SOME PHYSICAL AND CHEMICAL CHANGES ASSOCIATED WITH THE MATURATION OF GRIMES AND JONATHAN APPLES ON THE TREE AND DURING STORAGE.

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INTRODUCTION

With the development of transportation, storage facilities, and changes in cultural and fertilization practices, new problems have arisen in the field of tree fruit growing and handling. As a result of these changes, the ability to place acceptable fruit on the right market at the right time has come to be of increasing importance for financially successful fruit growing, and the grower has had to conform to the demands of distant markets, and to compete with far removed production centers as nearly as the nature of his product allowed.

With many fruits and their varieties, earliness has consistently neeted a premium to the grower over the bulk of the same crop or variety to reach the market. To benefit from these higher prices the grower likes to remove his fruit from the tree as soon as possible, and is often tempted to do so before the fruit has reached an acceptable stage of maturity.* The export market for apples demands fruit of comparatively small size, often obtained by the fruit before maturity, and affords another example of conditions under which the grower is tempted to harvest his fruit before it is sufficiently mature.

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*The word "mature", as used in this paper in reference to a stage of fruit development, may be defined as: having reached that state of development the fruit must obtain to continue the ripening processes with full development of characteristic quality and appearance after removal from the tree and under normal conditions of storage.

To curtail such practices, and to insure the consumer a product of fairly uniform and good quality, certain States and the Federal Government have had to set up regulatory and inspection service.

The problem is not solved simply with Government supervision of the harvest, however, but will be solved only when methods have been developed which will allow both the inspection service and the grower to accurately measure the condition of his fruit before it is removed from the tree. Further, with the use of such methods, we must be reasonably sure of the condition and quality which the fruit will obtain at the time it is placed on the retail market.

With most varieties of apples the picking date may vary over a considerable period without materially affecting the quality of the marketed product. A certain stage of maturity may occur, however, when the fruit will not obtain satisfactory quality if picked at or prior to this stage. From this it is apparent that a fruit may be defined as mature when it has reached such a stage in its development that the ripening processes will proceed in such a manner that fruit characteristic of the variety in appearance and edible quality will obtain after removal from the tree. The problem is: to measure that stage of maturity in the apple.

The determination of maturity by physical or chemical methods should involve only simple measurements, easily made and understood by the grower as well as the inspector; should be made at the orchard; and should involve only a comparatively small, random sample of fruit from the trees in question. Any change which the fruit normally undergoes during maturation, whether visible or invisible, would be suitable as an index of maturity as long as it could be readily measured and would be constant in application from year to year for a given variety in a general location or fruit producing region.

In some instances such indices have been developed for certain fruits, and have obtained general recognition and wide application. For example, on the west coast, harvesting of pears, especially the Bartlett variety, is largely regulated by the index known as the "pressure test," which measures the resistance of the flesh to the penetration of a plunger of given specifications into the flesh for a given depth. Experience has shown that the pressure test decreases as the fruit matures, and that for given localities, when it reaches a certain level, the fruit will mature properly after removal from the tree. While this index is empirical, it is quickly and easily made and has stood the test of commercial application, and is therefore a good index. With stone fruits such as the plum and apricot, color changes are very marked as maturity approaches, and picking recommendations have been made using these changes as an index.

In the case of the apple, however, no such satisfactory index has been found. While certain stages of maturity are easily recognized by the grower and inspector alike, the determination of the critical stages of maturity, including the earliest possible picking date, are still largely a matter of personal opinion and experience. Such personal judgment is an unsatisfactory index.

It was the purpose of this investigation to study certain physical and chemical changes which the apple normally undergoes as maturity approaches, and where possible, to associate these with the quality of the fruit picked at various stages of maturity during and after storage. Adequate indices to measure maturation in the apples thus might be developed.

LITERATURE REVIEW

Man's observations on the maturity of fruits probably began when he first started using the fruits of wild trees native to his land for food purposes. The better quality associated with the more attractive appearance of the mature fruit, and the softening of the fruit with the incidence of maturity were probably recognized in prehistoric times. These two factors have been so associated with fruit maturity, and hence good quality, through the ages, that now we unconsciously test fruit with the thumb to determine its hardness when buying, and are always attracted by the brightly colored product. Until comparatively recent times, when transportation and storage of fruit has revised our methods of growing and handling, these estimates of maturity were sufficient. Markets were local, and competition was not between widely separated regions, as it often is now.

The picking of relatively immature fruit by growers has increased in order that they might meet the demands of distant markets and of storage requirements. The research investigator has recognized this for some time, and there have been many attempts, some successful, but many failures, to measure fruit maturity in terms of figures and facts, and to thereby standardize harvest practices and to insure the consumer a product of uniform, high quality, and the grower the benefits to be obtained thereby.

Some of these attempts have been to standardize and measure those physical changes which fruits undergo during maturation, and which have been recognized in their more general aspects, such as softening and color development; others have been to correlate the invisible chemical and physical characteristics of the fruit with the maturation processes.

The development of methods designed to shed light on these problems of measuring maturation changes in the apple and related fruits are reviewed below.

<u>The Pressure Test</u>. The development of the "pressure test" by Murneek (58) at Oregon was the direct result of attempting to standardize the old practice of testing fruit for hardness with the thumb. The original test measured on a pan balance the resistance of the flesh of the fruit to the penetration of a marble into the flesh, but has been considerably refined until the pressure tester designed and described by Magness and Taylor (56) is now considered standard for apples and pears. This instrument measures in

pounds the resistance of the flesh of the fruit of apples and pears to a standard plunger 7/16 inches in diameter penetrating the fruit flesh 5/16 inches. Allen (1), Murneek (58), and Hartman (38), Lewis, Murneek, and Cate (49) and others have had marked success in applying this instrument in the measurement of maturity of the pear, and it is now considered a standard index of maturity for pears in the west, especially when used in conjunction with color estimates. However, an equally extensive number of investigators (24, 34, 35, 38, 50, 52, 53, 54, 63, 72, 80) have had little success in applying the pressure test to the apple as an index of maturity. The results have been highly variable, both with the same variety in the same general locality, and in different years. As a rule the pressure test of apples did not change materially during the maturation period, and such differences as were noticed were not sufficient to be of significant value. Thus, Neller and Overly (63) working with the Delicious variety in Washington found a decrease of only 0.3 pounds from September 2 to October 14; Jonathan decreased 0.6 pounds from August 19 to October 7, and Burroughs (13) found a decrease of only 0.75 pounds during three weeks covering the commercial harvest of the Wagener variety. As may be readily appreciated, these changes are much too small to be of value as a maturity index when almost daily differences of significant value are desired. These changes are among the smallest found, and Hartman (38) using the Jonathan, Grimes, and Ortley varieties found a decrease of 1 to 3 pounds during the three weeks period covering the range of the commercial harvest season of these varieties in Oregon. Magness and Diehl (52) found somewhat greater differences working with Winesap, Ben Davis, Rome Beauty, and Delicious varieties grown at Arlington, Virginia. The decreases were from 5 to 8 pounds for the first three varieties in the approximate harvest range of three weeks, except for the Delicious variety which showed a decrease of only 2 pounds during the two weeks from September 15 to 30. This decrease varies from one-fourth to one-third pounds per day, but tests were made only during the latter part of the picking season, so the results may not be applied to the critical stages of early maturity. Magness, Diehl, Haller, et. al (54) working with a large number of varieties grown in several widely separated localities, found in general that the pressure test decreased throughout the seaon, but that the changes were slight, and at no time of value as a measure of maturity. Further, they found that the pressure test for a given variety varied widely in different sections, and that the rate of decrease varied considerably, even in different sections of one locality. They also found that the pressure test varied considerably from year to year for a given variety grown in the same location, and concluded that the pressure test was not an adequate index of maturity, although it could be used as an estimate of possible storage life of the fruit, as will be shown later.

A large group of investigators have attempted to measure the effect of various fertilizers on the keeping quality of apples, and tested the fruit at harvest and at various times throughout the storage period with the pressure tester as a measure of hardness. Weinberger (80) tested the effect of potassium fertilizers and found that they had no effect on the pressure test of Williams, Stayman, and York varieties. Degman (24) tested the effect of nitrogen fertilizers on the keeping quality and pressure test of the Stayman, Williams, and York varieties, and found no influence of fertilizer on either keeping quality or pressure test. Gourley and Hopkins (31) corroborated the results of Degman and Weinberger (24) with Stayman, Jonathan, Wealthy, and McIntosh varieties grown in Ohio. Magness and Overley(55), Aldrich (2), Gourley and Hopkins (32), Plagge and Gerhardt (69), and others have added more evidence to failure of fertilizers to significantly effect the pressure test of apples.

The above results have been obtained in attempting to explain the differences often observed in the growth and development of apples under differing conditions of fertility, which growers have often considered to have a material effect on the maturation and keeping quality of the fruit. Plagge (70), Knowlton and Hoffman (47), Verner (79), Magness, Diehl, and Haller (53, 54),Aldrich (2), have all obtained results with a wide range of varieties under a wide range of conditions indicating that any possible effects of fertilizer on the keeping quality or the pressure test of apples can be more readily accounted for by differences in tree growth and other secondary factors than by the direct effect of the mineral nutrient used. Verner's results with York Imperial and Black Twig are especially illuminating in this regard. While he found that the pressure test averaged 20.6 pounds at the time of picking when nitrogen was applied and 23.4 pounds when no nitrogen was applied, the application of fertilizers had increased the size of the fruit, caused the formation of more leaf area per fruit, and subsequent shading of the fruit, and other such changes, as color, that would affect the quality of the fruit at the time of harvest, and hence its storage quality. The work of Haller and Magness (35) showed definitely that leaf area per fruit affected fruit quality, at least thirty leaves per fruit being necessary for the best development of flavor, and that where the leaf area became excessive, shading might materially effect the development of color and storage quality of the fruit. The work of Plagge (70) indicated that successive applications of nitrogen to the tree increased the susceptibility of Grimes and Jonathan to certain physiological storage disturbances, but there was no effect on the pressure test.

In general, the results of many experiments designed to test the efficiency of the pressure test as an index of maturity and as a measure of the effect of cultural conditions in relation to keeping quality of the fruit have yielded only negative results. The value of the pressure test as an index of maturity may be summarized in the words of Magness.

> "The rate of softening seemed to be rather variable . . . . and indicates that the hardness of the fruit as a test for picking will need be used with considerable caution."

Hartman (38) in making a critical study of the pressure test as applied to the pear found that: (1) the temperature of the fruit at the time the test is made, (2) the removal of part of the crop, (3) the turgidity of the fruit, and (4) the russetting and coloring of the fruit, all had a marked effect on the pressure test. He also believes that such factors as cultural conditions and the length of the growing season may affect the pressure test. The observations of Magness, Diehl, Haller, et. al. (54) substantiate this view in the case of apples, as in their extensive tests a variety grown in northern regions with a relatively short growing season was always more firm than the same variety grown further south, although the mean temperatures of the two localities were much the same. The original work on the pressure test by Murneek (58) indicated that fruit size had a very marked effect on the pressure test, but most observers since that time have taken random samples of fruit, and we have little data indicating the mean size of fruit in most of the work cited above. Degman and Weinberger (25) and Verner (79) considered fruit size in their investigations, the former selecting fruit of uniform size to overcome the size influence. That this factor has been more or less overlooked is surprising, for cultural and environmental conditions undoubtedly varied widely with resulting differences in fruit size, which may possibly account for some of the rather wide differences found within varieties.

In general, however, the mass of evidence indicates that the pressure test changes too slowly to serve as an adequate index of maturity of apples, and that variability in the test under different conditions of environment and cultural conditions makes it unreliable.

Fruit Size. Whitehouse (81), Verner (79), and Magness and Diehl (52) have shown that as long as water supply and nutrients do not become limiting there is a gradual increase in fruit size as long as it remains on the tree. However, the general level of nutrition, size of crop, and other cultural and climatic factors may markedly influence the actual size of the fruit. For these reasons fruit size is a poor index of maturity, although it was usually noted that the fruit should obtain its characteristic size, at least, for the conditions under which it was grown before it was harvested.

Color. Color is another commonly used measure of maturity which has come to us from the past. As early as 1906 Corbett (19) made rather definite observations on the effect of the ground color of Rome Beauty apples at the time of picking on their quality in storage, and recommended that picking be delayed until a yellow ground color developed. More recently Magness, Diehl, Haller, et. al. (54) studied the development of the ground color of a large number of varieties growing under different conditions, and developed a chart for the more accurate measurement of ground color. The results of their work indicated that a ground color value of 3, or nearly yellow, should develop for most varieties before the fruit was harvested. However, their results also showed that the development of ground color varied widely under different conditions and in different years. Varietal differences are involved as well, and the effect of nitrogenous fertilizers on fruit color is very marked, all of which indicates that ground color changes are not to be relied upon as an index of maturity. Plagge, Maney, and Gerhardt (72) showed that Grimes growing under very similar conditions, except that one group was in bluegrass sod and the other in clover sod, showed a difference in the development of ground color, the fruit from the trees in bluegrass sod maintaining a greener fruit color during the ripening period than the trees in clover sod, although they were otherwise the same. Both sets of trees received a basic nitrogen application yearly, and there were no apparent differences in the nutritional level of the two plots indicated in their report.

Magness (50) indicated that the development of ground color might well be considered with the pressure test in measuring maturity. This assumption receives support in the work of Pentzer, Magness, and Haller (67) and Allen (1) in their work with pears, where definite picking recommendations and limitations could be made for general localities when pressure test and fruit color were considered in conjunction. The work of Plagge, Maney, and Gerhardt indicated among other things that the changes in the ground color were too slow to be of value as an index of maturity, which, with the variability found by Magness and his co-workers in the development of ground color would indicate that ground color development, like the pressure test, should be considered only a supplementary measure of maturity, and not an adequate index.

The development of red color by the colored apple varieties has sometimes been used as an index to maturity, but has gradually fallen into disrepute because of the variability caused by climatic and cultural conditions. Marshall and Waldo (57) indicated that red color development was a very poor index of maturity under Michigan conditions. However, with varieties which normally develop rather high color at full maturity it has been repeatedly shown (24, 31, 42, 35, 47, 55, 70, 71, 72, 73, 80) that fruit picked in an immature stage, with low color development, is especially subject to certain physiological storage diseases, and hence has poor storage quality.

<u>Separation of Fruit from the Tree</u>. The ease of separation of the fruit from the tree has been considered by some to be a good index of maturity. However, this index has never been measured in exact terms, but usually has been estimated as the tendency of the fruit to drop from the tree, which usually does not occur until the fruit is in a rather advanced stage of maturity. As the fruit is still growing at this time if the water requirements of the tree have been met, it is often to the growers advantage to leave his fruit until it starts to drop because of the increased tonnage he obtains, and hence he may be inclined to use dropping of the fruit as a measure of maturity. Magness, Diehl, Haller, et. al. (54) attempted

to estimate this character as a basis for predicting maturity, but pointed out that rather wide differences were noted in different years, and were not at all correlated with maturity. Thus, they state:

> "All varieties grew very rapidly, attained large size, and adhered remarkably well, and under these conditions a medium sized crop on hign N trees with good water supply resulted in the fruit holding on the trees."

They also felt that the length of the growing season and difference in climatic conditions exerted a marked effect on the ease of separation. Magness (50) believes that consideration of the pressure test, ground color development, and the ease of separation of the fruit from the tree should all be considered in estimating fruit maturity.

Color of Seeds. Magness, Diehl, Haller, et. al. (54) and Plagge, Maney and Gerhardt (72) reported on the color of the seeds at the time of harvest, and the possibility of using this as an index of maturity. They found, however, that with all but the earliest summer varieties the seeds had changed to a dark brown color well before the fruit matured, with such varieties as Grimes, Stayman, Rome Beauty, York, and Jonathan. Plagge, Maney, and Gerhardt found that the rate of development of seed color varied under bluegrass sod and clover sod in the case of the Grimes variety. Magness and his co-workers showed that the number of days from blossoming it took for the seed to become brown varied a great deal between different varieties, and with the same variety grown in different regions. They also reported great variability in this factor in different years in the same locality. They place little reliance on this factor as an index of maturity for late summer and fall varieties. Its value as an index for early summer varieties has not been determined.

Growing Season. Magness and his co-workers (54) determined the growing season for a number of varieties in different years, and found that they ran about the same for a given locality. However, variations up to ten days or more were common, so it is apparent that this is not a good index for measuring maturity.

Electrical Resistance. Moore (62) developed an instrument called the "electrical maturity tester" in an attempt to find a more accurate index of maturity for pears, under Oregon conditions, than the pressure test and color changes. He found that this instrument gave rather reliable results with the common pear varieties, and offered a wider range during a given time than the pressure test, even though the rate of change was diminishing rapidly as maturity approached. Thus, he found a change of seven units in the reading obtained from his instrument in the week preceding harvest, while the pressure test change was only 2.3 pounds. The correlation with maturity was very good and he recommended its use with pears in Oregon. St. John and Morris (77), using Jonathan, Rome Beauty, Winesap, and Delicious varieties, measured the electrical conductivity of the expressed juice and found a slight decrease in conductivity with approaching maturity. They did not, however, have sufficient data to test the significance of their results.

All the characteristics mentioned above have been used in attempting to measure apple maturity, but no one of them has been found adequate. Some, when used in relation with others, hold promise of giving a rather close estimate of optimum picking maturity (52, 54, 57), but none, either alone or in combination offers any clue as to the earliest stage of maturity at which the fruit may be picked, and still be expected to develop characteristic flavor and quality in storage.

Storage Studies. Magness and Overley (55), Degman and Weinberger (25), Knowlton and Hoffman (47), Gourley and Hopkins (31, 32), Magness, Diehl, and Haller (53), Miller and Overley (63), have studied the changes in the pressure test during the storage period, and the effect of cultural conditions, etc. on the storage quality of the fruit as reflected by the pressure test. It has been found, in general, with all varieties, and under the various conditions of experimentation that the pressure test decreases throughout the storage period, with the exceptions of the work of Plagge, Maney, and Gerhardt (72), who found no decrease in the pressure test of Grimes stored from the picking dates in August and September to January 4 the following year. Degman and Weinberger (25) and Aldrich (2) also found a failure of Rome Beauty to decrease during the last part of the storage period. The work of Magness and his co-workers may be taken as representative in this matter. They found that the pressure test decreased throughout the storage period, and that the rate of decrease was dependent on the storage temperature (51), high temperature favoring a rapid drop in the pressure test. His work also indicated that fruit picked early in the season at a higher pressure test remained higher throughout the storage period at all temperatures, until the time physiological breakdown due to senescence set in. However, the rate of decrease was more rapid with this early picked fruit, so that the differences between the various pickings was not as great at the end of the storage season as the differences at the time of picking. Magness indicated also that the general level of the pressure test may be considered as an index of the storage quality of the fruit. That is, fruit that is relatively hard for the time it is picked for storage will have a longer storage life, and will develop better quality in storage, than fruit which is relatively soft at the time of picking.

The change of the ground color during storage was investigated by Magness, et. al., and Plagge, Maney, and Gerhardt. They found that the ground color continued to change in storage, and the former group that it developed more rapidly at the higher storage temperatures. The later the fruit was picked the more rapid was the change of the ground color in storage, and the early picked fruit never lost the green color until it was removed from storage, or to moderately high storage temperatures.

Chemical Studies. Considerable work has been done in determination of certain of the chemical constituents of the apple and their changes through the growing season and during the storage period. It is not necessary to review all of this work at this time, but most of that dealing with the pre-harvest changes and the storage work completed under normal conditions and storage temperatures are pertinent to this work.

