	+13, +19.
15	- 5, - 6, +17, +20.
16	- 2, - 3, - 9, +17, +22.
17	- 5, - 6, +15, +16, +18.
18	- 1, - 2, - 5, - 6, +17.
19	- 7, -10, +13, +14.
20	- 5, +15.
21	
22	- 3, +16.

(1) Correlation coefficients significant (22 df)

(+) positive at 1% level.

(-) negative at 1% level.

Identification key for measurements shown on the opposite page.

1-Leaf	nitrogen.
2- "	potassium.
3- "	phosphorus.
4- "	calcium.
5- "	magnesium.
6- "	manganese.
7- "	iron.
8- "	copper.
9- "	boron.
10- "	molybdenum.
11- "	aluminum.
12-Fruit	nitrogen.
13- "	potassium.
14- "	phosphorus.
15- "	calcium.
16- "	magnesium.
17- "	manganese.
18- "	iron.
19- "	copper.
20- "	boron.
21- "	molybdenum.
22- "	aluminum.

Table 28. Highly significant correlations between measurements made on Red Delicious, Jonathan and McIntosh trees on EM XIII rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented on the opposite page.

COLUMN A	COLUMN B
1	+18.
2	+ 3, - 4, + 9, -10, +14, -16, -17, -18.
3	+ 2, + 9, +14, +20.
4	- 2, - 9, +10, +16, +17, +18.
5	
6	+22.
7	
8	
9	+ 2, + 3, - 4, +13, +14, -16, -17, -18, +20.
10	- 2, + 4, +16, +18.
11	-21.
12	
13	+ 9, +14.
14	+ 2, + 3, + 9, +13, +20.
15	+17, +19.
16	- 2, + 4, - 9, +10, +17, +18.
17	- 2, + 4, - 9, +15, +16, +19.
18	+ 1, - 2, + 4, - 9, +10, +16.
19	+15, +17, +22.
20	+ 3, + 9, +14.
21	-11.
22	+ 6, +19.

(1) Correlation coefficients significant (22 df)
(+) positive at 1% level.
(-) negative at 1% level.

Identification key for measurements shown on the opposite page.

1-Leaf	nitrogen.	
2-	"	potassium.
3-	"	phosphorus.
4-	"	calcium.
5-	"	magnesium.
6-	"	manganese.
7-	"	iron.
8-	"	copper.
9-	"	boron.
10-	"	molybdenum.
11-	"	aluminum.
12-Fruit	nitrogen.	
13-	"	potassium.
14-	"	phosphorus.
15-	"	calcium.
16-	"	magnesium.
17-	"	manganese.
18-	"	iron.
19-	"	copper.
20-	"	boron.
21-	"	molybdenum.
22-	"	aluminum.

Table 29. Highly significant correlations between measurements made on Red Delicious, Jonathan and McIntosh trees on M. XVI rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented on the opposite page.

COLUMN A	COLUMN B
1	+ 5, + 6, +10, -15, -16, -17.
2	+ 3, - 7, -11, +14, -16, -17, -18.
3	+ 2, +14, -16.
4	+10, +18.
5	+ 1, + 6.
6	+ 1, + 5, + 9, -15, -19.
7	- 2, +11.
8	
9	+ 6, +21.
10	+ 1, + 4.
11	- 2, + 7.
12	+16.
13	+14.
14	+ 2, + 3, +13.
15	- 1, - 6, +17.
16	- 1, - 2, - 3, +12, +17, +18, +19, +22.
17	- 1, - 2, +15, +16, +18.
18	- 2, + 4, +16, +17.
19	- 6, +16.
20	
21	+ 9.
22	+16.

(1) Correlation coefficients significant (22 df)

(+) positive at 1% level.

(-) negative at 1% level.

Leaf calcium showed a positive correlation with leaf molybdenum in EM II, XIII and XVI.

Leaf iron was correlated positively with leaf aluminum in EM I, II, VII and XVI, and with fruit iron in EM I, II and V.

Leaf boron showed a negative correlation with fruit magnesium in EM I, VII and XIII, and a positive correlation with fruit boron in EM I, II, V and XIII.

Fruit potassium and fruit phosphorus were correlated positively in all six rootstocks considered.

Fruit calcium and fruit manganese were correlated positively in EM II, V, VII, XIII and XVI.

Fruit magnesium was correlated positively with fruit manganese in EM V, VII, XIII and XVI, with fruit iron in EM V, XIII and XVI, and with fruit aluminum in EM V, VII and XVI.

Fruit manganese and fruit iron showed a positive correlation in EM I, V, VII and XVI.

In summary, Table 30 presents all highly significant correlations between determinations made on all three varieties grown on all six rootstocks.

Identification key for measurements shown on the opposite page.

1-	Leaf	nitrogen.
2-	"	potassium.
3-	"	phosphorus.
4-	"	calcium.
5-	"	magnesium.
6-	"	manganese.
7-	"	iron.
8-	"	copper.
9-	"	boron.
10-	"	molybdenum.
11-	"	aluminum.
12-	Fruit	nitrogen.
13-	"	potassium.
14-	"	phosphorus.
15-	"	calcium.
16-	"	magnesium.
17-	"	manganese.
18-	"	iron.
19-	"	copper.
20-	"	boron.
21-	"	molybdenum.
22-	"	aluminum.

