

THE RELATION OF THE NUTRIENT ELEMENT CONTENT OF THE
LEAVES AND FRUITS TO THE STORAGE QUALITY OF
JONATHAN APPLES IN REGULAR AND
CONTROLLED ATMOSPHERES

By
GERHARD BÜNEMANN

AN ABSTRACT

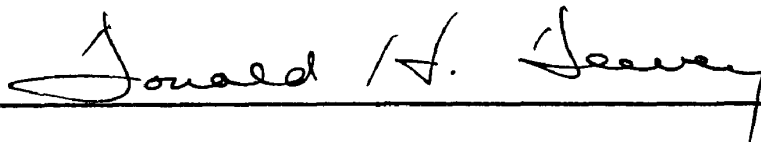
Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and Applied
Science in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

1958

Approved



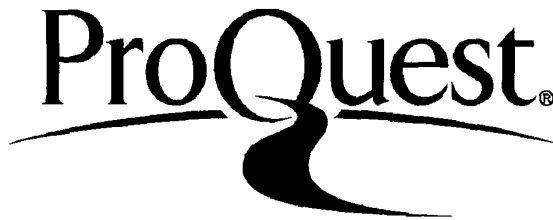
ProQuest Number: 10008566

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



ProQuest 10008566

Published by ProQuest LLC (2016). Copyright of the Dissertation is held by the Author.

All rights reserved.

This work is protected against unauthorized copying under Title 17, United States Code
Microform Edition © ProQuest LLC.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

A survey was conducted on 16 fruit farms in Kent county, Michigan, to investigate the effects of mineral nutrient levels on the storage quality of Jonathan apples in regular refrigerated storage and in controlled atmosphere storage.

Comparative lots of fruit from individual trees were held at 35-36° F. in regular storage and at 32° F., 2.5% CO₂ and 3% O₂ in controlled atmosphere storage. Fruit observations before storage (in October), after regular storage (in March), and after controlled atmosphere storage (in May) included flesh firmness, ground color, breakdown development, Jonathan spot and related epidermal disorders. Respiratory activity was determined at each of these examination periods for the apples of 6 orchards in 1956 and 5 orchards in 1957.

Methods for obtaining well-dried, non-caking and non-caramelized dry matter of mature fruits were devised. The complexometric determination with ethylene diamine tetraacetic acid (EDTA) was satisfactorily adapted for measuring the calcium content of the fruit tissue.

The survey showed that the selected orchards received essentially similar spray programs, but varied in age of the trees and in soil management and fertilizer practices. Leaf analyses gave a reliable basis for the description of the nutritional status of the orchards with respect to nitrogen, phosphorus, potassium, calcium, magnesium and manganese. The fruit analyses data were used for comparison with quality changes in the fruit during storage.

Foliar applications of calcium nitrate in 1957 on selected trees increased the calcium content of the fruit and had a slight effect upon the formation of a darker ground color. They did not affect the storage quality of the fruit.

The firmness of the fruit tissue was decreased with an increased nitrogen content of the fruit to the extent that a highly significant correlation existed. Magnesium was of similar effect in 1957, but not in 1956. Leaf nitrogen was negatively correlated with firmness in many cases. Flesh firmness at harvest gave no indication of breakdown which subsequently occurred during storage.

The soluble solids content of the expressed juice of the fruits was lowest at the highest nitrogen levels. There was a highly significant positive correlation of soluble solids to the incidence of water core in the fruit.

The respiratory activity of the fruit was generally uniform with the exception of the two orchards in which a high incidence of breakdown was observed in 1957. The potassium level in the leaves and fruits of the trees in these orchards was low.

Certain trees produced fruit susceptible to breakdown in 1957 which appeared consistently in both regular and controlled atmosphere storage, as well as in subsequent holding tests. Although primarily associated with large fruit size, it occurred in apples of all sizes.

Jonathan spot did not occur with equal intensity on the same trees in both years. No relation to nutritional factors was discovered. A closely related epidermal disorder, previously

believed to be controlled atmosphere storage injury, was found on fruit in regular storage. It was not prevented by controlled atmosphere storage.

The survey led to the conclusion that mineral analyses of the fruit can be a valuable supplement to the leaf analyses when the storage behavior of apples is studied.

THE RELATION OF THE NUTRIENT ELEMENT CONTENT OF THE
LEAVES AND FRUITS TO THE STORAGE QUALITY OF
JONATHAN APPLES IN REGULAR AND
CONTROLLED ATMOSPHERES

By

GERHARD BUNEMANN

A THESIS

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and Applied
Science in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

1958

ACKNOWLEDGMENTS

The author expresses his appreciation for the encouragement of Dr. H. B. Tukey, head of the Department of Horticulture, and extends his sincere gratitude to Dr. D. H. Dewey and Dr. A. L. Kenworthy for their constant aid, encouragement and guidance throughout this study.

The writer is also greatly indebted to Dr. E. J. Benne, Mr. S. T. Bass, and staff of the Department of Agricultural Chemistry for carrying out chemical and spectrographical analyses on leaf and fruit samples, and for their assistance in adapting the EDTA method for calcium analysis in fruit tissue; and to Dr. H. C. Beeskow for assistance in editing the manuscript and for his services on the guidance committee.

Grateful acknowledgment is accorded the following Michigan apple growers, whose cooperation made these experiments possible: Vernon Bull, Carol and Herrick Chase, John Coffee, Clarence Crawford, Ellis Gilson, Mark and Bennett Hersey, Lloyd Hill, Erwin Klenk, George Kober, Merlin Kraft, Carl May, Carl Momber, Wilbur Reister, Arnold Schaefer, Sr., Arnold Schaefer, Jr., and William and John Schaefer.

TABLE OF CONTENTS

	Page
INTRODUCTION.	1
REVIEW OF LITERATURE.	3
METHODS AND MATERIALS	16
Procedure of the survey and storage operation.	16
Leaf and fruit analyses.	25
Fruit firmness	30
Ground color	30
Soluble solids	31
Respiration	31
Storage disorders	32
Breakdown	32
Jonathan spot	32
Statistical	33
RESULTS	35
Leaf and fruit analyses	35
Survey and storage operation	41
Fruit firmness	46
Ground color	48
Storage disorders.	51
Breakdown	51
Jonathan spot	55
Respiration	57
DISCUSSION	62
SUMMARY AND CONCLUSIONS	71
LITERATURE CITED.	75
APPENDIX	82

LIST OF TABLES

TABLE	PAGE
1. Age, source of nursery stock, and planting distance of trees in experimental plots.	17
2. Soil management and fertilizer practices in experimental orchards	18
3. Spray materials used in experimental orchards	20
4. The average leaf composition values in 1956 and 1957, compared with the standard values used for the nutrient element balance chart.	35
5. Correlations of the leaf analyses of 1956 and 1957 for the individual elements (17 orchards)	36
6. Correlations of the leaf content at midseason with the fruit content at harvest and after controlled atmosphere storage, and of the fruit analyses before and after storage. 18 samples 1956	37
7. Correlations of the nutrient contents of leaves, immature and mature fruit	38
8. Calcium content of immature fruit harvested prior to the calcium nitrate applications; 1957.	39
9. Effects of calcium nitrate treatments upon the calcium, magnesium, and nitrogen content of mature fruits; 1957	40
10. Correlation of the calcium content of immature and mature fruit; 1957.	40
11. Correlations between the pressure test readings at harvest, after regular storage, and after controlled atmosphere storage.	46
12. Correlations between fruit flesh firmness and nutrient element contents of fruits and leaves. . .	47
13. Correlations between the ground color values at harvest, after regular storage, and after controlled atmosphere storage.	49
14. The effect of three spray applications of calcium nitrate on the average ground color of the fruit; 1957	49

LIST OF TABLES--Continued

TABLE		PAGE
15.	Correlations between fruit soluble solids and water core, firmness, and nutrient element levels. . . .	50
16.	The effect of calcium nitrate sprays upon the soluble solids level; 1957	51
17.	Example for the predisposition of the fruit to breakdown; 1957	52
18.	Comparison of the soluble solids content at harvest and the development of internal breakdown in storage; 1957.	52
19.	Breakdown susceptibility compared to size, water core, firmness, and nutrient levels; 1957.	53
20.	Comparison of the $\frac{Mg}{Ca}$ ratios of the fruit with the incidence of breakdown; 1957	54
21.	Classification of the orchards according to the severeness of Jonathan spot and skin browning in 1956 and 1957.	55
22.	The relation of fruit and leaf potassium content to fruit respiration at harvest and to breakdown in storage	57

LIST OF FIGURES

FIGURE	PAGE
1. Storage operation in 1956-57 (first season). Weekly averages of atmosphere composition and fruit temperatures at thermocouples no. 5 and no. 6.	42
2. Storage operation in 1957-58 (second season). Weekly averages of atmosphere composition and fruit temperatures at thermocouples no. 5 and no. 6.	44
3. Respiration of apples from orchard 16 (approximately normal potassium level) and orchard 4 (low potassium level) at harvest and following regular and controlled atmosphere storage	59
4. Respiration of apples from orchard 3 (approximately normal potassium level) and orchard 4 (low potassium level) at harvest and following regular and controlled atmosphere storage	61

LIST OF APPENDIX TABLES

TABLE	PAGE
1. Leaf analyses. Orchard averages, 1956.	83
2. Leaf analyses. Orchard averages, 1957.	84
3. Element balance chart indexes for 1956 and 1957 leaf analyses	85
4. Apple fruit analyses. Orchard averages, 1956	86
5. Apple fruit analyses at harvest. Orchard averages, 1957	87
6. Immature fruit analyses. Orchard averages, 1957. . . .	88
7. Calcium analyses (complexometric titration) of immature and mature fruit; 1957	89
8. Controlled atmosphere storage data; 1956-57 and 1957-58	91
9. Fruit firmness expressed as average pressure readings on the Magness-Taylor pressure tester in pounds. . .	93
10. Ground color. Orchard averages	96
11. Respiration measured at 75° F. as mg CO ₂ evolved per kg fruit per hour; 1956.	97
12. Respiration measured at 75° F. as mg CO ₂ evolved per kg fruit per hour; 1957.	98
13. Breakdown development in storage, 1956 and 1957, and in holding tests, in 1957.	99
14. Observations and analytical data grouped according to the incidence of breakdown; 1957.	102
15. Average Jonathan spot and skin browning by orchards . .	105
16. Skin disorders compared with the nutrient contents of Jonathan apples. Orchard averages, 1956	106
17. Skin disorders compared with the nutrient contents of Jonathan apples. Orchard averages, 1957	107

INTRODUCTION

Numerous surveys have been made to determine the nutrient supply of orchards in relation to fruit yields and vegetative growth of the trees. In Michigan, the interpretation of leaf analyses for fertilizer recommendations in orchards (Kenworthy, 1949) has become a standard practice for apples. The consideration of the effect different nutrient levels may have on the general keeping quality and upon the formation of storage disorders is an essential application of this research.

A leading apple variety in Michigan is Jonathan. According to the Michigan Cooperative Crop Reporting Service (1957) Jonathan has ranged from 18 to 29% of the total Michigan crop for the years 1950-57. In annual production of Jonathan apples, Michigan ranks first, with one-fourth to one-third of the total yield of this variety in the United States. Therefore, Jonathan apples have found extensive use for various purposes on Midwestern markets. They were generally marketed before February when stored in regular refrigerated storage. Controlled atmosphere storage methods have extended the potential marketing period by three or more months.

To determine the influence of nutrition upon the keeping qualities of Jonathan in regular and in controlled atmosphere storage, it appeared advantageous to select orchards in which climatic and soil conditions were similar, and which were managed properly to produce high grade fruit. Personal factors on the part

of the individual operator were the greatest single reason for differences in management of the orchards. Spraying, soil management and pruning were generally quite uniform, whereas fertilizer applications showed the greatest variations in the selected orchards. Deficiency symptoms were neither visible nor previously reported in any of the orchards.

With these trees it was attempted to determine the effect of individual nutrients upon measurements used in the evaluation of fruit quality, as well as upon occurrence of storage disorders.

REVIEW OF LITERATURE

Most research on the nutritional factors influencing the keeping quality of tree fruits has been conducted on the effects of nitrogen, potassium, and boron.

Haynes and Archbold (1926) studied the effect of the nitrogen level upon the respiratory consumption of carbohydrates and acids. The loss of total sugars, alcohol insoluble residues, and acids (as malic acid) per unit of nitrogen was constant, although the absolute values varied widely. This confirmed a previous suggestion by Archbold (1925) that high nitrogen values in the fruit are usually associated with a high respiratory activity.

According to Magness and Overley (1929) and Weinberger (1930) nitrogen fertilizers without the addition of other nutrients resulted in equally firm fruit as complete (NPK) or partly complete NP, PK) fertilizer treatment. Their results were substantiated by Degman (1930) who found no consistent change in the keeping quality of Stayman, York Imperial, and Williams, as indicated by pressure tests and storage counts of breakdown. However, other orchard practices such as pruning, irrigation, etc., which result in excessively large fruits adversely affected the keeping quality. Gourley and Hopkins (1930) showed a marked increase of the nitrogen content in the fruits, in many cases well over 100%, with increased amounts of nitrogen fertilizers. The increase was constant up to an application of 8 lbs of N per tree; further augmentation of the

nitrogen fertilizer quantities did not further increase the nitrogen of the fruit in the same proportion, but sometimes resulted in a smaller increase. Respiration, specific gravity of the juice, and acidity did not show any significant correlation. In storage trials with Jonathan apples for 3 seasons no significant differences in keeping quality or in development of disorders were observed. Similar results were obtained on the Winesap variety.

Nitrate application in the month of August, according to Aldrich (1931), caused a slightly more pronounced decrease of the firmness during storage as compared with the control fruit in the variety York Imperial, but did not affect Stayman Winesap and Rome Beauty. When repeated the following season, no effect upon the keeping quality was observed.

Magness et al. (1940) studied the influence of nitrogen on the fruit color and concluded that nitrogen applications should be no greater than is necessary for satisfactory growth and yield. Trees receiving their nitrogen after leaf fall the preceding year developed high fruit color, but the leaf nitrogen content of such trees was low, indicating a possible loss from the root zone. The addition of potassium apparently did not affect color development.

On Cortland apples a reduction of scald by increased nitrogen fertilizer applications was observed by Savage (1941). Although brown core in McIntosh apples could not be correlated with the fertilizer practices by Smith (1942), Smock and Boynton (1944) found that under certain circumstances this disorder can be increased with increased applications of nitrogen fertilizer. No effect was

observed on scald. They present evidence for lower fruit firmness, higher respiration rate, and greener ground color with higher nitrogen. Similar observations were made in a comprehensive study by Eaves (1947-51); he concluded that high nitrogen caused delayed maturity, increased size, reduced red color, and more rot in storage, but that it resulted in less scald. On both McIntosh and Northern Spy he associated good fruit quality with leaf nitrogen contents below 2.1%.

Hill et al. (1950) established a "quality score" for flavor, texture, appearance and miscellaneous factors (hardness, "greasiness", and ground color of the fruit), and compared it with the nitrogen content of the leaves. They found that a low quality score was generally associated with high nitrogen levels in the leaves.

Foliar applications of urea-nitrogen increased the yield, leaf size, tree growth, and fruit bud development, according to Blasberg (1953). Fruits from sprayed trees were less firm than from trees fertilized with nitrogen through the soil. Fruit from sprayed trees had a lower level of soluble solids, but there were considerable seasonal fluctuations. On the plots receiving nitrogen the fruit color was decreased one year, improved the next year, as compared with the checks.

Generally, no accurate statement of the influence of nitrogen on the keeping quality of apples can be made, in spite of the fact that most research on the influence of the nutrient level has been concerned with this element.

The second single nutrient in importance among previous investigations is potassium. According to Brown (1929) good keeping quality was associated with high percentages of potassium and phosphate in the apple. However, the author does not present sufficient evidence from the results of her own work. Weinberger (1930) found no significant differences in firmness at harvest time between half K, single K (= 5 lbs. KCl per tree), double K, or nitrogen only. Decay and storage scald showed no marked difference except in Rome Beauty; in this variety potassium sulfate and potassium magnesium sulfate applications resulted in less scald than an application of nitrogen only.

The effect of potassium fertilizers upon the firmness and keeping quality was studied by Beaumont and Chandler (1933). In apples and peaches they found that a deficiency of potassium tended to make both fruits firmer at picking time, but hastened softening during storage.

A study on a more complex basis was only recently conducted by Weeks et al. (1952) on the effect of rates and sources of nitrogen, phosphorus, and potassium on the mineral composition of McIntosh foliage and fruit color. Some observations on the quality were included in their work. Increases in leaf nitrogen were associated with increased color. At high nitrogen levels potassium may determine the intensity of red color development. Phosphorus may become limiting with high rates of inorganic nitrogen; the fruit yield was increased with high rates of inorganic nitrogen, but the yield of fancy fruit was decreased. Trees with a high

nitrogen level gave the softest fruit, the ones with a low nitrogen supply had the hardest fruit at harvest.

Seasonal trends in the supply of several nutrients must also be considered. Research by Rogers et al. (1953) gives some information on the migration of mineral nutrients to and from the leaves. The only elements continuously accumulated were calcium and magnesium, whereas nitrogen, phosphorus, and to a minor extent potassium were translocated from the leaves before abscission, and therefore presumably constitute an important source of supply for the following season's growth.

A seasonal effect was also reported by Wilkinson (1957) on the Cox's Orange Pippin apples from a NPK fertilizer trial. The potassium content of the apples was increased 12% and 15%, respectively, in the two years of the investigation, but the application of superphosphate had no effect on any of the constituents measured. Grass cover (sod) increased the phosphorus concentration about 30%, and also increased the potassium and magnesium contents when no nitrogen was applied simultaneously. It was noted in this work that a wide range of differences between seasons, orchards, and samples may be expected.

Some investigators were concerned with the influence of boron on storage disorders and general keeping quality. Burbel (1937) and Degman et al. (1937) reduced the formation of internal cork, but Burbel noted an increase of bitter pit formation on Red Spy and Wealthy after the boron application. Batjer and Haller (1942) applied borax to Jonathan and other apple varieties and

caused slightly faster softening in storage. Jonathan from the borax plots removed from storage in January and post-ripened at 70° F. for one week had 50% spoilage from breakdown and decay, whereas check fruit had only 20%. Fruits on boron-fertilized trees developed color earlier than checks. Quite similar results were reported by Wilcox and Woodbridge (1943) who define the optimum range of boron content in the apple fruit to be 7 to 24 ppm (dry weight basis). Fruit containing boron in excess of this range invariably showed a considerably higher percentage of water core which, according to the authors, is a frequent origin of breakdown.

Recently, the element calcium received considerable attention by Garman and Mathis (1956). They published results of studies on the mineral balance as related to the occurrence of Baldwin spot (bitter pit). They observed a higher calcium content for fruits free of this disorder than for affected fruit. Injection treatments with calcium or ammonium salts did not produce any spot, whereas potassium and magnesium salts produced spot on 9 and 20% of the fruit respectively. A spray application of calcium nitrate reduced the amount of Baldwin spot considerably.

The influence of heavy mulch on the mineral content of foliage and fruit was investigated by Wander and Gourley (1943). The mulch resulted in an appreciable increase in potassium, a slight increase in phosphorus, and a decrease in calcium, magnesium, and boron in the leaves. Approximately the same trend was found in the fruit, except for magnesium, which was somewhat higher in fruit grown under mulch treatment than under clean cultivation.

This review indicates there are numerous assumptions, but few indisputable proofs, for effects of most of the nutrients, except nitrogen, on general fruit qualities before or after storage.

Specific investigations have been carried out to determine the cause and origin of various "physiological storage disorders" such as Jonathan spot and related disorders on other varieties, Jonathan breakdown or internal breakdown, and other forms of parenchymatic disorders. Other disorders, such as soft scald and storage scald, and various quality aspects of commercial or academic interest have been included. The Jonathan spot disorder was discussed in the literature about fifty years ago, when several attempts were made to explain its cause. Norton (1913) assumed that in storages using ammonia as a refrigerant the spot is caused by the minute amount of ammonia gas which will always be present in such rooms. He subjected fruit in a 4 liter container to the fumes produced by one drop of ammonia (NH_3) and produced an epidermal spot disorder. He realized, however, that ammonia was not the only cause, because spots were occasionally observed on the fruit before harvest. Scott (1914) assumed the spot to be a surface injury produced by arsenic, whereas Cook and Martin (1914) believed it to be caused by an *Alternaria* fungus. A similar fruit spot on the variety Wealthy, however, could be induced only with infection after a needle puncture (Stakman and Rose, 1914).

A detailed description of Jonathan spot was presented in the Manual of Fruit Diseases by Hesler and Whetzel in 1920. Numerous causal theories were given, like gas, physiological causes, sulfur,

ammonia, fungal growth (e. g., *Alternaria*), and influence of a preceding dry season. The authors recommended avoiding over-maturity at harvest, storage without delay, and consumption of the fruit in a few days after removal from storage as means of avoiding spot development.