Experiments conducted to show the changes undergone by the various carbohydrate and nitrogenous fractions throughout the life of the fruit on the tree are not so numerous. Howlett (43) started with the flower before it opened and set, and continued his investigations up to the time the fruit was about three-fourths inches in diameter. Murneek (59) investigated the changes in the carbohydrate and nitrogen fractions of the apple throughout this period, and continued his investigations nearly to the time of harvest, although his sampling dates were rather far apart in the later stages. Caldwell (14) started his investigations as soon as he could tell which of the fruit had set, and which would be shed in the first drop. Archbold (4) started one month after set. While the present investigation is more concerned with the changes taking place at the time the fruit is maturing, and immediately before, these investigations are of interest in indicating the general trend in the various fractions, and the point of development of those changes at the approximate time of maturity.

In general, the work on the changes in the chemical fractions of the fruit during the early life of the fruit are in agreement, and the general trend in the various constituents may be indicated. Murneek (59) has shown that the flowers are high in percent nitrogen at the time of blossoming, and that this fraction decreases immediately after blossoming, competition between developing leaves and fruit becoming so keen that he believes fruit set is materially affected by the nitrogen available to the tree during the very early stages of fruit development. After this initial drop, nitrogen increases in the fruit, although the percent nitrogen decreases slightly, due to the rapid growth of the fruit. He also believes that fruit set may be materially increased by insuring an adequate supply of nitrogen at this time, and that the later "drops" will also be decreased thereby. Murneek also showed that changes in the nitrogen and carbohydrate fractions were very rapid in the very early life of the blossom-fruit, and that closely spaced sampling dates were necessary to secure an accurate picture of the changes taking place. While an adequate supply of nitrogen and carbohydrates were necessary at the time of fruit blossoming and set, there was a decrease in the carbohydrates at the time of set, but carbohydrates soon started to increase in the young developing fruit. This increase was more or less regular throughout the period of development, the rate of increase slowing up with the rapid increase in the size of the fruit when calculated on a percentage basis, but the actual amounts kept right on increasing rather rapidly. Starch accumulation starts comparatively early in the life of the fruit according to the work of Murneek (59), Howlett (43), and Askew (8), and continues to accumulate until shortly before maturation. At this time the formation of starch apparently is stopped, and the available supply is rather rapidly hydrolyzed. Archbold (4) and others indicate that starch may always be present in large amounts in some varieties at the time of harvest, and never in others. Some varieties are intermediate in character, and may show varying amounts of starch present at maturity in different years.

In dealing with the period immediately preceding maturation and the period of maturation, the work of Plagge, Maney, and Gerhardt (72) is illuminating. They found that during the period of maturation, reducing sugars increased slightly up to the time of maturity, when there was a slight decrease. Delaying storage after the time of harvest had little effect on the reducing sugars of fruit picked at maturity, although on earlier picked fruit, delaying storage resulted in an increase in reducing sugars which was nearly proportional to the time of delay. Total sugars showed only slight increase from the period of August 14 to September 14, after which they nearly doubled in a week's time, only to fall off somewhat during the last week the fruit was on the tree, September 26 to October 7. After a period of two weeks delay in storage, which should have much the same effect as a longer period in storage, they found the total sugars tended to come to a constant point of 58 percent on dry weight basis regardless of the time of harvest. Caldwell (14), in studying the changes throughout the life of the fruit from a time shortly after it had set, found a steady increase in reducing sugars, sucrose, and total sugars of the fruit on the tree in all the varieties he studied. These two investigatons agree rather closely on the changes taking place in the soluble carbohydrates during the period of fruit development. Plagge, Maney, and Gerhardt also reported on the starch content of the fruit, and found that it was almost constant over the period of the investigation. In this respect it is interesting to compare their work with that of Bigelow, Gore, and Howard (10), who, working with several varieties, report a slight rise in reducing sugars during a comparable period, and a more rapid rise in sucrose during the same time, much as in the case of Plagge, Maney, and Gerhardt. However, they found that the rapid rise in sucrose was due to an inversion of starch during the same period, to the point of disappearance. After the starch had disappeared the sucrose content of the fruit decreased rapidly as it was inverted. The main point of disagreement between the two investigations lies in the failure of the starch to decrease in the Grimes apples used by Plagge and his co-workers, even though sucrose was increasing rapidly. Archbold (4) also reports a gradual increase in all the soluble carbohydrate fractions, although the rapid increase in sucrose was not apparent, as in the two investigations reported above. She used Bramley's Seedling variety in her investigation, which is always devoid of starch at harvest.

In general, as has been pointed out, (10, 51, 63), there seems to be a relation in the apple between the soluble sugar fractions and the starch content of the fruit.

The acid fraction of the apple has been studied by Archbold (4), Haynes (39), Magness and Diehl (52), Caldwell (14), Plagge, Maney, and Gerhardt (72), among others, and all report a decrease in the titratable acidity during maturation. However, in no case are the actual changes very great. The reserve acid of the fruit apparently is stored rather early in the life of the fruit, as indicated in the work of Archbold, Haynes, and Caldwell, and acid is slowly lost by respiration throughout the life of the fruit, both on the tree and in storage. Kidd and West (46), Haynes (39), and Plagge, Maney, and Gerhardt (72) all concur that any market deviations in the acid content of the fruit, either on the tree or during the storage life of the fruit, is conducive to the development of physiological breakdown in storage. High acidity is usually associated with low carbohydrate content, and unless the ratio between these substances is rather fixed, storage disorders may be expected. Haynes and Archbold (40) and Archbold (5) indicate that low nitrogen and high sugars favor good storage quality. None of the work showed any value in the acidity changes as an index of maturity, as the changes were very slow and gradual. The use of acidity measurements for storage purposes, however, offers some promise, especially when it is considered in connection with the general carbohydrate level of the fruit.

That portion of the carbohydrate fraction of the apple tissue which yields to hydrolysis by dilute acids, and is variously termed the acid hydrolyzable fraction or the hemicellulose fraction has been shown by Archbold (4), Archbold and Widdowson (7), and Murneek (59, 60), to decrease during the maturation period. The exact nature of this fraction is somewhat questionable, due to the empirical nature of the method for its determination. Murneek (60) seems to think that only the true hemicellulose is estimated by the method commonly used for its determination, and considers this substance to be a very important storage product in the apple tree and fruit. If this is true it may play a part equally as important as other storage products, such as starch, in the apple fruit.

The pectic constituents have received a great deal of attention in more recent years, especially in regard to their relation to the softening of fruits, with the approach of maturity and during senescence (3). The work on the changes of the pectin fractions in the developing of apple fruit are in good agreement, as may be seen by comparing the work of Carre (15,16), Carre and Horne (17), and others. These workers agree that in the early stages of maturity there is very little or no soluble pectin present in the apple fruit. However, at optimum maturity and during the storage period, the soluble pectin fraction increases greatly at the expense of the insoluble pectin fraction. Total pectin remained at the same level throughout the maturation period, and the only changes noted occurred when the insoluble forms started to be hydrolyzed to the soluble form. Because this change occurred only late in the natural life of the apple fruit on the tree it is of little value as an index of earliest maturity. Gourley and Hopkins (32) found larger percentages of soluble pectins in maturing Jonathans, and thought that there was a definite increase during the maturation period. However, their results are too incomplete and variable to be significant in this regard.

Archbold and Widdowson (7), Bigelow, Gore, and Howard (10), Neller and Overly (63), and Burroughs (13) indicate that the dry weight fraction increases steadily, although slowly, throughout the maturation period.

While certain trends are readily apparent in the various carbohydrate, nitrogenous, and other chemical fractions of the apple fruit during its period of development on the tree, they are relatively slow and variable when considered as indices of maturity, as shown by the above investigators. Cultural and climatic conditions may affect all of them. While the fruit is a dynamic organism, and is undergoing constant change with the approach of maturity, and during senescence, either on the tree or in storage, there are certain relations between the various compounds present which are found throughout the life of the fruit, and which shift only slowly with the various stages of maturity and semescence. Thus, in the early life of the fruit a certain relation between the various soluble and insoluble carbohydrate fractions is to be recognized, the main features of which indicate that photosynthesised materials are being stored in the fruit and used for growth. As maturity approaches the synthesis and transfer of these products cease, possibly under the control of enzymatic forces (78) or mechanically through restrictions developing in the abscission layer. As time continues, there is a shift of the equilibrium of these carbohydrates from the insoluble forms to the soluble forms, and the sugars increase at the expense of the reserve materials. The supply of sugars is then gradually used in respiration, the rate depending upon the storage temperature. As certain, unknown limits of reserve materials obtain, a natural breakdown known as physiological breakdown occurs. Similar relations obtain with the acid, nitrogenous, and other fractions, and all are inter-related with each other. The sum of these changes and relations determine the life of the fruit, and such changes as we measure proceed relatively slowly throughout the life of the fruit. There is no "leveling off" period which would indicate a definite stage of maturity, and there is no rapid shift of equilibria which would indicate a change from the immature stage to the mature or senescent stage. Because of this, and the variability found in the actual amounts of the various fractions, none of them has been found to have appreciable value as a measure of maturity.

A tremendous amount of work has been done investigating the chemical changes during the storage period, especially in regard to the effects of various treatments on the storage life of the fruit. In this investigation we are more interested in the senescence of the apple fruit during its natural storage life at the temperatures commonly employed, and for that reason only those will be considered.

Bigelow, Gore, and Howard (10) state that the apple fruit continues its development throughout its storage life, and that the changes are merely continuations of those occurring during its life on the tree. Thus, they show that all fractions for which they analyzed continued the trend started on the tree, during the storage period, the rate, of course, depending largely on the storage temperature. After the fruit is removed from the tree any starch left was rapidly hydrolyzed to sucrose, resulting in an increase in this fraction, which was also shown by Archbold (4), Plagge, Maney, and Gerhardt (72), Neller and Overley (63), and others. Sucrose reached a maximum upon complete hydrolysis of starch, and was then hydrolyzed to reducing sugars, resulting in a decreased sucrose content in storage, and an increase in the reducing fraction. Evans (28) indicated that in apple fruit in storage the reducing fraction consisted of fructose and glucose, which were always present in the ratio of 2:1.

The acid fraction continues to decrease slowly throughout the storage life of the fruit, the rate being determined by the storage temperature, as with the other fractions. Haynes (39) indicated that under cold storage conditions the acid fraction was liable to be more variable than in common storage, and Plagge and Maney (71), and others (39, 51, 72), have shown that unbalance in the acid-carbohydrate relation was very liable to cause an increase susceptibility to storage disorders, if it were not the actual cause.

The pectic fraction, which was shown earlier to change but very slightly during the natural life of the fruit on the tree (15, 16, 17, 34) undergoes quite rapid changes during the storage period, although these are merely a continuation of those just beginning at the time the fruit is fully ripe on the tree. Thus, both Haller (34), Carre (15, 16), and Carre and Horne (17) have shown that soluble pectin increases rather rapidly, the insoluble pectin decreases, and the total remains about the same for a considerable period of the storage life of the fruit. As Carre and Horne (17) show, the accumulation of soluble pectins results directly from the hydrolysis of the insoluble forms and thereby accounts for the lack of change in total pectin. As pectins are used in respiration and are broken down into more simple compounds, this lack of change in the total pectin is at first problematical. However, Carre (15, 16) and Carre and Horne (17) showed that certain of the middle lamella pectic compounds are not determined in the usual procedure, and upon analyzing for these, they found that they decreased during the storage period until they disappeared. It was during this period that the total pectic constituents showed no change. After the disappearance of these middle lamella pectic constituents the total pectin, as determined by the usual procedure, showed a decrease, as has been shown by Carre, Haller, and Magness and Diehl (52).

Haller (34) correlated the changes in the pectic constituents with the presdure test of Joanthan apples in storage very well.

While this paper does not deal with respiration changes in the apple during maturity or storage, or the relation of respiration changes with the time of harvest, it is thought best to outline these changes, as found by other investigators, to establish the general trend of metabolic activity found in the developing and stored fruit.

The respiration of apple fruit during storage is of interest in connection with the changes in the chemical constituents which occur. Bigelow, Gore, and Howard (10), Gore (30), Harding (36), and Magness and Diehl (52), among others, made rather complete respiration studies. Bigelow, Gore, and Howard concluded that respiration is a function of the complete carbohydrate content of the apple, and not of the acid, or any one of the carbohydrate fractions. Burroughs (13) studied the respiration changes of the Wagener apple picked at various times, and stored at 68.5 degrees F. both with and without initial storage at 32 degrees F. He found that the rate of respiration increased more slowly with early harvested fruit than with the later pickings, but that an increased rate of respiration always followed the harvest period. His results also showed that the later pickings had a higher rate of respiration than the early. When fruit was removed from storage at 32 degrees to 68.5 degrees the rate of respiration increased greatly, and actual stimulation occurred. This was greater in the early harvested samples than in the later. In early harvested fruit this increase was often maintained at the higher storage temperature, but in the later pickings the respiration rate soon returned to its normal value. He also found that the respiration rate followed the van't Hoff Law between 32.5 and 68.5 degrees F. Harding (36) substantiates these results. Onslow, Kidd, and West (65) found that approximately half of the reducing sugars was used in respiration, and considered this to be the fructose fraction. They believed the glucose fraction to be inactive.

Correlations. In attempting to correlate physical and chemical changes of the apple fruit during maturity and storage, certain trends are evident, but are, on the whole, too gradual to be of value in measuring maturity. It has been shown (13, 24, 25, 52, 53, 54) that the pressure test decreases somewhat during the maturation period, but that the rate of change is too slow to be of value as a picking index. This may be correlated with the work of Carre (15, 16), and Haller (34) on the pectic constituents, which they show to change very slowly, if at all, during the period immediately preceeding maturation. The pressure test has been shown to change more rapidly as a rule, in storage, which again correlates with the work of the above investigators on the pectic constituents.

While Magness and his co-workers (50, 52, 53, 54, 55) Marshall and Waldo (57) and others have indicated that red color changes are not to be considered of value in estimating maturity, Corbett (19), Magness, and Diehl (52), Plagge and Maney (71) have noted that fruit picked before a normal amount of color has developed invariably were subject to storage disorders. While color may be variable, and for many varieties a poor index of maturity, it may be equally true that for certain varieties a given amount of color development is necessary to insure good storage quality.

Davis and Blair (23) studied the maturation of McIntosh and Fameuse varieties of apples and developed a semi-quantitative starch chart, based on the iodine test, for starch content for these varieties, and made definite picking recommendations based on this work. They were also able to correlate picking maturity of these varieties with the total solids content, as measured by the refractometer. This last test may be questioned on the basis of Caldwell's investigation (14) where he indicated that the sugar content of the apple fruit varied widely in different seasons, the variations being accounted for largely by climatic conditions. The results obtained with the starch determinations, however, offer a possible lead for these varieties which normally have starch present, but rapidly decreasing at the time of maturity.

Neller and Overley(63) developed a rather complex "Maturity Formula", which, unfortunately, is based largely on the mature characters of the fruit, and therefore offers little in the way of determining the early stages of maturity.

MATERIALS AND METHODS

Orchards and Varieties. In 1934 Grimes and Jonathan fruits were selected for investigation, and both varieties were taken from the orchards of E. D. McCain at Frederick, Maryland. (Figs. 1 and 2). The Jonathan trees selected were twenty-two years old, spaced 25 x 40 and the Grimes trees were thirteen years old, spaced 25 x 40, with peaches interplanted between the rows. Further selection was made on the trees of these varieties, thirty-six trees of each variety being selected for uniformity of growth and crop, and rather high vigor. The trees are growing on a Penn gravelly loam soil, and the orchard receives a basic treatment of five pounds of nitrate of soda per tree yearly. No modifications in this treatment were made. A weed sod was well established, and was mowed previous to harvest.

In 1934 pickings were made at six consecutive, weekly intervals starting August 23 with the Grimes and August 27 with the Jonathan. Six trees were selected at random from the original thirty-six selected trees each week, and two bushels of fruit were taken from each tree as a sample. Care was taken to insure a random sample of fruit from each tree, and fruit was selected around the tree, in the middle, and at the top. It was hoped, by this procedure, to secure samples that amply represented the variation to be found on a given tree and between trees,

Figure 1. Grimes trees selected in 1934 at Frederick, Maryland, showing trees picked at each harvest date.

Figure 2. Jonathan trees selected in 1934 at Frederick, Maryland, showing trees picked at each harvest date.

Figure 3. Grimes trees selected in 1935 at Colesville, Maryland showing trees picked at each harvest date.

Figure 4. Jonathan trees selected in 1935 at Frederick, Maryland showing trees picked at each harvest date.

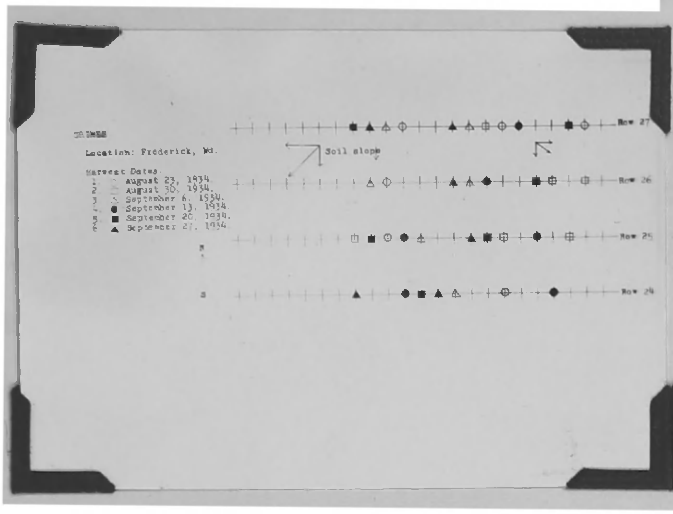

Figure 1.

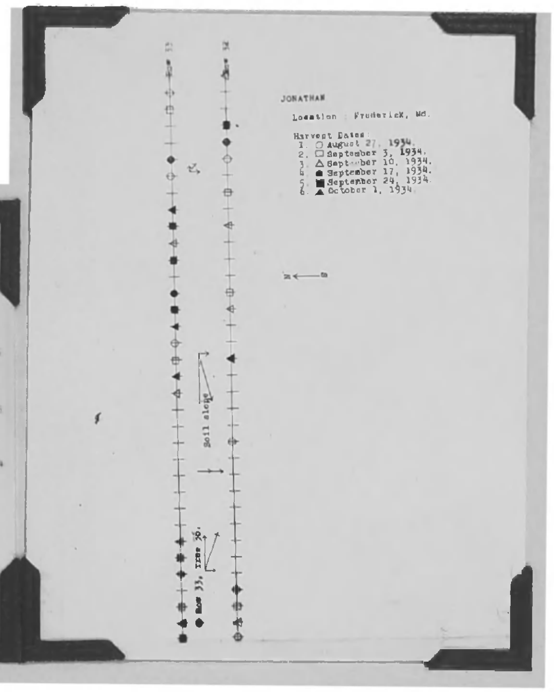

Figure 2.

Figure 3.

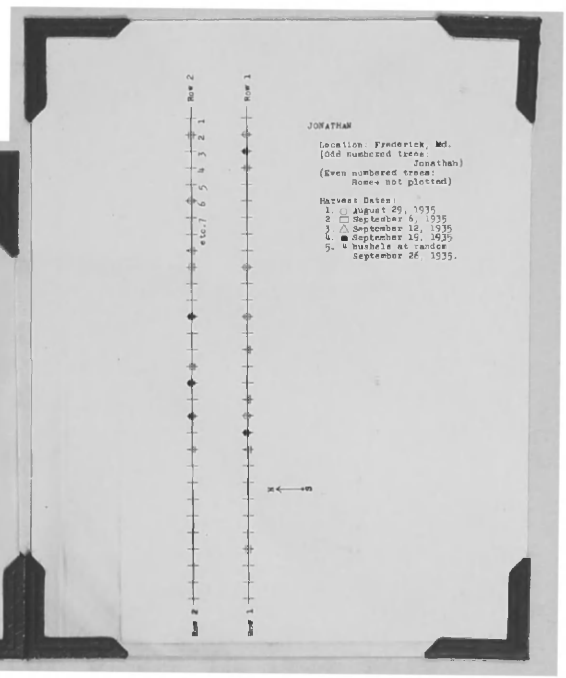

Figure 4.

thereby enhancing the value of any significant values found later in the investigation.