Table 50. Highly significant correlations between measurements made on Red Delicious, Jonathan and McIntosh trees on EM. I, II, V, VII, XIII and XVI rootstocks. The measurements in column A are correlated with the measurements in column B as indicated (1). The key to the numbers is the same for both columns and is presented on the opposite page.

COLUMN A	COLUMN B
1	+ 2, + 5, + 9, -11, +12, -16, -22.
2	+ 1, + 3, - 7, + 9, -10, -11, +13, +14, -16, -17, -18 /-22
3	+ 1, + 2, -12, +14, -16, -17, +20, -22.
4	
5	- [illegible], -11, -17, -18, -22.
6	-15, -20.
7	- 2, - 5, + 8, +11, +17, +18.
8	+ 1, + 7, + 9, +18.
9	+ 1, + 2, + 3, + 6, +14, -16, -17, +20, +21, -22.
10	- 2, +16.
11	- 1, - 2, - 5, + 7, +16, +17, +18.
12	+ 1, - 3, +16, +17, +18, +19.
13	+ 2, +14, -22.
14	+ 2, + 3, + 9, +13, +19, +20.
15	- 6, +17, +18, +19, +21. [illegible]
16	- 1, - 2, - 3, - 9, +10, +11, +12, +17, +18, +19, -22
17	- 2, - 3, - 5, + 7, - 9, +11, +12, +15, +16, +18, +19
18	- 2, - 5, + 7, + 8, +11, +12, +1[illegible], +16, +17. /+21
19	+12, +14, +15, +16, +17, +22.
20	+ 3, - 6, + 9, +14, -16.
21	+ 9, +15, +17.
22	- 1, - 2, - 3, - 5, - 9, -13, +16, +19.

(1) Correlation coefficients significant (142 df)

(+) positive at 1% level.

(-) negative at 1% level.

DISCUSSION

Influence of rootstocks on leaf composition.

Nitrogen: In this study there were no significant differences between rootstocks in influencing leaf composition. Warne and Wallace (1935) and the East Malling report for 1959 (Anon. 1960) reported differences between rootstocks in affecting the nitrogen composition of the leaf. However, they did not indicate if their differences were significant. Kenworthy (1960) obtained significant differences between rootstocks in affecting leaf composition in Cortland trees, but not in McIntosh trees.

The reports on the influence of rootstocks on leaf nitrogen do not show a consistent arrangement of rootstocks with respect to their influence on leaf nitrogen. Also, this arrangement does not show a relation with the influence of rootstocks on the vigor of the tree. The results of the present study indicate that if rootstocks did have an influence on the nitrogen economy of the tree, their influence could not be detected by leaf analysis.

Thomas (1927) has shown that inorganic nitrogen is changed into amino acids in the roots of the apple tree. Beakbane (1953) reported that dwarfing rootstocks had a highly parenchymatous phloem and xylem and, therefore, contained more living tissue per unit volume of the roots than vigorous rootstocks. If these two factors have an influence on the nitrogen nutrition of the trees which is affected by rootstocks, leaf analysis failed to show it. However, this may be the result of the fact that the differences in vigor between the rootstocks under study was very slight and differences in nutrition could be masked by environmental variations. A carefully controlled experiment could show statistical differences between rootstocks in the nitrogen nutrition of the tree.

Potassium: Rootstocks influenced significantly the potassium composition of the scion leaves. The influence of rootstocks on potassium deficiency has been the most frequently reported rootstock-nutrient relation in clonal rootstocks. The results of this study are in general agreement with those obtained by Hatton and Grubb (1924), Wallace (1931), Warne and Wallace (1935), Bane (1939), Vaidva (1938), Hoblyn (1940-41), Roach (1947), and Kenworthy (1960).

Invariably, trees on EM V and II were reported to be the most susceptible to leaf scorch resulting from potassium deficiency, and at the same time the leaves on those trees had the lowest potassium content values. Rootstocks EM I, XIII and XVI were reported to have little or no susceptibility to leaf scorch.

In this study, trees on EM V and II had consistently the lowest leaf potassium values, trees on EM VII, XIII and XVI had intermediate values, and trees on EM I had the highest values. These differences were obtained in spite of the fact that the potassium available in the soil was relatively high (188 to 436 pounds per acre) and was about twice the optimum required for Michigan crops (McCall, 1960). In a situation where soil potassium values would be a limiting factor, differences between rootstocks could become more acute with respect to the development of potassium deficiency.

The range in leaf potassium values between trees on various rootstocks is relatively narrow in spite of the statistical differences obtained. This is an indication that in situations where soil potassium is relatively abundant, differences due to rootstocks would not have to be taken into consideration when using leaf composition values for diagnostic purposes.

Phosphorus: The results obtained with this element were in general agreement with those obtained by Warne and Wallace (1935), Vaidya (1938), Roach (1947) and Kenworthy (1960), with respect to the fact that there were differences between rootstocks in influencing the leaf content of this element. The results of this study agree with other workers in the fact that trees on the EM V and VII are usually reported as being high in leaf phosphorus.