Another manual (Heald, 1926) distinguished Jonathan spot from "Jonathan Freckle." Spot is described as "circular depressed spots, minute to 1/4 inch in diameter, always centering at lenticels, with a shallow area of necrotic tissues, but no internal necrotic areas as in bitter pit." The "freckle," on the other hand, consisted of "circular areas of discolored tissue up to 1/4 inch in diameter, only skin deep and not becoming depressed." It was mentioned that this type of disorder appeared only in storage.

According to Pentzer (1925) the bluish black color of the Jonathan spot was related to the pH of the cell sap. He found the tissue adjacent to the spots had a pH 4.7, and normal tissue a pH 3.8. In an extensive study Plagge (1942) found that storing Jonathan apples in a carbon dioxide concentration of approximately 7% extended the feasible storage period until the first of June. The acidifying effect of carbon dioxide on the tissues was used as an explanation for the absence of the spot. This, however, seems to be contrary to findings of Thornton (1933) which showed the response of the various plant tissues, such as tulip bulbs, potatoes, carrots, apples, etc., to storage in 0% to 75% CO₂. These tissues increased in pH of the extracted juice with above normal CO₂. However, if the oxygen was removed during the CO₂

treatment, the pH of the cell sap was decreased. As an explanation of this remarkable reduction in acidity when CO₂ was applied in the presence of oxygen, Thornton suggests there may be an "indirect effect when living tissue is exposed to carbon dioxide" in the presence of oxygen, whereby the sap becomes more alkaline. Plagge and Maney (1941) supposed that storage in pliofilm box liners resulted in an environment which tended to promote the acidity and thereby prevented the formation of spots. This leads back to Pentzer's (1925) assumption that an acidifying medium such as wrappers acidified with a harmless acid could help prevent Jonathan spot.

The apparent discrepancies cannot be resolved completely, but it should be emphasized that the paper by Thornton (1933) is the only one in which data of pH determinations are given.

Spot disorders of the fruit are described not only for the Jonathan variety, but for Northern Spy (Smock, 1947), Red Rome (Baker and Maxie, 1952), and Wealthy (Stakman and Rose, 1914). Corresponding to Plagge's (1942) results on Jonathan, Smock (1947) prevented the spot on Northern Spy by controlled atmosphere storage (10% CO₂ + 2% O₂ at 40° F). The spot on Red Rome was reduced with activated charcoal air purifiers in the storage and also with 1/2 lb. of shredded oil paper per crate of apples in experiments conducted by Baker and Maxie (1952).

Keijer and Dijsterhuis (1956) emphasized the distinction between lenticel spot and storage spot on Jonathan. The occurrence of lenticel spot was greater after the application of sulfur

containing fungicides, whereas organic mercury sprays tended to increase the storage spot.

Trout et al. (1940) mentioned, very briefly, an injury which they call "superficial scald" on Jonathan. It "sometimes occurs in the less mature fruit and in some forms is similar to Jonathan spot." Their description of this disorder closely resembled that of "Jonathan Freckle" (Heald, 1926).

Ballinger (1955) and Dewey et al. (1957) confirmed the findings of Plagge (1942) that controlled atmosphere storage prevents the occurrence of Jonathan spot when the apples are held under these conditions up to seven months.

The breakdown observed on Jonathan apples is mostly to be classified as internal breakdown (Palmer, 1931; Rose et al., 1951). Brooks and Fisher (1926) noted in a fertilizer trial that only apples from unfertilized plots developed internal breakdown. They associated the occurrence of water core in the fall with the development of internal breakdown in storage, particularly in the largest apples. Magness (1929) likewise warned of producing too large Jonathan apples because of possible storage troubles.

Gourley and Hopkins (1931) found that ample moisture conditions during the last two months of the growing season favored the development of breakdown, whereas a moisture deficiency resulted in firm small apples which were seldom affected. Heavy pruning, a light crop, and overmaturity seemed to favor the trouble. No immediate relation was found consistently between nitrate fertilizer applications and decay or breakdown.

The influence of soil moisture was stressed by Haller and Harding (1938). The fruit obtained from irrigated trees was 55% larger than from non-irrigated trees. Irrigated apples were softer than non-irrigated ones and more susceptible to breakdown during storage.

Overley and Overholser (1932) demonstrated an influence of fertilizer treatments upon the fruit size, and the effect of fruit size, in turn, upon the firmness, whereas potassium decreased the size and increased the firmness. Breakdown development depended on the seasons, but fertilizer treatments seemed to have some influence. Plots with potassium fertilization, alone or in combination with phosphorus (to a lesser degree even in combination with nitrogen) reduced breakdown in years with medium or great susceptibility. Nitrogen alone clearly promoted the disorder. It was not quite clear whether the cause was merely the fertilizer program or rather the fruit size produced in the respective treatment.

Batjer and Haller (1942) reported that a considerable increase of breakdown resulted with the application of borax to the trees. Gourley and Hopkins (1930) unsuccessfully tried to induce breakdown with nitrogen fertilization.

Shear and Horsfall (1948) could not find any significant difference in breakdown of Stayman apples as related to varying nitrogen contents of the leaves.

Early picking increased the percentage of breakdown somewhat, according to Haller (1943); preharvest drop preventing sprays likewise increased the occurrence of breakdown, but the different

materials did not give significant differences. There was as great a variability between replicate lots as between treatments.

Brooks and Harley (1934) state that breakdown as well as soft scald are greatly increased by delayed storage. They recommend carbon dioxide treatments as a basis for practical control of both disorders.

It was confirmed by Trout et al. (1940) that breakdown developed more readily in fruit of larger size and of more advanced maturity. It occurred at all storage temperatures, but was more readily produced at 32° F, according to these authors. Plagge (1942) attempted to control breakdown as well as Jonathan spot by controlled atmosphere storage. He found breakdown occurred at 32° F. even though more than 7% CO₂ was employed. This disorder was retarded by controlled atmosphere storage in experiments of Dewey et al. (1957), but it was not prevented completely.

Soft scald seems to be the least investigated of the three main disorders of Jonathan. It appears as blister-like sunken areas that extend in irregular patterns over the fruit; it is never found in temperatures above 38° F., and therefore Wright (1953) classified it as a cold temperature injury. Brooks and Harley (1934) recommended exposure of the apples to 20% CO₂ for a few days, if they are to be stored at 32° F., in order to prevent soft scald. This treatment has been reported by these authors to have beneficial effects upon firmness with no objectionable effect upon flavor or quality of the fruit.

Soft scald was produced experimentally by Carrick (1929) by enclosing apples in a glass jar at room temperature for several days. In storage, a temperature of 30° favored the development of this disorder.

Haller and Lutz (1941) reduced greatly the percentage of soft scald at a storage temperature of 36° F. as compared to 32° F., but the higher temperature increased the amount of Jonathan spot. They did not observe a consistent difference of the two temperatures in the amount of decay or breakdown.

No significant influence of preharvest drop prevention sprays on scald could be observed by Haller (1943); Dewey et al. (1953) substantiated these findings in a trial in Michigan.

METHODS AND MATERIALS

Procedure of the survey and storage operation

Commercial orchards concentrated in an area southwest of Sparta, Michigan, were selected as sources of experimental material for this study. The proximity of the plots to each other made it possible to obtain fruit grown under relatively similar micro-climatic influences. Thus, the fruit could be harvested at a similar stage of maturity on any given day. Sixteen of the 18 orchards chosen were located between the Kent-Ottawa county line and 1/2 mile east of Peach Ridge Avenue, and between 9 Mile Road in the south and 1/2 mile north of 10 Mile Road in the north. The other two orchards were about 8 miles north, near Casnovia.

Five trees in each orchard were selected for uniformity of appearance and fairly representative growth and development for the orchard. The age, source of nursery stock and methods of cultivation were recorded and are summarized in Table 1. Most of the trees were of medium age, and only four different sources of the planting material were named by the farmers.

The more pertinent facts of orchard management techniques are shown in Tables 2 and 3. They indicate that there were some different practices in the soil and fertility management, whereas the spray schedule and the materials employed were rather uniform.

Samples of approximately 100 leaves from the periphery of the tree were collected on August 3 and 4, 1956. They were taken

TABLE 1
AGE, SOURCE OF NURSERY STOCK AND PLANTING DISTANCES
OF TREES IN EXPERIMENTAL PLOTS

Orchard	Age 1956 (years)	Source of Trees ^a (nursery)	Planting Distance (feet)	Soil Description
1	14	Greening	40 x 40	silt loam
2	20	Greening	40 x 40	clay loam
3	35	Ilgenfritz	30 x 30	silty clay loam
4	16	Ilgenfritz	35 x 35	silt loam
5	16	Greening	28 x 28	silty clay loam
6a	29	Hallman	40 x 40	silt loam
6b	21	Stark	26 x 26	silt loam
7	14	Greening	28 x 28	silt loam
8	17	Greening	28 x 28	clay loam
9	18-20	Stark	28 x 28	loam/clay loam
10a	30-35	Greening	40 x 40	silty clay loam
10b	30-35	Greening	40 x 40	silty clay loam
11	6	Greening	18 x 18	silt loam
12	38	Greening	32 x 32	clay loam
13	21	Ilgenfritz	40 x 40	silty clay loam
14	22	Greening	40 x 40	silt loam
15	22	Greening	40 x 40	silty clay loam
16	22	Greening	40 x 40	silty clay loam

^aGreening's Nurseries, Monroe, Michigan.

Ilgenfritz Nurseries, Monroe, Michigan.

Hallman, Benton Harbor, Michigan (not in business now).

Stark Bros., Louisiana, Missouri.

TABLE 2
SOIL MANAGEMENT AND FERTILIZER PRACTICES
IN EXPERIMENTAL ORCHARDS

Orchard	Trees in Sod Since	Additional Organic Material	Soil Fertilizer Practice (per tree basis)	Urea Sprays 1956 ^a
1	1955	mulch	none since 1954	1
2	1946	mulch	1.3 lb N	1
3	1935	mulch	3 lb N 1 lb P 1 lb K	3
4	1948	---	1.7 lb N	--
5	1947	mulch every three years	.65 lb N	1
6a	1936	mulch (occasionally)	dolomitic limestone	--
6b	1938	mulch (occasionally)	.5 lb N .5 lb P .5 lb K	--
7	1949	mulch every 2 yrs; manure ev. yr.	.2 lb N .8 lb P .8 lb K	3
8	1948	---	.65 lb N	1
9	1944	manure ev. 2-3 yrs.	.5 lb N .5 lb P .5 lb K	3
10a	1944	---	1 lb N	--
10b	1944	---	1 lb N	--
11	(cover crop)	---	.7 lb N .7 lb P .7 lb K	--
12	1935	manure every year; mulch ev. 4 yrs.	.3 lb N 1.4 lb P 1.4 lb K	5
13	1948	manure ev. 4-5 yrs.	1.8 lb N 1.8 lb P 1.8 lb K	--

TABLE 2--Continued

Orchard	Trees in Sod Since	Additional Organic Material	Soil Fertilizer Practice (per tree basis)	Urea Sprays 1956 ^a
14	1937	mulch ev. 4 yrs.	.3 lb N 1.0 lb P 1.0 lb K	--
15	1937	mulch ev. 2-3 yrs.	.3 lb N 1.0 lb P 1.0 lb K	--
16	1937	mulch ev. 3 yrs.	.5 lb N 2.0 lb P 2.0 lb K	--

^aOnly 1956 data, because small crop in 1957 did not call for foliar application of urea.

TABLE 3
SPRAY MATERIALS USED IN EXPERIMENTAL ORCHARDS

Orchard	Fungicides	Insecticides
1	sulfur, glyodin, fermate	Lead arsenate, parathion
2	sulfur, phygon, captan	DDT, lead arsenate, dieldrin, malathion
3	sulfur, captan, mercury	DDT, parathion, acaricides, TEPP
4	captan, mercury	DDT, lead arsenate, acaricides ^b
5	sulfur, glyodin, fermate	DDT, TEPP, parathion, acaricides
6a, 6b	copper, sulfur, phygon, captan, mercury, glyodin	DDT, DDD, TEPP, parathion, lead arsenate, acaricides
7	sulfur, captan, phygon	DDT, TEPP, parathion, ovotran
8	sulfur, phygon, ferbam, glyodin	DDT, DDD, BHC, parathion, malathion
9	sulfur, glyodin	DDT, parathion, malathion
10a, 10b	sulfur, captan, glyodin, mercury	DDT, DDD, malathion, dieldrin, parathion, acaricides
11	sulfur, copper, captan	DDT, parathion, malathion
12	sulfur, captan, phygon, mercury	DDT, lead arsenate, TEPP, acaricides
13	sulfur, phygon, glyodin, mercury	DDT, parathion, systox, lead arsenate
14	sulfur, captan	DDT, parathion, acaricides
15	sulfur, captan	DDT, parathion, acaricides
16	sulfur, captan, mercury	DDT, TEPP, parathion, malathion, dieldrin, rothane, acaricides

^aOrchards 5, 7, 12, 13, 14, 15, 16 received iron containing materials as fungicides in 1957.

^bAcaricides are all agents which specifically control mites, such as EPN 300, Aramite, Systox, Dimite, Ovex, Chloro-benzilate, and Kelthane.

from shoots at least 10 inches in length, chosen at random, and within easy reach from the ground. To remove dust and spray residues, the leaves were briefly washed in distilled water with the addition of a small quantity of a common detergent, then dried at 105° C. until brittle, and ground in a Wiley mill in preparation for spectrograph, flame photometer and Kjeldahl analyses.

The 1957 leaf samples were taken on July 27 in the same manner as in the previous year from the same trees.

In 1957 fruit samples of approximately 15-20 young fruits were collected on June 20 and 22 in all orchards with a sufficiently promising fruit set. These immature fruits were used to ascertain the mineral supply of fruits as compared to that of leaves and of mature fruits.

Three foliar applications of calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, were given in 1957 at the rate of 6-7 gal. of .125% solution per tree on the second and fourth tree in each of the selected orchard lots. The calcium nitrate sprays were applied June 24, August 3, and September 14, 1957; the total amount applied was approximately 3 oz. per tree.

The mature fruit for storage tests was harvested into eastern apple boxes October 5, 6, and 7, in 1956. There was a good crop on all the trees, and the fruit were picked from the ground and equally from all sides of the tree. The apples were immediately placed into cold storage for removal of the field heat. From each tree one bushel was used for controlled atmosphere storage and one for regular refrigerated storage. The fruit for

regular storage was stored until late February in a well-managed commercial storage at approximately 35° F. and 85-90% relative humidity. The fruit for controlled atmosphere storage was cooled in the same room and then transported by truck to East Lansing upon completion of the harvest operation. It was stored in a tilt-up storage building (Pflug et al., 1957) designed and constructed for controlled atmosphere purposes.

Whenever the carbon dioxide concentration increased above 2.5%, the excess was absorbed with sodium hydroxide (Pflug et al., 1957). If the oxygen was decreased below 3%, an air pump was employed to raise it slightly above that level. The temperature was to be about 32° F. for the storage air; approximately the same fruit temperature was expected after a certain period of cooling.

The temperatures at the top and on the bottom of the stack of the controlled atmosphere fruit were recorded daily from thermocouples.

After completion of the storage period, in the latter part of February in both storage seasons, the fruit stored in the regular commercial storage was shipped to East Lansing by truck and was placed into a storage room at 32-33° F.

A few fruit samples were taken from the boxes at harvest time in 1956 for a tentative mineral analysis. When it seemed feasible to carry out such an analysis, a complete set of fruit samples from the same season was prepared upon inspection of the controlled atmosphere fruit in May 1957.

In fall 1957, the fruit was harvested on September 28-30, about 3-5 days before the commercial harvest in most orchards. Since the yield in most orchards was considerably smaller than in 1956, fruit had to be taken not only at easy reach from the ground, but also from inside the tree and from the upper part of its periphery.

For obtaining a more accurate and truly representative fruit sample for mineral analysis with a high degree of comparability between trees, six fruits were taken from each tree 4-5 days before the actual harvest. The fruits were picked around the trees from twigs and spurs which were assumed to have been pointing downward throughout most of the season. Thus, more uniform material (except for a response to the foliar nutrient applications) was hoped to have been obtained. The 6 fruits were cut into 1/4 to 1/8 inch pieces suitable for drying. After pre-drying at temperatures between 80-90° C., the samples were finally dried at 100° C until completely dry. This procedure of drying minimized caramelization. The samples were taken from the oven individually and were ground while still hot. They were placed into 2 oz. wide mouth sample jars and these were closed tightly immediately, so as to avoid caking of the ground substance.

At harvest, after regular storage and after controlled atmosphere storage samples of 20 fruits in 1956, and 15 fruits in 1957 were tested for ground color with the Cornell Color Chart (Southwick and Hurd, 1948). Firmness readings were obtained with the Magness-Taylor pressure tester (Magness and Taylor, 1925), and

soluble solids readings with a Zeiss-Opton hand refractometer. The fruit was cut along the equatorial plane, and internal abnormalities were recorded. The visual inspection was to include observations of Jonathan spot, skin browning, lenticel spot, soft scald, and decay; furthermore, after cross-cutting, water core, breakdown, brown core, and possible internal injuries attributable to storage conditions were recorded.

At each inspection time, i.e., in fall, after regular storage, and after controlled atmosphere storage, a composited sample of approximately 30 apples from six orchards in 1956 and from five orchards in 1957 was used for respiration studies. The fruit were initially weighed and placed into 5-gallon wide-mouth pickle jars and closed with an air-tight lid. The respiratory activity of the fruit was measured by CO_2 evolution according to the method described by Claypool and Keefer (1947).

Flavor ratings proved unsuccessful because of the large quantity of fruit involved.

A holding study upon removal from storage was made with the 1957 fruit to check the possible inherent differences in shelf life of the fruit from the individual trees. Twenty fruit from each tree were placed into drawers of ripening cabinets held at room temperature of 70-75° F. for 10 days. The fruits were then inspected carefully and all external and internal disorders which had developed were recorded.

Leaf and fruit analyses

The mineral analyses of leaf and fruit tissues were made in the Agricultural Chemistry laboratories of Michigan State University.

The material was prepared as described before: the nitrogen content was determined by the Kjeldahl method, potassium on the flame photometer, and the other elements on the spectrograph according to a modified spark method of the A.O.A.C. (1955).

It was suspected the calcium content of the fruits was below the lower useful range of the spectrographic method used, because it is present only in very small amounts (below 1% of dry matter) in apple fruits as compared to leaves (Garman and Mathis, 1956) and to other fruits (Strachan et al., 1951). Therefore, another method was applied by the author which would yield reliable data even at very low levels of calcium. Since the magnesium readings were available from the spectrographic determination, the complexometric titration of Ca + Mg with ethylene diamine tetraacetic acid (EDTA) and subsequent subtraction of Mg seemed to be very promising.

No reports were found in the literature (Barnard et al., 1956, 1957; Biedermann and Schwarzenbach, 1948; Diehl et al., 1950; Diehl and Ellingboe, 1956; Hildebrand and Reilley, 1957) that calcium has been determined in fruit tissues. Therefore, a detailed outline of the relatively simple procedure was included here, as it has proved most efficient and of a very satisfactory degree of reproducibility. Since magnesium data were available from the spectrograph readings, no differential titration was needed; accordingly, the method presented here was modified for the determination of calcium only.

The complexometric titration was based upon the property of EDTA (ethylene diamine tetraacetic acid) to complex selectively the ions of calcium and magnesium. The amount of divalent ions present in one gram of dry matter was found by dissolving the ash in acid solution and subsequently titrating at a buffered pH of 10.0 to 10.5. At first the EDTA complexes all the calcium ions present, and then all the magnesium ions, and finally the magnesium which is part of the indicator. This exchange of the magnesium from the indicator for sodium from the EDTA causes the color change of the indicator from pink or purple to pure blue.

The titration was carried to an endpoint which did not retain the slightest purple tinge. Practice on both standards and fruit samples was necessary. The calcium value was obtained by subtracting the meq Mg^{++} in 1 g of dry matter, as determined spectrographically, from the total meq cations.

Materials needed:

1. EDTA ("Versenate" or "Versene") = ethylene diamine tetraacetic acid (disodium-dihydrogen salt): 2 g in 1 liter H_2O (approximately).
2. Indicator: 0.5 g Eriochrome Black T (Baker, F 241) was mixed with 4.5 g Hydroxylamine $\cdot$ HCl and was dissolved in 120 ml ethanol. A new solution was made up every three weeks.
3. Calcium standards: generally, a calcium chloride standard was recommended, but calcium oxalate seemed more suitable in this work, since it gave an endpoint

more similar to the one obtained with the fruit samples. Descriptions of both standards follow:

- a) Calcium oxalate standard. 1 g of calcium oxalate was dried overnight at 80° C, and then stored in a desiccator. It was dissolved in H₂O, with the addition of approx. 10 ml HCl (1:1) and approx. 5 ml HNO₃ (conc.) and made up to 500 ml in a volumetric flask. This standard contained 3.12 mg or .1557 meq Ca in 5 ml solution.