In 1935 the same varieties were used for study. The Jonathan variety was taken from the same orchard as in 1934, but a younger planting of trees (Fig. 4) was used because the older Jonathans failed to set a crop. These trees were thirteen years old at the time and were planted 20 x 40, a filler row of peaches occurring between the rows. The rows were planted to alternating trees of the Jonathan variety and Rome Beauty variety. Selection of trees was made on the same basis as in 1934, except that only twenty-five trees were selected, and only five weekly pickings were planned. The cultural conditions under which the trees were grown were the same as those in 1934.

Samples were taken as in 1934, the pickings starting August 29, 1935. Due to the tendency for the fruit to drop in this year the grower found it necessary to harvest the bulk of the crop during the week before the last harvest date planned in the investigation, so that the last picking is not representative. A random sample of four bushels was taken from several trees as a substitute for the regular picking, and represents the fruit left on the tree after the bulk of the crop was harvested, presumably because it was considered more immature.

The Grimes trees selected for study in 1935 were thirteen years old, and were located in an orchard owned by G. Rust Canby near Colesville, Maryland. (Fig. 3). The orchard and trees were selected on the same basis as those reported above, and, as with the Jonathan variety, twenty-five trees were selected, five to be harvested each week until the completion of the harvest. As in the case of the Jonathan variety, the fruit started to drop before the five weekly pickings could be completed, and the grower found it necessary to harvest the bulk of the crop between the third and fourth picking dates. The last two samples, in this case, represent four bushels taken at random from several trees, and are not representative of the regular pickings for the reasons given above.

The Grimes orchard was grown under a sod crop system with a yearly nitrogen application of six pounds of sodium nitrate per tree. The sod crop was of weeks, and was mowed previous to harvesting. The soil type was a fertile, upshur loam. The trees were planted thirty feet square.

Other pickings of Grimes were taken from a nearby orchard located at Olney, Maryland. These trees were about twenty years old, and were of interest because they were very devitalized, and had received no nitrogen applications for many years. Weekly samples of two to four bushels were taken from August 29 to September 19, at which time the fruit was harvested by the grower. The orchard was in a permanent, though light, weed, sod crop, which showed the lack of nitrogen nearly as much as the trees themselves.

After harvest the fruit was removed immediately to College Park, Maryland, where it was placed in storage. In 1934 the fruit was not washed, or treated in any way except for grading, before placing in storage. In 1935 the fruit was washed and graded before being stored. The storage temperature was uniform in the two years, and was 32 degrees F. Humidity in storage was approximately 80 - 85 percent relative humidity.

The fruit was graded for size before storing; three size groups were arbitrarily determined upon: (1) under 2-1/4 inches, (2) 2-1/4 to 2-1/2 inches, and (3) over 2-1/2 inches, hereafter referred to as the small, medium, and large size groups respectively, and all the fruit was allocated to its appropriate size group. The fruit from each tree was kept separate throughout, and counts were made to determine the proportionate number of fruit from each tree falling into each size group, and thereby the average fruit size for the tree could be calculated.

Three lots of twenty fruits each then were selected at random from each size group from each tree, as far as the material allowed, was weighed, and placed in open bags in storage. This fruit was used for the chemical determinations, and also as measure of the loss of weight in storage. One lot was used immediately, and one at the time of each storage sample.

The physical determinations were made on lots of fruit selected from the remainder of the fruit from each size lot from each tree, which was stored in bushel baskets.

Temperature and rainfall data for Frederick, Maryland are given in figs. 5 and 6 for 1934 and 1935,

Figure 5. Temperature and rainfall data for the period covering the picking dates of Grimes and Jonathan varieties in 1934, at Frederick, Maryland.

Figure 6. Temperature and rainfall data for the period covering the picking days of the Jonathan variety in 1935, at Frederick, Maryland.

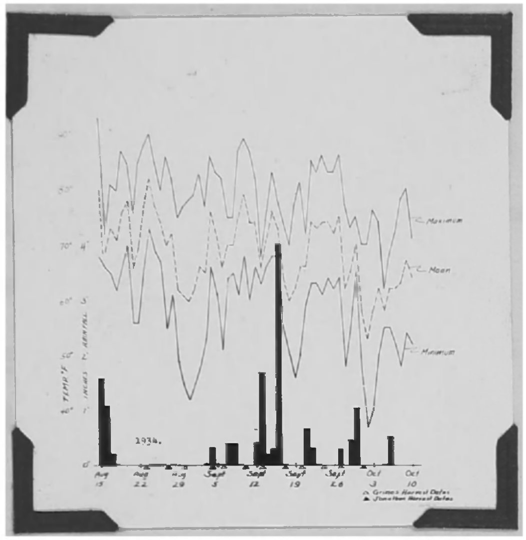

Figure 5.

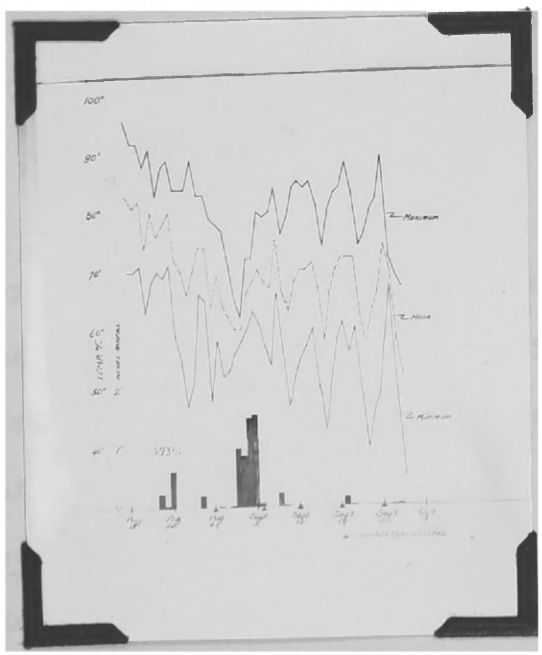

Figure 6.

respectively. These data were obtained from the United States Weather Bureau in Washington, D. C. from records compiled by the Government Weather Station at Frederick, Maryland. The data presented covers the entire harvest period under investigation and the preceding and following week. These records were obtained that the influence, if any, of climatic factors upon the maturation processes could be determined.

Pressure Test. Pressure test measurements were made on all lots of fruit at the time of harvest, and at the dates storage samples were taken. For each test, samples of twenty fruits were selected at random from each lot of fruit, and the pressure test was made after color estimates, electrical maturity tester readings, and observational notes had been taken on the sample. A Magness and Taylor type of pressure tester was used throughout.

The pressure test was made at three points about the circumference of the fruit at the cheek, with the skin removed. The sixty readings thus obtained from the twenty fruits were averaged, and the average was considered as the pressure test of the lot.

Electrical Maturity Tester. The identical samples of fruit used for the pressure test data were used in obtaining the electrical maturity tester readings. The fruit was tested again at three points around the circumference at the cheek, but the skin was not removed for this test. An average of the sixty readings thus obtained was considered to be the electrical maturity tester reading for the lot. The electrical maturity tester used is similar to that devised by Moore. The readings are reported directly as read on the instrument in milliampers, multiplied by 100 for ease in handling. A potential of three volts was maintained between the electrodes throughout this investigation.

In 1934 the electrical maturity tester readings were taken at storage temperature, starting with the second harvest, as the instrument was not obtained until this time. In 1935 the readings were taken at room temperature, and this difference in temperature accounts for the difference in mean level of the readings in the two years -- about ten units.

Color. Ground color estimates were made on the Grimes variety in both years, using a Magness and Diehl (52) color chart. Percentage red color for the Jonathan variety was estimated by inspection in each year. The same samples of fruit used for the pressure test and electrical maturity tester readings were used in each case.

Miscellaneous. In 1935 estimates were also made on shrinkage and russeting, using the same fruit used in the above investigations.

Chemical Samples. Samples of twenty fruits from each size group from two trees each of Grimes and Jonathan were preserved for chemical analysis in 1934. Slices of one-third to one-sixth of the total fruit, depending on its size, were taken from each of the twenty fruits, peeled and cored, and sliced into thin slices with a meat slicer. One hundred grams of this fruit flesh was preserved immediately in sufficient hot 95 per cent alcohol to make the final concentration approximately 70 per cent. These samples were stored in sealed tin cans until the analyses were run. To each sample 0.5 grams of calcium carbonate were added. During the time the samples were in storage there was no apparent deterioration due to the metal container.

Total Solids. Total solids were determined after extraction of the entire one hundred gram sample on a Soxhlet extraction apparatus for eight hours, which was the time found to be necessary for extraction of the soluble carbohydrates. The entire alcohol insoluble residue was weighed after 72 hours drying under forced draft at 65 degrees C. No caramelization was found in the insoluble residue at this temperature. After the alcohol extract was made to volume at 1000 ml., 50 ml. aliquots of the alcohol soluble material were taken and the alcohol soluble material was determined by drying at 65 degrees C. for seventy-two hours. Caramelization was lacking or very slight at this temperature. The total dry weight was found by adding these two dried portions, and deducting the calcium carbonate added to the sample.

Reducing Substances. After extraction was complete the alcohol soluble portion was made to volume at 1000 ml. Aliquots of 100 ml. of this extract were evaporated on a sand bath, with cool air blowing over the sample constantly to keep the temperature of the solution down. After the alcohol was evaporated the sample was diluted with distilled water to approximately 100 ml., and cleared with neutral lead acetate. The excess lead was removed with calcium oxalate. The aliquot was made to volume of 250 ml. from which 50 ml. aliquots were taken for the determination of reducing substances. The Munson-Walker reduction and the Schaeffer and Hartman iodometric determination for CuO was used, and reducing substances calculated as invert sugar from the Munson and Walker conversion tables.

Total Sugars. From the sample cleared for reducing sugar determinations 100 ml. aliquots were taken and 10 ml. HCl (Sp. Gr. 1.1250) added. This was allowed to stand at room temperature over night, and total sugars were determined on the hydrolyzed solution the following day. The acid was neutralized with NaOH and the sample made to volume at 250 ml. from which 50 ml. camples were taken for reduction, as under reducing sugars, and converted to invert sugar, using the Munson and Walker conversion tables.

Sucrose. Sucrose was calculated as the difference between total sugars and reducing sugars.

Starch. It was felt that the determination of starch should be as accurate as possible in this investigation, as some hope was held that the changes in the starch content of the fruit might be very indicative of the stage of maturity. For this reason the method of Denny (26) was used in this investigation.

TABLE I -- Differences in the Per Cent Starch in Various Tissues as Determined by the Method Used (From Denny (26)).

Plant and Tissue.	Quantitative Test for Starch.	Per Cent Starch on Air Dry Weight by Following Methods			
		Acid Hydrolysis of Powder.	Modified Walton and Coe.	Takadiastase: Without Acid Hydrolysis.	Calcium Chloride Extraxtion.
Grape Twig	+	23.0	5.24	5.01	5.31
Dahlia Root	-	55.6	10.96	0.87	
Apple Fruit Flesh (York)	+	44.0	15.36	13.20	14.02
Apple Fruit Flesh (Sutton)	+	34.8	5.73	5.72	5.13
Apple Fruit Flesh(Greening)	+	32.6	1.78	1.44	0.67
Apple Fruit Flesh(McIntosh)	+	31.6	2.80	2.82	0.23
Potato Tuber	+	73.6	63.60	63.60	66.60

Denny showed conclusively (table I), using a wide range of material, that the common methods of starch analyses on many plant materials, were liable to rather large error, especially in the presence of certain compounds. At the beginning of this investigation comparisons were made using samples of Yellow Transparent fruit flesh to further test the claims made by Denny. Table II shows the results obtained which substantiate Denny's claims. From that point on the method of Denny was used entirely. As the method has not been extensively used it is described in detail here.

In the analysis for starch in this study 0.5 gram samples of the alcohol insoluble fraction were used throughout. This fraction was first ground to pass a hundred mesh screen with a Wiley micromill.

The weighed, powdered tissue was placed in a mortar, moistened with water, and disintegrated by grinding. This method of grinding in a mortar was later modified slightly by use of a bâll mill, in which the powdered sample was placed in a small glass jar, with several small, smooth stones, and 10 ml. water were added. A few drops of toluene were added to deter bacterial development. These jars were rotated overnight, which was found to be sufficient time to allow thorough disintegration of the powdered material. Microscopic examination of the material at the end of the grinding period showed that most of the cells were ruptured, and that none was not directly exposed to the extracting solutions.

TABLE II — Comparison of Takadiastase Digestion and Denny's Method of Starch Determination on Yellow Transparent Fruit.

Sample	Per Cent Dry Weight: Takadiastase Digestion	Per Cent Dry Weight: Calcium Chloride Extraction (Denny)	Per Cent Non-Starch (As Determined by Takadiastase Digestion
1.	13.22	3.74	72
2.	14.98	5.73	62
3.	18.02	5.26	81
4.	7.25	5.15	29
5.	7.14	5.33	25
6.	9.83	5.10	48
7.	7.37	5.40	27
8.	5.73	5.17	10

After grinding, the material was transferred with a small jet of water to a large centrifuge tube, capacity 100 ml., the amount of water necessary to make the transfer being measured, usually 20 ml. Small test tube "wash" bottles were used to make the transfer, with the tubes marked in 10 ml. graduations, so the amount of water used could be readily determined. A quantity of $CaCl \cdot 6H2O$ equal to twice the amount of water used in grinding and making the transfer (about 60 grams for the ten ml. water used in grinding and the 20 ml. water used in making the transfer) was weighed out, added to the centrifuge tube containing the material, and the tube placed in a boiling water bath for twenty minutes. It was then brought to a boil over a free flame, centrifuged, and the clear liquid decanted into a liter beaker. A very small quantity of the solid material floated to the top of the extraction solution during the action of the centrifuge. Most of this adhered to the sides of the centrifuge tube, but a small amount was transferred to the beaker. As this was always a very small portion of the total, it was disregarded. The liquid in the centrifuge tube always became clear with sufficient centrifuging, although the time necessary varied widely. Four volumes of water were added to the decanted liquid in the beaker.

To the residue in the centrifuge tube, 20 ml. of concentrated calcium chloride solution (2 parts $CaCl \cdot 6H2O$) to 1 part water by weight) were added. Again the material was heated with the extraction solution in a boiling water bath for twenty minutes, brought to a boil over a free flame, centrifuged, and decanted. About four successive extractions with calcium chloride were found to be necessary with most samples. However, the residue was tested microchemically after the third extraction. In a few cases where microchemical examination showed little starch present, tests were made after the first or second extraction. In any case, extraction was repeated until one extraction was made after microchemical examination of the reside with iodine showed no more starch to be present. After this last extraction a single extraction was made in which the residue was allowed to stand overnight in contact with the calcium chloride extracting solution.

To the decanted and diluted solution in the beakers a few drops of a saturated solution of iodine in ten per cent potassium iodide was added, and additional amounts were added until an excess of iodine was apparent in the solution. This could be tested for in the solution, even when it turned a very dark blue, by observing the froth formed when the mixture was stirred violently, or by observing a drop of the solution on the end of a stirring rod. A precipitate of starch-iodide usually formed within a few hours, but was always allowed to stand overnight to insure complete precipitation, and to allow larger particles of the precipitate to form.

The starch-iodide precipitate was then transferred quantitatively to a fine asbestos mat which had previously been prepared on a Buchner funnel. The precipitate was washed first with cold and then hot 95 percent alcohol, which removed the calcium chloride, potassium iodide, and some of the iodine. The asbestos mat and precipitate was then transferred with a little water and a rubber tipped stirring rod to a 200 ml. Erlenmeyer flask, placed on a sand bath, and boiled slowly for a few minutes. Care was taken to prevent bumping. The starch-iodid precipitate was broken up by this process and the iodine volatilized, as could be seen by the color of the solution. It was then placed on a steam bath for an hour or so until all the iodine had been volatilized, as could be readily determined by the odor of the mixture.

After all the iodine was removed the solution was cooled, enough freshly made takadiastase solution added to make 0.05 gms. takadiastase, and 10 cc of an acetic acid-sodium acetate buffer solution (p.H. 5.4) was added. A few cc. of toluene were added to prevent bacterial and mold growth.

The sample was placed in an incubator at 38 degrees C. for forty hours, the mixture being stirred at short intervals throughout the incubation period. At the end of this period the disappearance of the starch was checked microchemically with iodine. The solution was filtered into a 250 ml. volumetric flask, washing the asbestos until the volumetric flask was nearly full. It then was made to volume, and reducing sugars determined by the usual method.

Total Nitrogen. Total nitrogen was determined by the unmodified Kjeldahl method. Microchemical tests on the residue and alcohol soluble material were made with diphenylamine, and at no time was there any indication of nitrate nitrogen in either fraction. This corroborates the findings of Fletcher (29) and Degman (24). For this reason it was not considered necessary to use the modified nitrogen procedure.

Care was taken in the evaporation of the alcohol from the alcohol fraction, based on the observations of Ranker (74), who showed that small amounts of water might materially affect the nitrogen determination. Preliminary trials showed that a considerable portion of the nitrogen might be lost if dehydration was incomplete, so it was always carried to the point where no moisture was present before the chemicals for the determination were added.

A 0.5 gram sample of the alcohol insoluble fraction was used in each case, and 100 ml. aliquots of the alcohol soluble fraction. The two portions were run separately, and the total nitrogen determined by addition.

RESULTS

Pressure Test. While the pressure test has never yielded consistent and decisive information on the maturity of the apple fruit, it was deemed advisable to test its efficiency under Maryland conditions, and to compare it with other developmental changes studied. It was found that duplicate lots of fruit always checked very closely, indicating that 20 fruits constituted an adequate sample.

The results of the pressure test measurements were very consistent in seasonal trend, although the differences noted from week to week were not always statistically significant. At any one harvest date, and in both years of the test, there was a consistent inverse relation between size of fruit and the pressure test with both Grimes and Jonathan apples. (Figs. 7, 8, 9, and 10, tables IX, X, XI, and XII). In 1934 the difference between the size groups was less than in 1935 with both varieties, and in 1934 the Jonathan variety showed less variation between size groups than the Grimes.

To obtain an estimate of the pressure test of a random sample from the trees an average, weighted in proportion to the number of fruit falling in each size group, was calculated, and is shown in figs. 7, 8, 9, and 10 as solid black bars. The effect of maturation of the fruit on the pressure test may best be measured from these averages.

After the first week the Grimes, in 1934, shows a straight linear decrease in the pressure test, amounting to approximately three-fourths pounds per week, or about 0.1 pounds per day. For daily significance the decrease in the pressure test would have to be considerably larger than this, probably around one-half to three-fourths pounds per day, using sample sizes similar to the ones used in this investigation. During the first week the pressure test decreased approximately three pounds, a highly significant amount. This large initial decrease was probably due to a rather large increase in fruit size (fig. 20) as well as to the normal decrease due to maturation.

Figure 7. The pressure test by size groups and weighted average at weekly intervals for the Grimes variety, 1934.

Figure 8. The pressure test by size groups and weighted average at the weekly harvest intervals for the Jonathan variety, 1934.

Figure 9. The pressure test by size groups and weighted average at the weekly harvest intervals for the Grimes variety, 1935.

Figure 10. The pressure test by size groups and weighted average at the weekly harvest intervals for the Jonathan variety, 1935.