The range in leaf composition values between trees high in phosphorus and trees low in phosphorus could be of importance if phosphorus nutrition was a problem in apple trees. However, tree responses to phosphorus applications have been very rare and this tends to minimize the importance of any leaf composition differences that could be attributed to rootstock influence.

Calcium: The fact that there were significant differences between rootstocks in affecting leaf calcium was in agreement with the findings of Warne and Wallace (1935), Vaidya (1938), Roach (1947) and Kenworthy (1960).

There is, however, considerable disagreement among research workers in arranging rootstocks with respect to their influence on leaf calcium.

This is probably the result of the influence of various environmental factors, such as soil type, which modify rootstock effects. The range in composition between the high and the low calcium values does not seem wide enough to justify the consideration of rootstock differences in using standard leaf composition values for diagnosing purposes.

Magnesium: Rootstocks had a significant influence on the magnesium content of the scion leaves. Trees on EM XVI were always the highest in leaf magnesium, and those on EM I were always the lowest. The range in magnesium composition between the high and the low values was very wide and trees on EM XVI were particularly high in this element.

Warne and Wallace (1935), Vaidya (1938), Hoblyn (1940-41), Roach (1947) and Kenworthy (1960) have also reported differences between rootstocks in affecting leaf magnesium. Again, there is some variation in the relative influence of individual rootstocks.

This study showed that trees on EM I and VII were those having the lowest leaf magnesium content and was in close agreement with Hoblyn's findings which indicated that trees on EM I and VII were highly susceptible to magnesium deficiency.

The relatively wide range in leaf magnesium found in this study indicates a possible need for further assessment of the influence of rootstocks on magnesium nutrition. If a consistent influence of rootstocks is established, this factor would have to be taken into consideration, conceivably a higher level of soil magnesium would be necessary for certain rootstocks to attain the desired level of magnesium nutrition as reflected by leaf analysis.

Manganese: This study showed that rootstocks had a significant effect upon influencing leaf manganese. Roach (1947) reported differences between rootstocks in this respect without reference as to their statistical significance.

In this work, trees on EM XIII had a much higher leaf manganese content than trees on all the other rootstocks. Trees on EM II were the lowest in leaf manganese. Again, the range in leaf composition for this element was relatively large and further study would be required in order to determine with more certainty the influence of rootstocks on leaf manganese.

Iron: Rootstocks affected, significantly, leaf iron only in 1959. Differences did not exist when the data for two years were considered. Roach (1947) and Kenworthy (1960) have reported previously similar findings.

In this study, trees on EM I and XVI were at the high and low ends of the composition range, respectively. The pH values of the soil ranged between 5.3 and 7.4 (McCall, 1960) and it is improbable that iron availability problems existed in that soil. Under conditions less favorable for iron availability in the soil, differences between rootstocks as related to iron nutrition could become more important.

As a result of a relatively wide variation in the leaf iron values between trees, the significance of the differences found in this study may not have a practical application at the present time.

Copper: Significant differences between rootstocks in affecting leaf copper were found only when the data from two years were considered. Bould *et al.* (1950) reported differences in susceptibility to copper deficiency that he attributed to rootstock influences. The absence of acute problems in copper nutrition together with the fact that the differences found in this work were very small do not allow any conclusions of practical value.

Boron: Rootstocks affected significantly leaf boron values only in 1959. When the data from two years were considered, the differences were non-existent. Kenworthy (1960) is the only worker who has determined differences between rootstocks in this respect. In this study, trees on EM V showed the highest leaf boron values. The fact that problems in boron nutrition are relatively rate in Michigan orchards would tend to limit the practical interest of these findings. However, the development of an acute problem along this line would warrant further research on the subject.

Zinc, molybdenum and aluminum: There were no significant differences between rootstocks in affecting the leaf content of these elements except in the case where four sampling dates were considered, and in that case the actual differences were not considered to be of great importance. Kenworthy (1960) is the only worker who has determined differences in leaf zinc that could be attributed to the influence of rootstocks. No reports are known on the effect of rootstocks on leaf molybdenum and aluminum. In areas where the nutrition of one of these elements is a problem, further research into the possible influence of rootstocks on the nutrition of these elements would be required.

General discussion: Rogers and Beakbane (1957) pointed out that the effect of a root system on the top of the tree could be accounted for by three postulated mechanisms: (1) differences in nutrient absorption and metabolism; (2) differences in transport; and (3) differences in auxin metabolism.

In this study, the influence of rootstocks on leaf composition was evaluated and was found to be in general agreement with the findings of other research workers. The causes of the rootstock effect was not a part of this study. Therefore, the influence of the mechanisms mentioned was not determined. The respective role played by each of these mechanisms in influencing leaf analysis could be the subject of further research studies.

It also is possible that, under less favorable nutrient conditions than those found in this study, the differences between rootstocks as affecting the nutrition of the tree could be greater.

The influence of rootstocks on leaf composition had little or no relation to the relative vigor of the rootstocks studied. It should be remembered that the differences in vigor between the rootstocks considered were very slight and only very gradual variations in leaf composition would be expected.