For standardizing the EDTA 1 mg (= .0822 meq) of Mg¹ was added to the 5 ml aliquot of the calcium solution, giving:

$$\begin{array}{r} .1557 \text{ meq of Ca} \\ + .0822 \text{ meq of Mg} \\ \hline .2379 \text{ meq of Ca + Mg in standard.} \end{array}$$

The equivalence of the EDTA solution was calculated from the number of ml EDTA used to titrate the above mixture at a pH of 10.0-10.5; e. g., ave. 21.94 ml EDTA used:

$$\frac{.2379}{21.94} = .0109 \text{ meq cations per ml of EDTA}$$

- b) Calcium chloride standard (Diehl et al., 1950).

125.1 mg CaCO₃ (dry) was dissolved with a minimum of HCl necessary to bring it completely in solution, and made up to 500 ml in a volumetric flask. This

¹As MgCl₂ solution; amount calculated according to the normality of the solution.

gave an actual amount of 50.1 mg Ca in 500 ml solution. One ml contained $\frac{50.1}{500} = .1001$ mg calcium.

$$\frac{.1001}{20.04} = .005 \text{ meq/ml solution}$$

The titration of this standard with EDTA was carried out using 1 mg of magnesium in solution (= .0082 meq), and 6, 10, 12, 14 ml of the calcium chloride standard, containing .03, .04, .05, .06, .07 meq Ca, respectively. On the average .01037 meq of divalent cations were found to correspond to 1 ml of EDTA solution.

Because of greater similarity of the endpoint between calcium oxalate standards and fruit samples, the value .0109 meq cations per ml EDTA was used as a basis for calculating the percent of Ca in the dry matter of fruit.

4. Buffer: 135 g of C. P. ammonium chloride was dissolved in 1140 ml conc. NH_4OH and diluted to 2000 ml with distilled and de-ionized water. This buffer solution gave a pH of about 10.5. Occasionally this was checked on a pH meter.
5. Magnetic stirring equipment: the stirrer was run fast enough to produce a whirlpool of 1-2 inch depth. This facilitated the accurate observation of the color change.
6. Fluorescent light and a background against which the color change can be observed conveniently.

Procedure:

1 g of carefully dried and ground fruit sample was ashed in a small porcelain crucible at 55° C overnight. The ash was transferred into a 250 ml beaker. The crucible was rinsed quantitatively with 0.5 ml 1:1 HCl into the beaker and was washed quantitatively with distilled and deionized water. About 100-125 ml distilled and deionized water were added. Then sufficient ammonium buffer solution was added to bring the pH up to 10.0-10.1 (10 ml buffer should do). The water had to be added before the buffer to avoid undesirable precipitations. About 60 drops of Eriochrome Black T indicator were used and the titration was carried out quickly, to reach a clear blue endpoint exactly like the one achieved on the standard solution. Two parallel samples were run to check the agreement. The amount of calcium in the fruit was calculated according to the following example:

$$\begin{aligned}
 .0109 \text{ (meq/ml)} \times 6.6 \text{ (ml used)} &= .0719 \text{ meq Mg + Ca} \\
 .0719 - .0452 \text{ (meq Mg, spectrograph determination)} &= \\
 .0267 \text{ meq Ca} \\
 .0267 \text{ meq Ca} \times 20.04 &= .5150 \text{ mg Ca in 1 g dry wt.} \\
 &= .052\% \text{ Ca in fruit sample.}
 \end{aligned}$$

Interferences may be expected from any divalent ions; therefore, the quality of the distilled water was found to be of utmost importance. Metal ions, such as Fe, Mn, and Cu, which might

interfere with the endpoint were present in the fruit in such small amounts that they were neglected in the calculation.

This method was also suitable to determine the Ca + Mg in immature fruit samples. Because of the higher concentration of these elements as well as of interfering substances, and because of the possibility of precipitations it seemed advisable to reduce the weighed amount to .250 g in order to work with the same concentration of EDTA solution as in the determination of mature fruit contents.

Fruit firmness

The pressure readings as a measurement of flesh firmness were made with the Magness-Taylor pressure tester (Magness and Taylor, 1925; Haller, 1941) with a 7/16 inch plunger. Three pressure tests at pared surfaces were taken on each fruit of a sample of 20 (1956) or 15 (1957) fruits. All readings were made by the author.

Ground color

Ground color was numerically rated by comparison with the McIntosh Color Chart (Southwick and Hurd, 1948), on which the color variations between yellow and green are numbered from 1 to 5. The number of fruits in each of these color categories was recorded, and an average color value per tree computed. A fruit completely covered with red color was disregarded in the computation of the average. In 1956 the average was partly obtained from composite fruit samples (5 trees); in 1957 all trees were checked

individually, as far as sample material was available, and the orchard averages computed from at least four, but usually five, trees.

Soluble solids

The soluble solids in the fruit juice are used as an indication of the sugar content of the fruit. The readings were taken to determine whether the level of soluble solids was influenced by nutritional factors, and whether they had any influence upon the prevention or promotion of storage disorders and upon the general storage quality of the fruit.

The soluble solids content was determined with a Zeiss-Opton hand refractometer on the fruit juice obtained during the pressure testing. According to Strachan et al. (1951) the actual sugar content of Jonathan apples amounts to about 85% of the soluble solids reading.

Respiration

The respiratory activity of the fruit as indicated by the CO₂ evolution was measured by the method of Claypool and Keefer (1942) before storage, after regular storage, and after controlled atmosphere storage.

In 1956 fruit from six orchards, in 1957 fruit from five orchards were selected which were 2-1/4 inch and larger and met the minimum requirements of US #1 grade. The fruit were sealed into wide mouth 5-gallon glass jars at the rate of approximately 3.000 to 3.500 kg of fruit per jar (28-35 fruits depending on

size). The jars were connected with a flow board as described by Claypool and Keefer (1942), and an air flow of 200-300 ml was passed through the jars and into bubbling flasks. The readings were taken at approximately 24 hour intervals.

Storage disorders

Breakdown. The presence of breakdown was detected by gently applying pressure with the hand as the fruit was inspected. Doubtful cases were verified by cutting the fruit. The number of fruits affected was added to that found in the small sample from the same box which was cut for internal inspection (20 samples in 1956, 15 in 1957) upon removal from storage. To substantiate these observations, a sample of 20 fruits was selected in 1957 which met the requirements for US #1 grade; these were placed into ripening chambers at 70-75° F for two weeks. By adding the percentage values of the affected samples (i. e., after regular storage, after holding at 75° F.; after controlled atmosphere storage, after holding at 75° F.) a numerical "score" value was computed for use in all further comparisons and evaluations.

Jonathan spot. This disorder was observed and recorded in both years as the fruit was removed from regular storage. A single spot on a fruit was classified as affected, although it may have been commercially acceptable. The Jonathan spot was carefully distinguished from the lenticel spot in both years, whereas another disorder, called skin browning in the present work, was recorded as Jonathan spot in the first season. During the second

season spot and skin browning were recorded separately, and the total recorded as "total skin disorders."

Statistical

The statistical methods applied for evaluation of the results were selected according to the type of data available, and according to the layout of the survey (Wilcox, 1950). The correlation analysis with the determination of the r -value (Fisher, 1948) served as a useful tool in evaluating the data, even when some data became unavailable due to crop failure in certain orchards or on individual trees.

Yearly analytical data were related by correlation coefficients. Similarly, the influence of the nutrients upon fruit firmness, soluble solids, and storage disorders was tested by correlation coefficients. According to the availability of fruit quantities from the individual trees the number of degrees of freedom varied from one calculation to the other; the significance depending on the degrees of freedom available for the respective calculation, was indicated by one or two asterisks for the 5% and 1% levels, respectively.

When a treatment with calcium nitrate was introduced in the second year it was applied on 2 trees in every group of five trees. Therefore, a t -test with non-paired variables (Goulden, 1952) was employed to determine whether a difference between groups of treated and non-treated trees was reflected significantly in the averages of the two groups. The effect of the calcium nitrate

spray upon ground color and soluble solids was tested by the same method.

Internal breakdown and its relation to other factors was investigated by setting up groups of the "score" values used as an expression of the severity of the disorder in any given lot. A t-test could be applied to determine if differences in means of any factor were significant between the non-affected lots and those with the recorded incidence of breakdown. Any significance above the 5% level was accepted as sufficient.

The possibility of transformation by $\sqrt{x + 1/2}$ (Cochran, 1938; and Bartlett, 1947) was investigated on data which contained a large number of zero values, such as the data of breakdown and skin disorders. This transformation served to remove any zero values and to reduce the skewness of the distribution curve.

RESULTS

Leaf and fruit analyses

The nutrient element levels of the leaves, as determined by the Kjeldahl method for nitrogen, on the flame photometer for potassium, and spectrographically for phosphorus, calcium, magnesium, iron, manganese, boron, and copper, are given as orchard averages in Appendix tables 1 and 2. Converted into chart indexes they are presented in Appendix table 3, with an index of 100 as the standard value used by Kenworthy (1949). It is shown in Table 4 that most of the average values obtained in this study are slightly below the values found by Kenworthy (1949).

TABLE 4
THE AVERAGE LEAF COMPOSITION VALUES IN 1956 AND 1957,
COMPARED WITH THE STANDARD VALUES USED FOR
THE NUTRIENT ELEMENT BALANCE CHART

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Mn (ppm)	B (ppm)	Cu (ppm)
1956	2.20	.198	1.49	1.46	.402	.016	67 ^a	28	18
1957	2.15	.206	1.62	1.18	.364	.022	58	39	19
standard	2.33	.266	1.53	1.40	.408	.022	98	42	23

^aOrchard 3 omitted (cf. Appendix table 2)

No acute deficiency or excess of any element was noted in any of the orchards. The young trees of orchard 7 had a nitrogen index value above 100 in both years, whereas the average for all orchards was lower than the standard value. With the exception of orchards 16 and 9, phosphorus was generally at the standard level or slightly below it. A low level of potassium was observed in both

seasons in orchard 4, with index values of 73 and 83 in 1956 and 1957, respectively. The highest levels for potassium were found in orchards 5 and 8 with index values above 110. While the potassium values in 1957 were generally higher than in 1956, the reverse was the case with the leaf content of calcium and magnesium. Neither one of the latter two elements was present in excessive or deficient levels. The index value of 267 for manganese for orchard 3 in 1956 was a consequence of spray applications of manganese sulfate according to recommendations in the year previous to this survey. In 1957 no after-effect was visible any more. Notable seasonal differences were also found for iron and boron. Both showed a considerable increase in several orchards from 1956 to 1957.

TABLE 5
CORRELATIONS OF THE LEAF ANALYSES OF 1956 AND 1957
FOR THE INDIVIDUAL ELEMENTS (17 ORCHARDS)

N	.809**	Fe	NS
P	.724**	Mn	.819** ^a
K	.753**	B	NS
Ca	.510*	Cu	NS
Mg	.663**		

^aOrchard 3 was omitted because excessive levels of manganese occurred in 1956 due to a spray treatment with MnSO_4 in 1955.

Correlation coefficients between the indexes of the two seasons are presented in Table 5. The values indicate the general reliability of the foliar analysis data for nitrogen, phosphorus, potassium, calcium, magnesium, and manganese with respect to

**significant at 1% level

*significant at 5% level

analytical results as well as possible seasonal changes in nutrient availability and uptake.

Preliminary trials were made in the fall of 1956 to determine the nutrient composition of the fruit. The analytical results for the fruit at harvest are shown in Appendix table 4. Appendix table 4 also includes the analyses for all lots of fruit after removal from controlled atmosphere storage, and indicated considerable differences in nutrient levels between the two samplings. The fruit analyses at harvest in 1957 are tabulated correspondingly in Appendix table 5 as orchard averages, the immature fruit analyses in Appendix table 6.

TABLE 6
CORRELATIONS OF THE LEAF CONTENT AT MIDSEASON WITH THE
FRUIT CONTENT AT HARVEST AND AFTER CONTROLLED
ATMOSPHERE STORAGE, AND OF THE FRUIT
ANALYSES BEFORE AND AFTER STORAGE
18 SAMPLES 1956

Nutrient	At harvest	After C-A storage	Fruit before storage vs. fruit after C-A
N	.741**	.721**	.470*
P	.732**	.628**	.495*
K	.768**	.623**	.604**
Ca	NS ^a	NS ^b	NS ^b
Mg	.550**	NS	NS
Fe	NS	NS	NS
Mn	.547*	NS	NS
B	NS	NS	.743**
Cu	NS	NS	NS

^aBased on EDTA determination of calcium in fruit.

^bBased on spectrographic determination of calcium in fruit.

Correlation coefficients were computed for the leaf and fruit analyses using the 18 individual trees employed for tentative

fruit analyses. The correlation coefficients for the leaf content vs. the fruit analysis and for analyses of fruit before and after storage are given in Table 6. A significant correlation of leaf and fruit content was obtained both before and after storage only for nitrogen, phosphorus and potassium.

The correlation coefficients for the nutrient element contents of the leaves, immature fruits, and mature fruits are presented in Table 7. The correlation coefficients on 18 samples and on 90 samples between leaf and mature fruit differed considerably for all elements except for nitrogen, phosphorus and potassium, and indicated the importance of improving sampling and analytical techniques.

TABLE 7
CORRELATIONS OF THE NUTRIENT CONTENTS OF LEAVES,
IMMATURE AND MATURE FRUIT

	1956		1957			
	At harvest	After C-A	At harvest			Between Years
	leaf and mature fruit	leaf and mature fruit	leaf and mature fruit	leaf and immature fruit	imma- ture and mature fruit	mature fruit
Nutrient	18 trees	90 trees	83 trees	70 trees	70 trees	82 trees
N	.741**	.247*	.394**	.737**	.521**	NS
P	.732**	.336**	.423**	.333**	NS	.322**
K	.768**	.429**	.668**	.680**	.517**	.431**
Ca	NS	NS	NS	NS	NS	NS
Mg	.550*	NS	NS	NS	NS	NS
Fe	NS	NS	.255*	NS	NS	NS
Mn	.547 ^a	NS ^a	.779**	.678**	.579**	NS
B	NS	.406**	.250*	NS	NS	.409*
Cu	NS	--	NS	NS	NS	NS

^aDoes not include orchard 3 which had been sprayed with $MnSO_4$ the previous year.

The 1956 values of calcium are based upon spectrographic values (Appendix table 4); in 1957 the corresponding calculations were carried out on the orchard averages, because a calcium nitrate treatment had been applied on two out of every five trees.

Table 7 shows that nitrogen, phosphorus, potassium, and manganese were consistently correlated in leaf and fruit contents; the other elements did not always yield significant correlations: the r-values for boron were significant in two of the five comparisons. Iron contents of leaf and mature fruit were significant at the 5% level in one season; in other comparisons there were no significant correlations. Significant correlations in nutrient element content of the mature fruit for the two seasons occurred only for phosphorus, potassium, and boron.

The results from the complexometric titration with EDTA adapted by the author for the determination of calcium in the fruit are tabulated in detail in Appendix table 7. The immature fruit samples had been collected prior to the first application of calcium nitrate. As shown in Table 8, the trees selected as controls and for treatments were similar in their calcium content at that time.

TABLE 8
CALCIUM CONTENT OF IMMATURE FRUIT HARVESTED PRIOR
TO THE CALCIUM NITRATE APPLICATIONS; 1957

Treatment	n-1	Av. calcium content (% of dry matter)	t
Control	41	.27 $\pm$.047	NS
Calcium nitrate	28	.25 $\pm$.049	

The calcium content of mature fruit was significantly higher in apples from treated trees than from untreated trees, as shown by t-test in Table 9.

TABLE 9
EFFECTS OF CALCIUM NITRATE TREATMENTS UPON THE CALCIUM,
MAGNESIUM, AND NITROGEN CONTENT OF MATURE FRUITS; 1957

Nutrient (% of dry matter)	Untreated (51 samples)	Treated (33 samples)	t
Calcium	.0577 $\pm$.0115	.0685 $\pm$.0102	4.534*
Magnesium	.0466 $\pm$.0059	.0450 $\pm$.0057	NS
Potassium	.9138 $\pm$.0821	.9106 $\pm$.0919	NS
Nitrogen	.3089 $\pm$.0716	.3056 $\pm$.0591	NS

Regardless of whether only the values for the controls, or only those for the treated trees, or all the fruit were used, there were no significant correlations between the calcium contents of immature and mature fruits (Table 10).

TABLE 10
CORRELATION OF THE CALCIUM CONTENT OF IMMATURE
AND MATURE FRUIT; 1957

Control	.194	NS
Treatments	.0006	NS
All fruit	.0635	NS

The comparison of the magnesium and potassium contents of the fruit from trees treated and untreated with calcium nitrate (Table 9) showed that there were no depressing effects of the calcium on the levels of these two elements in the fruit. A comparison of the fruit nitrogen levels included in Table 9 indicated that the calcium nitrate spray did not have any influence on the level of this element either.

Survey and storage operation

General observations of the growth and development of the trees during the two seasons indicated that climatic influences were similar in all orchards. Furthermore, in each orchard, the five trees selected for the survey proved to be of satisfactory uniformity in vegetative growth, crop size and general appearance throughout the experiment. Data from tree no. 43 in orchard 9, however, had to be discarded because the tree was damaged by rodents.

The controlled atmosphere storage records of the two seasons are summarized as weekly averages on Appendix table 8 and graphically in figures 1 and 2. The curves on the figures indicate a greater variability in storage conditions during the first season of operation than in the second. The increase in oxygen in the sixth week of the 1956 season was caused by failure of the air pump to shut off automatically. Another severe increase of the oxygen concentration occurred in the 22nd and 23rd week; this was due to a leak in the absorber. In 1957 the operation resulted in considerably smoother curves. At the end of the season, in the 25th week, the air pump was disconnected and oxygen was added by opening the porthole. The rise in the oxygen concentration in the 26th week was caused by leaving the porthole open for 24 hours.

The fruit was cooled to 40° F. within the first week, then six to eight weeks were required to reduce the fruit temperature to 32-33° F. After cooling, fruit temperatures generally did not vary more than one degree F.

Figure 1 Storage operation in 1956-57 (first season).
Weekly averages of atmosphere composition
and fruit temperatures at thermocouples no.
5 and 6.