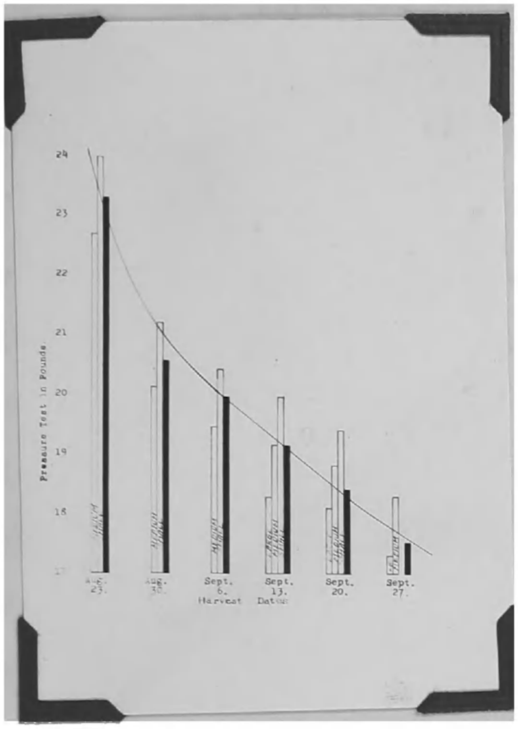

Figure 7.

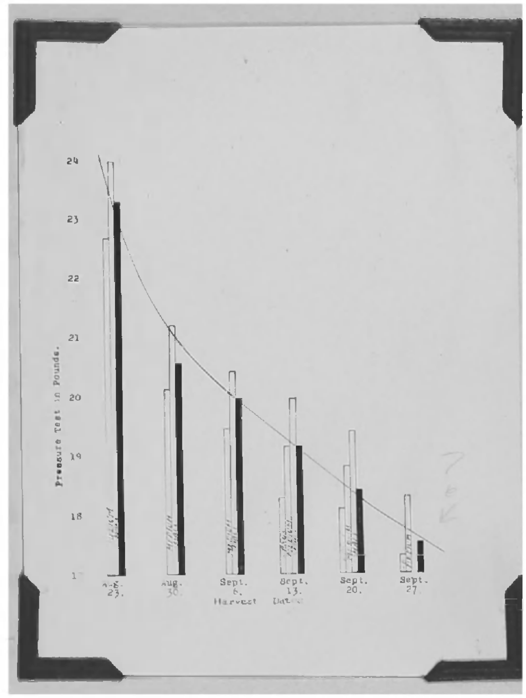

Figure 8.

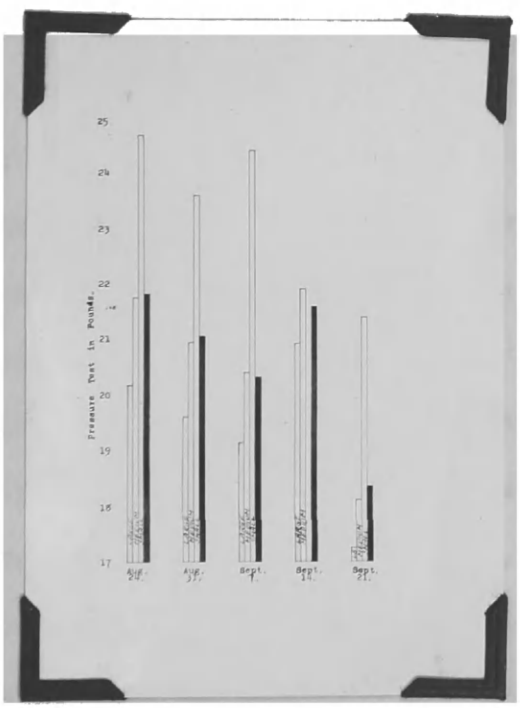

Figure 9.

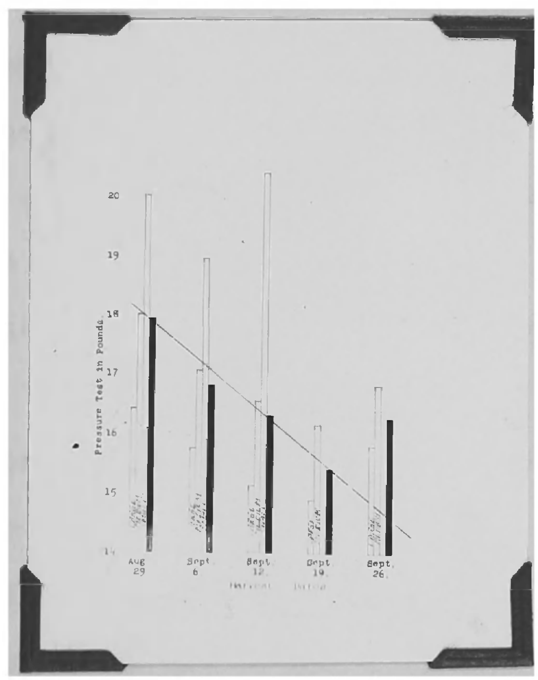

Figure 10.

The Jonathan variety showed the same trend in the pressure test as that described for the Grimes variety. A comparatively large initial drop was noticed during the first week, about one and one-half pounds, whereas a constant weekly decrease of approximately 0.75 pounds occurred in the following weeks until the last weekly interval, when no decrease was noticed. Except for the last weekly interval the weekly difference between the various size groups and the weighted average were statistically significant, although often barely so. On a daily basis, however, significance disappeared. The greater significance of the weekly differences found in the Jonathan variety as compared to the Grimes was due to the smaller variation between size groups found with the Jonathan fruit in this year.

In 1935 comparable samples could not be taken throughout the five weeks of the test, for after the third weekly picking of Grimes and the fourth of Jonathan, the fruit began to drop in both orchards, and it was necessary to harvest most of the fruit. As a result, the last two pickings of Grimes in 1935 and the last picking of Jonathan in 1935 represent one sample of each taken at random from several trees. The differences in maturity between the earlier samples and these later samples is apparent in the results obtained. (figs. 9 and 10).

It became apparent that the fruit was in a more advanced stage of maturity in 1935 than on similar dates in 1934. The first three pickings of Grimes in 1935 show a trend very similar to that of 1934, after the first picking, and a weekly decrease of approximately 0.75 pounds in the pressure test. The large initial drop in the pressure test noted in the first two pickings of Grimes in 1934 is absent,presumably because the fruit was more mature. The fourth picking of Grimes in 1935 was a random sample of fruit from several trees after first commercial harvest, and represents fruit left on the tree because it was considered more immature. A large increase in the pressure test is shown. (fig. 9). The fifth and last sample was similar to the fourth, but showed a very large decrease in the pressure test, falling closely in line with an extrapolation of the line of decrease for the first three weeks. This large decrease undoubtedly involves many factors among which water relations, decreased number of fruit on the tree, and a normal speeding up of the maturation processes,due to the lateness of the season, are probably prominent.

In 1935 results with the Jonathan variety compare closely with those described for Grimes in 1935, and the general trend in the pressure test was quite similar to that of the 1934 Jonathan pickings when differences in maturity at a given date are considered. After the fourth picking, when the bulk of the fruit had been removed, a random sample from several trees at the fifth weekly interval showed an increased pressure test, as was the case with the Grimes. (fig. 10).

As may be seen by comparing figs. 7, 8, and 9, likewise 8 and 10, the pressure test was very similar for a given variety on the same dates in the two years. However, as stated above, and as will be shown again later, the fruit was apparently in a more advanced state of maturity on any given date during the investigation in 1935 than in 1934. This difference was estimated to be about one or two weeks, and if comparisons are made on this basis, it is seen that the pressure test averaged about 1 to 1.5 pounds higher for a given stage of maturity in 1935 than in 1934 for both the Grimes and Jonathan varieties.

In an effort to determine the effect of date of harvest on the pressure test for apples of a given size the medium size group (2.25 to 2.5 inches) is plotted separately for Grimes (fig. 11), and Jonathan (fig. 12). Differences in seasonal trend with the same variety picked in 1934 and 1935 are evident in these figures, and a comparison may be made between the varieties by comparing the two figures. In general the trend is, in each case, similar to that for the weighted averages.

<u>Electrical Maturity Tester</u>. Moore (62) developed an instrument to make quick and easy determinations of the comparative conductivity of the flesh of fruits, which he called the "electrical maturity tester." In tests on various pear varieties he showed that the instrument registered differences as fruits matured, and even though the rate of change over daily intervals was slowing down,

Figure 11. The pressure test of Grimes fruit of a given size, 2-1/2 to 2-1/4 inches, throughout the harvest period in 1934 and 1935.

Figure 12. The pressure test of Jonathan fruit of a given size, 2-1/4 to 2-1/2 inches, throughout the harvest period in 1934 and 1935.

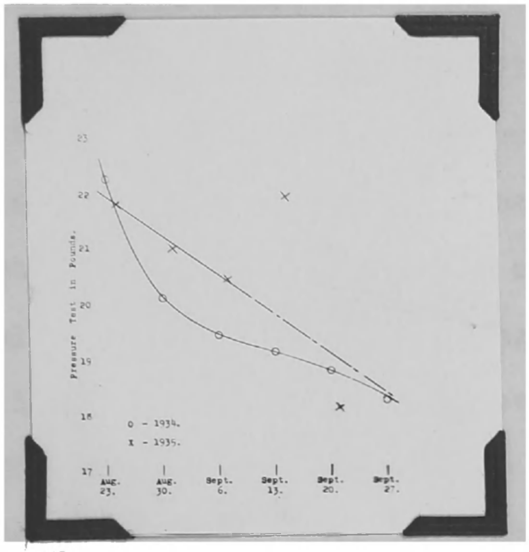

Figure 11.

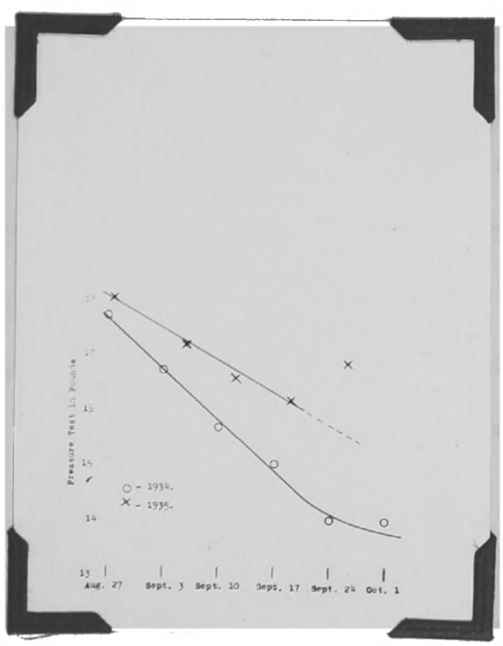

Figure 12.

the actual differences found were greater than with the pressure test. It was thought advisable to test this instrument with apples under Maryland conditions. The instrument is designed as a small, portable Ohmmeter, and readings are taken directly in milliamperes after setting an arbitrary and known potential between the electrodes. A standard setting, using a potential of three volts between the electrodes, was used throughout. The readings are reported in this paper as the direct milliamperes readings x 100 rather than as absolute units of resistance or conductivity because of ease of computation and the lack of advantage in changing them into the absolute units.

The same fruit samples used for the pressure test were used in taking the readings with the electrical maturity tester, and the same number of readings were taken in similar parts of the fruit, except that the skin was not removed. The results obtained are shown in tables XIII, XIV, XV, and XVI for the Grimes and Jonathan varieties in 1934 and 1935. These tables show that there is no correlation between fruit size and the readings obtained, and that there is considerable variation between the size groups.

The weighted averages tend to iron out the differences between the size groups and show what could be expected from a random sample from the tree. In 1934 the Grimes fruit showed a definite trend toward a lower electrical maturity tester reading with increased maturity.

These readings were taken for only the last five harvest dates, as the instrument was not available at the time of the first harvest, and were taken at storage temperature (32 degrees F). While the trend is apparent the results are more variable than the pressure test data, and there is no significance to the results on the weekly basis.

The Jonathan variety, on the other hand, while showing a similar lack of correlation between size groups and electrical maturity tester readings, show no evidence of decreasing in readings throughout the period under investigation.

In 1935 the results with both Grimes and Jonathan were similar to those found with these varieties in 1934, except that the readings were considerably higher because they were taken at room temperatures. With both varieties the variability was much greater in 1935 than in 1934, probably due largely to temperature differences at the time of testing. It is interesting to note that while variability of this reading is much greater than the pressure test, and while it is apparently affected markedly by very localized conditions, the results of 1935 did not reflect the different nature of the last two Grimes pickings and the last Jonathan harvest.

Color. Changes in the ground color of Grimes and the red color of Jonathan were made in both 1934 and 1935. The results for the ground color studies on the Grimes are given in tables XVII and XVIII. In 1934 the fruit was taken from Frederick, Maryland and shows a slight change from green to yellow throughout the period under study, but the differences are in no case significant. The 1935 results (fig. 15), representing only the last four pickings, are taken from fruit picked at Colesville, Maryland, and show a slightly different condition. In this case there seems to be a slightly accelerated change to the yellow color during the last two harvests, but it must be remembered that these pickings are not comparable to the other weekly pickings. In any case, the changes are not significant. Except for these last two picking dates in 1935 the results for the two years check closely. However, as has been shown by other workers, many factors affect the development of the yellow color. Both orchards and trees were selected for uniformly vigorous, moderately heavy bearing trees, and further selections were made for the trees of the experiment, so that the concordance of results may merely be an estimate of this high degree of selection. Table III indicates that this may be true, for it can be seen there that orchards may differ markedly in the ground color at the time of commercial harvest. In this case, the Olney orchard, which was very low in vigor and lacking in nitrogen, always gave very high ground color values. The more vigorous Colesville orchard tended to give a lower ground color values, and to remain green longer. In many vigorous orchards the fruit would drop long before the fruit reached the 2.5 to 3 ground color value recommended as being desirable before Grimes are harvested.

TABLE III -- Comparison of Pressure Test, Electrical Maturity Readings, and Color of Grimes Fruit from Vigorous Trees (Colesville) and from Low Vigor Trees (Olney), 1935.

Harvest Date.	Fruit Size Group.	Pressure Test (Pounds)		Electrical Maturity Tester Readings, Milliamps, x 100.		Ground Cover Value.	
		Colesville	Olney	Colesville	Olney	Colesville	Olney
August 24.	Large						
	Medium	21.76	22.28	29.25	29.92		
	Small	24.70	26.90	29.29	30.40		
August 31.	Large	19.64	20.52	27.06	28.62	2.40	2.04
	Medium	20.95	22.52	26.97	28.85	2.70	2.05
	Small	23.61	26.72	27.68	27.50	2.77	2.02
September 7.	Large	19.14	20.26	29.84	29.34	2.25	1.79
	Medium	20.40	22.81	30.26	29.16	2.52	1.87
	Small	24.41	30+	29.58	31.78	2.50	1.95
September 14.	Large	20.92	19.92	27.12	29.33	3.00	2.78
	Medium	21.90	21.68	27.43	24.90	3.28	2.62
	Small		25.10		29.83	3.10	

The results of the study of the development of the red color in the Jonathan apples are shown graphically in figs. 13 and 14, and tables XIX and XX. It will be seen that the development of red color followed a considerably different course in the two years. In 1934 the first three to four weeks were marked by rather warm, dry weather, with comparatively few nights with low temperatures. Between the third and fourth weeks there was an abundant rainfall, and the minimum temperatures were considerably lower. This hastened the development of the red color, as was readily apparent in the orchard at the time. While at the time of the fourth picking the apples had only an average of ten per cent red colored surface by the time of the fifth picking a week later, the per cent had risen to nearly forty per cent and this increased another six or seven per cent during the following week.

In 1935 there were heavy rainfalls just prior to the second picking of Jonathan, and a series of nights throughout the harvest period with low minimum temperatures, as shown in fig. 6. This evidently accounts for the rather regular development of red color in this year.

While it is a common observation, and has been shown many times, that the development of red color in the colored apple varieties may be readily influenced by cultural and environmental factors, the fact stands that in this orchard, and under different climatic conditions in the two years, the development of red color was the only factor

Figure 13. Per cent red color by size groups and weighted average at the weekly harvest intervals for the Jonathan variety, 1934.

Figure 14. Per cent red color by size groups and weighted average at the weekly harvest intervals for the Jonathan variety, 1935.

Figure 15. Change in weighted average ground color of Grimes fruit at the weekly harvest intervals and throughout the storage period, 1935.

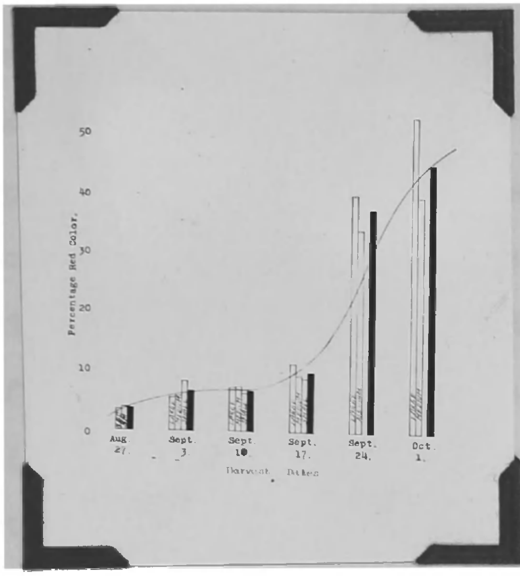

Figure 13.

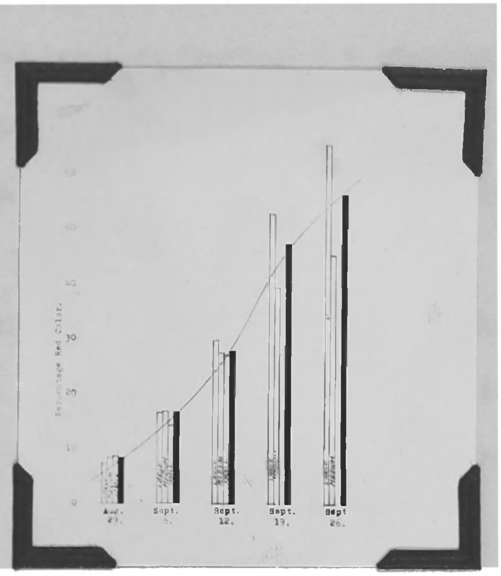

Figure 14.

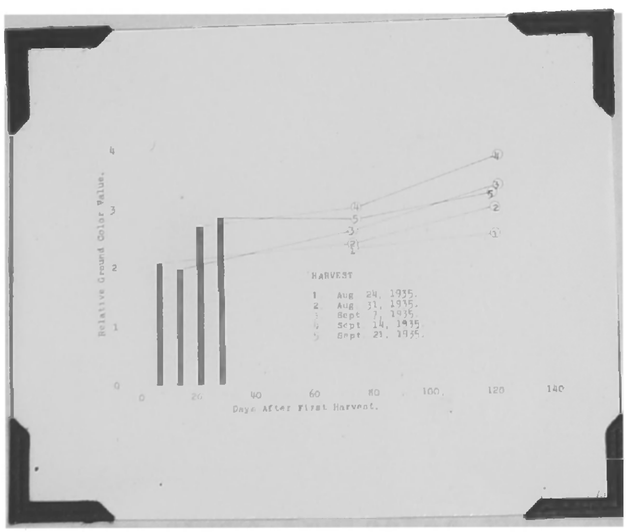

Figure 15.

closely associated with fruit quality after storage. In 1934 the first four Jonathan harvests, with under ten per cent red color, never developed characteristic flavor in storage, and were decidedly flat and inferior in quality at the end of the storage tests, whereas the last two pickings developed excellent flavor and quality, entirely characteristic of good quality Jonathan apples. This difference was very marked. In 1935 the first two pickings failed to develop good quality in storage, the third picking was good, and the last two very good. In both years the fruit which developed good quality had passed the point where a random sample had obtained more than twenty-five per cent red color. It is felt that further study should be given to this point, with the random selection of fruit emphasized.

Figures 16 to 19 summarize the data for the weighted averages of the pressure test, the electrical maturity test, and the development of ground color in Grimes and the red color in Jonathan in 1934 and 1935 during the harvest period. Because of the great variability of the electrical maturity test in 1935 this line is dotted in to indicate an approximate trend only.