On the basis of the present study, it is difficult to see an immediate need for any modification of the standard composition values, as used for diagnostic purposes, to account for rootstock differences.

In some instances, the knowledge of the presence of a rootstock particularly susceptible to inducing relatively high or low nutrient levels, could lead to the application of appropriate corrective measures. However, leaf analysis should reflect the need for the corrective measures although soil tests or analysis might indicate an adequate supply of the element in question.

Influences of rootstock on fruit composition.

In this study there were significant differences between rootstocks in affecting the potassium, copper, boron, zinc and aluminum composition of the fruit. These results were in general agreement with the findings of other workers in that differences in fruit composition could be attributed to root-stock influences. However, where some differences existed, they were either non-significant or too small to be of practical value. In the case of boron and zinc, however, the range in composition between the high and the low values is relatively wide.

Another observation made in this study was that, in the case of several elements, the rootstock which induced the highest and the lowest leaf composition values also induced the highest and the lowest fruit composition values, respectively. This is an indication that the general nutrient level of the tree was particularly high or low in such cases.

Influence of rootstock on storage quality.

Red Delicious: The influence of rootstocks on the soluble solids content of the fruit, although significant, was too small to be of practical importance.

Rootstocks also had a significant effect on the percent of the fruit affected by storage scald. Fruit from trees on EM V were the lowest and fruit from trees on EM I and II were the highest in storage scald.

Savage (1941) and Smock and Boynton (1944) reported reduced scald incidence in McIntosh with nitrogen applications. Kidd and West (1938) found that apples growing in potassium deficient soil were less susceptible to storage scald. Batjer and Haller (1942) reported that the addition of Borax to a soil not particularly low in boron reduced scald in Red Delicious apples. The effects of potassium and boron were attributed to advanced maturity of the fruit at picking time.

During the 1959 season, trees on EM V were the highest in leaf nitrogen and boron and the lowest in leaf potassium. Fruit from trees on EM V showed relatively high nitrogen and very high boron content and relatively low potassium content.

The reduction in storage scald may be attributed to one or a combination of these nutrient factors as affected by the EM V rootstock. The most important factor seems to be, however, the high boron level in the leaves and particularly in the fruit. This effect may be a direct one or an indirect one through advanced maturity of the fruit. Further investigation of these influences may help in clarifying the effect of EM V on storage scald.

Jonathan: Rootstocks had a significant but small influence on the flesh firmness of the fruit. Rootstocks also had an appreciable influence on the incidence of fruit russeting. Trees on EM XIII and XVI had relatively low percentages of russeted fruit.

Mitchell (1960) found that there was an inverse relation between the vigor of the tree and the percent of the fruit affected by russeting. His findings are in close agreement with the results of this study, since the fruit from trees on the most vigorous rootstocks, EM XIII and XVI, showed the lowest russeting incidence.

The negative correlation found between leaf magnesium and fruit russeting may have a close relation with the previous findings. Boynton (1954) indicated that trees showing magnesium deficiency were very sensitive to spray injury. In this study, trees on EM XIII and XVI had the highest leaf magnesium values and the lowest incidence of fruit russeting.

McIntosh: Rootstocks had no significant influence on any of the storage measurements considered. It is to be noted that the rootstock effect on storage scald observed in Red Delicious was not evident for McIntosh.

General discussion: Under various conditions, rootstocks have been reported to influence the susceptibility of the fruit to several storage disorders. However, in the present study, differences in leaf and fruit composition as affected by rootstock, had little influence on the storage quality of the fruit, except for the few cases already mentioned. The incidence of storage disorders, with the exception of storage scald, was not particularly high during the 1959-1960 storage season. In a season in which the incidence of such disorders would be very high, rootstock effects could be of wider significance. This possibility, however, would require further investigation.

Influence of varieties on leaf composition.

The fact that varieties had a significant influence on leaf composition is in general agreement with the results obtained by other workers. There was, however, some variation as to the relative position of some varieties in the leaf composition range for certain elements. This probably resulted from differences in environmental factors and the fact that this study was conducted exclusively on clonal rootstocks. Whereas, almost all other reports on the subject were based on varieties growing on seedling rootstocks.

The differences between varieties with respect to leaf nitrogen, although significant, were not large enough to be of diagnostic concern.

When leaf potassium was considered, the differences between varieties became quite important. In every case, Red Delicious and Northern Spy leaves were much higher in potassium than leaves from Jonathan and McIntosh trees. Since the soil had an abundant supply of potassium, the ability of Red Delicious and Northern Spy trees to accumulate more potassium in the leaves, does not necessarily alter standard values for diagnosing purposes, but may be the result of luxury consumption. Possibly, the soil supply of potassium need not be as high for varieties such as Red Delicious and Northern Spy as for varieties such as McIntosh and Jonathan.

In the case of phosphorus, Delicious and Northern Spy leaves were again the highest in phosphorus content. Due to the fact that phosphorus has rarely been a problem in apple tree nutrition, the practical significance of these differences cannot be evaluated at the present time.