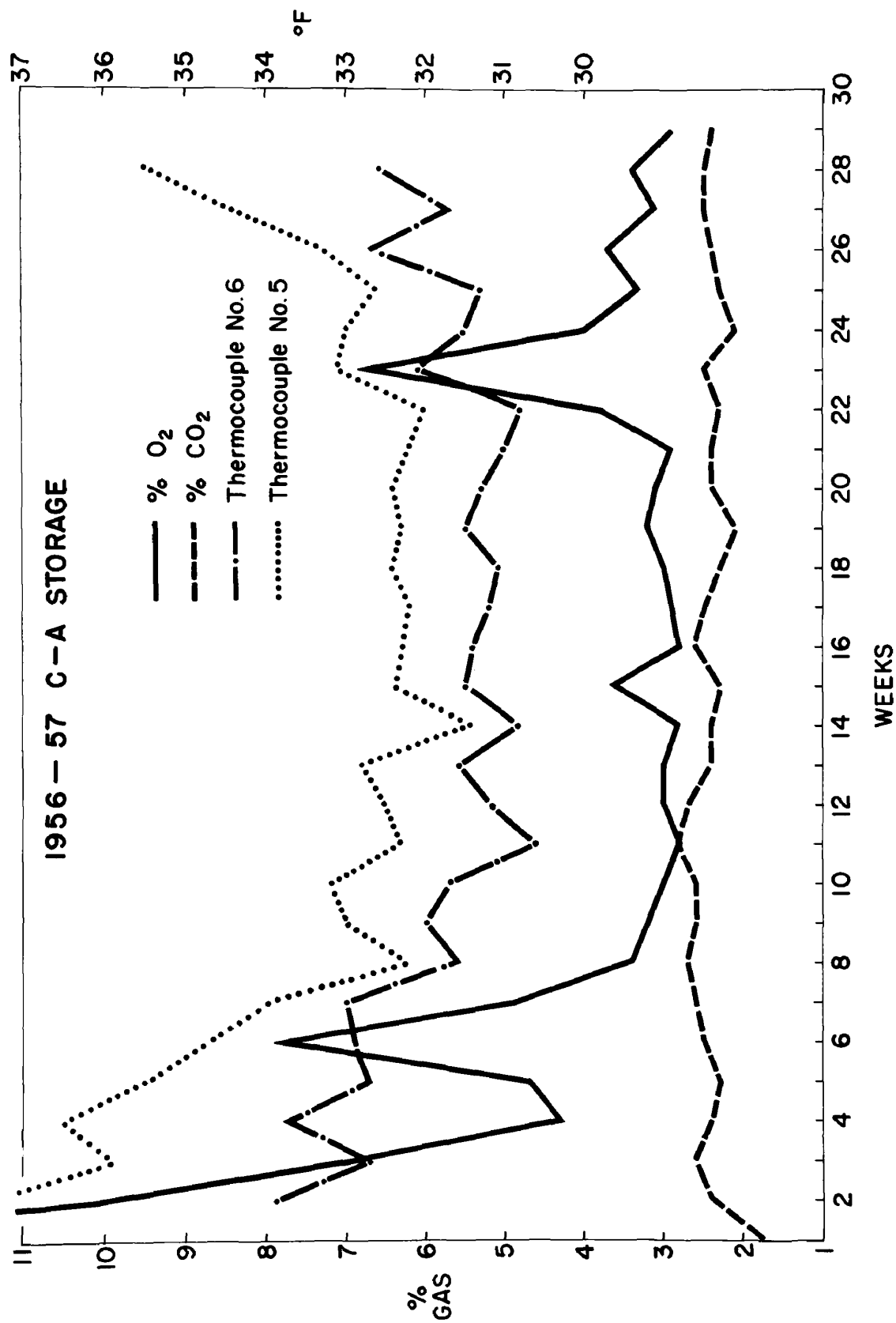
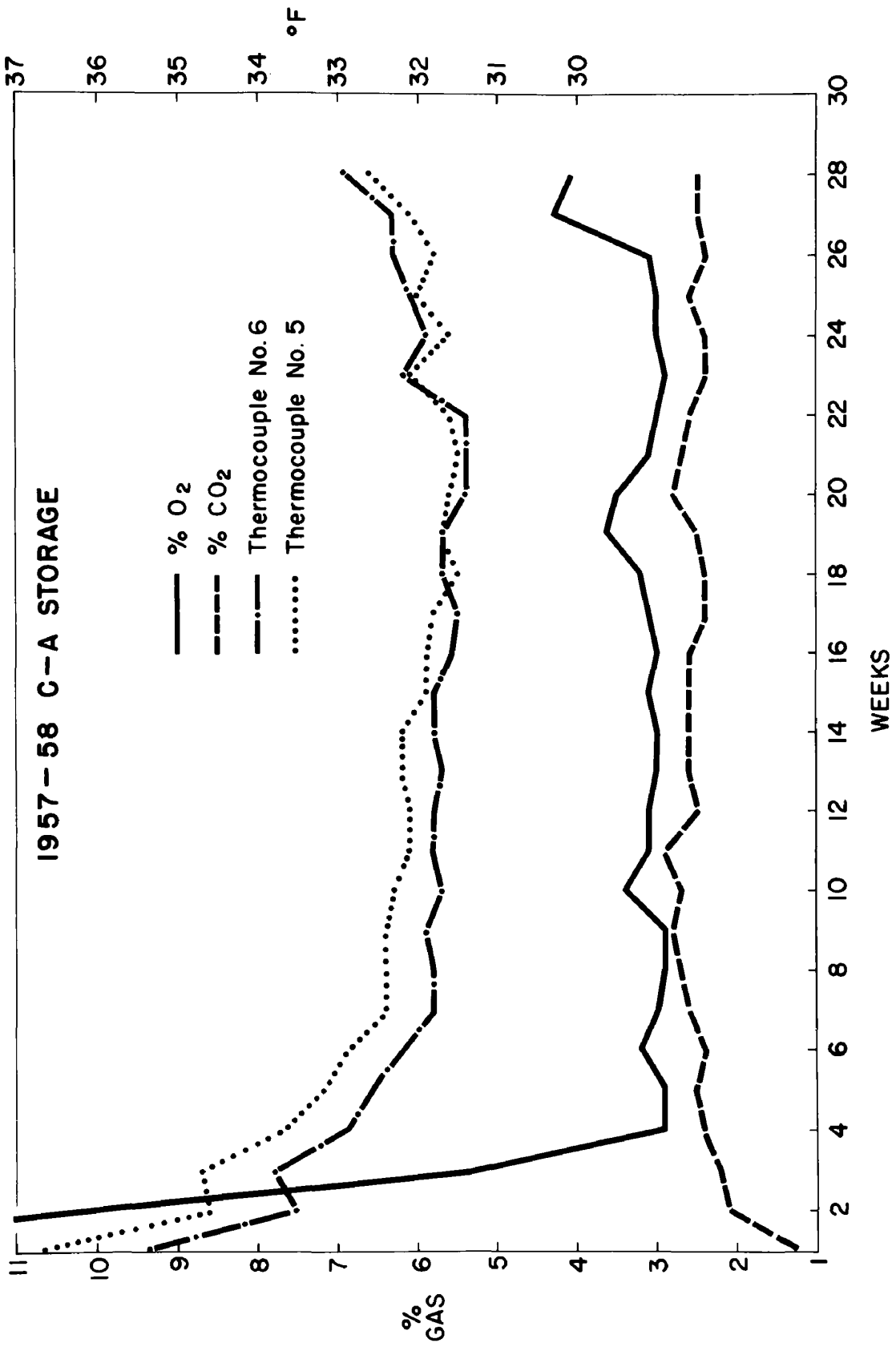


Figure 2 Storage operation in 1957-58 (second season).
Weekly averages of atmosphere composition and
fruit temperatures at thermocouples no. 5 and 6.



Fruit firmness

Firmness data, expressed as averages for 20 or 15 fruits, for the 1956 and 1957 seasons, respectively, are shown in Appendix table 9. The averages show the fruit at harvest were of approximately equal firmness in the two seasons. Equal changes took place in storage both years, with softening amounting to 4.7-5.9 pounds in regular storage and 3.8-4.5 pounds in controlled atmosphere storage.

TABLE 11
CORRELATIONS BETWEEN THE PRESSURE TEST READINGS AT HARVEST,
AFTER REGULAR STORAGE, AND AFTER
CONTROLLED ATMOSPHERE STORAGE

Correlations	r
Harvest 1957 vs. reg. storage 1957	.371**
Harvest 1957 vs. C-A storage 1957	.532**
Reg. storage 1957 vs. C-A storage 1957	.522**
Harvest 1956 vs. harvest 1957	NS
Reg. storage 1956 vs. C-A storage 1956	.931**

The correlations in Table 11 were calculated from the pressure totals of the individual trees to facilitate the process of computation. Firmness after regular storage in 1956 showed a highly significant correlation with firmness after controlled atmosphere storage in the same season. The correlations of fruit firmness at harvest and after the two methods of storage showed high significance on the complete set of data collected in 1957. Between years, however, there was no correlation in the firmness of fruit from individual trees at harvest.

The only nutrient element consistently correlated with the pressure test readings was the nitrogen in fruit and leaf

(Table 12). The limited number of pressure readings at harvest time in 1956 did not show a significant correlation with fruit nitrogen. However, when the fruit was removed from regular and controlled atmosphere storage, additional readings were made and a significant negative correlation was found. This negative relationship between the nitrogen content of fruit and flesh firmness also existed in 1957. Agreement of the negative correlations of leaf nitrogen and firmness, as shown in Table 12, with those of fruit nitrogen and firmness were expected in view of the relationship of fruit and leaf nitrogen levels. The correlation between leaf nitrogen and firmness after controlled atmosphere storage in the 1956 season was not significant. The data of 1957 showed highly significant correlation coefficients for leaf nitrogen and fruit firmness.

TABLE 12
CORRELATIONS BETWEEN FRUIT FLESH FIRMNESS AND NUTRIENT
ELEMENT CONTENTS OF FRUITS AND LEAVES

Analyses	PRESSURE TESTS					
	1956			1957		
	harvest	reg. stor.	C-A	harvest	reg. stor.	C-A
	<u>mature fruit</u>					
N	NS	-.304*	-.279**	-.547**	-.459**	-.374**
P	NS	NS	NS	NS	NS	NS
K	-.635**	NS	-.353**	NS	NS	-.269*
Ca	NS	NS	NS	NS	NS	NS
Mg	NS	-.329*	NS	-.375**	-.400**	-.493**
	<u>leaf</u>					
N	-.400*	NS	NS	-.708**	-.655**	-.486**
K	NS	NS	-.271**	.262*	.218*	.265*
	<u>immature fruit</u>					
N	--	--	--	-.559**	--	--

The phosphorus content of both leaf and fruit was not significantly correlated with fruit firmness.

The potassium content of the fruit was negatively correlated with the pressure readings of fruit from controlled atmosphere storage in the 1956 and 1957 seasons, but in the latter only at a 5% level of significance. Leaf potassium was likewise negatively correlated with the firmness of fruit from controlled atmosphere storage in 1956, but showed a positive correlation for all samples in 1957.

The relationship of fruit calcium to flesh firmness was studied after the EDTA method of analysis was adapted. As shown in Table 12, no significant correlation was observed between the calcium content of the fruit and fruit firmness at harvest or after storage.

The magnesium content of fruits was not correlated with fruit firmness at harvest or after controlled atmosphere storage in 1956, whereas in 1957 significant negative correlations were found both at harvest and after the two methods of storage.

Flesh firmness was not significantly related to average fruit size.

Ground color

Appendix table 10 records the observations on ground color. Using orchard averages, the correlations between the ground color at harvest and after regular and controlled atmosphere storage were tabulated in Table 13. Also, similar correlation coefficients were determined on individual lots in 1957.

The values for ground color were significantly correlated within years, indicating that the change from green to yellow during storage proceeded at approximately the same rate within one type of storage. Ground color at harvest and after controlled atmosphere

storage was not significantly correlated by years. However, ground color for fruit from regular storage was positively correlated for the two years.

TABLE 13
CORRELATIONS BETWEEN THE GROUND COLOR VALUES AT HARVEST,
AFTER REGULAR STORAGE, AND AFTER
CONTROLLED ATMOSPHERE STORAGE

		Orchard Averages	Trees Within Orchards
	Harvest vs. regular storage	.590*	--
1956	Reg. storage vs. C-A storage	.883**	--
	Harvest vs. C-A storage	.590*	--
	Harvest vs. regular storage	.784**	.615**
1957	Reg. storage vs. C-A storage	.720**	.531**
	Harvest vs. C-A storage	.706**	.345**
1956	Harvest	NS	--
	vs. Reg. storage	.668*	--
1957	C-A storage	NS	

No significant correlation between the ground color and the flesh firmness was found.

TABLE 14
THE EFFECT OF THREE SPRAY APPLICATIONS OF CALCIUM NITRATE
ON THE AVERAGE GROUND COLOR OF THE FRUIT; 1957

	At harvest		After reg. stor.		After C-A stor.	
	Control	Tmt.	Control	Tmt.	Control	Tmt.
Ground color	2.54	2.79	1.66	1.69	1.86	2.00
Difference		.25		.03		.14
t		2.79*		.298		3.63*

Apples from trees treated with calcium nitrate in 1957 were significantly greener in ground color than fruit from non-treated trees at harvest and upon removal from controlled atmosphere storage (see Table 14). After regular storage, however, the color values

were not significantly different.

Soluble solids

The percent soluble solids in the juice of fruit from the individual trees before and after storage were significantly correlated in both seasons as shown in Table 15. The fruit with high soluble solids showed an appreciable amount of water core in 1957. No significant correlation was found on flesh firmness, as determined by pressure tests.

TABLE 15
CORRELATIONS BETWEEN FRUIT SOLUBLE SOLIDS AND WATER CORE,
FIRMNESS, AND NUTRIENT ELEMENT LEVELS

	At harvest 1956	After C-A 1956	At harvest 1957
After reg. storage	.643**	.635**	.621**
After C-A storage	.673**	--	.590**
Water core at harvest	-- a	--	.449**
Firmness at harvest	NS	--	NS
Mature fruit N	--	-.399**	-.483**
P	--	-.234*	-.269*
K	--	-.327**	NS
Ca	--	NS	NS
Mg	--	NS	NS
B	--	NS	-.253*
Leaf N	--	-.261*	NS
K	--	NS	NS

^aNo water core observed in 1956.

Table 15 shows also the relationship of nutritional factors to soluble solids. In both seasons the nitrogen and phosphorus contents of the fruit were negatively correlated with the soluble solids. Potassium was negatively correlated with soluble solids in 1956, boron in 1957. The leaf nitrogen content, however, was negatively correlated

only at the 5% level in the 1956 season, and the leaf potassium in none of the two seasons.

Table 16 shows that the calcium spray treatments in 1957 did not affect the soluble solids readings of the harvested fruit.

TABLE 16
THE EFFECT OF CALCIUM NITRATE SPRAYS UPON THE
SOLUBLE SOLIDS LEVEL; 1957

Treatment	n-1	Soluble solids	t
Control	50	14.14 $\pm$.81	NS
Calcium nitrate	32	14.26 $\pm$.54	

Storage disorders

Breakdown: The incidence of flesh breakdown of the fruit during regular and controlled atmosphere storage in the 1957 season showed one orchard (no. 4) was highly susceptible to this disorder, whereas all others except for two trees in orchard 2 were relatively free of it. A holding test of two weeks at 75° F. after storage substantiated these results: they showed a high incidence of breakdown for fruit from orchard 4 held in either type of storage. The calculated score values, shown in Appendix table 13, reflect the predisposition of the fruit from individual trees to this disorder in the 1957 season. For example, it is shown in Table 17 that trees 7 and 8 of orchard 2 were consistently susceptible to the disorder, regardless of storage method. Tree 18 in orchard 4 showed considerably less inherent susceptibility to breakdown in 1957 than the other four trees of this orchard.

TABLE 17
EXAMPLE FOR THE PREDISPOSITION OF THE FRUIT TO BREAKDOWN
(CF. APPENDIX TABLE 13); 1957

Orchard	Tree	Reg. stor. (%)	holding (%)	C-A stor. (%)	holding (%)	Total ("score")
2	6	0	0	2	30	32
	7	0	10	23	95	128
	8	2	20	12	95	129
	9	0	0	0	5	5
	10	0	0	0	15	15
4	16	19	65	13	75	172
	17	31	65	27	100	223
	18	3	15	1	45	64
	19	16	35	24	70	145
	20	16	40	15	95	166

The mean soluble solids readings at harvest for the individual fruit lots free of internal breakdown were found to be similar to the mean soluble solids of fruit having a high incidence of breakdown. These were compared by the t-test as shown in Table 18.

TABLE 18
COMPARISON OF THE SOLUBLE SOLIDS CONTENT AT HARVEST AND THE
DEVELOPMENT OF INTERNAL BREAKDOWN IN STORAGE; 1957

Classification	n-1	Soluble solids	t
Fruit without breakdown	26	14.05 $\pm$.78	NS
Fruit with breakdown	55	14.59 $\pm$.67	

The trees are grouped by the incidence of breakdown in Appendix table 14. The group averages for fruit size, incidence of water core, flesh firmness, and nutrient content are listed in order of increasing amount of breakdown in Table 19. In addition, fruit free of breakdown are compared with affected fruit by t-test in this table.

TABLE 19
BREAKDOWN SUSCEPTIBILITY COMPARED TO SIZE, WATER CORE,
FIRMNESS, AND NUTRIENT LEVELS; 1957

A. Handling observations				
Breakdown "score"	Size (no. of fruit per box)	Water core (in 15 fruits)	Firmness (av. pounds)	
0	174.1 $\pm$ 14.4	4.5 $\pm$ 3.1	20.24 $\pm$	.88
1 - 7	155.6 $\pm$ 12.3	7.5 $\pm$ 4.9	20.61 $\pm$	1.05
10 - 30	153.3 $\pm$ 14.5	7.0 $\pm$ 4.6	20.20 $\pm$	1.22
32 - 90	154.3 $\pm$ 14.9	7.4 $\pm$ 5.1	20.11 $\pm$	1.45
128 - 223	149.6 $\pm$ 25.1	11.0 $\pm$ 4.1	19.99 $\pm$	1.27
All affected lots (av. 1 - 223)	153.4 $\pm$ 14.4	7.8 $\pm$ 4.9	20.29 $\pm$	1.22
Comparison of unaffected and affected lots (t)	5.906*	2.263*	NS	

B. Nutrient levels in fruit tissue				
Breakdown "score"	N (%)	K (%)	Ca (%)	Fe (ppm)
0	.299 $\pm$.038	.932 $\pm$.068	.067 $\pm$.009	37.4 $\pm$ 11.1
1 - 7	.286 $\pm$.059	.925 $\pm$.079	.060 $\pm$.012	37.1 $\pm$ 11.8
10 - 30	.320 $\pm$.072	.888 $\pm$.059	.062 $\pm$.012	34.4 $\pm$ 8.7
32 - 90	.325 $\pm$.091	.926 $\pm$.072	.057 $\pm$.014	35.3 $\pm$ 9.5
128 - 223	.337 $\pm$.052	.777 $\pm$.051	.060 $\pm$.013	27.8 $\pm$ 8.5
All affected lots (av. 1 - 223)	.313 $\pm$.073	.898 $\pm$.086	.060 $\pm$.012	34.5 $\pm$ 12.4
Comparison of unaffected and affected lots (t)	NS	NS	NS	NS

The t-test shows that the affected and the non-affected groups of apples differed primarily in fruit size (Table 19). The number of fruit in lots free of breakdown averaged 174 per box and was significantly different from the average number in affected lots (154 apples per box). The six most seriously affected lots had the largest fruit (150 apples per box on the average). Within a susceptible lot of apples, however, the development of breakdown in storage was not limited to the fruit of larger size.

Only elements showing a trend possibly related to breakdown were included in Table 19. None of these nutrient elements differed significantly between susceptible and non-susceptible fruit. Although there were no significant effects of potassium content on the incidence of breakdown, it is evident in Table 19 and in Appendix table 14 that very seriously affected lots ("scores" 128-223) generally had potassium contents considerably lower than lots which showed only a minor percentage of breakdown ("score" 0-90) at each inspection.

In order to statistically evaluate this trend, the "score" values were transformed by $\sqrt{x + 1/2}$ and correlated to the potassium content. It was found that there was a significant negative correlation ($-.372^{**}$) between the potassium content of the fruit and the incidence of breakdown.

TABLE 20
COMPARISON OF THE $\frac{\text{Mg}}{\text{Ca}}$ RATIOS OF THE FRUIT WITH THE
INCIDENCE OF BREAKDOWN; 1957

Groups	n-1	$\frac{\text{Mg}}{\text{Ca}}$ ratio (av.)	t
Fruit free of breakdown	26	$1.111 \pm .225$	NS
Fruit with breakdown (score 32-223)	55	$1.061 \pm .437$	

The lack of influence of the $\frac{\text{Mg}}{\text{Ca}}$ ratio upon the incidence of breakdown in storage is shown in Table 20. Trees producing fruit free of breakdown (score 0) showed no significant difference between the average values of the $\frac{\text{Mg}}{\text{Ca}}$ ratios from those with serious breakdown (score 32-223).

Jonathan spot: The observations on Jonathan spot and skin browning for the two seasons are summarized on Appendix table 15. In this table the orchards are arranged according to the frequency of occurrence of spot and skin browning in 1957. In most of the orchards the five trees produced a fairly uniform percentage of affected fruit. Wide differences from one tree to the other were noted in a few instances, however, as indicated by the standard deviations.

The occurrence of Jonathan spot and accompanying skin browning in the various orchards was dissimilar from one season to the other. This is shown in Table 21 which classified the orchards according to arbitrary groups of "low" (0-10%), "medium" (10-25%), and "high" (25% and more) incidence. Also, no significant correlation was found for the susceptibility of individual trees from one year to the other.

TABLE 21
CLASSIFICATION OF THE ORCHARDS ACCORDING TO THE SEVERENESS OF
JONATHAN SPOT AND SKIN BROWNING IN 1956 AND 1957

Classes		Orchards	
		1956	1957
Low	(0 - 10%)	3, 12	2, 4, 9, 10a, 10b, 11, 12
Med.	(11 - 25%)	4, 9, 10a, 10b, 11	3, 5, 7, 8, 13, 16
High	(25 %)	1, 2, 5, 6, 7, 8, 13, 14, 15, 16	1, 6, 14, 15

The possible influence of various nutrients upon development of the spot disorder was studied by correlation analysis. With the exception of fruit potassium content ($r = + .271^*$) in 1957, calculated on individual trees, no significant correlation of the mineral content of the fruit to skin disorders was found. This was indicated by grouping the analytical and observational data according to the percentage of the skin disorders in the two seasons, as shown in Appendix tables 16 and 17.

The orchards with a high percentage of skin disorders had slightly lower ground color ratings in both years, which may suggest a slightly more advanced maturity. Also, a considerably higher proportion of apples from these orchards was covered with red color. However, in 1957, there were several striking exceptions in which the bushy shape of the trees and the resulting light conditions may have adversely affected the color development of the fruit. On the other hand, among the orchards with low incidence of skin disorders in 1957, there were some with a relatively high portion of fruits with a complete red coloration (orchards 2, 4, 16). This can be attributed to the open structure of the trees, and also to the rather light crop of these trees in 1957.

The effect of storage methods upon skin disorders is shown in Appendix table 15. Jonathan spot was almost completely prevented by storage in controlled atmosphere. Skin browning, however, occurred to approximately the same extent in controlled atmospheres as in regular storage.

Comparison by the t-test showed that the average occurrence of skin browning during controlled atmosphere storage was not significantly different from that on apples in regular storage. There was

a high correlation ($r = .793^{**}$, 81 d. f.) of the incidence of this disorder during regular and controlled atmosphere storage.

Respiration

The respiratory activity of the fruit is recorded in Appendix tables 11 and 12, and presented in figures 3 and 4. The respiration of the fruit before and after storage was similar in both years for most of the orchards for which the carbon dioxide evolution of the fruit was measured.