A typical growth curve, based on the average weight per apple of Grimes in 1934, is shown in fig. 20. The straight line curve indicates that growth of the fruit was normal. The only significant difference noted was that the Jonathan variety was larger in both years than the Grimes. The actual growth rate for both Jonathan and

Figure 16. The weighted average pressure test, electrical maturity tester readings, and ground color estimates for the Grimes variety at the weekly harvest intervals, 1934.

Figure 17. The weighted average pressure test, electrical maturity tester readings, and per cent red color for the Jonathan variety at the weekly harvest intervals, 1934.

Figure 18. The weighted average pressure test, electrical maturity tester readings, and ground color, estimates for the Grimes variety at the weekly harvest intervals, 1935.

Figure 19. The weighted average pressure test, electrical maturity tester readings, and per cent red color for the Jonathan variety at the weekly harvest intervals, 1935.

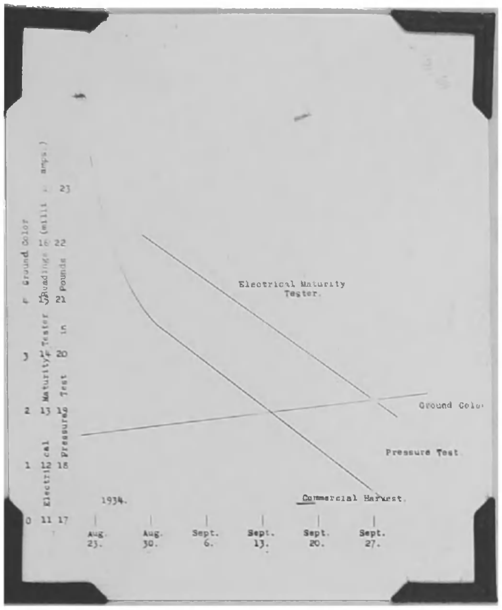

Figure 16.

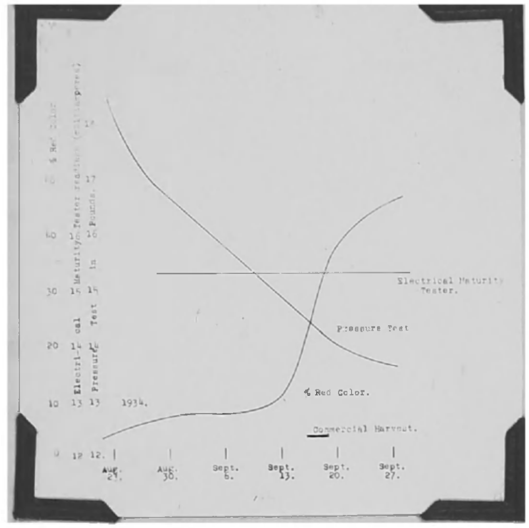

Figure 17.

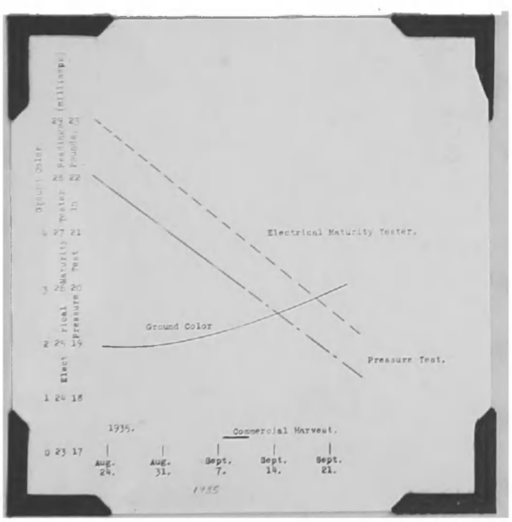

Figure 18.

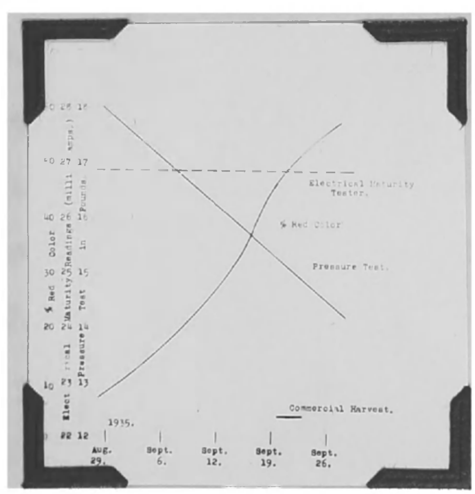

Figure 19.

Grimes was somewhat different in the two years, but this may be due to the selection of trees, and should not be attributed to differences in response to climatic and cultural conditions in the two years. It must be recalled that these data are based on different sets of trees at each weekly interval, and that slight irregularities may be due to variation in the trees from which the samples were drawn.

Storage Results. The effect of storage at 32 degrees F. on the various lots of fruit was followed through the storage period. Samples for pressure test, etc. were taken during the last week in November and December for the Grimes in 1934 and both Grimes and Jonathan in 1935. In 1934 Jonathan samples were taken the last week in November, and the last week of January of 1935.

The effect of storage of Grimes apples in 1934 on the pressure test is shown in fig. 21 and table IX, which give the initial weighted average pressure test at each harvest date, and the value obtained at the time the storage samples were taken. The pressure test decreases in storage, and the final value at the end of the storage period depended primarily on the value at the time of harvest, although the earlier pickings had a slightly greater rate of decrease, as is shown by the fact the range between the first and last harvest at the time of picking was nearly seven pounds, whereas it is only three pounds at the end of the storage period. The more rapid rate of decrease in pressure test apparently occurs fairly early in the storage life of the fruit, as is shown by the fact that the spread between the highest and lowest storage samples at the time of the first sampling was no larger than at the second storage sampling, indicating a similar rate of decrease in pressure test for all lots of fruit in the second period. In this case the average rate of decrease was a little greater during the period from harvest to the first storage sampling than the period between the first and second storage sampling.

Figures 22 and 23, and table XI show data for the Jonathan variety in 1934. The results are very similar, except for two points. First, the average decrease in pressure test was slightly greater during the second half of the storage period, and second, the earlier pickings showed the greatest rate of decrease, and the later pickings the least (fig. 23), although the last picking showed a slightly greater rate of decrease than the fifth picking, corresponding very closely with the fourth picking. Figure 23 shows the accumulated decrease in pressure test after a given number of days in storage, and indicates the comparative rate of decrease. The early and late pickings showed the highest rate of decrease, and the middle pickings the lowest.

The results during storage in 1935 are given for Grimes in table X. If the last two pickings are not considered, and remembering that the first three pickings would correspond most closely with the second, third, and fourth harvests in 1934 on the basis of comparative

Figure 20. The growth curve by size groups and weighted average for the Jonathan variety, based on average weight per fruit, for the harvest period, 1934.

Figure 21. The weighted average pressure test of Grimes fruit at the weekly harvest intervals, and throughout the storage period, 1934.

Figure 22. The weighted average pressure test of Jonathan fruit at the weekly harvest intervals, and throughout the storage period.

Figure 23. The loss in pressure test of Jonathan fruit during the storage period in 1934, based on the weighted average pressure test at the time of harvest and at the time storage samples were taken.

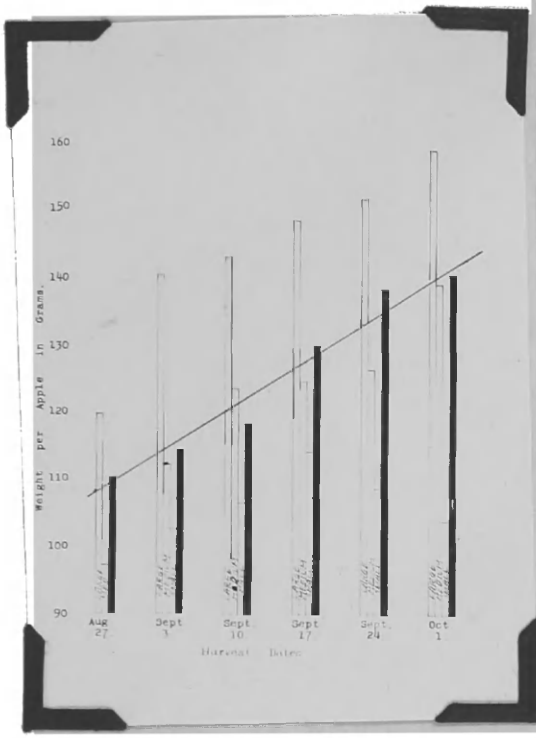

Figure 20.

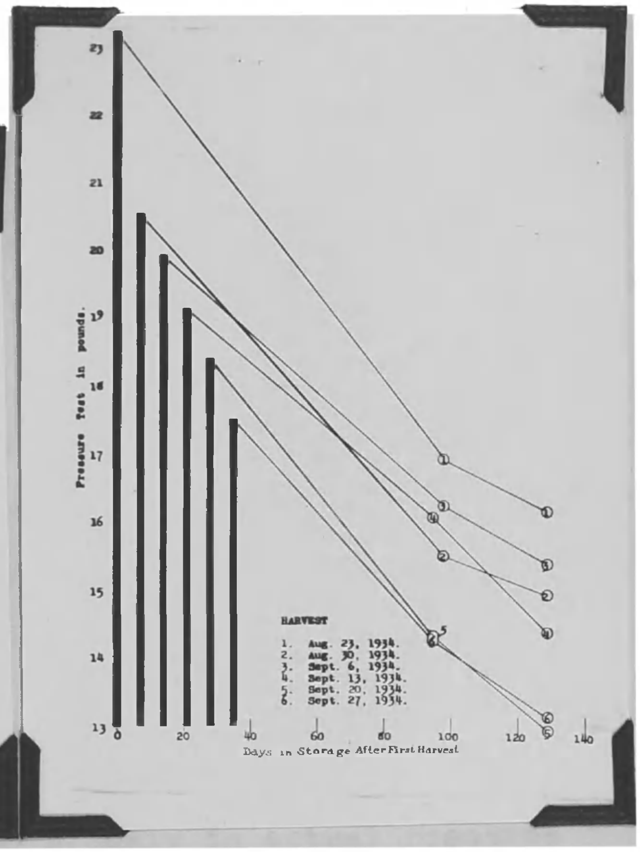

Figure 21.

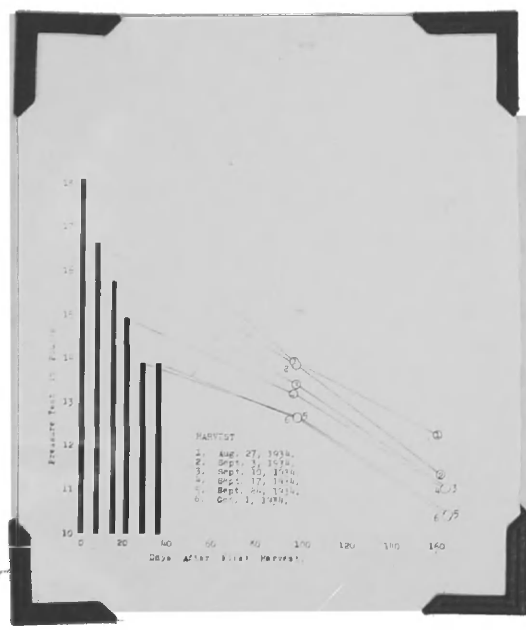

Figure 22.

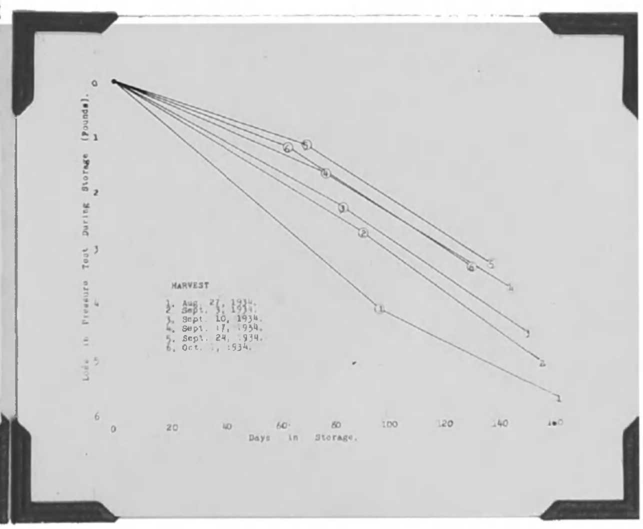

Figure 23.

maturity at the time of harvest, the results agree surprisingly well. For the first three pickings the pressure test drops to the same level at the end of the storage period as in 1934, and the main difference lies in the fact that the rate of decrease during the second half of the storage period was very much less than in 1934.

The fourth and fifth pickings behaved somewhat differently than comparative pickings in 1934, but it should be remembered that the fruit in this case was not representative of the other pickings. The fourth picking, which gave a high pressure test at harvest showed a high rate of decrease, so that at the time the storage samples were taken, it corresponded closely in actual pressure test with the first three pickings. It was, however, still decreasing at a greater rate than any of these pickings. The fifth picking was low at harvest, and while it showed the lowest rate of decrease throughout the storage period, the rate of decrease was undiminished, with the result that the pressure test of this group was low at the time of the first storage sample, and very much lower than the others at the end of the storage period.

The effect of storage in 1935 on the pressure test of Jonathan fruit is shown in table XII. If we compare the first four pickings of 1935 with the middle four of 1934, with which they compare most closely on the basis of physiological maturity, it will be seen that they correspond very closely. The fifth picking of Jonathan in 1935 cannot be considered as representative, but it falls in very closely with the last picking of 1934, with which it corresponds, and does not show the wide divergence from the normal as was the case with the "off" pickings of Grimes. While the pressure test at the end of the storage period is about one pound higher in 1935 than in 1934 it must be remembered that the Jonathan fruit was left in storage nearly a month longer in 1934. For the same number of days in storage the results of the 1935 tests compare very closely with those of 1934.

Data taken with the electrical maturity tester with Grimes in 1934 are shown in fig. 24 and table XIII. In this case, there is only slight variation during the storage period, and although the earlier pickings show a decreased reading over that obtained at the time of harvest, the later pickings show very little change or even an actual increase. There was quite a marked drop between the first and second storage samples, the significance of which is not known.

The 1934 electrical maturity tester data for the Jonathan variety during the storage period is shown in table XV. In general there is very slight decrease throughout the storage period, with a slightly greater rate of decrease in the last half of the storage period. The last picking shows an exaggerated rate of decrease during the first half of the storage period, but no reason is known for this.

The data for Grimes in 1935 are shown in table

XIV. The very great decrease during the first half of the storage period is caused by the lowering of the temperature in storage. The 1934 readings were made on fruit brought to 32 degrees F. before testing, while the 1935 readings at the time of harvest were made at room temperature. In general the difference between the 0 degrees C. storage temperature and the common 20-25 degree C. room temperature caused a difference of about ten units on the electrical maturity tester, if the results in the two years are considered to be comparable. The decrease during the second half of the storage period, however, is about twice as great as that shown in 1934, and the final reading obtained is about one unit lower. The high value obtained for the second storage sample of the first picking is probably due to incipient breakdown, which markedly affects the electrical maturity tester readings. There seems to be no relation between the time of harvest and the rate of decrease.

Similar data for the 1935 Jonathan apples, shown in fig. 25 and table XVI compare rather closely with the 1934 data, except for the initial large drop during the first half of the storage period due to the temperature difference. The rate of decrease during the second half of the storage period is somewhat larger in 1935 than in 1934, and the final readings are about a unit lower. Whether or not this decrease would continue if the fruit were left in storage long enough to compare with the 1934 Jonathan fruit is not known. There seems to be no relation

Figure 24. The weighted average electrical maturity tester readings of Grimes fruit at the weekly harvest intervals, and throughout the storage period, 1934.

Figure 25. The weighted average electrical maturity tester readings of Jonathan fruit at the weekly intervals, and throughout the storage period, 1935.

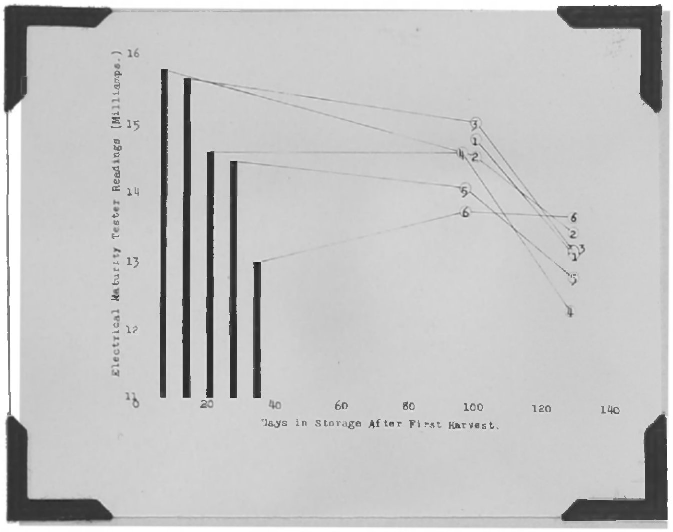

Figure 24.

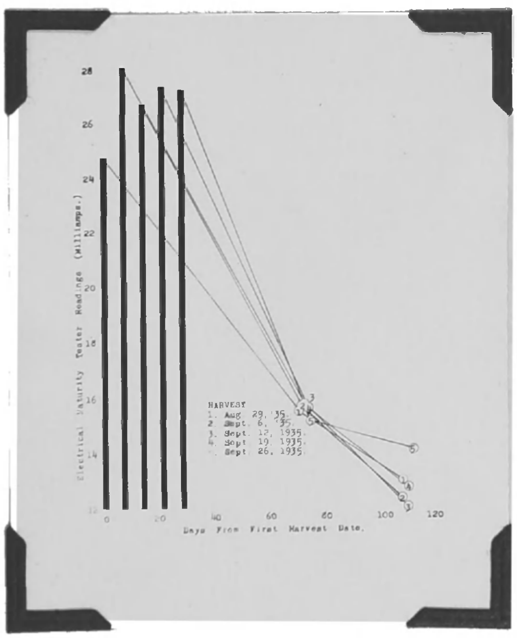

Figure 25.

betweem the time of harvest and the final reading, or the rate of decrease.

In 1934 the development of the ground color of the Grimes variety was studied during the storage period. It was found to increase slightly during the storage period, and the rate of increase was greater in the second half of the storage period than the first, as is shown in fig. 15 and table XVIII. In general the various pickings tended to maintain their rank as at the time of harvest, although this was not true in all cases. We may summate the various changes in the measurements discussed above to get a general picture of the developmental changes in the apple during maturation as measured by these physical methods shown graphically for the harvest period in figs. 16 - 19. Both Grimes and Jonathan show a steady decrease in pressure test during the maturation period, but the change is too slow to be very valuable as a maturity index, and the variability from year to year makes it impossible to state at what pressure the fruit may be considered mature. During storage the fruit continues to decrease in pressure test, although fruit harvested at weekly intervals tend to maintain the same rank as at harvest. The rate of decrease is greatest with earlier harvested fruit, however, and at the end of the storage period the range in pressure test is not as great as between the various harvest dates.

The electrical maturity tester gave results that are much too variable to be of value as an index of maturity. During the harvest period, however, the Grimes fruit tended to show a decreased reading with increasing maturity, whereas the Jonathan fruit showed little change from week to week. During storage the decrease was very slight, and there was no apparent relation between time of harvest and the final reading obtained. The effect of temperature on the reading obtained with the electrical maturity tester is very great as shown in the readings for the two years with both varieties, the readings being taken the first year at 32 degrees F. and at room temperatures in 1935.

The Grimes fruit shows a slight increase in yellow ground color during the harvest period, but this is not great enough to be used as a maturity index, and as shown by readings from other orchards, and by other investigators, many factors may affect the ground color at the time of harvest. There is a slight change in the ground color during the cold storage period.