The differences between the leaf calcium content of the different varieties, although significant, were relatively small. In this study, Jonathan and McIntosh leaves had the highest calcium content. In the case of magnesium, Delicious had the highest leaf content of this element. The differences in leaf magnesium among the different varieties were not large enough to be of immediate concern.

Among the five major elements just mentioned, Red Delicious and Northern Spy leaves very frequently showed the highest leaf composition values. When the seven minor elements were considered, Delicious and Jonathan dominated the higher nutrient values. McIntosh leaves were, in general, medium to low in nutrient element composition as compared with the other three varieties. Therefore, Red Delicious can be considered to be a variety with a relatively high nutritional level, Northern Spy and Jonathan would be intermediate, and McIntosh would be intermediate to low in nutrient element composition.

Further investigation is needed to ascertain whether the characteristic high or low levels for various elements in a variety are indicative of a nutrient requirement, or are only the result of luxury comsumption without significance as regards quality and size of the crop.

Influence of varieties on fruit composition.

There were significant but small differences between varieties with respect to fruit composition for all elements with the exception of molybdenum.

Jonathan fruit was relatively high in nutrient content for several elements. This may have been due, in part, to the relatively small size of the fruit harvested in 1959. Jonathan fruit was particularly high in iron content. This was probably due to the relatively high iron nutrition level of the trees which was also reflected in the high iron content of Jonathan leaves.

Delicious fruit was relatively high in boron and was parallel with the high boron level of Delicious leaves. Finally, McIntosh fruit was relatively high in zinc and aluminum. McIntosh leaves were high in aluminum, but not in zinc. Another point to be noted is that on a percent dry weight basis, the fruit was higher in boron content than the leaves. For phosphorus, copper and zinc, both leaves and fruit had comparable values.

The previous examples indicate that varieties showing a high level of a given nutrient in the leaves, also showed a parallel high level in the fruit for the same element. The frequent occurrence of this parallelism between leaves and fruit indicates that high and low nutritional levels in the tree are frequently reflected in both the leaves and the fruit.

Influence of sampling dates on leaf composition.

The results of this study are in general agreement with the findings reported by other research workers. The leaf content of nitrogen, potassium, phosphorus and boron, decreased from the first to the last sampling date in an orderly manner. Leaf calcium and aluminum increased as the season progressed. Leaf magnesium and manganese showed little variation.

This is probably one of the rare times in which the seasonal variation in leaf copper, boron, zinc and molybdenum has been reported for apples. Askew et al. (1936) reported a downward trend in fruit boron as the season advanced.

This study shows that the sampling of tree leaves for nutrient diagnosis can be done at the same time period used for trees growing on seedling rootstocks and for trees growing on clonal rootstocks. Clonal rootstocks did not appear to exert any particular influence on the seasonal trend, of the elements considered, that was different from seedling rootstocks.

Influence of storage treatments on storage observations on the fruit.

Red Delicious:

(1) Soluble solids: The increase in the soluble solids content of the fruit during storage was due to the hydrolysis of starch and other fruit constituents to sugars.

(2) Flesh firmness: The decrease in flesh firmness during storage was also expected. The fact that the decrease in flesh firmness in CA storage was greater than in regular storage is difficult to explain. The difference between regular and CA storage was, however, relatively small and should be of little concern.

(3) Storage scald: The control of this disorder in Red Delicious by CA storage has not been very successful. The findings of this study are similar to those reported by Smock (1958).

Jonathan:

(1) Soluble solids: There was a significant decrease in soluble solids during storage. The decline was relatively small and was probably the result of a net loss of sugars as a result of respiratory activity in the fruit.

(2) Flesh firmness: Flesh firmness decreased during storage as was expected. The decrease was greater in regular storage and was probably the result of higher respiration and trans-

piration rates in this type of storage. Similar results were reported by Dewey et al. (1958) and Bünemann et al. (1959).

(3) Ground color: The ground color of the fruit became more yellow during storage. Fruit from regular storage showed a greater change in that direction than fruit from CA storage. This was expected in view of the faster ripening occurring in regular storage. Bünemann et al. (1959) reported comparable results.

(4) Jonathan spot: CA storage resulted in almost absolute control of this disorder. This result was in agreement with the findings of Plagge (1942), Ballinger (1955), Dewey et al. (1957), and Bünemann et al. (1959).

(5) Soft scald: There was a small difference between the incidence of this disorder in regular and CA storage. The fact that this is a low temperature disorder and that regular storage was maintained at 32° F indicate that the low soft scald incidence may be the result of a low occurrence of the disorder in the 1959 season. Dewey et al. (1957) found that CA storage inhibited soft scald in Jonathan apples.

McIntosh:

(1) Soluble solids: The small increase in soluble solids during storage indicates a slight ripening activity of the fruit.

(2) Flesh firmness: There was, as expected, a considerable decrease in the flesh firmness in both types of storage. No advantage of CA over regular storage was noted in this respect.

(3) Ground color: The change in ground color from green to yellow was very slight in both regular and CA storage and reflected a slight ripening of the fruit.