Generally speaking, there was no noticeable change in respiratory intensity from one year to the other. There were no marked differences in the carbon dioxide production as a result of storage method.

TABLE 22
THE RELATION OF FRUIT AND LEAF POTASSIUM CONTENT TO FRUIT
RESPIRATION AT HARVEST^a AND TO BREAKDOWN IN STORAGE

		Orchard averages				
Orchard		4	2	3	7	9
1956	leaf K%	.95	1.29	1.66	1.52	1.57
	fruit K%	.793	.823	1.028	1.004	.988
1957	leaf K%	1.16	1.37	1.55	1.46	1.50
imm.	fruit K%	1.24	1.26	1.72	1.49	1.68
mat.	fruit K%	.746	.828	.907	.922	1.014
1957	CO ₂ at 75° F. (av. mg/kg/hr)	41.1	29.4	25.2	28.1	25.0
1957	breakdown ("score")	154	62	27	26	0

^aDuring first 10 days following harvest.

An orchard (no. 4) with low potassium values in both years showed a high respiratory activity. Orchard 2, the one with the next lowest potassium content, was only slightly higher in respiration intensity than the other three orchards shown in Table 22 for comparison. No development of physiological disorders occurred in the respiration studies at harvest, but after regular and controlled atmosphere storage about half of the fruit in orchards 4 and 2 were affected by internal breakdown. This was verified by the breakdown percentage and "score" data computed from the entire samples from the individual trees. The average "score" data obtained are included in Table 22 to demonstrate the probable interrelationship of potassium content, respiration, and breakdown development of the fruit in storage in 1957.

The upper graphs in figures 3 and 4 represent orchards which produced fruit with a normal respiration rate, and the lower ones the fruit with increased CO_2 evolution. In 1956, when practically no breakdown was observed, fruit of orchard 4 had a respiration intensity similar to that of fruit from other orchards.

Figure 3 Respiration of apples from orchard 16 (approximately normal potassium level) and orchard 4 (low potassium level) at harvest and following regular and controlled atmosphere storage.

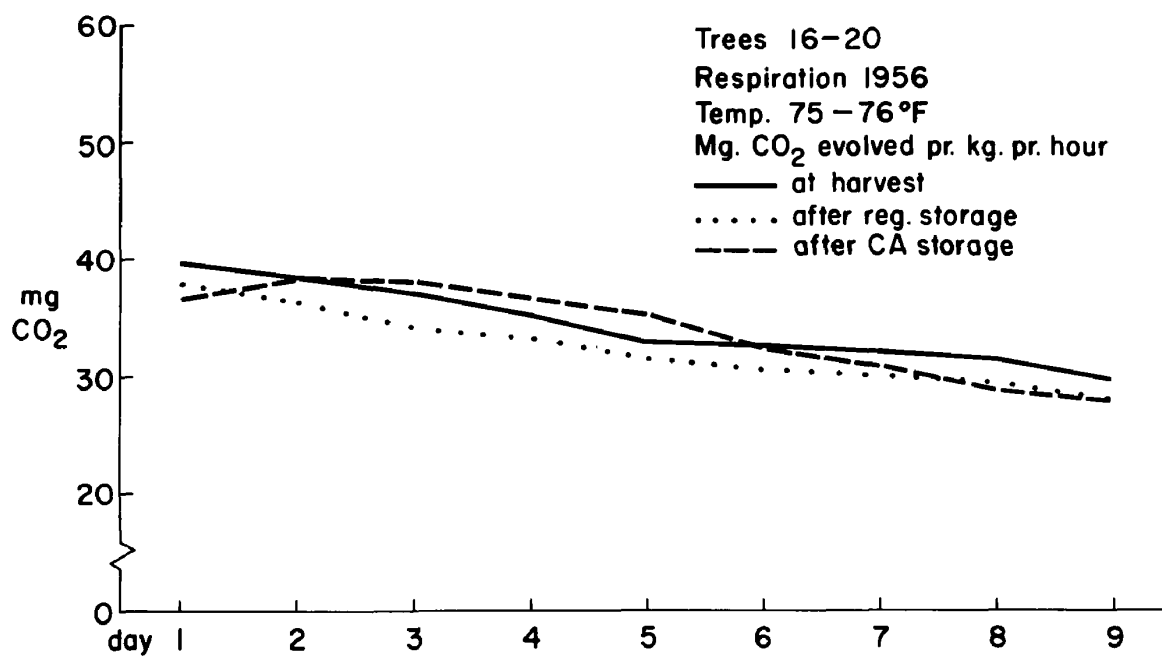
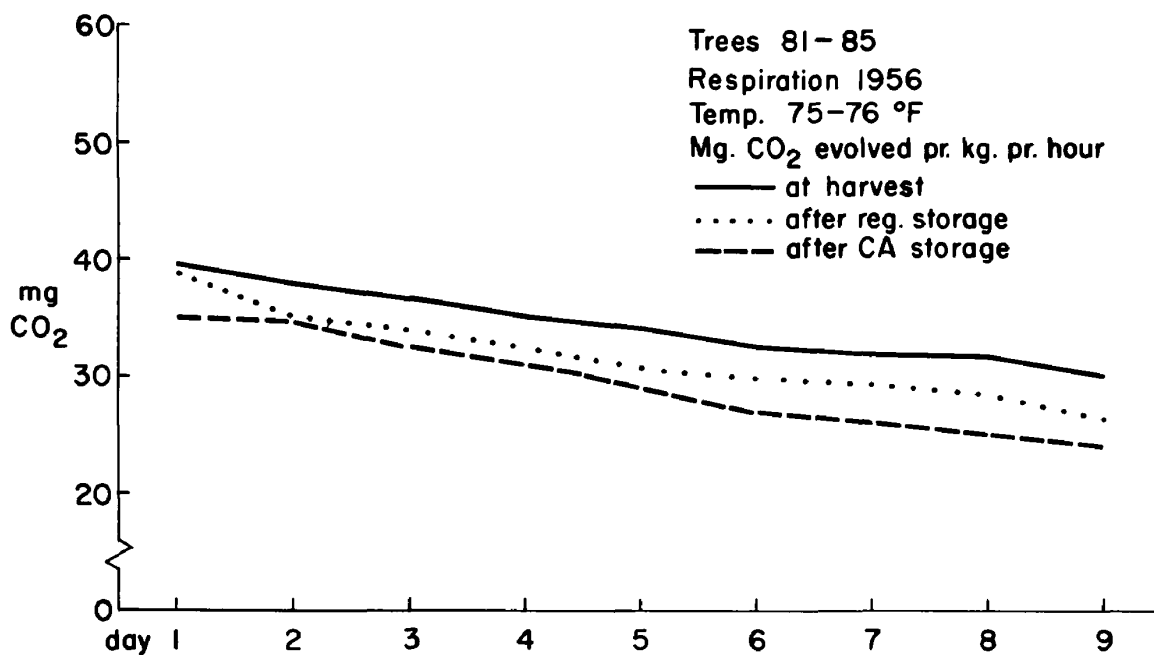
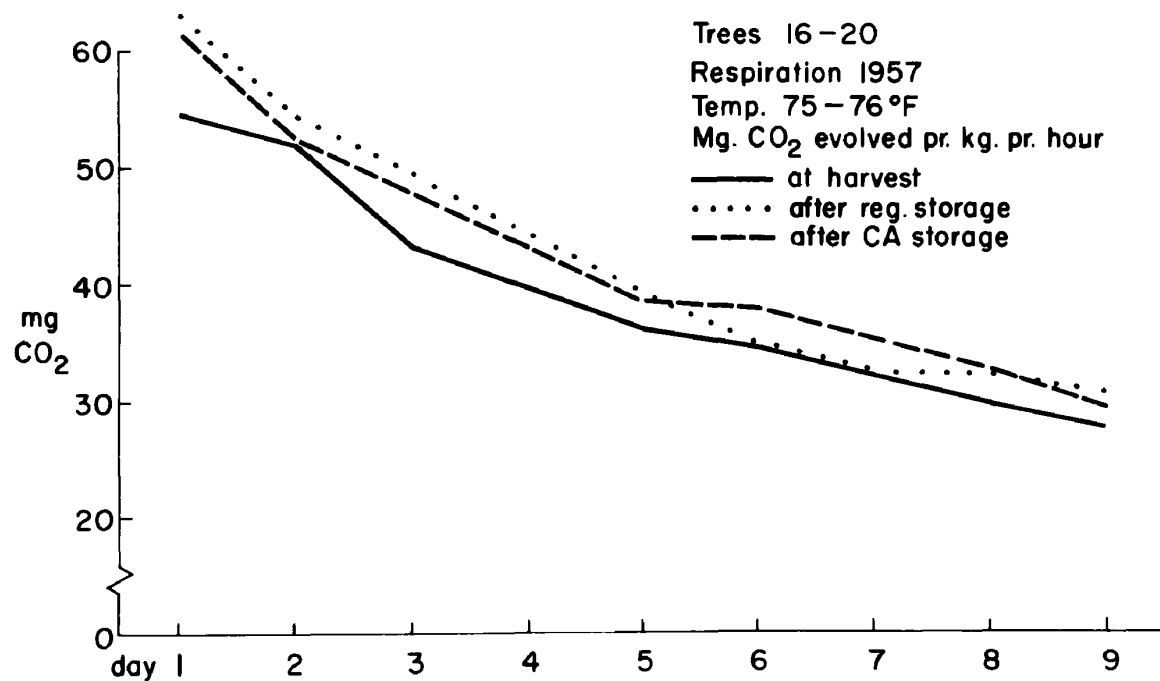
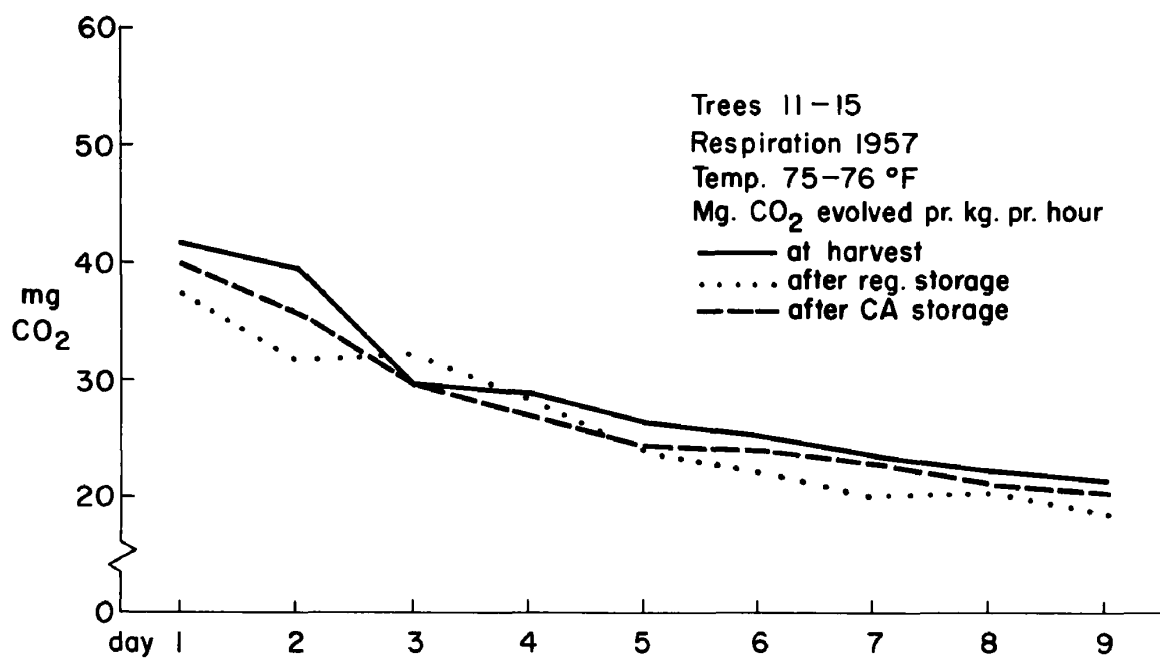


Figure 4 Respiration of apples from orchard 3 (approximately normal potassium level) and orchard 4 (low potassium level) at harvest and following regular and controlled atmosphere storage.



DISCUSSION

The leaf composition values obtained in this survey are comparable to those used by Kenworthy (1949) as standards of evaluation for the nutrient element balance chart. In both years the leaf nitrogen content in several orchards was below the minimum levels listed in a survey of Michigan orchards by Kenworthy (1950). No extremely low values were found for phosphorus, whereas in 1956 some potassium values were almost as low as the lowest ones reported in the above survey. The leaf calcium content in 1956 was similar to the standard level, but in 1957 the leaves of several trees had a relatively low calcium content. Magnesium was close to the normal values, iron slightly lower, manganese considerably lower, copper slightly higher, and boron generally below the average value. In comparison with Hill's (1952) values from grower orchards of McIntosh the nitrogen in the investigated Jonathan trees was high, phosphorus about the same but less variable, potassium about the same, and magnesium considerably higher. Kenworthy's (1950) survey, comparing the two varieties in Michigan, showed lower values in leaves of McIntosh for nitrogen, potassium, and magnesium, whereas phosphorus was present at a higher level than in Jonathan.

On the element balance chart the standard index value is 100; an index value below 60 or above 140 must be considered a serious deficiency or excess, respectively. For all nutrients the orchards studied had index values between 70 and 135 on the nutrient element balance chart; the majority were between 80 and 115. This indicates that the deviation from the standard value was within the normal range.

The leaf contents of 1956 and 1957 were significantly correlated for nitrogen, phosphorus, potassium, calcium, magnesium and manganese. Iron increased in several orchards from 1956 to 1957, probably as a consequence of increased iron carbamate fungicide applications, the boron increase in the second year was attributed to its higher availability with increased moisture in 1957.

Preliminary analysis of the fruit from 18 orchards for the same elements as the leaves in 1956 showed that nitrogen, phosphorus, potassium, magnesium, and manganese were present in the fruit at levels which were correlated significantly to the respective leaf content in the summer. The correlations were not so high for the same 18 fruit lots analyzed after controlled atmosphere storage; the corresponding correlation computations of all 90 lots reached only the 5% level of significance for nitrogen, and no significance for magnesium and manganese. The boron analyses after controlled atmosphere, however, were significantly correlated with those of the leaves.

To obtain data with a higher comparability, a more accurate sampling method was introduced in 1957, such as picking six fruits for mineral analysis from similar positions and from all around the tree. Further improvement is suggested by selecting the fruit carefully with respect to the position on the tree. "Twin" or "triplet" fruits, or neighboring apples on similar positions on a branch should be used for comparative studies on certain treatments and effects.

Proper drying of the fruit samples may affect the accuracy of the results. The procedure employed in 1957 yielded a much better sample quality than the method used in 1956. It was possible after a pre-drying period to remove the fruit temporarily in order to

liberate space for other fresh fruit samples. When all the material was dried at the first level, the final drying to hard crispness was accomplished with a much greater number of samples per oven load.

The extra care and effort in the preparation of samples was compensated by the reduction in time required for weighing and preparing the dried samples for the nitrogen, potassium, and spectrographic analyses.

In the present survey it was found that the effect of nitrogen upon the fruit firmness was more consistently evident from the fruit contents than from the leaf analysis values, even though some individual r -values were higher when computed with the leaf nitrogen values. The interpretation of the potassium effect is more difficult, since in 1957 fruit firmness was negatively correlated to leaf content and positively correlated to fruit content; in 1956 firmness was negatively correlated with both leaf and fruit content. The effects of the nitrogen and potassium levels upon the soluble solids were more definite for fruit analysis values than for leaf values. The negative correlation of the fruit nitrogen level with the soluble solids was significant at the 1% level, whereas a leaf nitrogen correlation was found only in the first season and only at the 5% level of significance.

The use of immature fruit in a survey or as a diagnostic tool for the prediction of storage quality of the fruit needs considerably more experimentation. Although the nitrogen, phosphorus, potassium, and manganese of immature fruits were significantly correlated with both leaves and mature fruits, the definite levels needed to predict their influence upon storage defects are not

known. Furthermore, the optimum sampling date needed to provide conclusive data must be investigated. It is believed that some of the elements present at rather low levels would need to be determined with a higher degree of precision before storage effects could be associated with their concentration level. Only the negative correlation between the nitrogen content of immature fruit and the firmness in the fall was significant.

A comparison of the two storage seasons showed that it was possible to reduce the oxygen content in the controlled atmosphere room considerably faster in the second year than in the first year. Quality characteristics as measured here, were similar for the two seasons, indicating that differences in the establishment of the desired atmosphere composition were of minor effect.

The beneficial effects of the controlled atmosphere storage over regular storage upon quality was evident with regard to the preservation of firmness, fresh appearance, and greenish ground color. Still more valuable was the complete prevention of Jonathan spot by controlled atmosphere which has been reported previously by Plagge (1942), Ballinger (1955), and Dewey et al. (1957). A skin disorder, referred to in this study as skin browning, which Ballinger (1955) and Dewey et al. (1957) considered to be controlled atmosphere injury was found on fruit in regular storage as well. They perhaps recorded it as Jonathan spot in the control samples from regular storage, because skin browning seemed to be related to Jonathan spot in that the same tissues were affected. It occurred more frequently on lots which were susceptible to spot. Controlled atmosphere storage did not prevent skin browning.

In spite of the low temperature (32° F.) in the controlled atmosphere room no soft scald occurred. Contrary to the findings of Trout et al. (1940) internal breakdown was not significantly increased at this temperature. This agreed with the results of Haller and Lutz (1941) who compared storage at 32° F. and 36° F. The intensity of breakdown appearance in individual fruits was retarded, but the percentage of affected fruit was not reduced by controlled atmosphere.

In agreement with Gourley and Hopkins (1930), the results of the present survey showed that breakdown was not induced by the higher nitrogen levels encountered. However, the general finding that an excessive leaf nitrogen content adversely affects the keeping quality of fruit (Beaumont and Chandler, 1933; Magness et al., 1940; Eaves, 1947-51; Hill et al., 1950) was not disproved by the results presented here, because no really high nitrogen levels were found in this survey.

The relationship of a low potassium level with increased respiratory activity and greater susceptibility of the fruit to breakdown development was found only in the second season. In the first year the excellent growing conditions may have compensated adverse effects of unbalance among nutrients so that scarcely any breakdown development was observed in that season. Such seasonal differences had been shown previously by Haller and Lutz (1941).

In 1957, the high respiratory rate at harvest for apples of the two orchards with a low level of potassium was also found after regular and controlled atmosphere storage. A great portion of apparently sound fruit from these orchards invariably developed

breakdown symptoms during the respiration studies conducted for two weeks at 75° F.

Degman and Weinberger (1934) did not find any relationship between potassium shortage and respiration of apples in storage. Increased respiration was found in smaller sized fruit in experiments of Smock (Smock and Neubert, 1950), whereas in the present survey the fruit affected with breakdown was significantly larger in size than that of completely sound fruit. Within a susceptible lot, breakdown was observed on fruit of all sizes; this excludes the assumption of size as a causal factor.

Haller and Lutz (1937) produced a slight climacteric rise in some lots of Jonathan apples at 70° F. with a peak after 4-5 days. The carbon dioxide development in the lot picked first (Sept. 6, near Washington, D. C.) was 25 mg of CO₂ per kg fruit per hour on the first day after harvest and rose to 29 mg. The lot picked 19 days later had a much less pronounced rise, from 24.5 mg on the first day to 26.5 mg on the seventh and eighth day. The last picked lot (Sept. 30) produced 28 mg CO₂ on the first day and reached the climacteric after 4 days with a CO₂ evolution of 31 mg per kg fruit per hour. The fruit used in the present survey in 1956 was picked 2-3 days after commercial harvest, and a climacteric was not necessarily expected. In 1957, however, the fruit was harvested at a stage of still incomplete abscission, 3-5 days before commercial harvest; a gradual downward line was produced in the respiration studies at 75° F., beginning with a carbon dioxide evolution of about 40 to 42 mg per kg fruit per hour in the lots not susceptible to breakdown. It is to be noted, however, that the

fruit was cooled at 36° F. for three days, before being shipped to East Lansing, and the warm-up period during the 3-4 hours of truck transport may have eliminated the possibility of obtaining the small climacteric rise which otherwise could perhaps be observed on Jonathan apples. Porrit and Fisher (1953) reported that post-climacteric fruit of Jonathan and two other varieties was not correlated with late harvesting.

Evidence for storage quality changes attributable to the calcium nitrate treatment, as suggested by Garman and Mathis (1956) for bitter pit on Baldwin apples, was not obtained for Jonathan in 1957. The calcium content in the fruits was significantly increased by this treatment, but no depressing or enhancing effect of the calcium upon other nutrients was noted. The only effect on quality was a slight retardation of yellowing of the ground color. This may have been related to the observation of a change in maturation of the leaves in the fall. No data were collected on this effect, however.

The calcium determination by complexometric titration with EDTA proved to be a useful method for analyzing large numbers of fruit samples. An adaptation for differential titration would easily be possible in instances where magnesium values are unavailable from other methods of analysis. As long as interfering ions are present only in minute quantities, the method is quite sensitive. The removal of interfering ions, as suggested by Diehl et al. (1950), did not prove necessary for fruit tissues.