Edibility Tests. In both seasons the fruit was tested for edible quality during the storage period. The tests were usually made at the time of the first storage sample near the end of November and again around the first of January. The tests at the time of the first storage sample were made by members of the Horticultural Department of the University of Maryland, and those at the beginning of the year by these same individuals, and by a large number of growers attending the Maryland Horticultural Society meetings, where samples of the fruit were on display. In 1934 and 1935 neither group could detect any consistent difference in the edibility of Grimes fruit harvested at the different picking dates. Apparently, at the time the tests were made, there was no difference in the fruit from the different picking dates, except in their ability to stand up in storage. In this respect the intermediate pickings proved best (tables V and VI). The early samples were rather badly shriveled, and the last pickings showed more shriveling than the intermediate group. No protection was taken against the development of scald in these storage studies, and by the end of the storage season all had developed some scald. However, no consistent difference between groups could be noticed, and the storage temperature was such that scald development could be more or less expected, as shown by Plagge and Maney (71).

In the case of the Jonathan variety marked differences were noted in the edibility of the fruit from the various pickings in both years. In 1934 all samples of Jonathan harvested before September 24 failed to develop good quality in storage, and were rated as poor. The fruit from these pickings was uniformly flat in flavor, and the flesh was lacking in solid, crisp texture. The last two pickings on September 24 and October 1, however, developed good edible quality, and the flesh was fair to good in texture. The difference was very marked in this year, In 1935 the various testers found that the Jonathans harvested at the first two harvest dates, August

TABLE IV -- Pressure Test, Electrical Maturity Tester Readings, and Maximum Diameter of Lots of 50 Grimes and Jonathan Fruit Harvested at Weekly Intervals from June 25, 1935 to the Commercial Harvest Period, 1935.

Harvest Date.	Pressure Test (Pounds)		Electrical Maturity Tester Readings Milliamps, x 100.		Maximum Diameter (cm.)	
			GRIMES			
	A*	B	A	B	A	B
June 25.			48.57	42.52	3.45	3.36
July 2.			43.15	43.97	3.79	4.00
July 9.			41.68	37.47	4.65	4.22
July 16.			40.62	41.05	4.91	4.49
July 23.			37.08	36.32	5.43	4.73
July 30.			37.82	35.37	5.31	4.87
August 6.	24.38	30+	37.92	36.15	5.76	4.84
August 21.	21.25	25.92	33.62	33.92	6.42	5.51
August 29.	22.08	25.87	26.77	28.85	6.05	5.34
September 6.	21.44	23.43	28.03	28.96	6.05	5.47
September 11.	19.77	20.43	28.45	25.56	6.54	5.74
			JONATHAN			
	A	B	A	B	A	B
June 25.			51.33	46.75	3.93	3.51
July 2.			44.77	43.43	4.23	3.69
July 9.			41.55	38.37	4.66	4.10
July 16.			41.01	38.90	5.08	4.40
July 23.			38.60	35.28	5.55	4.60
July 30.	24.77	30 +	37.08	33.53	5.53	4.69
August 6.	22.13	25.83	36.70	34.65	6.02	4.98
August 21.	18.62	21.40	31.75	30.80	6.47	5.52
August 29.	18.67	19.77	27.52	25.52	6.40	5.75
September 6.	16.83	19.09	28.27	28.29	6.68	5.73

NOTE: *Columns headed A give figures from fruits taken from high vigor tree and Colume B from low vigor trees.

TABLE V -- Average Per Cent Loss in Weight per Thirty Days in Storage by Size Groups of Grimes and Jonathan Fruit, 1934.

GRIMES							JONATHAN						
Harvest Date.	Harvest Date to End of November			End of November to End of December			Harvest Date.	Harvest Date to End of November.			End of November to End of January		
	Large	Medium	Small	Large	Medium	Small		Large	Medium	Small	Large	Medium	Small
August 23.		1.18	1.31		1.18	1.38	August 27.		.60	.71		.35	.30
August 30.		1.00	1.12		1.15	1.08	September 3	.88	.73	.71	.88	.70	.46
September 6.		.29	.26		.95	.66	September 10.	.21	.28	.29	.50	.54	.60
September 13.	.48	.89	.66	.99	.33	.43	September 17.	.41	.50	.21	.93	.64	.60
September 20.	.44	.56		1.18	1.16		September 24.	.71	.80		.79	.80	.84
September 27.	.83	1.13		1.56	1.55		October 1.	.85	.94		1.16	.85	

TABLE VI -- Average Per Cent Loss in Weight per Thirty Days in Storage by Size Groups of Grimes and Jonathan Fruit, 1935.

GRIMES					JONATHAN				
Harvest Date.	Harvest Date to End of November.		End of November to End of December.		Harvest Date.	Harvest Date to End of November.		End of November to End of December	
	Large	Medium	Large	Medium		Large	Medium	Large	Medium
August 24.		1.53		1.41	August 29		1.30		1.40
August 31. 31.	1.53	1.55	.54	.98	September 6.	1.56	1.78	1.38	1.53
September 7.	.92	1.53		1.38	September 12.	1.83	1.40	1.46	1.35
September 14.	3.28	1.43	1.52	1.71	September 19.			1.29	1.35
September 21.				1.68	September 26.	.95	1.21	.94	1.12

29 and September 6, were uniformly poor in quality and texture. The third picking, on September 12, was found to be of fair edible quality, and to have fair texture, while later pickings were rated as being of good quality and fair to good texture.

In the case of the Jonathan variety it is apparent that edible quality after storage is closely dependent on the stage of maturity at harvest. In correlating other changes of the fruit at the time of harvest, the only factor studied which showed close correlation to the edible quality after storage was the development of the red color. In both years the fruit developed fair to good edible quality after the fruit showed twenty-five per cent red color, as measured on a random sample of fruit taken from all parts of the trees. In 1934 the development of red color was very late in the season and very rapid, so the difference between the fourth and fifth pickings, between which the twenty-five per cent point was passed, was very marked. In 1935 the development of red color was rather gradual throughout the five week period. The third picking, made on September 12, showed a red color development of practically twenty-five per cent. After this the per cent red color was considerably higher. The third picking was also the first to show fair edible quality after the storage period, and the later pickings showed good edible quality.

<u>Miscellaneous Studies</u>. In 1935 two trees of Grimes and two of Jonathan were selected early in the

summer at Frederick, Maryland. With each variety, one tree was selected for high vigor, and the other for low vigor, as measured by the length and diameter of the terminal growth of the previous season, and the amount of and color of the foliage in the early summer. Measurements were taken on the diameter of the fruit and with the electrical maturity tester, starting June 25, and continued until the time of harvest, fifty fruit being used in each case. Pressure tests were taken after August 6 for the Grimes and after July 30 for the Jonathan, these being the first dates on which the pressure test fell to a point measurable with the pressure tester. The results of these early season measurements are shown in table IV.

With the Grimes variety the size of the fruit from the low vigor tree was smaller than from the more vigorous tree. This difference in size is reflected in the pressure test data, which show that the fruit from the high vigor tree consistently had the lower pressure test. The electrical maturity tester measurements fell steadily throughout the early season, from a high of around forty-five units on June 25, to around twenty-six units at the time of the commercial harvest, shortly after September 11. The rate of decrease was fairly uniform until the 21st of August, after which the change was very small.

The Jonathan variety showed a trend very similar to the Grimes in growth of fruit and the pressure test in comparing the high and low vigor trees. The electrical maturity tester readings were somewhat higher than for the Grimes variety on the June 25th sampling, averaging around forty-eight units. The values at the end of the season, September 6, were in the same range as the Grimes, or about twenty-six units. As with the Grimes, the last two or three samples showed a decreased rate of change. One rather noticeable difference in the case of the Jonathan fruit is the fact that the low vigor tree gave somewhat lower electrical maturity tester readings throughout the season. As no correlation was noticed between fruit size and the electrical maturity tester readings in the regular harvest of either 1934 or 1935 it appears that this difference, although slight, denotes a definite physiological difference in the fruit of the two trees.

The fruit from both the Grimes and Jonathan trees used in this study was harvested commercially during the week following September 11, and the storage results with Jonathan harvested on younger trees from the same orchard indicated that the Jonathan fruit had reached maturity by this date. The electrical maturity tester, however, showed no decrease after August 29, some two weeks previous to this date. Thus, it is evident and substantiates the data from the weekly picking tests that the electric maturity tester does not provide an adequate measure of fruit maturity.

Results of Chemical Studies

Chemical analyses were made for dry matter, reducing substances, sucrose, total sugars, starch, and total nitrogen content at the various harvest dates and at the times storage samples were taken, for both Grimes and Jonathan in 1934. All data on the chemical analyses are given in tables XXI to XXVI on the dry weight basis, but only typical changes or trends in the various fractions are shown graphically. The per cent dry matter was comparatively constant throughout the harvest and storage period for all samples, and the results calculated on the fresh weight basis therefore follow closely the trends shown on the dry weight basis. For this reason data calculated on the fresh weight basis are omitted.

Dry Matter. The percent dry matter for Grimes is shown in fig. 26 and table XXI to range between 16.8 per cent to 18.7 per cent during the six weekly harvests. By comparing this with fig. 5 it is seen that low percentages of dry matter are correlated with periods of rainfall, probably caused by intake of water after periods of high rainfall. Tables XXII and XXIII show the values obtained at the time samples were taken from storage. In general the percent dry matter remained constant throughout the storage period, and its value at the end of the storage period depended on the percent dry matter present at the time of picking.

Similar data are shown in fig. 27 for the Jonathan fruit. The results are very similar in that low, dry matter content coincides with periods of high rainfall, and the dry matter content at the end of the storage period depands on the value at the time of harvest.

The dry matter content of the Jonathan variety was about two per cent lower than that of the Grimes variety. The storage results also check closely with those of the Grimes variety, and are shown in tables XXV and XXVI.

Reducing Substances. The reducing substance content of the Grimes variety is graphically shown on the dry weight basis in figs. 28 and table XXI. As is shown in the figure there was considerable variation between the size groups, and the medium size fruit usually had the highest reducing sugar content, the only exception being the fifth picking of September 30, when the large size group was considerably higher than the medium size group. While the range at the time of the various pickings, including the various size groups, varies from 31.5 per cent to 38.5 percent the weighted averages show a much smaller range, 35 per cent to thirty-eight per cent. This variation is comparatively small. There is no trend apparent in the reducing sugar content during this period.

The data for the storage period are shown, on a dry weight basis, in tables XXII and XXIII. There was a slight increase in the reducing sugar content during the first half of the storage period in all cases except the fourth harvest, which remained the same. The fruit harvested early in the season appeared to show a slightly greater increase at the time of the first storage sample, the fourth showed no increase, and the last two pickings were intermediate. All except the last picking showed a rather sharp rise between the first and second storage sample. There was no apparent cause for the decrease shown in the last picking in the last half of the storage period, but, as will be shown later, there was a corresponding increase in sucrose in this sample, indicating the failure of sucrose to be inverted to reducing sugars in this picking.

The data for the reducing sugars of the Jonathan variety are presented on a dry weight basis in fig. 29 and table XXIV. As with the Grimes variety, there was no apparent seasonal trend in the reducing sugar content during the period under investigation. In the case of the Jonathan variety, however, the variability between the size groups was much smaller, and the absolute quantities were somewhat greater, running from forty per cent to fifty per cent of the dry matter.

The change in reducing sugars during the storage period is shown graphically in fig. 33 and tables XXV and XXVI. At the end of the first half of the storage period the per cent reducing substances was about the same as at the time of harvest, some pickings showing a slight increase and some a slight decrease. The fifth picking, which showed a loss of reducing substances at the time of the first storage sample and had the lowest reducing substance con-

Figure 26. The per cent dry matter by size groups and weighted average for the Grimes variety at the weekly harvest intervals, 1934.

Figure 27. The per cent dry matter by size groups and weighted average for the Jonathan variety at the weekly harvest intervals, 1934.

Figure 28. The per cent reducing substances by size groups and weighted average for the Grimes variety at the weekly harvest, intervals, 1934.

Figure 29. The per cent reducing substances by size groups and weighted average for the Jonathan variety at the weekly harvest intervals, 1934.

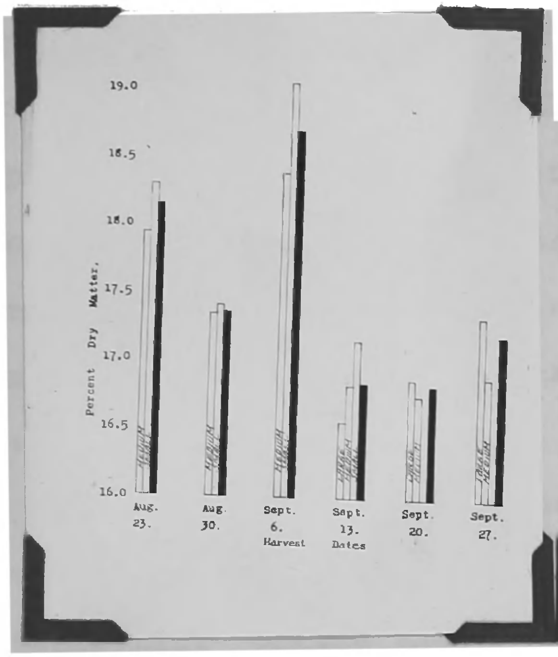

Figure 26.

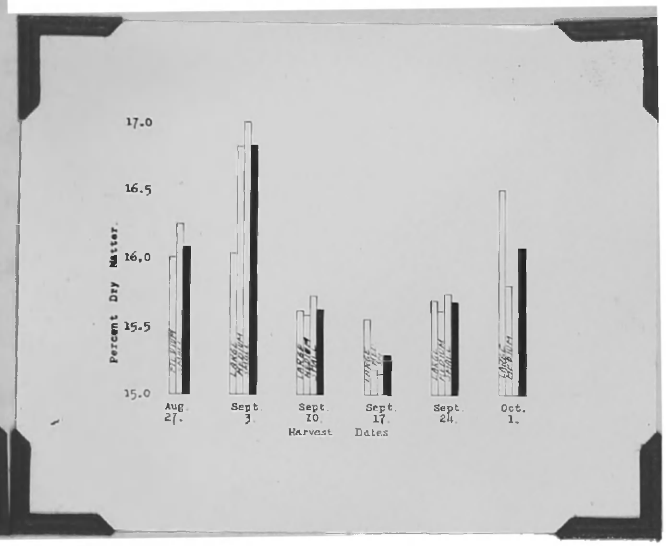

Figure 27.

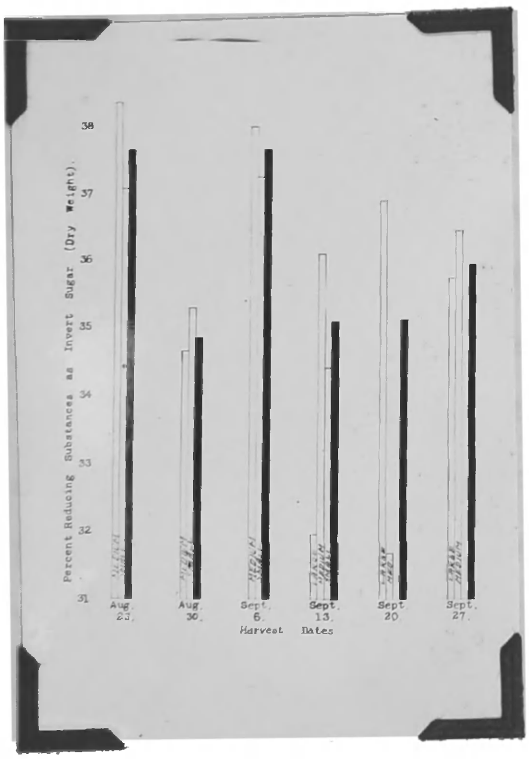

Figure 28.

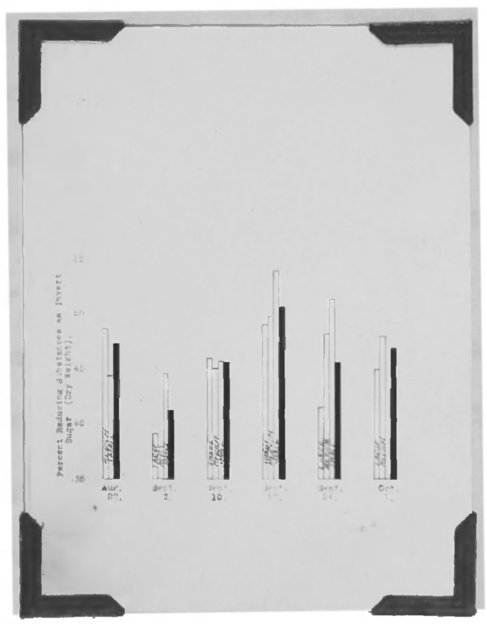

Figure 29.

tent was highest in sucrose at this time, as will be shown later. During the second half of the storage period, however, all samples showed an increase in reducing sugars, the final values ranging around fifty-five per cent. There is no apparent relation between the time of harvest and the percentage reducing substances at the end of either the first or second storage periods, so it must be assumed that the variation found is the natural variation due to sampling.

Sucrose. The sucrose content of the Grimes variety is shown on the dry weight basis in fig. 30 and table XXI. Unlike the reducing sugars, a definite seasonal trend is apparent in the case of the sucrose content. It was very low at the beginning of the harvest period, the first sample being approximately six per cent sucrose on the dry weight basis. By the second week this had jumped to about sixteen per cent after which there was a weekly increase of two or three per cent until the last picking, which dropped off to twenty per cent sucrose. The variation between size groups was small, the greatest variation being shown in the mid-period pickings, where differences of five to ten per cent were apparent between the size groups. In general, the larger size groups had the highest sucrose content. Figure 34 and tables XXII and XXIII show the relation between the sucrose content at harvest and during the storage period. There was a distinct tendency for the sucrose content of all groups to come to a value between twenty per cent and twenty-five per cent, which resulted in a sharp increase in the case of the first picking, and a decrease in some of the later pickings. The fourth picking remained rather high in sucrose content at this time -- about twenty-eight per cent, which is apparently associated with a low reducing sugar content in this group, indicating failure of inversion. During the second half of the storage period there was a tendency for the sucrose content of the first pickings to fall off, probably associated with the nearly complete disappearance of starch in the early harvested fruit by the end of the storage period. The later pickings increased slightly. The sucrose content at the end of the storage period, therefore, varied more widely than at the time of the first storage sample.

The results of the sucrose analyses for the Jonathan variety at the harvest dates are given on a dry weight basis in table XXVII. As is shown in the table, there was only a slight variation in sucrose content between the various size groups, and as in the Grimes, the larger size groups tended to have the highest sucrose content. This was especially so in the last two harvests, where the greatest variation was found. The weighted averages showed a seasonal trend somewhat similar to that found in the Grimes variety, although not so clear-cut. The sucrose content of the initial picking was very low, about three per cent but this had increased to nearly twenty per cent by the time of the second harvest date. Later pickings varied around the twenty per cent point, with a slight tendency to increase until the last picking, which dropped off to about fifteen per cent sucrose. The absolute values were slightly lower than with the Grimes variety. Figure 35 and tables XXV and XXVI show the trend of the sucrose content during the storage period for the Jonathan variety, on a dry weight basis. As in the Grimes, the sucrose content tended toward a constant point, varying between thirteen and eighteen per cent at the time the first storage sample was taken. The fifth picking fell out of line in this case, and was considerably higher, and, as shown earlier, had the lowest reducing substance content at this time, indicating failure of the sucrose to be hydrolyzed to reducing substances. Unlike the Grimes, there was no apparent trend in the sucrose content during the second half of the storage season, most of the pickings coming to a rather constant point of about sixteen per cent. In general, except for the first picking, the magnitude of the sucrose content remained practically constand throughout the storage season, seemingly tending toward a constand level.