(4) Storage scald: The incidence of this disorder was low when the fruit was removed from both regular and CA storage. However, when the fruit was exposed to 75° F for seven days, there was no further increase in scald in the fruit from CA storage, whereas the fruit from regular storage was seriously affected. Smock (1958) has shown that scald was reduced greatly and sometimes prevented by CA storage. Also the extended life of apples from CA storage has been reported by Kidd and West (1936), Allen and Smock (1938) and Smock (1958).

(5) Brown core: This disorder was completely prevented by CA storage at 38° F. CA storage also resulted in an extended shelf life of the fruit when placed at 75° F for seven days. Smock (1958) reported similar results.

(6) Mealy breakdown: The incidence of this disorder was prevented by both regular and CA storage. Moreover, CA storage resulted in an extended shelf life of the fruit when placed at 75° F

for seven days. Comparable findings have been reported by Blanpied (1959).

General discussion: From the previous discussion, it can be concluded that so far as the results of this study can show, fruit from trees on clonal rootstocks will respond to storage treatments in a similar way as fruit from trees on seedling rootstocks.

Correlation studies.

Leaf nitrogen was correlated negatively with leaf aluminum in two out of three varieties, but only in two out of six rootstocks. This is probably the first time that such relation has been presented and the significance of this finding cannot be evaluated at the present time.

Leaf nitrogen was correlated positively with fruit nitrogen in two out of three varieties, and in two out of six rootstocks. A similar finding was reported by Bünemann (1958). This result shows that nitrogen levels in the tree are often reflected in both leaves and fruit.

A positive correlation occurred between fruit nitrogen and fruit magnesium in two out of three varieties. This relation has not been reported before and no explanation can be offered for its occurrence.

The negative correlation found between leaf nitrogen and the flesh firmness of the fruit at harvest and after storage in all three varieties was in agreement with the results of Smock and Boynton (1944), Weeks et al. (1952), Collins (1957), and Bünemann (1958).

Along a similar line is the negative relation between fruit nitrogen and the flesh firmness of the fruit before and after storage in two out of three varieties. Bünemann (1958) reported a similar finding.

Leaf and fruit nitrogen were correlated negatively with the incidence of storage scald in McIntosh fruit from regular storage kept for seven days at 75° F. Smock and Boynton (1944) indicated that large nitrogen applications may reduce the incidence of storage scald. However, as a result of the generally accepted negative relationship between high nitrogen levels and general storage quality, the practical use of the previous finding appears to be limited in scope.

The positive correlation between leaf nitrogen and the incidence of scald in McIntosh fruit from CA storage kept for seven days at 75° F, although in the opposite direction of the previously reported relation, is not very meaningful in view of the very low scald incidence in the fruit subjected to that treatment.

The positive relation between fruit nitrogen and the ground color score of Jonathan fruit was probably due to the slight delay in maturity resulting from a higher nitrogen level in the tree.

The positive relation between fruit nitrogen and the incidence of brown core after regular storage was closely related to a similar relation between brown core and the soluble solids content and the flesh firmness of the fruit. This relation will be discussed later in the text.

Other correlations between leaf or fruit nitrogen and other observations reported by various research workers did not occur consistently in this study.

Leaf potassium was correlated positively with leaf phosphorus in four out of six rootstocks and with fruit phosphorus in three out of six rootstocks. This relation has rarely been reported and its occurrence may be the result of a rootstock effect, since the relation occurred only when individual rootstocks were considered and did not occur when individual varieties were studied.

The positive relation between leaf and fruit potassium had been reported before by Bunemann (1958) and was evident in this study in two out of three varieties and in all six rootstocks. This relation revealed the close parallelism existing between leaf and fruit in reflecting the potassium levels in the tree.

Leaf potassium was correlated positively with leaf boron in four of the six rootstocks. This relation apparently has not been reported before and may be the result of a rootstock effect. A similar idea can apply to the negative relation between leaf potassium and leaf aluminum which occurred in three out of six rootstocks.

The negative relation between leaf potassium and fruit magnesium in four out of six rootstocks is closely linked with the findings of other workers. Boynton and Compton (1945), Cain (1953a), and Eaves and Kelsal (1954) have reported a negative relation between leaf potassium and magnesium. The positive relation between fruit potassium and magnesium was not in line with the previous findings. Wilkinson (1958) reported a similar relation and suggested that high potassium fruits may draw magnesium from the leaves.

The negative correlation between leaf potassium and fruit iron has not been reported before and cannot be explained on the basis of this study.

A positive relation between leaf and fruit phosphorus was found in two out of three varieties and in three out of six rootstocks. This relation revealed the interdependence of leaves and fruit with the nutritional level of the tree. Similar results were reported by Bünemann (1958).

The negative relation between leaf phosphorus and fruit magnesium occurred in four out of six rootstocks and may be due to a rootstock effect. Previous reports on the occurrence of this relation could not be found.

Fruit phosphorus was correlated positively with leaf copper and boron in two out of three varieties. Kenworthy and Harris (1960) reported a similar relation between phosphorus and boron, but a negative relation between phosphorus and copper.

The positive correlation between leaf phosphorus and the flesh firmness of the fruit at harvest and after storage has not been reported before and its implications are not apparent at this time.

A positive correlation between leaf calcium and leaf molybdenum occurred in two of the three varieties and in three out of six rootstocks.