No pre-harvest factor or group of factors explained the occurrence of Jonathan spot. As indicated on Appendix table 15 by

the standard deviations, the five trees in each orchard plot usually showed fairly close agreement in percentage of affected apples, yet there was no definite individual susceptibility of given trees for the two seasons. A pre-harvest influence on the trees, which may vary in intensity and in locality from season to season, seemed to be responsible for the spot formation and also for skin browning. This should be investigated more specifically.

The results presented indicated that the deterioration in storage and the development of important storage disorders of Jonathan apples in certain seasons was primarily a matter of predisposition prior to placement in storage. The general belief (Trout et al., 1940; Smock and Neubert, 1950) that water core is a frequent cause of breakdown could neither be firmly supported nor disproved. A significantly higher rate of water core at harvest was observed in the lots which later produced breakdown, but there were many exceptions. Water core may not be the cause, but merely an associated factor of breakdown. Upon inspection of the fruit the original water core tissue could sometimes be recognized around the vascular bundles.

Regular refrigerated storage (35-36° F.) until the end of the normal marketing period of Jonathan apples, as used in these tests, yielded the higher percentages of disorders and quality defects. Controlled atmosphere storage of commercial duration (7 months) resulted in higher quality except for lots from orchards with a severe incidence of breakdown. Whether potassium or other factors were of greatest influence on the prevention of breakdown could not be clarified beyond doubt during the two seasons of the present

work. The consistency with which the disorder occurred in the same lots regardless of the storage methods points out the need for additional research on the problem.

SUMMARY AND CONCLUSIONS

A survey was conducted for two years on 16 Michigan fruit farms to observe effects of the nutritional status of Jonathan apple orchards upon the harvested fruit.

The nutrient content of the leaves, which is used in the determination of the nutritional status of Michigan orchards, was compared with the nutrient content of fruit. The results indicated that, for studies of post-harvest behavior of the fruit, the fruit analyses may be more reliable than the leaf analyses.

The nutrient elements differed in the extent of effects upon fruit quality factors before and after storage. Correlations of firmness, soluble solids and storage disorders with nutrient element levels in leaves and fruits were attempted, and it was found that the nitrogen level was the most important single nutrient factor. Effects of phosphorus, potassium, and magnesium were likewise determined by the correlation method, but less consistency was observed. T-tests were applied to test for differences caused by calcium nitrate spray treatments in 1957. No significant relationships of iron, manganese, boron, and copper to keeping quality in general were found.

The Jonathan apples were stored in a farm-operated refrigerated storage at 35-36° F., and comparative samples in an experimental controlled atmosphere storage at 32° F. with 2.5% CO₂ and 3% O₂. The controlled atmosphere storage proved satisfactory in maintaining high fruit quality until May for both seasons.

Pressure test readings used as a measure of fruit firmness were significantly correlated by individual trees at harvest and after storage within one season; pressure tests either at harvest or after storage were not significantly correlated for seasons. Nitrogen was the only nutrient element with a consistent influence upon fruit firmness, showing a negative correlation. The loss of flesh firmness in storage was greater for large fruit than for small fruit. The development of breakdown could not be predicted from the pressure test data.

The soluble solids content of the fruit juice had a significant negative correlation with nitrogen, and, somewhat less, with phosphorus. Potassium was inconsistent in its effects on soluble solids from one season to the other. Different moisture supply, light conditions and temperatures during the two growing seasons may have caused this variation.

Water core of the fruit which occurred in 1957 was associated with high soluble solids at the time of harvest. In most cases, water core disappeared during storage. The incidence of internal breakdown was not positively identified with water core, even though a browned water core pattern was sometimes visible in the cross-section of a fruit affected with breakdown upon removal from storage.

Breakdown was more prevalent in large fruit than in small fruit. However, susceptible lots contained affected fruit of medium and small size. Controlled atmosphere did not prevent its development.

Jonathan spot, which is usually the disorder responsible for the greatest economic losses in storage, was not consistently

associated with any nutrient element. The fruit of individual trees is predisposed to Jonathan spot at harvest; its development, however, depended upon the conditions under which the fruit was stored. Spot was entirely prevented by controlled atmosphere storage, whereas skin browning occurred in controlled atmosphere as well as in regular storage. The lots of fruit susceptible to Jonathan spot were generally affected by the skin browning regardless of storage method. Variations in susceptibility seemed to be an orchard characteristic rather than of individual trees. The occurrence was unrelated by years, suggesting that nutritional factors alone are not responsible.

The storage conditions utilized, 35-36° F. in regular storage and 32° F. in controlled atmospheres, did not favor soft scald development.

Three calcium nitrate sprays in 1957 increased the calcium content of the fruit but did not alter the keeping quality appreciably.

Respiration studies indicated that limited potassium may greatly increase the respiratory activity and the susceptibility of the fruit to internal breakdown. These effects were observed in the 1957 season with less favorable growing conditions. The observations of the potassium level in leaves and fruit and respiratory activity in relation to that of other lots of fruit may lead to a technique of predicting breakdown susceptibility.

The results of this survey indicate that the mineral nutrient level in the fruit may influence the storage quality of apples. However, non-nutritional factors, such as temperature, rainfall, and certain cultural methods as well as the storage conditions employed modify these nutritional effects.

Further study of some orchard plots utilized in this study is suggested, especially with regard to the influence of the potassium level and different respiratory rates upon the formation of internal breakdown.

LITERATURE CITED

- Aldrich, W. W. 1931. Effect of fall application of sodium nitrate upon the color, keeping quality, and nitrogen content of apples.
Maryland Agr. Exp. Sta. Bul. 326
- A. O. A. C. 1955. Official Methods of Analysis.
Eighth edition, pp. 856-859
- Archbold, H. K. 1925. Chemical studies in the physiology of apples.
II. The nitrogen content of stored apples.
Ann. Bot. 39, 97-107
- Baker, C. L. and E. C. Maxie. 1952. An apparent retardation of a physiological spot on Red Rome apples in storage by activated charcoal and shredded oiled paper.
Proc. ASHS 59: 312-314
- Ballinger, W. E. 1955. Storage of Jonathan apples in controlled atmospheres and film crate liners.
Unpublished M.S. thesis. Mich. State Univ.
- Barnard, A. J., W. C. Broad, H. Flaschka. 1956-57. The EDTA titration: Nature and methods of end point detection.
Chemist-Analyst 45: 86, 111; ibid. 46:18, 46,76
- Bartlett, M. S. 1947. The use of transformations.
Biometrics, March 1947, pp. 39-52
- Batjer, L. P. and M. H. Haller. 1942. Fruit maturity and growth of apple trees as affected by boron content (Preliminary report).
Proc. ASHS 40: 29-30
- Beaumont, J. H. and R. F. Chandler. 1933. A statistical study of the effect of potassium fertilizers upon the firmness and keeping quality of fruits.
Proc. ASHS 30: 37-44
- Biedermann, W. and G. Schwarzenbach. 1948. Complexons XI: The complexometric titration of alkaline earths and some other metals with Eriochrome Black T.
Chimia 2: 56
- Blasberg, C. H. 1953. Response of mature McIntosh apple trees to urea foliar sprays in 1950 and 1951.
Proc. ASHS 62: 147-153
- Brooks, C. and D. F. Fisher. 1926. Water core of apples.
Journ. of Agr. Res. 32: 223-260

- Brooks, C. and C. P. Harley. 1934. Soft scald and soggy breakdown of apples.
Journ. of Agr. Res. 49: 55-69
- Brown, Janet W. 1929. Chemical studies in the physiology of apples. XI. The relation between mineral constitution of apples and the soil on which they are grown.
Ann. Bot. 43: 817-831
- Burbel, A. B. 1937. Control of internal cork of apple with boron.
Proc. ASHS 35: 169-175
- Carrick, D. B. 1929. The storage of apples.
Cornell Ext. Bul. 189
- Claypool, L. L. and R. M. Keefer. 1942. A colorimetric method for CO₂ determination in respiration studies.
Proc. ASHS 40: 177-186
- Chochran, W. G. 1938. Some difficulties in statistical analysis of replicated experiments.
Empire Journ. of Exp. Agr. 6: 157-175
- Cook, M. T. and G. W. Martin. 1914. The Jonathan spot rot.
Phytopathology 3: 119-120
- Degman, E. S. 1930. Firmness and keeping quality of fruits as affected by nitrogen fertilizers.
Proc. ASHS 26: 182-186
-
- L. P. Batjer, L. O. Regeimbal, and J. R. Magness.
1937. Further investigations on the use of boron for control of internal cork of apples.
Proc. ASHS 35: 165-168
-
- _____ and J. H. Weinberger. 1934. Studies on firmness and keeping quality of certain fruits.
Maryland Agr. Exp. Sta. Bul. 366
- Dewey, D. H., W. E. Ballinger, and I. J. Pflug. 1957. Progress report on the controlled atmosphere storage of Jonathan apples.
Mich. Agr. Exp. Sta. Quart. Bul. 39: 691-700
-
- A. E. Mitchell and R. R. Lipsit. 1953. Storage quality of Jonathan and Delicious apples as affected by growth regulator pre-harvest sprays.
Mich. Agr. Exp. Sta. Quart. Bul. 36: 3-10
- Diehl, H. and J. Ellingboe. 1956. Indicator for titration of calcium in presence of magnesium using disodium-dihydrogen-ethylenediamine tetraacetate.
Anal. Chemistry 28: 882-884

- Diehl, H., C. A. Goetz, and C. Hach. 1950. The versenate titration for total hardness.
American Water Works Assn. 42: 40-48
- Eaves, C. A. Cold storage and plant nutrition.
Canada Dept. of Agr. Exp. Sta. Kentville, N. S.
Progress report for 1947-51, pp. 47-58
- Fisher, R. A. 1948. Statistical methods for research workers.
Oliver and Boyd, Edinburgh and London, 10th ed.
- Garman, P. and W. T. Mathis. 1956. Studies of mineral balance as related to occurrence of Baldwin spot in Connecticut.
Conn. Agr. Exp. Sta. Bul. 601
- Goulden, C. H. 1952. Methods of statistical analysis.
John Wiley and Sons, Inc.
- Gourley, J. H. and E. F. Hopkins. 1930. Some relations of nitrogen to keeping quality of fruit.
Proc. ASHS 26: 167-173
- _____ and E. F. Hopkins. 1931. Nitrate fertilization and keeping quality of apple fruits. Chemical, physiological, and storage studies.
Ohio Agr. Exp. Sta. Bul. 479
- Haller, M. H. 1941. Fruit pressure testers and their practical application.
USDA Cir. No. 627
- _____ 1943. Effect of preharvest drop sprays on the storage quality of apples.
Proc. ASHS 42: 207-210
- _____ and P. L. Harding. 1938. Relation of soil moisture to firmness and storage quality of apples.
Proc. ASHS 35: 205-211
- _____ and J. M. Lutz. 1937. Soft scald of Jonathan apples in relation to respiration.
Proc. ASHS 34: 173-176
- _____ and J. M. Lutz. 1941. A comparative study of storage at 32° and 36° F. of apples grown in the Potomac river valley.
USDA Tech. Bul. 776, pp. 17-21
- Haynes, D. and H. K. Archbold. 1928. Chemical studies in the physiology of apples. X. A quantitative study of chemical changes in stored apples.
Ann. Bot. 42: 965-1017
- Heald, F. D. 1926. Manual of plant diseases.
New York, McGraw-Hill Book Co.

- Hesler, L. R. and H. H. Whetzel. 1920. Manual of fruit diseases.
New York, Macmillan Company
- Hildebrand, G. P. and C. N. Reilley. 1957. New indicator for
complexometric titration of calcium in presence of magnesium.
Anal. Chemistry 29: 258-268
- Hill, H. 1952. Foliage analysis as a means of determining orchard
fertilizer requirements.
Rep. Thirteenth Int. Hort. Congr.
- _____. F. B. Johnston, H. B. Heeney, and R. W. Buckmaster. 1950.
The relation of foliage analysis to keeping quality of McIntosh
and Spy varieties of apples.
Scientific Agriculture 30: 518-534
- Keijer, E. J. and Dijksterhuis, H. P. 1956. Bewaarziekten bij apples.
De invloed van verschillende schurftbestrijdingsmiddelen.
Meded. Dir. Tuinb. 19: 810-814
- Kenworthy, A. L. 1949. A nutrient element balance chart.
Mich. Agr. Exp. Sta. Quart. Bul. 37: 17-19
- _____. 1950. Nutrient element composition of leaves from
fruit trees.
Proc. ASHS 55: 41-46
- _____. 1953. Nutritional conditions of Michigan orchards:
A survey of soil analyses and leaf composition.
Mich. Ag. Exp. Sta. Tech. Bul. 237
- Magness, J. R. 1929. Relation of leaf area to size and quality in
apples.
Proc. ASHS 25: 285-288
- _____. L. P. Batjer, and L. O. Regeimbal. 1940. Correlation
of fruit color in apples to nitrogen content of leaves.
Proc. ASHS 37: 39-42
- _____. and F. L. Overley. 1929. Effect of fertilizers on
storage quality of apples.
Proc. ASHS 26: 180-181
- _____. and G. F. Taylor. 1925. An improved type of pressure
tester for the determination of fruit maturity.
USDA Cir. 350
- Michigan Cooperative Crop Reporting Service. Michigan agricultural
statistics. USDA Agr. Marketing service 1957
- Mitchell, A. E., A. C. Dowdy, E. J. Klos, and R. H. Fulton. 1955-56.
Spraying calendar, Michigan State Univ. Ext. Bul. 154

- Norton, J. B. S. 1913. Jonathan fruit spot.
Phytopathology 3: 99-100
- Overley, F. L. and E. L. Overholser. 1932. Some effects of fertilizer upon storage response of Jonathan apples.
Proc. ASHS 28: 572-577
- Palmer, R. C. 1931. Recent progress in the study of Jonathan breakdown in Canada.
Scientific Agriculture 11: 243-258
- Pentzer, W. T. 1925. Color pigment in relation to the development of Jonathan spot.
Proc. ASHS 22: 66-69
- Pflug, I. J., M. W. Brandt and D. H. Dewey. 1957. An experimental tilt-up concrete building for the controlled atmosphere storage of apples.
Mich. Agr. Exp. Sta. Quart. Bul. 39: 505-510
-
- P. Angelini, and D. H. Dewey. 1957. Fundamentals of carbon dioxide absorption as they apply to controlled atmosphere storages.
Mich. Agr. Exp. Sta. Quart. Bul. 40: 131-138
- Plagge, H. H. 1942. Controlled atmosphere storage for Jonathan apples.
Refrig. Engineering 43: 215-220
-
- _____ and Maney, T. J. 1941. Some responses of apples in storage to polyfilm liners and wrappers.
Ice and Refrigeration 101: 201-205
- Porritt, S. W. and D. V. Fisher. 1953. The physiological condition of apples entering storage.
Can. Dept. of Agr. Fruit and Veg. Prod. Res. Ctte. 74-77
Hort. Abstr. 24: 3519, 1954
- Rogers, B. L., L. P. Batjer, and A. H. Thompson. 1953. Seasonal trend of several nutrient elements in Delicious apple leaves expressed on a percent and unit area basis.
Proc. ASHS 61: 1-5
- Rose, D., L. P. McCulloch and D. F. Fisher. 1951. Market diseases of fruits and vegetables. Apples, pears, quinces.
USDA Misc. Pub. No. 168
- Savage, E. F. 1941. Some factors affecting the storage quality of the Cortland apple.
Proc. ASHS 38: 282-288
- Scott, W. M. 1914. A new fruit spot on apple.
Phytopathology 1: 32-34

- Shear, G. M. and F. Horsfall. 1948. Color as an index of nitrogen content of leaves of York and Stayman apples.
Proc. ASHS 52: 57-60
- Smith, W. W. 1942. Development of the storage disorder brown core in McIntosh apples.
Proc. ASHS 41: 99-103
- Smock, R. M. 1947. The "spot" disease of Northern Spy apples.
Proc. ASHS 50: 95-99
- _____ and D. Boynton. 1944. The effects of differential nitrogen treatments in the orchard on the keeping quality of McIntosh apples.
Proc. ASHS 45: 77-86
- _____ and A. M. Neubert. 1950. Apples and apple products.
Interscience Publishers, Inc., New York
- Southwick, F. W. and Melwin Hurd. 1948. Harvesting, handling and packing apples.
Cornell Ext. Bul. 750
- Stakman, E. C. and R. C. Rose. 1914. A fruit spot of the Wealthy apple.
Phytopathology 4: 333-336
- Strachan, C. C., A. W. Moyls, F. E. Atkinson, and J. E. Britton. 1951. Chemical composition and nutritive value of British Columbia tree fruits.
Can. Dept. of Agr. Publ. 862
- Thornton, N. C. 1933. Carbon dioxide storage. III. The influence of carbon dioxide on the oxygen uptake by fruits and vegetables.
Contrib. Boyce Thompson Inst. 5: 371-402
- _____ 1933. Carbon dioxide storage IV. The influence of carbon dioxide on the acidity of plant tissue.
Contrib. Boyce Thompson Inst. 5: 403-418
- Trout, S. A., G. B. Tindale, and F. E. Huelin. 1940. Investigations on the storage of Jonathan apples grown in Victoria.
CSIR Bul. 135, Melbourne
- Wander, I. W. and J. H. Gourley. 1943. Effect of heavy mulch in an apple orchard upon several soil constituents and the mineral content of foliage and fruit.
Proc. ASHS 42: 1-6
- Weeks, W. D., F. W. Southwick, M. Drake and J. E. Steckel. 1952. The effects of rates and sources of nitrogen, phosphorus, and potassium on the mineral composition of McIntosh foliage and fruit color.
Proc. ASHS 60: 11-21

- Weinberger, J. H. 1930. The effect of various potash fertilizers on the firmness and keeping quality of fruits.
Proc. ASHS 26: 174-179
- Wilcox, J. C. 1950. Use of the survey method in horticultural research.
Scientific Agriculture 30: 137-149
- _____ and C. G. Woodbridge. 1943. Some effects of excess boron on the storage quality of apples.
Scientific Agriculture 23: 332-341
- Wilkinson, B. G. 1957. The effect of orchard factors on the chemical composition of apples. I. Some effects of manurial treatments- and of grass.
Journ. hort. Sci. 32: 74-84
- Wright, R. T. 1953. Physiological disorders.
Plant diseases. The Yearbook of Agriculture 1953, pp. 830-834

APPENDIX

APPENDIX TABLE 1
LEAF ANALYSES. ORCHARD AVERAGES, 1956

Orchard	Nutrient Elements								
	B (ppm)	Ca (%)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	N (%)	P (%)
1	17	1.19	14	.017	1.30	.440	57	2.23	.162
2	19	1.05	17	.015	1.29	.368	30	1.99	.176
3	25	1.15	17	.015	1.66	.424	488	2.32	.226
4	27	1.26	18	.013	0.95	.550	61	2.57	.174
5	38	1.68	21	.015	1.78	.404	47	2.21	.214
6	37	1.51	20	.014	1.72	.354	55	2.08	.214
7	42	1.56	15	.018	1.52	.436	70	2.18	.222
8	34	1.39	21	.015	1.84	.324	79	1.91	.204
9	32	1.79	20	.024	1.57	.415	105	2.56	.250
10a	29	1.63	19	.015	1.43	.398	73	2.14	.160
10b	25	1.65	14	.015	1.51	.406	72	2.08	.180
11	27	1.45	20	.015	1.26	.376	142	2.58	.190
12	28	1.68	20	.015	1.63	.418	98	2.46	.190
13	26	1.57	15	.017	1.45	.390	88	2.11	.182
14	24	1.59	16	.015	1.33	.378	41	2.01	.186
15	27	1.36	16	.016	1.51	.418	31	1.84	.190
16	23	1.30	23	.012	1.58	.346	27	2.12	.252

APPENDIX TABLE 2
LEAF ANALYSES. ORCHARD AVERAGES, 1957

Orchard	Nutrient Elements								
	B (ppm)	Ca (%)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)	N (%)	P (%)
1	49	1.25	17	.019	1.43	.32	50	2.35	.18
2	44	.96	17	.015	1.37	.34	25	1.82	.20
3	32	1.15	19	.016	1.57	.39	38	2.42	.21
4	32	1.04	22	.020	1.16	.46	85	2.31	.17
5	61	1.14	19	.035	1.97	.36	36	1.96	.21
6	32	1.09	18	.013	1.90	.32	39	2.09	.25
7	42	1.19	18	.037	1.47	.39	72	2.06	.22
8	31	1.32	21	.015	1.82	.36	61	2.08	.22
9	23	1.30	19	.018	1.63	.41	60	2.21	.23
10a	21	1.45	25	.016	1.64	.34	42	2.17	.18
10b	27	1.36	19	.013	1.68	.36	44	2.01	.18
11	26	1.13	18	.017	1.49	.34	129	2.53	.18
12	56	1.16	19	.038	1.52	.37	88	2.29	.22
13	45	1.20	17	.033	1.71	.32	81	2.15	.19
14	61	1.19	19	.024	1.79	.37	49	1.92	.23
15	45	1.04	20	.024	1.79	.38	58	2.00	.19
16	43	1.01	20	.018	1.61	.36	31	2.20	.25

APPENDIX TABLE 3
ELEMENT BALANCE CHART INDEXES FOR 1956 AND 1957 LEAF ANALYSES

Orchard No.	N		P		K		Ca		Mg		Mn		Fe		B		Cu	
	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957
1	99	100	84	89	89	96	90	93	106	85	82	79	89	93	68	108	91	94
2	86	80	87	94	89	93	83	78	93	89	49	69	85	85	71	93	94	94
3	100	103	100	96	106	101	88	88	103	98	267 ^a	74	85	87	79	82	94	96
4	109	99	87	86	73	83	93	82	124	108	84	94	80	95	81	99	95	99
5	95	86	97	96	111	120	114	87	99	92	78	74	85	128	95	114	98	96
6	90	91	97	106	108	117	106	85	91	85	82	75	83	80	94	82	97	95
7	95	89	99	99	99	97	108	90	105	98	88	89	91	133	100	93	92	95
8	84	90	94	99	114	113	99	96	85	92	92	84	85	84	90	81	98	88
9	109	95	106	101	102	104	119	94	101	100	103	83	104	91	87	94	97	96
10a	93	94	84	89	95	105	111	102	99	89	89	76	85	87	84	70	97	102
10b	90	88	89	89	99	107	112	98	99	92	89	77	85	80	79	77	91	96
11	110	108	91	89	87	98	103	87	94	89	119	113	85	89	81	76	97	95
12	105	98	91	99	105	101	114	88	101	94	100	96	87	135	82	109	97	96
13	92	93	89	91	96	108	108	90	97	85	96	93	89	123	80	103	92	94
14	81	87	91	91	99	112	93	82	101	95	71	83	87	104	81	103	93	97
15	87	84	90	91	99	112	93	82	101	95	71	83	87	104	81	103	93	96
16	92	95	117	106	102	103	95	81	90	92	70	71	68	91	76	101	100	97
AVERAGE	94	93	93	95	98	105	102	89	99	92	96	83	85	100	82	94	95	96

^aThis index value was caused by foliar spray of MnSO₄ in the previous year.