Total Sugars. The total sugars reflect the variations found in the sucrose content very closely, during the picking period (tables XXI and XXIV). As shown above, the reducing sugar content remained rather constant during this period, and only the sucrose content changed materially, or showed a seasonal trend. Therefore, it would be expected that the total sugars should follow the sucrose content. The absolute amounts are greatest for the Jonathan variety because of its higher reducing sugar content.

Figure 30. The per cent sucrose by size groups and weighted average for the Grimes variety at the weekly harvest intervals, 1934.

Figure 31. The per cent starch by size groups and weighted average for the Grimes variety at the weekly harvest intervals, 1934

Figure 32. The per cent starch by the size groups and weighted averages for the Jonathan variety at the weekly intervals, 1934.

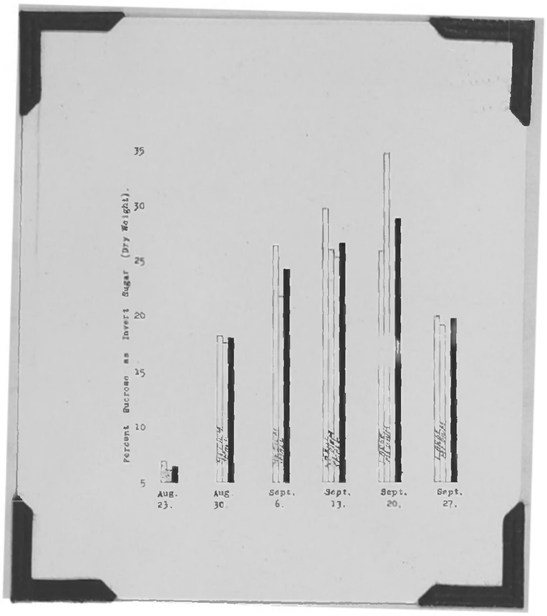

Figure 30.

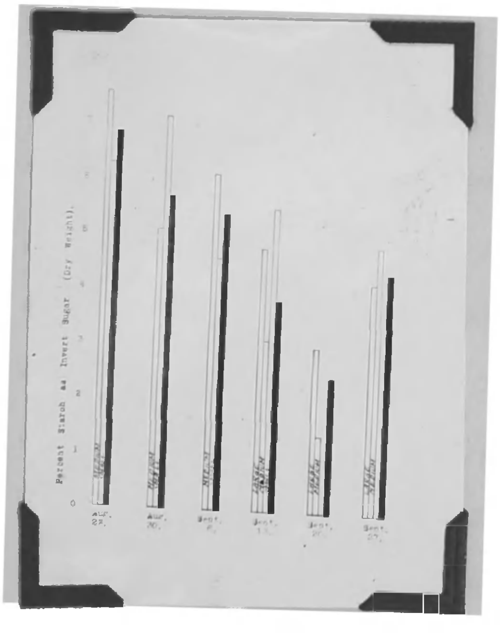

Figure 31.

Figure 32.

In the case of the Grimes variety the total sugar curve almost exactly duplicates that for sucrose, and need not be discussed further. The Jonathan variety, however, (fig. 36) shows an interacting effect, the total sugar content increasing to a maximum at the fourth picking and decreasing thereafter.

In both cases the total sugar content is relatively low at the time of the first picking because of the low sucrose content at that time. As the changes in reducing sugars and sucrose during storage were rather small for both varieties, the same hold for the total sugars (tables XXII, XXIII, XXV, and XXVI). With the Grimes variety there is a tendency for the total sugar content to reach a value of about sixty-two per cent at the end of the storage season. The results at the end of the first half of the storage period are considerably more variable, but even so the tendency for all to come to a common level is apparent at that time. The net trend for all Grimes pickings is toward a slight increase in total sugars during the storage period, which reflects most closely the increase in reducing substances during the storage period. As all the starch has not been hydrolyzed at that time, it seems that inversion of carbohydrates is progressing slightly faster than respiration in using the carbohydrates, and that hydrolysis of starch to sucrose is equalized by hydrolysis of sucrose to reducing substances with a net result of slightly increased reducing substances and total sugar content.

With the Jonathan variety there is a trend similar to that

Figure 33. The weighted average per cent reducing substances at the weekly harvest intervals and throughout the storage period for the Jonathan variety, 1934.

Figure 34. The weighted average per cent sucrose at the weekly harvest intervals and throughout the storage period for the Grimes variety, 1934.

Figure 35. The weighted average per cent sucrose at the weekly harvest intervals and throughout the storage period for the Jonathan variety, 1934.

Figure 36. The weighted average per cent total sugars at the weekly harvest intervals and throughout the storage period for the Jonathan variety, 1934.

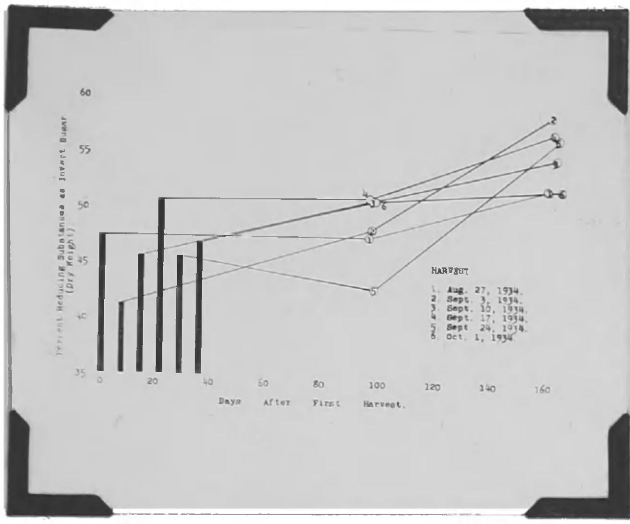

Figure 33.

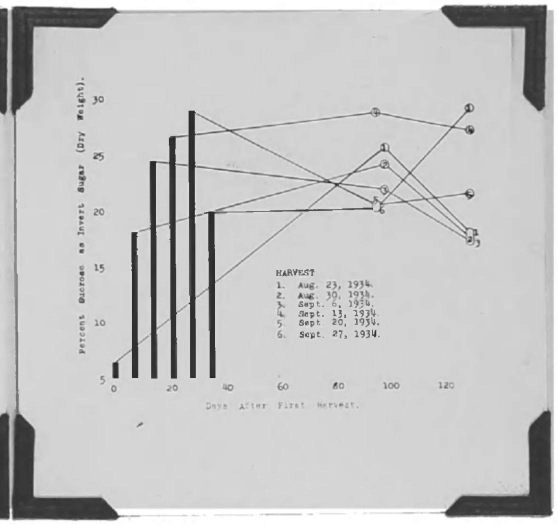

Figure 34.

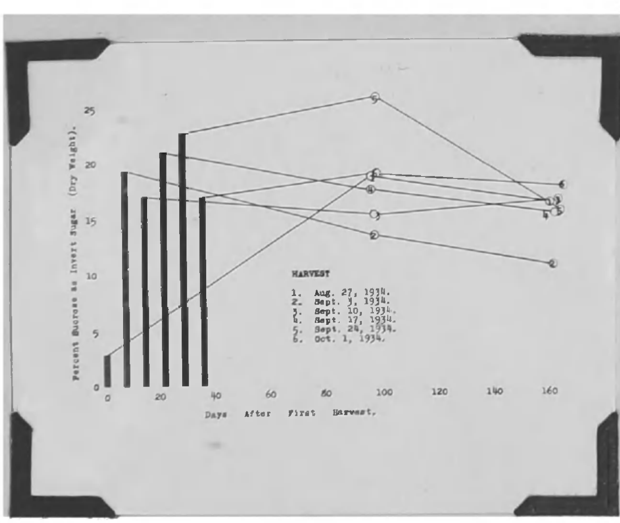

Figure 35.

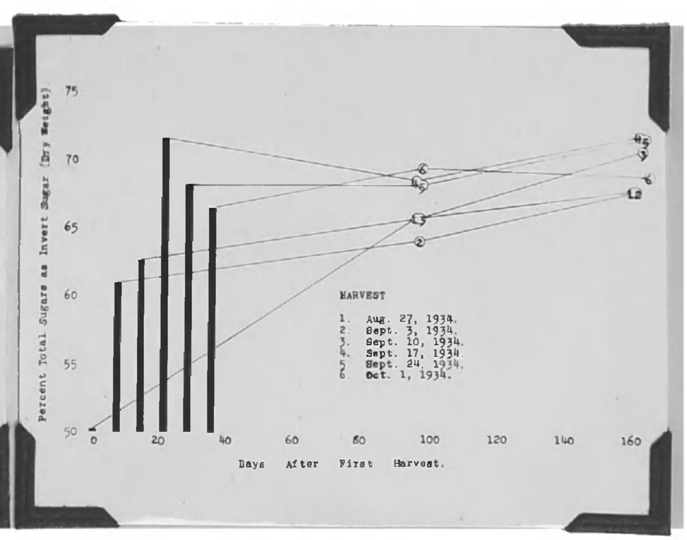

Figure 36.

found in the Grimes for the total sugars to come to a common point at the end of the storage season, which, in this case, was about seventy per cent on a dry weight basis, and about eleven per cent on a fresh weight basis. Because the general level of the total sugars at the time of harvest was below this point, there is an upward trend in the total sugar content throughout the storage period. Practically all the starch had disappeared by the end of the second storage period, and it would be expected that the total sugars would soon begin to fall off due to respiratory losses. As in the case of the Grimes, this most nearly reflects the trend in the reducing sugars.

Starch. As brought out above, starch determinations were carefully made using a method designed to get at the absolute quantities of starch and exclude all other substances which might interfere with the determination. Microchemical checks were run on all samples, and in no case did the macrochemical method give a positive starch result where the microchemical test showed there was none. All starch determinations were made on fruit samples of 1934.

The data for the starch determinations on Grimes are given in fig. 31 and table XXI, on the dry weight basis. The starch content of Grimes was high at the time of the first picking, averaging around seven per cent. During the following weekly intervals there was a regular decrease until a low of about 2.5 per cent was reached at the time of the fifth picking. The last picking showed an increase to a little over four per cent. No reason can be advanced for this increase during the last weekly interval, but it is interesting to note that the sucrose content decreased in this weekly interval, while the reducing sugar content remained about the same. Apparently, for some reason, there was either polymerization of sucrose to starch during this time, or failure of starch to be hydrolyzed.

Variation in the starch content of the various size groups is moderate in nature, and there is no apparent correlation between size group and starch content, the variation found apparently being due to sampling.

Fig. 37 and tables XXII and XXIII give the changes of the starch content of Grimes during storage. It is apparent that starch rapidly decreases in storage, although in the Grimes variety it did not disappear entirely, even by the end of the storage period. By the time of the first storage sampling, the starch content had reached a low percentage, except for the third picking, and tended to come to a common level of about 0.4 per cent, regardless of the amount present at the time of harvest. Thus, as a rule, the early pickings probably showed a higher rate of starch inversion than the later pickings. The period between the first and second storage sampling was marked by a very slow decrease in the starch content, all samples falling close together, and centering about 0.2 to 0.3 per cent starch. At this time there seems to be a tendency for the earliest pickings to have the lowest starch content, although the small amounts of starch

Figure 37. The weighted average per cent starc
at the weekly harvest intervals and
throughout the storage period for t
Grimes variety, 1934.

Figure 38. The weighted average per cent starc
at the weekly harvest intervals and
throughout the storage period for t
Jonathan variety, 1934.

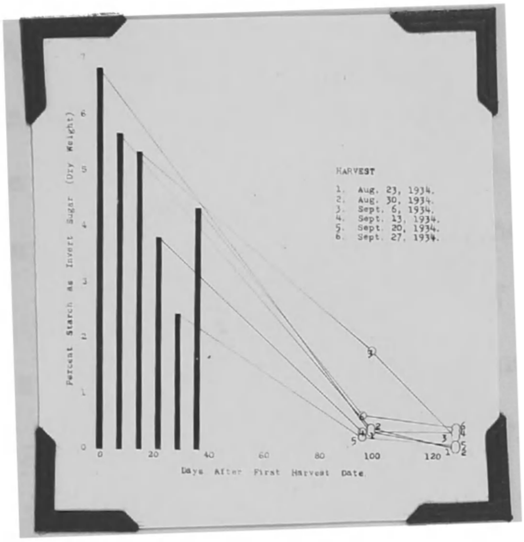

Figure 37.

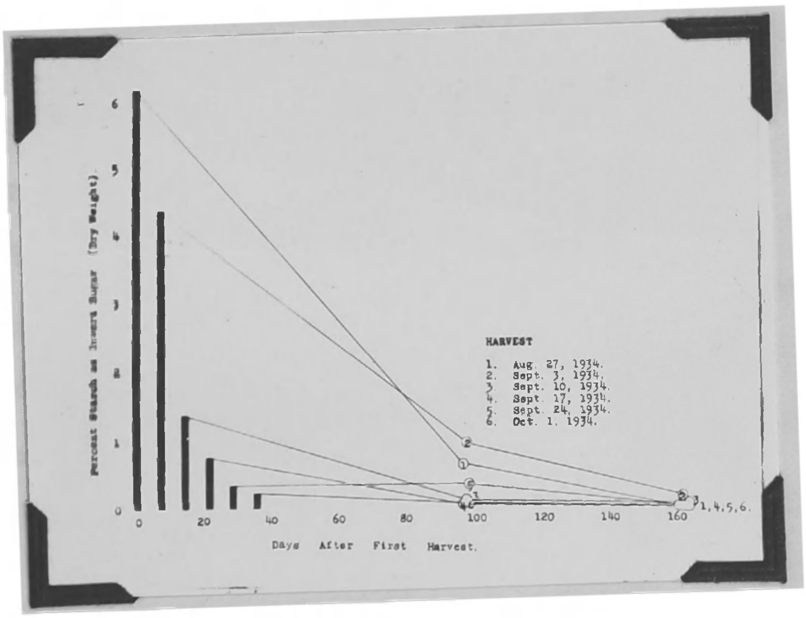

Figure 38.

present at this time make it difficult to show this clearly, and such differences as exist are not significant.

It is apparent, taking the starch content in relation to the sugar content of the Grimes fruit, that starch inversion has proceeded more rapidly than carbohydrates were utilized in respiration, and the incrdase in total sugars, and reducing substances especially, may be accounted for by this inversion of starch.

The starch content of the Jonathan fruit during the harvest period is shown on the dry weight basis in fig. 32 and table XXIV. At the time of the first picking the starch content of Jonathan was about one per cent lower than that of the Grimes, or around six per cent. The starch content of the Jonathan variety decreased much more rapidly during the harvest period than did that of the Grimes. By the time of the third picking it had dropped off to nearly one per cent and by the end of the picking season the starch content was only 0.2 per cent. Variation between the different size groups was less in the case of the Jonathan than with the Grimes, probably due to the small amounts of starch present in the later pickings. Again, there was no correlation between the size groups and the starch content.

Figure 38 and tables XXV and XXVI show the trend of starch during the storage period in the Jonathan variety. As with the Grimes, there was a rapid inversion of starch during the storage period. By the end of the first half of the storage period the starch content of all samples had fallen below one per cent, and the later pickings, which were very low at the time of harvest, had decreased to only a trace of starch. During the second half of the storage period the decrease in starch continued. Only the second and third pickings showed any starch at all at the end of the second half of the storage period, and only a trace was apparent in these pickings. All other samples were devoid of starch, as was shown both by the analyses and microchemical examination.

Nitrogen. Total nitrogen determinations were run of the flesh of both the Grimes and Jonathan varieties. The results are shown for the Grimes variety in tables XXI to XXIII and for the Jonathan variety in tables XXIV to XXVI.

Variation between the size groups was at times rather high, but in general was not excessive. There was no correlation between size groups and the nitrogen content of the fruit flesh.

With the Grimes variety the nitrogen content decreased during the first four weekly intervals, and then showed a sharp rise to a high point at the time of the last picking. While the actual amounts of nitrogen present in the apple were rather small, 0.4 to 0.65 per cent, the variation throughout the picking season amounted to over thirty per cent of the nitrogen present at the first and last pickings.

No explanation is evident for the apparent seasonal changes in the total nitrogen content of the Grimes, but from a study of the changes taking place in storage (tables XXII and XXIII) it would seem that the trends were more accidental than real, for the variation during the storage period is quite large in the case of some of the samples, as pickings five and six. This would indicate a rather large variation between samples which, unfortunately, did not appear at the time the harvest samples were taken. There could be no gain in nitrogen during the storage period, and as the dry weight remained constant throughout the storage period, the per cent nitrogen should either remain the same, or perhaps decrease slightly due to the use of stored nitrogen and its liberation. Within limits of error the total nitrogen content of the Grimes flesh did average about the same, with one or two exceptions.

There was no apparent seasonal trend of total nitrogen content in the Jonathan fruit flesh (table XXIV) although the last two pickings showed a lower nitrogen content than the previous pickings. Variation between the size groups was not overly great, except in one case, where the small apples showed a very high nitrogen content. There was no apparent correlation between nitrogen content and the size groups. The nitrogen data during storage are presented in tables XXV and XXVI, where again it can be seen that the variation between samples is rather large, as several of the samples appear to lose or gain rather large amounts of nitrogen. However, the general tendency is to average about the same amount as at

TABLE VII -- Weight Per 100 Fruit of Certain Chemical Constituents of Grimes Fruit by Trees and Size Groups at the Weekly Harvest Intervals, 1934.

Harvest Date.	Fruit Size Group.	Tree Nos.	Grams per 100 Fruits: Reducing Substances	Sucrose	Total Sugars	Starch	Total Nitrogen
August 23.	Medium	26	751.5	0.0	751.5	99.3	6.03
		2	556.8	288.5	845.3	151.6	7.01
	Small	26	442.6	112.2	554.8	57.0	4.18
		2	507.4	43.6	550.9	91.4	3.79
August 30.	Medium	4	585.3	311.7	897.0	56.5	4.53
		27	623.7	324.0	947.6	119.5	4.74
	Small	4	522.1	255.0	777.1	61.6	3.98
		27	548.4	293.5	841.9		4.31
September 6.	Medium	22	673.4	467.5	1140.9	158.2	4.49
		33	728.6	393.6	1122.2	68.1	4.53
	Small	22	605.0	403.3	1008.3	80.4	3.67
		33	559.4	284.3	843.7	63.03	3.00
September 13.	Large	19	665.8	675.1	1323.0	106.0	5.14
		28	678.3	590.6	1268.9	93.9	5.16
	Medium	19	710.0	372.6	1082.6	70.1	3.72
		28	567.6	569.8	1137.4	38.3	4.91
	Small	19	490.7	443.8	934.5	82.4	3.43
		28	573.6	334.4	908.0	86.8	3.51
September 20.	Large	11	787.0	503.0	1290.0	67.4	6.25
		18	831.4	630.0	1461.4	63.6	6.75
	Medium	11	558.4	637.8	1196.2	17.7	4.25
		18	653.7	685.8	1339.5	38.8	4.58
September 27.	Large	30	805.5	410.5	1216.0	80.8	8.94
		20	869.2	532.8	1402.0	109.8	8.34
	Medium	30	639.5	346.6	986.1	58.7	7.19
		20	678.8	346.8	1025.7	79.4	7.45

TABLE VIII -- Weight Per 100 Fruit of Certain Chemical Constituents of Jonathan Fruit by Trees and Size Groups at the Weekly Harvest Intervals, 1934.