There was also a similar relation between fruit calcium and molybdenum in all three varieties. These relations apparently have not been reported before. A reason for this interaction may be found in the soil where increased molybdenum availability occurs at higher pH values.

The positive relation found between fruit calcium and manganese in all three varieties and in five out of six rootstocks, has been reported previously by Kenworthy and Harris (1960).

The positive correlations which existed in McIntosh between leaf calcium and the ground color scores and the incidence of brown core cannot be explained at the present time.

A positive correlation between fruit magnesium and manganese was found in four out of six rootstocks. The same relation has been reported before by Kenworthy and Harris (1960). A similar relation occurred between fruit magnesium and iron and between fruit magnesium and aluminum in three out of six rootstocks. Comparable relationships have not been reported elsewhere.

A positive correlation between leaf magnesium and the percent soluble solids occurred in Red Delicious, but the relation was reversed in Jonathan. Fruit magnesium was correlated positively with the percent of scald found in Red Delicious after CA storage. No explanation can be offered for these findings.

The positive relation between leaf manganese and fruit copper in Red

Delicious was reversed in Jonathan. Here again, these results cannot be explained.

Leaf iron was correlated positively with leaf aluminum in all three varieties and in four out of six rootstocks. This is probably the first time such relation is reported. The close relation between iron and aluminum may be explained on the basis of simultaneous soil availability, a related uptake and translocation or a combination of these factors.

There was a positive correlation between leaf and fruit iron. This result shows again that both the leaf and the fruit can reflect variations in nutrient conditions in the tree for certain elements.

Fruit iron and manganese were correlated positively in two out of three varieties and in four out of six rootstocks. This result shows that although these two elements have been found to be antagonistic by Sommers and Shive (1942), a positive relation can still occur in certain parts of the plant.

The positive relation between leaf and fruit boron occurred with all three varieties, and with four out of six rootstocks. This, once more, reflects the close relation between the nutrient content of both leaves and fruit.

Leaf boron was correlated negatively with leaf magnesium in two out of three varieties, and with fruit magnesium in three out of six rootstocks. Negative relationships between boron and calcium have been reported, but apparently none so far between boron and magnesium in apples. Merrill _et al._

(1957) corrected toxic symptoms resulting from high boron in tung leaves by increasing the magnesium level in the leaves.

The negative relation between leaf boron and the soluble solids content of the fruit at harvest in two out of three varieties may be explained by a delay in maturity resulting from lower boron levels. Batjer and Haller (1942) reported that borax applications advanced the maturity of the fruit. The opposite influence of low boron levels may also be valid in explaining the previous relation.

The negative relation between leaf boron and the ground color score of Jonathan fruit indicates that the higher boron levels were associated with increased yellowing of the ground color of the fruit. Haller and Batjer (1946) noted that the change from green to yellow ground color was hastened on trees receiving heavy boron applications. This relation may be linked closely to that mentioned in the previous paragraph.

A positive correlation between fruit boron and the incidence of brown core after regular storage was determined but could not be related to the findings of other workers. The influence of the boron level on fruit maturity may have a relation to the incidence of brown core, but this possibility requires further study.

Further study would also be required to elucidate the reasons for the occurrence of a negative relation between fruit copper and the ground color score of the fruit, the positive relation between leaf molybdenum and the incidence of scald in Red Delicious after CA storage and the positive relation between fruit molybdenum and the incidence of fruit russeting found after regular storage.

The positive correlations between the percent soluble solids at harvest and after storage and the flesh firmness at harvest and after storage were in agreement with the findings of Bünemann (1958) among other workers. These relationships show that variation in the soluble solids content and the flesh firmness of the fruit after storage can be predicted at harvest. The relation between soluble solids and the flesh firmness points out the interdependence of both factors in their contribution to the storage quality of the fruit.

The negative relation found between the soluble solids content and the ground color of Jonathan and McIntosh fruit is an indication that fruit with a more yellow ground color is, in general, at a more advanced stage of maturity and shows a higher soluble solids content.

A negative relation between the flesh firmness and the ground color score of the fruit was determined in McIntosh and showed that increased yellowing of the ground color was associated with increased fruit firmness when these determinations were made after storage. The fact that this relation occurred only in McIntosh showed that the relation between soluble solids and flesh firmness is more direct and important than the relation between ground color and either soluble solids or flesh firmness.

The positive correlation between the ground color scores of the fruit at harvest and after storage was reported also by Bünemann (1958) and others and indicates the close relation between the harvest and post-storage condition of the fruit.

In Jonathan, there was a positive correlation between the incidence of fruit russeting and the soluble solids and the flesh firmness of the fruit. These relations have not been reported elsewhere and nothing is known as to the reasons for their occurrence.

The positive relation between the incidence of brown core after regular storage and fruit nitrogen and the negative relations between brown core after regular storage and the soluble solids content and the flesh firmness of the fruit at harvest and after storage indicate that a lower incidence of brown core may be associated with a more advanced degree of maturity of the fruit at harvest. The opposite, however, could also be possible.

The positive relation between the incidence of storage scald in Red Delicious after regular and after CA storage also shows a predisposition of the fruit to this disorder when the fruit was placed in storage.