APPENDIX TABLE 4
APPLE FRUIT ANALYSES. ORCHARD AVERAGES, 1956

Orchard	Trees	B (ppm)	Ca (%)	Cu (ppm)	Fe (ppm)	K (%)	Mg (%)	Mn (ppm)	N (%)	P (%)
A. At Harvest										
2	7, 8	36	.043 ^a	7.2	12	.750	.043	5.9	.289	.051
4	16, 19, 20	32	.044	7.0	14	.683	.047	6.2	.291	.042
6	26, 28	41	.037	8.2	13	.988	.048	5.7	.232	.081
8	36-40	62	.044	5.7	10	.921	.040	6.1	.232	.075
9	41-45	20	.047	6.3	14	.998	.026	7.7	.321	.080
15	76-80	28	.058	6.6	12	.879	.042	5.3	.387	.045
B. After C-A Storage (complete)										
1		45	.19 ^b	5.8	49	.897	.055	5.5	.52	.09
2		41	.20	5.1	47	.823	.052	3.9	.55	.10
3		40	.15	4.4	26	1.030	.044	6.3	.63	.10
4		32	.13	3.7	49	.793	.045	3.6	.64	.07
5		52	.12	3.1	40	1.054	.042	3.0	.66	.10
6		38	.11	3.6	28	1.082	.038	3.4	.66	.08
7		50	.17	4.3	33	1.004	.050	4.3	.63	.10
8		61	.19	4.0	50	.956	.046	4.5	.56	.10
9		26	.16	5.2	45	.931	.058	5.7	.67	.11
10a		34	.16	3.5	37	.983	.047	4.1	.59	.08
10b		35	.14	3.9	42	.941	.044	4.2	.64	.09
11		34	.16	4.0	41	.911	.045	5.2	.69	.09
12		42	.16	4.1	46	1.003	.048	4.2	.72	.09
13		34	.13	3.7	31	1.014	.044	4.1	.65	.08
14		56	.22	6.7	43	.959	.069	5.9	.59	.12
15		40	.21	5.8	51	.828	.062	5.1	.53	.08
16		31	.12	4.0	36	.930	.041	2.9	.63	.09

^aDetermined by complexometric titration.

^bDetermined by spectrophotographic analysis.

APPENDIX TABLE 5
APPLE FRUIT ANALYSES AT HARVEST. ORCHARD AVERAGES, 1957

Orchard	B (ppm)	Cu (ppm)	Fe (ppm)	K (%)	Mg (%)	Mn (ppm)	N (%)	P (%)	Ca (%)
1	69	4.3	33	.907	.053	4.7	.355	.09	.068
2	79	4.5	43	.828	.048	3.8	.280	.10	.062
3	79	4.9	41	.907	.050	4.1	.402	.10	.051
4	61	5.7	23	.746	.046	4.5	.337	.06	.057
5	70	3.7	27	1.052	.049	3.1	.316	.09	.057
6	61	4.6	38	.959	.044	4.7	.265	.09	.067
7	58	3.9	39	.922	.043	4.4	.305	.09	.065
8	57	3.7	25	.941	.038	3.6	.303	.07	.061
9	48	3.9	33	1.014	.049	4.1	.350	.10	.067
10a	67	3.2	29	.916	.045	3.8	.288	.07	.060
10b	67	3.5	33	.886	.042	3.9	.279	.08	.061
11	41	3.6	38	.896	.054	7.0	.440	.09	.056
12	70	4.6	59	.834	.051	4.8	.273	.10	.061
13	51	3.8	35	.901	.043	4.3	.268	.09	.067
14	62	4.5	37	.935	.046	4.3	.270	.09	.071
15	51	4.1	30	.928	.039	3.6	.228	.06	.057
16	57	4.6	33	.921	.047	3.6	.260	.10	.059

APPENDIX TABLE 6
IMMATURE FRUIT ANALYSES. ORCHARD AVERAGES, 1957

Orchard	B (ppm)	Cu (ppm)	Fe (ppm)	K (%)	Mg (%)	Mn (ppm)	N (%)	P (%)	Ca (%)
1	37	13	56	1.57	.19	16	1.60	.19	.24
2	38	13	51	1.26	.20	12	1.39	.20	.29
3	23	17	53	1.75	.17	12	1.99	.22	.24
4	22	17	54	1.24	.20	23	1.78	.18	.29
5	--	--	--	----	----	--	----	----	----
6	37	13	47	1.75	.18	14	1.56	.22	.28
7	54	14	50	1.49	.18	16	1.46	.21	.22
8	43	14	52	1.76	.20	19	1.78	.23	.25
9	46	17	103	1.68	.20	21	1.58	.22	.23
10a	37	15	62	1.60	.20	18	1.71	.21	.25
10b	21	16	60	1.69	.16	14	1.64	.21	.24
11	24	15	76	1.82	.20	32	2.15	.21	.28
12	36	12	60	1.65	.14	13	1.70	.17	.29
13	30	12	41	1.76	.16	15	1.71	.19	.30
14	42	14	52	1.81	.18	12	1.60	.22	.31
15	--	--	--	----	----	--	----	----	----
16	29	12	46	1.80	.18	10	1.64	.22	.28

APPENDIX TABLE 7
CALCIUM ANALYSES (COMPLEXOMETRIC TITRATION)
OF IMMATURE AND MATURE FRUIT, 1957

Tree	Immature Fruit		Mature Fruit	
	Control	Treatment	Control	Treatment
1	.23	---	.043	----
2	---	.23	----	.097
3	.22	---	.046	----
4	---	.32	----	.084
5	.21	---	.068	----
6	.28	---	.060	----
7	---	.28	----	.073
8	.23	---	.055	----
9	---	.25	----	.068
10	.39	---	.053	----
11	.24	---	.061	----
12	---	.22	----	.064
13	.25	---	.029	----
14	.24	---	.048	----
15	.23	---	.054	----
16	.28	---	.049	----
17	---	.30	----	.075
18	.35	---	.047	----
19	---	.23	----	.052
20	.28	---	.054	----
21	---	---	.062	----
22	---	---	----	.064
23	---	---	.047	----
24	---	---	----	.061
25	---	---	.052	----
86 ^a	.27	---	.061	----
87	---	.31	----	.062
88	.30	---	.072	----
89	---	.25	----	.070
90	.29	---	.070	----
31	.21	---	.071	----
32	---	.22	----	.051
33	.26	---	.081	----
34	---	.22	----	.057
35	.21	---	----	----
36	.26	---	.066	----
37	---	.27	----	.065
38	.21	---	.062	----
39	---	.27	----	.085
40	---	---	.068	----

^aTrees 26-30 were replaced by trees 86-90 in the same orchard.

APPENDIX TABLE 7--Continued

CALCIUM ANALYSES (COMPLEXOMETRIC TITRATION)
OF IMMATURE AND MATURE FRUIT, 1957

Tree	Immature Fruit		Mature Fruit	
	Control	Treatment	Control	Treatment
41	.21	---	.073	----
42	---	.25	----	.081
43	---	---	.034	----
44	---	.20	----	.074
45	.27	---	.071	----
46	---	---	.043	----
47	---	.25	----	.061
48	.25	---	.056	----
49	---	.22	----	.067
50	.31	---	.072	----
51	---	---	.050	----
52	---	.28	----	.067
53	.25	---	.052	----
54	---	.18	----	.083
55	.26	---	.055	----
56	.29	---	.057	----
57	---	.08	----	.070
58	.29	---	.041	----
59	---	.24	----	.060
60	.38	---	.054	----
61	.31	---	.055	----
62	---	.25	----	.068
63	.34	---	.060	----
64	---	.29	----	.068
65	.26	---	.056	----
66	.30	---	.063	----
67	---	.31	----	.064
68	.33	---	.060	----
69	---	.27	----	.078
70	.29	---	.071	----
71	.35	---	.059	----
72	---	.30	----	.063
73	.27	---	.070	----
74	---	.32	----	.076
75	.33	---	.087	----
76	---	---	.061	----
77	---	---	----	.057
78	---	---	.048	----
79	---	---	----	.071
80	---	---	.048	----
81	.34	----	.069	----
82	---	.28	----	.069
83	.26	---	.058	----
84	---	.24	----	.055
85	.29	---	.043	----

APPENDIX TABLE 8
 CONTROLLED ATMOSPHERE STORAGE DATA 1956-57
 WEEKLY AVERAGES OF DAILY MEASUREMENTS

Period		Temperature		Atmosphere	
Dates	Week	T.C. #5	T.C. #6	CO ₂ (%)	O ₂ (%)
12-18	1			1.7	14.9
Oct. 19-25	2	37.5	33.9	2.4	10.0
26- 1	3	35.9	32.7	2.6	6.9
2- 8	4	36.5	33.7	2.4	4.3
Nov. 9-15	5	35.5	32.7	2.3	4.7
16-22	6	34.7	32.9	2.5	7.8
23-29	7	34.0	33.0	2.6	4.9
30- 6	8	32.2	31.6	2.7	3.2
Dec. 7-13	9	33.0	32.0	2.6	3.2
14-20	10	33.2	31.7	2.6	3.0
21-27	11	32.3	30.6	2.8	2.8
28- 3	12	32.5	31.2	2.7	3.0
Jan. 4-10	13	32.8	31.6	2.4	3.0
11-17	14	31.4	30.8	2.4	2.8
18-24	15	32.4	31.5	2.3	3.6
25-31	16	32.3	31.4	2.6	2.8
1- 7	17	32.2	31.2	2.5	2.9
Feb. 8-14	18	32.4	31.1	2.3	3.0
15-21	19	32.3	31.5	2.1	3.2
22-28	20	32.4	31.3	2.4	3.1
1- 7	21	32.2	31.0	2.4	2.9
Mar. 8-14	22	32.0	30.8	2.3	3.8
15-21	23	33.1	32.1	2.5	6.7
22-28	24	32.7	31.5	2.1	4.0
29- 4	25	33.0	31.5	2.3	3.3
Apr. 8-11	26	32.6	31.3	2.4	3.7
12-18	27	33.3	32.7	2.5	3.1
19-25	28	34.5	31.7	2.5	3.4
May 26- 2	29	35.5	32.6	2.4	2.9

APPENDIX TABLE 8--Continued

CONTROLLED ATMOSPHERE STORAGE DATA 1957-58
WEEKLY AVERAGES OF DAILY MEASUREMENTS

Period		Temperature		Atmosphere	
Dates	Week	T.C. #5	T.C. #6	CO ₂ (%)	O ₂ (%)
4-10	1	36.8	35.4	1.4	16.4
Oct. 11-17	2	34.6	33.5	2.1	10.1
18-24	3	34.7	33.8	2.2	5.2
25-31	4	33.7	32.9	2.4	2.9
1- 7	5	33.2	32.6	2.5	2.9
8-14	6	32.9	32.2	2.4	3.2
Nov. 15-21	7	32.4	31.8	2.6	3.0
22-28	8	32.4	31.8	2.7	2.9
29- 5	9	32.4	31.9	2.8	2.9
6-12	10	32.3	31.7	2.7	3.4
Dec. 13-19	11	32.1	31.8	2.9	3.1
20-26	12	32.1	31.8	2.5	3.1
27- 2	13	32.2	31.7	2.6	3.0
3- 9	14	32.2	31.8	2.6	3.0
Jan. 10-16	15	31.9	31.8	2.6	3.1
17-23	16	31.9	31.6	2.6	3.0
24-30	17	31.8	31.5	2.4	3.1
31- 6	18	31.5	31.7	2.4	3.2
7-13	19	31.7	31.7	2.5	3.6
Feb. 14-20	20	31.6	31.4	2.8	3.5
21-27	21	31.5	31.4	2.7	3.1
28- 6	22	31.6	31.4	2.6	3.0
7-13	23	32.1	32.2	2.4	3.0
Mar. 14-20	24	31.6	31.9	2.4	3.0
21-27	25	32.0	32.1	2.6	3.0
28- 3	26	31.8	32.3	2.4	3.1
4-10	27	32.1	32.3	2.5	4.8
Apr. 11-17	28	32.6	32.9	2.5	4.1

APPENDIX TABLE 9
FRUIT FIRMNESS EXPRESSED AS AVERAGE PRESSURE READINGS
ON THE MAGNESS-TAYLOR PRESSURE TESTER
IN POUNDS. (7/16 INCH PLUNGER)

Tree	1956			1957		
	Harvest	Reg. Storage	C-A Storage	Harvest	Reg. Storage	C-A Storage
1		13.06	16.07	20.06	15.21	17.01
2		15.34	17.15	21.80	15.50	16.56
3	21.10	-	16.12	20.12	15.17	16.01
4		-	16.65	20.72	15.43	15.51
5		-	16.00	19.17	14.17	15.65
6	21.96	15.98	15.94	18.98	15.58	17.76
7	22.20	15.42	16.60	22.13	17.66	15.98
8	20.99	15.90	16.27	-	17.12	16.30
9	21.85	16.87	17.11	22.22	16.13	18.56
10	21.65	16.62	17.95	20.45	16.30	17.38
11		-	15.77	19.00	13.46	16.27
12		-	16.55	18.27	14.33	16.86
13	20.78	-	15.50	18.72	13.00	15.60
14		-	15.95	18.73	13.35	15.11
15		12.90	16.31	19.42	13.14	15.81
16	19.76	14.54	16.20	18.76	14.88	15.50
17	21.08	15.95	17.11	19.57	15.47	15.28
18	20.50	15.21	16.45	19.22	14.56	15.33
19	20.29	14.47	17.14	19.76	14.71	16.03
20	20.35	15.91	16.25	19.66	15.15	15.36
21	18.20	15.75	15.92	20.28	16.43	16.37
22	18.65	14.60	15.83	20.81	17.05	17.01
23	18.75	15.76	16.30	20.65	16.47	16.12
24	18.98	14.42	15.78	-	17.74	16.31
25	21.55	17.25	14.90	-	17.15	17.68
26	22.01	14.46	13.73	-	-	-
27	19.70	15.59	15.40	-	-	-
28	20.20	15.24	15.74	-	-	-
29	20.90	15.94	15.50	-	-	-
30	-	-	16.34	-	-	-
31	-	-	15.81	20.97	15.57	16.31
32	-	-	16.15	21.45	15.75	16.82
33	-	-	16.60	21.73	16.15	17.47
34	-	-	14.97	19.23	15.10	15.87
35	-	-	16.42	20.17	15.41	15.97
36	20.84	15.42	16.31	19.86	16.20	16.00
37	20.97	16.14	17.07	21.25	16.47	17.83
38	18.93	14.90	15.08	20.05	15.33	16.65
39	19.95	14.20	15.55	-	15.56	16.66
40	19.30	14.55	14.81	-	16.01	16.94

APPENDIX TABLE 9--Continued
 FRUIT FIRMNESS EXPRESSED AS AVERAGE PRESSURE READINGS
 ON THE MAGNESS-TAYLOR PRESSURE TESTER
 IN POUNDS. (7/16 INCH PLUNGER)

Tree	1956			1957		
	Harvest	Reg. Storage	C-A Storage	Harvest	Reg. Storage	C-A Storage
41	21.30	14.03	15.75	19.47	14.12	15.53
42	21.85	14.10	15.50	19.17	15.64	16.22
43	22.80	15.45	17.50	-	-	-
44	20.08	14.10	15.87	20.97	17.08	17.33
45	20.40	13.82	14.80	19.78	13.22	16.45
46	-	-	15.97	20.88	15.83	17.27
47	-	-	16.16	20.43	15.81	16.73
48	-	-	16.30	20.15	15.15	17.05
49	-	-	15.45	20.35	14.46	15.88
50	-	-	16.60	21.11	15.83	17.53
51	-	-	15.31	22.77	16.37	16.74
52	-	-	16.33	21.02	17.80	16.81
53	-	-	16.16	21.68	14.78	16.46
54	-	-	16.73	21.34	16.70	16.62
55	-	-	16.29	20.72	15.61	16.73
56	-	-	15.73	18.92	15.52	16.42
57	-	-	15.30	18.55	14.72	16.15
58	18.25	13.60	15.45	18.60	14.07	15.85
59	-	-	16.61	18.53	14.61	15.52
60	-	-	16.75	19.10	13.31	15.70
61	-	14.16	16.69	18.95	13.77	15.76
62	-	-	-	18.90	14.75	16.00
63	20.07	-	16.50	18.87	14.26	15.77
64	-	-	15.57	18.53	14.06	15.57
65	-	-	16.35	-	16.38	16.47
66	-	-	16.70	20.14	15.55	15.95
67	-	12.21	16.75	20.88	15.61	16.28
68	22.32	-	17.38	20.02	16.60	16.43
69	-	-	17.27	19.21	15.02	15.78
70	-	-	16.92	20.02	15.58	15.53
71	-	-	15.99	21.63	15.91	17.15
72	-	-	16.13	20.86	15.85	15.70
73	-	-	15.53	21.07	15.97	16.18
74	-	-	14.72	21.50	15.78	16.91
75	-	11.85	14.53	20.98	16.56	16.97
76	22.62	-	18.46	21.67	16.76	16.90
77	-	16.17	17.74	21.06	16.65	16.08
78	-	-	16.60	21.30	16.45	16.65
79	23.10	-	18.09	-	16.56	-
80	24.20	-	-	21.42	16.61	17.57

APPENDIX TABLE 9--Continued
 FRUIT FIRMNESS EXPRESSED AS AVERAGE PRESSURE READINGS
 ON THE MAGNESS-TAYLOR PRESSURE TESTER
 IN POUNDS. (7/16 INCH PLUNGER)

Tree	1956			1957		
	Harvest	Reg. Storage	C-A Storage	Harvest	Reg. Storage	C-A Storage
81	-	16.20	16.79	21.93	16.34	16.22
82	-	15.59	14.85	21.77	16.07	16.97
83	-	14.21	15.15	19.93	15.60	16.97
84	-	14.32	13.79	20.92	16.03	15.48
85	-	15.11	15.45	20.90	15.95	16.75
86		-	16.28	20.90	15.93	17.12
87		-	15.47	21.00	15.46	16.25
88	21.90	13.95	15.90	-	16.68	17.83
89		-	15.88	19.57	14.24	16.83
90		-	15.29	19.07	13.97	15.87
Average	20.77	14.91	16.28	20.26	15.53	16.42

APPENDIX TABLE 10
GROUND COLOR. ORCHARD AVERAGES

Orchard	1956			1957		
	At Harvest	After Regular Storage	After C-A Storage	At Harvest	After Regular Storage	After C-A Storage
1	2.8	1.6	1.8	2.8	1.7	1.7
2	2.7	1.8	1.8	2.5	1.8	2.5
3	3.2	---	1.8	2.7	1.7	2.0
4	3.0	1.5	1.7	2.9	1.7	2.2
5	2.8	.16	2.0	1.8	1.1	1.7
6a	1.8	1.1	1.2	---	---	---
6b	2.1	1.5	1.5	2.9	1.6	2.1
7	---	---	1.8	2.8	1.9	2.1
8	2.7	1.5	1.5	2.4	.16	1.9
9	2.7	1.6	1.8	2.7	1.4	1.7
10a	---	---	1.8	2.3	1.7	1.9
10b	---	---	1.7	2.6	1.6	1.8
11	3.0	2.2	2.6	3.1	2.2	2.2
12	3.1	1.6	1.7	3.3	2.2	2.4
13	2.6	1.1	2.0	2.1	1.2	1.3
14	---	1.4	1.6	2.1	1.4	1.5
15	2.0	---	1.7	2.2	1.7	1.5
16	---	1.6	2.2	3.0	1.7	2.2
Average	2.7	1.5	1.8	2.6	1.7	1.9
s. d.	$\pm .13$	$\pm .08$	$\pm .11$	$\pm .18$	$\pm .13$	$\pm .13$

APPENDIX TABLE 11
RESPIRATION MEASURED AT 75° F. AS MG CO₂ EVOLVED PER KG FRUIT PER HOUR; 1956

Day	Orchard 2			Orchard 4			Orchard 5		
	Harvest	Reg.	C-A	Harvest	Reg.	C-A	Harvest	Reg.	C-A
	Storage			Storage			Storage		
1	38	--	--	40	38	37	41	--	--
2	38	--	--	39	36	38	40	--	--
3	38	--	--	37	34	38	39	--	--
4	37	38	34	35	33	37	38	28	--
5	35	27	32	33	32	35	36	28	--
6	34	26	31	33	31	33	35	27	31
7	34	25	29	32	30	31	34	26	29
8	34	25	28	32	29	29	34	25	28
9	32	24	27	30	28	28	32	25	27
10	--	24	26	--	28	27	--	21	26
Av.	37	--	--	35	35	33	37	--	--

Day	Orchard 8			Orchard 9			Orchard 16		
	Harvest	Reg.	C-A	Harvest	Reg.	C-A	Harvest	Reg.	C-A
	Storage			Storage			Storage		
1	51	42	--	--	--	40	40	39	35
2	56	40	42	--	--	41	38	35	35
3	46	37	40	--	29	38	37	34	33
4	46	35	42	--	29	36	36	33	31
5	46	34	41	--	28	34	34	31	29
6	42	33	38	--	27	31	33	30	27
7	42	32	36	--	28	29	32	30	26
8	41	32	34	--	26	27	32	29	25
9	41	30	33	--	25	26	30	27	24
10	--	30	30	--	25	26	--	27	24
Av.	45	35	37	--	--	33	35	32	29

APPENDIX TABLE 12
RESPIRATION MEASURED AT 75° F. AS MG CO₂ EVOLVED PER KG FRUIT PER HOUR; 1957

Day	Orchard 2			Orchard 3			Orchard 4		
	Harvest	Reg. Storage	C-A	Harvest	Reg. Storage	C-A	Harvest	Reg. Storage	C-A
1	43	46	56	42	37	40	55	63	61
2	42	36	45	40	32	36	52	55	53
3	36	38	42	30	32	30	43	49	48
4	33	34	36	29	28	27	40	44	43
5	28	29	33	26	24	24	36	39	39
6	26	26	31	25	22	24	35	35	38
7	25	22	29	23	20	23	32	32	35
8	23	23	29	22	20	21	30	32	33
9	22	22	25	21	18	20	28	31	29
10	21	20	24	21	18	18	26	29	30
Av.	30	30	35	28	25	26	38	41	41

Day	Orchard 7			Orchard 9		
	Harvest	Reg. Storage	C-A	Harvest	Reg. Storage	C-A
1	49	42	43	41	37	40
2	46	36	41	43	32	35
3	38	32	36	36	28	30
4	34	31	33	29	26	27
5	31	28	30	27	25	24
6	29	25	29	25	23	25
7	28	22	27	24	21	22
8	26	22	24	23	20	21
9	24	22	23	21	19	19
10	23	21	23	21	19	18
Av.	33	28	31	29	25	26

APPENDIX TABLE 13--Continued
 BREAKDOWN DEVELOPMENT IN STORAGE, 1956 AND 1957, AND IN
 HOLDING TESTS, IN 1957. (RECORDED AS % OF THE
 FRUIT IN EACH BOX AND AS TOTAL
 "SCORE", SEE TEXT).

Tree	1956		1957				Total ("score")
	Reg. Storage (%)	C-A Storage (%)	Reg. Storage (%)	Holding (%)	C-A Storage (%)	Holding (%)	
36	0	0	0	0	0	0	0
37	0	0	0	0	0	10	10
38	0	0	0	0	0	15	15
39	1	0	4	5	0	5	14
40	2	0	0	0	0	50	50
							av. 18
41	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0
43	0	0	0	0	-	-	-
44	0	0	0	0	0	0	0
45	1	0	0	0	0	0	0
							av. 0
46	.5	0	0	0	0	0	0
47	0	0	0	0	0	0	0
48	.5	0	0	0	0	0	0
49	2	;	0	0	0	0	0
50	2	0	0	0	0	0	0
							av. 0
51	0	0	1	15	1	45	62
52	.5	0	0	0	0	0	0
53	0	0	0	10	0	15	25
54	0	0	0	0	0	5	5
55	0	0	0	0	1	10	11
							av. 21
56	0	0	0	5	1	20	26
57	0	0	0	0	0	10	10
58	0	0	0	0	0	45	45
59	0	0	0	0	1	20	21
60	0	0	0	25	0	65	90
							av. 38
61	0	0	0	5	0	0	5
62	0	0	0	0	0	0	0
63	6	0	0	0	0	0	0
64	.5	0	0	0	0	0	0
65	0	0	0	0	0	10	10
							av. 3
66	0	0	6	20	4	60	90
67	0	0	1	0	0	0	1
68	0	0	0	0	0	5	5
69	0	0	0	5	3	15	23
70	6	0	0	0	0	5	5
							av. 25

APPENDIX TABLE 13--Continued
 BREAKDOWN DEVELOPMENT IN STORAGE, 1956 AND 1957, AND IN
 HOLDING TESTS, IN 1957. (RECORDED AS % OF THE
 FRUIT IN EACH BOX AND AS TOTAL
 "SCORE", SEE TEXT).

Tree	1956		1957				Total ("score")
	Reg. Storage (%)	C-A Storage (%)	Reg. Storage (%)	Holding (%)	C-A Storage (%)	Holding (%)	
71	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0
73	.5	0	0	0	0	0	0
74	1	0	0	0	0	0	0
75	0	0	0	0	0	0	0
							av. 0
76	0	0	0	0	5	0	5
77	0	0	0	0	2	5	7
78	0	0	0	0	0	30	30
79	0	0	0	0	-	-	-
80	0	0	2	10	0	25	37
							av. 20
81	.5	0	0	0	0	5	5
82	0	0	0	0	0	5	5
83	0	0	0	0	0	0	0
84	0	0	0	0	0	5	5
85	0	0	1	15	2	35	53
							av. 14
86	0	0	0	0	0	0	0
87	0	0	0	0	0	0	0
88	0	0	0	0	0	0	0
89	0	0	0	0	0	0	0
90	11	6	0	0	0	0	0
							av. 0

APPENDIX TABLE 14
OBSERVATIONS AND ANALYTICAL DATA GROUPED ACCORDING TO THE INCIDENCE OF BREAKDOWN; 1957

Total Score	Tree	Av. Size Fruits pr. box (no)	Water Core in 15 Fruits (no)	Crop per Tree (bu)	Fruit Firmness Total _a 15 Fruit _a (lbs)	Fruit Content						
						N (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	B (ppm)	Mn (ppm)
0	4	168	2	8	932	.309	1.000	.084	.051	39	70	4.7
0	15	159	2	9	874	.393	.871	.054	.051	41	82	4.0
0	36	157	14	2	894	.344	.909	.066	.044	36	66	3.9
0	41	182	0	4	876	.316	1.000	.073	.045	30	36	2.8
0	42	203	0	4	863	.379	.988	.081	.042	35	41	4.4
0	44	188	0	4	944	.344	1.080	.074	.054	27	56	4.9
0	45	181	0	4	890	.330	.987	.071	.053	39	58	4.3
0	46	148	13	2	940	.262	.937	.043	.043	24	60	3.8
0	46	166	9	2	919	.239	.884	.061	.045	29	56	3.8
0	48	175	3	2	907	.330	.920	.056	.049	34	62	3.8
0	49	163	9	2	916	.344	.919	.067	.044	27	54	3.4
0	50	180	12	2	950	.267	.922	.072	.043	33	102	4.3
0	52	170	12	2	946	.295	.827	.067	.045	36	80	4.0
0	62	174	0	4	850	.274	.919	.068	.050	83	69	5.5
0	63	173	0	4	849	.225	.768	.060	.050	37	91	3.6
0	64	175	0	3	834	.365	.839	.068	.054	44	40	4.9
0	71	203	4	2	973	.274	.871	.059	.051	36	72	5.1
0	72	150	10	2	939	.330	.899	.063	.048	44	64	4.3
0	73	173	5	2	948	.281	.926	.070	.043	47	53	4.3
0	74	192	10	1	967	.281	.989	.076	.042	32	63	3.8
0	75	180	4	2	944	.246	.992	.087	.045	28	57	4.1
0	83	154	8	6	897	.260	.928	.058	.044	41	59	4.1
0	86	177	0	3	940	.365	.969	.061	.045	47	59	6.0
0	87	166	--	3	945	.281	.988	.062	.046	41	48	5.8
0	88	166	0	3	---	.218	.920	.072	.043	34	64	3.5
0	89	192	0	3	881	.260	.889	.070	.046	39	78	4.1
0	90	186	0	3	858	.253	1.030	.070	.041	27	56	4.0

APPENDIX TABLE 14--Continued
OBSERVATIONS AND ANALYTICAL DATA GROUPED ACCORDING TO THE INCIDENCE OF BREAKDOWN; 1957

Total Score	Tree	Av. Size Fruits pr.box (no)	Water Core in 15 Fruits (no)	Crop per Tree (bu)	Fruit Firmness Total 15 Fruit ^a (lbs)	Fruit Content						
						N (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	B (ppm)	Mn (ppm)
1	67	151	13	8	940	.267	.895	.064	.042	32	46	4.1
5	3	155	5	8	905	.365	.934	.046	.058	27	72	4.8
5	9	164	15	2	1000	.197	.866	.068	.047	40	93	3.9
5	11	151	2	9	855	.344	.893	.061	.045	44	103	3.9
5	13	143	3	9	842	.421	.863	.029	.053	25	47	3.9
5	21	152	14	2	913	.323	.990	.062	.041	30	60	3.4
5	22	153	15	2	936	.288	1.140	.064	.041	23	78	3.1
5	23	156	4	3	929	.330	1.010	.047	.046	24	59	3.8
5	54	150	11	2	960	.274	.918	.083	.039	42	53	3.6
5	61	168	1	4	853	.302	.776	.055	.056	100	76	6.1
5	68	150	12	5	901	.239	.908	.060	.045	44	48	4.5
5	70	172	1	10	901	.253	.850	.071	.047	30	42	5.1
5	76	178	5	2	975	.260	.984	.061	.044	27	43	3.4
5	81	154	4	6	987	.267	.932	.069	.037	33	49	3.6
5	82	140	7	6	980	.302	.875	.069	.048	27	38	4.1
5	84	133	6	6	941	.204	.926	.055	.047	33	53	3.3
7	77	175	10	2	948	.232	.961	.057	.033	33	40	3.4
10	5	156	0	8	863	.351	.939	.068	.045	35	61	4.0
10	37	152	8	2	956	.337	.921	.065	.036	27	43	3.7
10	57	131	0	3	835	.400	.869	.070	.054	30	33	7.0
10	65	150	--	2	---	.197	.870	.056	.046	31	64	4.1
11	31	167	10	1	944	.302	.896	.071	.048	35	63	5.0
11	55	149	14	2	998	.365	.882	.055	.049	33	62	4.9
14	39	large	--	1	---	.260	.886	.085	.037	22	66	3.8
15	10	164	12	2	920	.246	.786	.053	.050	52	110	3.9
15	38	129	8	2	902	.323	.999	.062	.034	27	45	3.2
20	1	149	3	8	903	.372	.844	.043	.055	34	47	5.1
20	33	163	6	2	978	.281	.936	.081	.041	34	57	4.6

APPENDIX TABLE 14--Continued
OBSERVATIONS AND ANALYTICAL DATA GROUPED ACCORDING TO THE INCIDENCE OF BREAKDOWN; 1957

Total Score	Tree	Av. Size Fruits pr.box (no)	Water Core in 15 Fruits (no)	Crop per Tree (bu)	Fruit Firmness Total 15 Fruit ^a (lbs)	Fruit Content						
						N (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	B (ppm)	Mn (ppm)
21	59	131	1	3	834	.411	.779	.060	.052	39	42	6.5
23	69	148	13	6	864	.253	.900	.078	.036	35	46	4.2
26	56	148	7	3	851	.477	.933	.057	.059	33	43	7.4
29	32	166	8	2	965	.295	.921	.051	.043	30	54	3.9
30	34	176	4	2	865	.344	.935	.057	.041	58	59	4.3
30	78	173	11	2	958	.239	.807	.048	.038	30	56	3.7
32	6	164	1	2	854	.365	.848	.060	.052	46	76	4.3
33	25	medium	--	2	--	.295	1.050	.052	.042	34	89	2.6
35	53	142	14	2	976	.234	.908	.052	.037	28	57	3.2
37	80	190	12	2	964	.176	.942	.048	.040	33	51	3.6
39	35	152	11	2	908	----	----	----	----	--	--	---
45	2	153	0	8	981	.379	.818	.097	.054	30	95	4.8
45	58	139	2	3	837	.449	.933	.041	.061	39	41	6.5
47	24	large	--	-	---	.346	1.070	.061	.041	24	63	2.8
50	40	large	--	1	---	.253	.991	.068	.039	22	63	3.6
53	85	156	5	6	940	.265	.942	.043	.049	32	84	3.1
61	12	172	6	9	822	.400	.960	.064	.051	43	87	4.4
62	51	---	10	2	1020	.225	.896	.050	.039	28	83	4.0
64	18	146	15	5	865	.253	.688	.047	.047	23	61	4.6
65	14	148	0	9	843	.449	.950	.048	.049	52	76	4.5
90	60	148	6	3	859	.463	.964	.054	.052	50	46	7.6
90	66	143	14	8	906	.330	.925	.063	.045	35	41	4.1
128	7	177	11	2	996	.323	.749	.073	.047	40	50	3.7
129	8	150	--	2	---	.267	.871	.055	.046	35	68	3.1
145	19	---	4	2	889	.337	.750	.052	.054	16	77	4.5
166	20	159	14	3	885	.309	.777	.054	.047	24	66	4.9
172	16	141	12	5	844	.421	.790	.049	.043	25	54	4.4
223	17	121	14	5	881	.365	.725	.075	.047	27	48	4.1

^aIn fall, 1957.

APPENDIX TABLE 15
AVERAGE JONATHAN SPOT AND SKIN BROWNING BY ORCHARDS (%)

Orchard	1956			1957		
	Spot and Skin Browning (Reg.) Storage	Skin Browning (C-A)	Total Skin Disorders (Reg.) Storage)	Spot (Reg.) Storage)	Skin Browning (Reg.) Storage)	Skin Browning (C-A)
10a	20 $\pm$ 5.1	2	4 $\pm$ 2.3	2 $\pm$ 1.3	1	1
10b	32 $\pm$ 9.4	2	5 $\pm$ 1.8	4 $\pm$ 1.9	0	2
4	16 $\pm$ 2.2	2	5 $\pm$ 4.4	5 $\pm$ 4.4	0	0
2	37 $\pm$ 15.8	2	6 $\pm$ 3.6	3 $\pm$ 1.8	2	6
11	12 $\pm$ 5.3	5	6 $\pm$ 1.8	6 $\pm$ 1.8	0	0
9	12 $\pm$ 8.6	2	8 $\pm$ 3.1	7 $\pm$ 2.7	1	2
12	9 $\pm$ 5.0	1	8 $\pm$ 4.4	7 $\pm$ 3.2	1	1
16	35 $\pm$ 4.6	2	12 $\pm$ 9.4	10 $\pm$ 7.0	2	1
3	7 $\pm$ 6.0	3	14 $\pm$ 8.0	13 $\pm$ 6.8	1	1
8	34 $\pm$ 15.9	2	14 $\pm$ 2.7	14 $\pm$ 2.7	0	2
13	27 $\pm$ 5.4	2	15 $\pm$ 8.4	14 $\pm$ 7.7	1	2
7	30 $\pm$ 18.9	3	16 $\pm$ 10.7	14 $\pm$ 9.9	2	10
5	32 $\pm$ 9.7	1	25 $\pm$ 7.8	20 $\pm$ 6.7	5	0
15	37 $\pm$ 6.9	3	26 $\pm$ 22.9	21 $\pm$ 18.3	4	11
1	34 $\pm$ 16.9	3	40 $\pm$ 3.9	33 $\pm$ 10.5	7	3
14	61 $\pm$ 10.7	9	43 $\pm$ 14.7	11 $\pm$ 6.1	33	27
6	32 $\pm$ 9.4	2	49 $\pm$ 12.8	38 $\pm$ 11.4	11	9

APPENDIX TABLE 16
SKIN DISORDERS COMPARED WITH THE NUTRIENT CONTENTS OF JONATHAN APPLES. ORCHARD AVERAGES, 1956

Orchard No.	Skin Disorders (%)	N (%)	K (%)	Mg (%)	B (fruit) (ppm)	Fe (ppm)	Mn (ppm)	N+K+Mg ^a (meq)	Fall Ground Color Av.	No. of red fruits in 30 fruits ^b
3	7	.63	1.086	.044	40	26	6.3	.7493	3.2	0
12	9	.72	.998	.048	42	50	4.2	.8144	3.1	5
11	12	.69	.891	.045	34	39	5.2	.7586	3.0	6
9	14	.67	.935	.058	26	38	5.7	.7612	2.7	5
4	16	.64	.793	.045	32	33	3.6	.6985	3.0	7
10a	20	.59	.983	.047	34	37	4.1	.7117	---	-
10b	25	.64	.941	.044	35	42	4.2	.7499	---	-
13	27	.65	1.014	.044	34	32	4.2	.7612	2.6	5
7	30	.63	1.004	.050	50	33	4.3	.7470	---	-
5	32	.66	1.050	.042	52	40	3.1	.7767	2.8	4
6b	32	.66	1.082	.038	38	28	3.6	.7763	2.1	4
1	34	.52	.897	.055	45	49	5.7	.6445	2.8	14
8	34	.56	.976	.046	61	50	4.4	.6780	2.7	14
6a	35	.63	1.036	.044	58	34	4.8	.7526	1.8	9
16	35	.63	.930	.047	31	36	2.9	.7187	---	8
2	37	.55	.825	.052	41	45	3.9	.6418	2.7	12
15	37	.53	.830	.062	40	51	7.7	.6386	2.0	24
14	61	.63	.930	.047	31	43	5.9	.7659	---	12

^aNo Ca values available

^bFruit which were fully covered with red color

APPENDIX TABLE 17
SKIN DISORDERS COMPARED WITH THE NUTRIENT CONTENTS OF JONATHAN APPLES. ORCHARD AVERAGES, 1957

Orchard No.	Skin Disorders (%)	N (%)	K (%)	Ca (%)	Mg (fruit) (%)	B (ppm)	Fe (ppm)	Mn (ppm)	N+K+Ca+Mg (meq)	Fall Ground Color	No. of red fruits in 30 fruits ^a
10a	4	.288	.916	.060	.045	67	29	3.8	.5211	2.3	5
10b	5	.279	.886	.061	.042	67	33	3.9	.4909	2.6	4
4	5	.337	.748	.057	.046	59	23	4.5	.4996	2.9	10
2	6	.280	.828	.062	.048	79	43	3.8	.4837	2.5	19
11	6	.440	.896	.056	.054	41	38	7.0	.6151	3.1	4
9	8	.350	1.014	.067	.049	42	32	4.1	.5812	2.7	8
12	8	.273	.834	.061	.051	68	59	4.8	.4814	3.3	0
16	12	.260	.921	.059	.047	57	33	3.6	.4784	3.0	12
3	14	.401	.907	.051	.050	79	45	4.1	.5853	2.7	1
8	14	.303	.941	.061	.038	57	27	3.6	.5234	2.4	14
13	15	.268	.901	.067	.043	51	35	4.4	.4889	2.1	3
7	16	.306	.922	.065	.043	58	39	4.5	.5177	2.8	11
5	25	.316	1.052	.057	.049	70	27	3.1	.5588	1.8	17
15	26	.228	.928	.057	.039	51	30	3.6	.4610	2.2	22
1	40	.355	.907	.068	.053	69	33	4.7	.5626	3.8	15
14	43	.228	.935	.071	.046	62	37	4.3	.5055	2.1	27
6b	49	.275	.959	.067	.044	61	38	4.7	.5918	2.4	19

^aFruit which were fully covered with red color.