In McIntosh, the positive relation between the incidence of storage scald after regular and CA storage and the incidence of the same disorder after the fruit from both types of storage was held for seven days at 75°F indicates that that fruit susceptible to the disorder showed their susceptibility in almost every treatment. The same idea applies when we note the positive correlation between the incidence of brown core after regular and CA storage.

In Jonathan, the positive correlation between the incidence of soft scald after regular storage and the ground color score of the fruit after CA storage cannot be explained.

Finally, the positive correlation between the incidence of Jonathan spot and the incidence of fruit russeting indicate that common factors may or may not be related in affecting the susceptibility of the fruit to both disorders.

General discussion: The occurrence of the previous correlations shows that many of the relations found in trees growing on seedling rootstocks are also valid for trees growing on clonal rootstocks. Among the new relations reported, some may be the result of local environmental conditions. The discovery of other relations was made possible by the use of faster and more complete methods of element analysis and by the use of faster tools for statistical analysis. Finally, the particular use of clonal rootstocks is probably responsible for the occurrence of some of the relations not previously reported elsewhere.

SUMMARY

The influence of East Malling rootstocks, varieties and other related variables on the leaf and fruit composition of apple trees were evaluated in this study. The influence of rootstocks and storage treatments on the storage quality of the fruit was another aspect of the evaluation of the EM rootstocks represented in this study.

The rootstocks studied were EM I, II, V, VII, XIII and XVI. The varieties grown on these rootstocks were Northern Spy, Red Delicious, Jonathan and McIntosh. Leaf samples were taken five times at two-week intervals in 1959, and once (mid-July) in 1960. Fruit samples were taken at harvest in 1959 and placed in regular and CA storage.

The elements determined in the leaves and fruit were nitrogen, potassium, phosphorus, calcium, magnesium, manganese, iron, copper, boron, zinc, molybdenum and aluminum. Pre-storage observations made on the fruit were soluble solids and flesh firmness in all varieties and ground color in Jonathan and McIntosh only. Fruit of the Northern Spy variety were not available for nutrient composition and storage studies.

At the end of the storage period, flesh firmness and soluble solids determinations were made on all varieties. Storage scald, brown core and internal breakdown were determined on Red Delicious fruit. Ground color, soft scald, Jonathan spot and russeting were determined on Jonathan fruit. Ground color, storage scald, brown core and mealy breakdown were determined on McIntosh fruit.

Results obtained were as follows:

1. The influence of EM rootstocks on leaf composition was evaluated first in this study. Significant differences between rootstocks in affecting leaf composition were obtained for every element determined with the exception of nitrogen. The significant differences, however, were not large enough to require a change in standard leaf composition values, as used for diagnostic purposes, to account for rootstock differences.

2. The influence of EM rootstocks on fruit composition was evaluated next in this study. Where significant differences between rootstocks were obtained, they were relatively small, with the exception of fruit boron and zinc, which showed a wider composition range as related to rootstocks. In general, the rootstocks which induced the high and the low leaf composition levels also induced the high and the low fruit composition levels.

3. The influence of varieties on leaf composition was determined. Varieties were found to affect, significantly, leaf composition values for all the elements considered. Differences between varieties were particularly wide for leaf potassium. If leaf composition for all elements is considered, Red Delicious would be a variety with a relatively high nutrient level, Northern Spy and Jonathan would be intermediate and McIntosh would be intermediate to low in this respect.

It is not known whether characteristic high or low levels are related to differences in nutrient requirements or a result of luxury consumption in the case of high levels. The differences obtained between varieties in affecting leaf composition were not large enough to indicate a need for a change in standard leaf composition values as used for diagnostic purposes.

4. The influence of variety on fruit composition was studied. Differences between varieties were significant in this relation for all elements with the exception of molybdenum. The actual differences were small with the exception of Jonathan fruit, which was particularly high in iron, Red Delicious fruit, which was high in boron and McIntosh fruit, which was high in zinc and aluminum. There was a frequent parallelism between high and low nutrient levels in the leaves and in the fruit.

5. The seasonal variation of nutrient elements in leaves was determined. Leaf nitrogen, potassium, phosphorus and boron showed a decline and leaf calcium and aluminum showed an increase from the first to the last sampling date. Leaf magnesium and manganese showed little variation. The other leaf elements considered showed no definite seasonal trends. These seasonal trends were similar to those reported for leaves from trees on seedling rootstocks.

6. The influence of EM rootstocks on storage quality was assessed. Fruit from Red Delicious on EM V showed the lowest incidence of storage scald. Fruit from Jonathan on the vigorous EM XIII and XVI

rootstocks showed the lowest incidence of fruit russeting. Rootstocks had little or no influence on the incidence of the other disorders considered.

7. The influence of storage treatments on storage quality was evaluated. Fruit from trees on clonal rootstocks responded to storage treatments in a similar manner to fruit from trees on seedling rootstocks.

8. Highly significant correlations between measurements made on leaves and fruit were determined. Some of the relations obtained were similar to those reported previously for trees on seedling rootstocks. Other correlations are reported here for the first time.

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