Harvest Date.	Fruit Size Group.	Tree Nos.	Grams Per 100 Fruits: Reducing Substances	Sucrose	Total Sugars	Starch	Total Nitrogen
August 27.	Medium	8	956.9	47.9	1004.8	85.8	6.19
		34	1074.2	2.6	1076.9	155.3	6.98
	Small	8	784.0	0	784.0	134.6	5.03
		34	632.5	190.1	822.6	90.8	4.60
September 3.	Large	3	931.8	449.8	1381.6	101.7	5.22
		16	771.9	483.6	1255.5	111.1	6.99
	Medium	3	686.0	656.9	1343.0	77.6	5.58
		16	754.8	292.4	1047.3	95.9	4.86
	Small	3	791.6	275.7	1067.3	28.5	5.95
		16	754.5	283.9	1038.4	102.6	
September 10.	Large	1	1006.0	375.2	1356.2	32.2	4.86
		11	1029.1	356.6	1374.1	36.9	8.99
	Medium	1	884.6	300.2	1084.9	39.0	4.98
		11	890.1	323.6	1213.8	26.0	5.01
	Small	1	769.2	281.7	1050.9	6.5	4.12
		11	814.7	372.7	1165.8	19.7	6.55
September 17.	Large	5	1141.4	477.0	1618.4	55.0	5.64
		36	1137.7	503.5	1641.2	2.6	8.22
	Medium	5	952.5	396.9	1349.4	2.2	6.55
		36					
	Small	5	908.6	417.1	1325.7	3.2	5.73
		36	885.0	299.7	1184.7	34.3	5.15
September 24.	Large	4	967.3	664.1	1631.3	11.3	4.73
		35	1089.2	583.7	1673.1	3.0	4.78
	Medium	4					
		35	929.4	281.8	1211.2	6.4	3.58
	Small	4	889.9	173.1	1063.1	21.2	6.03
		35	893.8	393.4	1286.8	1.5	6.13
October 1.	Large	22	1181.1	562.8	1744.0	3.3	5.71
		32	1154.1	619.0	1773.2	7.9	5.48
	Medium	22	1063.2	350.8	1414.0	6.5	5.07
		32	928.8	515.3	1444.1	2.2	3.65

the time of harvest, and by the end of the storage season all the pickings ranged between .45 and .50 per cent nitrogen, which was the approximate range at the time of harvest.

From the total nitrogen data it is apparent that there are only very slight changes, if any, in the nitrogen content of the apple fruit flesh either during the maturation period, or during storage. Both varieties seem to vary around the 0.45 per cent nitrogen point, and to maintain this average throughout the period studied.

DISCUSSION

The problem outlined at the beginning of this investigation was to study the physical and chemical changes occurring in the apple fruit as maturity approaches and to attempt to correlate these changes with the quality of the fruit after a storage period. It is only by a more complete understanding of the changes occurring in the fruit during the maturation process, and the recognition of that time of harvest after which the fruit will develop its characteristic quality that we may solve the problem of when a fruit becomes mature.

From certain changes which have been studied in this paper, we may draw certain conclusions as to the nature of these changes and to a certain extent, furnish better bases for picking recommendations. The pressure test data, with the fruit of both Grimes and Jonathan, show a characteristic decrease in value throughout the maturation period, part of which is undoubtedly due to growth of the fruit. This is in general agreement with the work of Magness and his co-workers (54), Plagge, Maney, and Gerhardt (72), and others, although the changes noted in this investigation were less variable than reported by these investigators. This may be due to the larger samples used in this investigation, the more strict classification of material, or, as seems probable, a combination of these factors plus the fact that pressure test data on random samples was averaged by the method of weighted averages, on the basis of rather large samples from each tree. That the changes were seldom significant on a weekly basis, let alone a daily basis, substantiates the conclusions of other investigators that the pressure test is to be used with caution in determining fruit maturity. A comparison of the pressure test on the same variety from the same or very similar trees in different years, shows that climatic and other factors may markedly influence the pressure test. For these reasons it would seem that the pressure test is a very unreliable indicator of fruit maturity, and should not be used as an index except in the capacity suggested by Magness (50), as an indicator of storage potentialities, and as an adjunct to other methods of determining maturity.

In storage studies the pressure test again showed a similar trend to that found by most other workers. In this investigation the pressure test values of Grimes dropped during the storage period, whereas Plagge, Gerhardt, and Maney (72) failed to find any decrease in the pressure test of Grimes in their storage investigations. The results indicated that the change in pressure test during storage was rather constant for all pickings, except that the rate of decrease was greater for the early pickings, which had a high pressure test at the time of harvest. In general, however, the various pickings kept their respective rank throughout the storage period, although the variability between pickings was much smaller at the end of the storage season than between the pickings at the time of harvest. A study of the rate of decrease of the pressure test in storage shows that for the Grimes variety, the mid-season pickings showed the lowest rate of change, the earliest pickings the highest, and the late pickings were intermediate. This would suggest that the mid-season pickings were the best from the storage standpoint, and could be expected to have a longer storage life. As the fruit was not left in storage until physiological breakdown had become common this expectation was not checked, but the indications from observation and the data on shrivelling in storage would suggest this to be the case.

As no differences in the edible quality of Grimes fruit picked at various times were noted, the question of harvesting Grimes seems to revolve around its ability to stand up in storage without shrivelling or developing physiological diseases associated with storage.

The Jonathan fruit showed a correlation between the rate of softening and the time of picking throughout the storage season, the earlier picked fruit having the highest rate of decrease of the pressure test. As in the case of the Grimes, low rate of decrease of the pressure test may be associated with length of storage life. However, due to the variability of the pressure test between years, no recommendations can be made as to the best time of harvest for storage purposes. The earliest possible picking date after which the fruit may be expected to develop good quality in storage could not be determined by the pressure test.

The use of the electrical maturity tester as an index of maturity seems to be of less value than the pressure test. The variability of the readings was greater than with the pressure test, although the differences noted were of the same order. It is now apparent that this instrument offers little as an index for maturity for apples, although it seemed promising in 1935. In the case of the Grimes fruit a definite trend in the readings obtained with this instrument showed no break which could be attributed to a change in the physiological condition of the fruit, while with the Jonathan variety little or no change was noted over the period covered by the harvest investigations. The instrument usually showed lower readings after the storage periods, but the differences were not great, and were not significant. Early season tests with the electric maturity tester in 1935 with both Grimes and Jonathan showed a definite downward trend in the readings, but this leveled off in the case of the Jonathan and decreased greatly with the Grimes before the time the fruit was nearing maturity. As with the pressure tester, which gives good results with pears, the electric maturity tester has failed to show significant changes in the apple fruit with the approach of maturity.

Whereas Magness, Diehl, and Haller (53) recommend that ground color of Grimes be allowed to reach the three point on their color chart before the fruit is harvested, that stage was not reached in either of the two years of this investigation as long as the fruit was on the tree, except in the case of the devitalized Olney orchard, where the fruit reached this stage comparatively early in the season. Other observations on Grimes on vigorous trees substantiate this observation, and in most years on such trees the ground color of Grimes fruit will never reach this stage on the tree under Maryland conditions. Further, the slow rate of change in this index indicates that ground color change is of little value in determining picking maturity of Grimes.

The red color changes of the Jonathan variety, as determined in this work, were much more closely associated with the picking maturity of the fruit than the ground color changes of the Grimes fruit. In 1934 climatic conditions were such as to cause a relatively late and rapid development of the red color of the fruit, while in 1935 the red color changes were very gradual throughout the six weeks covered by the investigation. This six weeks period of time covered rather completely the entire period of color development in both years. Whitehouse (81) indicated that red color developed rather late in the season in most cases, but the results of 1935 do not substantiate this view. That it may develop during an earlier period if climatic conditions favor this type of change, is indicated. Fletcher (29) associated a high reducing sugar content with increased red color, but while the reducing sugar content of the 1934 season increased slightly throughout this period, it could not be correlated with red color development. Marshall and Waldo (57) seem to think that red color development is a very poor index of maturity under Michigan conditions. However, the results of this investigation indicate that at least twenty-five per cent of the surface of the average Jonathan fruit should be covered with red color before they are picked. This percentage should be based on a random sample of fruit from all parts of the tree, and several trees in the orchard should be considered in making a general picking recommendation for the orchard. The excellent correlation of picking maturity and red color development was affirmed by the quality the fruit obtained in storage. In both years the pickings made previous to the time that the fruit became at least twenty-five per cent covered with red color failed to develop good edible quality in storage, whereas after this point had been reached the fruit developed good quality characteristic of the variety. In 1935 this stage was reached at the time of the third weekly picking, although barely so. This picking developed fairly good quality in storage, but not as good as the pickings made at a later date. This index, especially when regarded with some of the results of the chemical analysis, was adequate in the two years of this investigation, and under the climatic and cultural conditions under which the fruit was grown. While further tests under more widely varying conditions may prove the color index to be inadequate as a general measure of the picking maturity of the Jonathan variety these tests indicate it is at least feasible under a limited range of conditions. With certain exceptions the chemical analyses fall closely in line with the results of Bigelow, Gore, and Howard (10), Plagge, Maney, and Gerhardt (72), Magness and Diehl (52), and others. In this work, the dry weight was found to vary considerably, but always in inverse proportion to the rainfall in the few days preceding the harvest. Bigelow, Gore, and Howard (10), Neller and Overley (63), and Burroughs, showed that in the fruit they studied the dry weight increased slightly throughout the growing season, but any such trend in the present work was obscured by the variation caused by rainfall during the time of the investigation. The Grimes variety ran slightly higher in dry weight than the Jonathan variety, but both showed the relation of dry weight to rainfall. It is possible that the higher percentage starch in Grimes at the time of harvest accounts for a good share of this difference in dry weight, as other fractions were about the same for the two varieties.

During the storage period the dry weight remained practically constant in both the Grimes and Jonathan varieties. Those having a high dry weight at the time of harvest maintained this level throughout the storage season.

The reducing sugar content of both the Grimes and Jonathan samples varied considerably during the harvest period, and with the Grimes variety these variations were associated with rainfall in the few days preceding the harvest time. In the case of the Jonathan variety, however, this correlation was not shown. This may be interpreted as a difference in the relation of soluble carbohydrates in the two varieties which may be affected differently by an increased hydration of the cells. The growth rate of both varieties seemed normal, and there were no indications that water was limited during this period. If the variations in reducing sugars apparently associated with rainfall are taken into account there seems to be a slight increase in the amount of reducing sugars present in the fruit as maturity proceeds.

The sucrose content of both the Grimes and Jonathan variety was very low at the time of the first harvest of each variety. By the second week this had increased greatly in each variety, and after that time there was a gradual increase in sucrose until the last harvest date, when it dropped off in both the Grimes and the Jonathan varieties. With the Grimes variety both reducing sugars and starch showed an increase in this last harvest, and these concurring changes in the other carbohydrate fractions suggests a shift in the carbohydrate equilibrium in the fruit. There was no apparent cause for such a shift unless it was caused by high minimum and maximum temperatures in the few days preceding the harvest. As no marked correlation between the carbohydrate equilibrium and temperature has ever been demonstrated for the apple, this is, of course, theoretical. It is difficult to see how such relatively small changes in temperature could have such an effect.

With the Jonathan variety the decrease in sucrose noted in the last picking is reflected by a rise in the reducing sugar content. The starch was nearly all hydrolyzed by this time, and there is no shift in the trend of the starch changes, indicating a shift only toward the simpler sugars. There is no apparent correlation with temperature in this shift.

While there were rather large and characteristic changes in the sucrose content of both varieties, these changes are not well correlated with approach of maturity. In each case although there was a rather marked increase a few weeks preceding the time the fruit reached maturity, the changes during the maturation period were not sufficient to be of value as a picking index. In both varieties there was a definite upward trend in sucrose until the last picking, at which time the sucrose content dropped off. The value of the changes in sucrose noted as a maturity index apparently lie in its use as an indicator of approaching maturity, based on the initial, large increase in sucrose noted in the second picking. The value of such an indexis slight, however.

The results of the storage studies are somewhat different than those reported by Bigelow, Gore and Howard (10). In their storage studies the sucrose content continued to increase in storage until all starch was hydrolyzed, when the sucrose content fell off rapidly, and the reducing sugar content rose proportionately. However, in these investigations the sucrose content tended to come to a constant value, whatever the picking date. It may be that the storage period of the fruit was not prolonged sufficiently to show the decrease in sucrose content noted by the above authors, for, in the case of the Grimes variety, there were still traces of starch present in most of the samples at the end of the storage period. This is probably the case, as their investigations were carried considerably further in time than the present. They continued most of their storage investigation up to March or April, as the varieties they used had a considerably longer storage life than Grimes or Jonathan.

As stated above, the sucrose content of the Grimes and Jonathan tended to rise to a constant value at both of the storage sample dates, although the variability was much greater at the time the first storage sample was taken. By the end of the storage season all pickings fell close to the sixteen per cent point for the Jonathan variety and averaged about twenty-three per cent for Grimes. This trend in sucrose content resulted in a marked increase in sucrose in the first sample harvested, and a smaller increase or decrease in successive samples. In the work of Plagge, Gerhardt, and Maney (72), it was found that after a two weeks delay in storing Grimes fruit there was a tendency for all lots, irrespective of picking date to come to the fifty-eight per cent total sugar content point. As variations in sucrose account for a considerable portion of the variation in total sugars, it would seem that the Grimes variety showed this same tendency to come to a definite sucrose equilibrium under their conditions also.

As has been pointed out with reducing sugars, there was a slight increase during the harvest period in all samples in storage. Therefore, as the reducing sugars behaved regularly in all cases, the total sugar curves tend to repeat the sucrose curves. The first harvest was relatively low, and there was a slight increase in total sugars during the last five pickings with both Grimes and Jonathan. In storage the total sugar content tended to come to a definite percentage in both varieties, this being sixty-two per cent for the Grimes and about seventy per cent for the Jonathan. For the most part this is merely a reflection of the sucrose values.

There is always a very direct relation between the various carbohydrate fractions. An increase in starch is accompanied by a decrease in the soluble carbohydrate forms, or a decrease in sucrose is reflected in an increase in reducing sugars. Other investigators have also found this to be true. In the Grimes variety the results obtained may be interpreted easily on this basis. The starch remaining in the fruit was rapidly hydrolyzed after the fruit was stored. This resulted in a large increase in sucrose in the samples harvested early in the season, when the starch content was high, and a smaller increase in successive samples. The general level of all soluble carbohydrate compounds increased in storage. With the establishment of new conditions at storage temperatures, and with the aging of the fruit, there was a gradual loss in starch throughout the rest of the storage period, accounted for by a slight shift in the carbohydrate relations to a higher content of the more soluble forms, and through loss in respiration. This respiration loss, under the cold storage conditions, is not very large, as compared to that at high temperatures, which is brought out by the respiration studies of various investigators.

The Jonathan variety shows similar changes in carbohydrate relations. While, in this case the general starch level was considerably less at any given stage than for the Grimes variety, except for the first picking, the trend was much the same. In the later pickings the starch percentage had reached a very low value at the time of harvest. However, even so there was some starch still present in all samples at the time of the first storage sample. With the early pickings the decrease had been very large, for in all cases the starch content was very low by the time the first storage sample was taken. It is probable that this low point was reached rather early in the storage life of the fruit, although, unfortunately, no sample was taken at that time to give information on this point. After this condition was reached there was a slow decrease in the starch content of Jonathan throughout the remainder of the storage season. While only a few of the samples showed any starch content at the end of the storage period, they indicate that the starch had just previously disappeared from the other samples. This slight decrease in starch is reflected in a similar slight increase in the soluble carbohydrate forms, with a small amount of the total carbohydrate content of the fruit probably used in respiration.

The starch content of both Grimes and Jonathan was relatively high at the time the first picking was made. The Grimes showed a rather large decrease during the harvest period, until the last picking, which showed a marked increase in starch. This increase was reflected in a decreased sucrose and reducing sugar content, and may reflect a period of high maximum and minimum temperatures occurring during the three days preceding harvesting.

Otherwise is it difficult to explain this sudden increase in per cent starch in this variety at this time, unless cessation of cambial activity of the tree happened to coincide with this particular time, with a resultant increase in available carbohydrates to the fruits. In the Jonathan variety there was a large decrease in starch content during the first four weeks of the harvest period, by which time the starch content had fallen below one per cent. After this time there were small decreases at the following weekly intervals, until a final starch percentage of approximately 0.2 per cent was reached at the time of the last picking date. This trend was very regular.

The fact that the Grimes variety showed a relatively high starch content throughout the harvest period would indicate that this fraction is of little value as a measure of picking maturity. The Jonathan variety, however, showed a marked trend in starch content, and the differences during the early part of the harvest period were quite large. By actual test storage quality, in this case, was associated with a starch content of less than 0.75 per cent on the dry weight basis. As the changes in Jonathan were large, and the trend was very definite, it may be that starch content, associated with red color development will give a good estimation of picking maturity. Further tests with a wider range of materials, grown under more varying cultural conditions, are necessary to see if such estimates would hold up under all Maryland conditions.

The total nitrogen determinations varied widely from week to week, and there is little indication that changes in nitrogen content are of any value as a picking index. Both the Grimes and Jonathan varieties showed about the same total nitrogen content. In both cases values were high in the first and last pickings, and intermediate in the others, but the variability was great. The large increase in both varieties in the last picking is hard to explain. As was suggested for the increased starch content found in Grimes in this picking, it may be partially accounted for by availability of more food materials to the fruits with the cessation of cambial activity about this time.

The samples varied rather widely in storage, but as a rule the nitrogen content of the fruit did not change enough to be significant in storage. The samples that were high at the beginning were high throughout the storage period, and samples that were low remained low. The wide variation found in a few cases indicates that the fruit varied a great deal in nitrogen content, and perhaps some of the differences found at the various picking dates are merely due to variation in the samples selected.

In attempting to correlate these various physical and chemical changes with picking maturity as measured by edibility after the storage period, we find that there is no correlation of any of the factors studied with picking date and subsequent quality of the Grimes variety.

In this case the fruit always developed good, edible quality in storage, although the early and late pickings showed more shrivelling than the intermediate harvests. The degree of shrivelling was reflected in the pressure test, which showed the intermediate pickings to have the slowest rate of decrease of the pressure test in storage. As far as the Grimes variety is concerned it is evident that the fruit may be picked rather early in the season, but, to obtain good market quality the harvest must be delayed until the fruit reaches a stage where it will stand up well in storage. Further studies on the development of the skin characters, as corking over of the lenticels and development of the cuticle, should give rather pertinent data on the proper stage to harvest Grimes with regard to its ability to stand up in storage.

The Jonathan variety, however, showed two factors to be closely associated, both with keeping quality, and edibility after storage. Furthermore, these factors were pertinent to the appearance and quality of the fruit at the time of harvest. The first was the development of red color, which required development of an average red color of twenty-five per cent on a random sample selected from all parts of the tree. The second factor, which may be indirectly associated with the development of red color, and which showed quite large differences of a definite trend, was the starch content at the time of harvest. It may be possible to directly compare the changes in these two factors during the maturation period by the development of a quick, semi-quantitative test for starch which can be applied in the orchard.

SUMMARY AND CONCLUSIONS

The purpose of the investigation here reported has been to study certain physical and chemical changes in the fruit of Grimes and Jonathan apples, and, where possible, to correlate these changes with the edible quality of the fruit after storage. To this end, Grimes and Jonathan fruit was harvested at weekly intervals from selected trees in 1934 and 1935, and measurements taken with the pressure tester and "electrical maturity tester," and estimates of ground color changes of Grimes and red color development of Jonathan were made. In 1934 chemical analyses were made for the carbohydrate fractions of the fruit, including reducing substances, sucrose, total sugars, and starch; and for the total nitrogen content of the fruit. The same data were collected at two intervals during the storage period.

Changes found in these measurements and determinations at the weekly harvest intervals and during storage were appraised on the bases of the time of harvest, and edible quality of the fruit, at the end of the storage period, with the view in mind of establishing picking indices for the varieties.

The results of these investigations may be summarized:

1. The pressure test of both Grimes and Jonathan

decreased regularly throughout the six weeks covered by the harvest period in 1934, and through the regular pickings in 1935. The weekly decreases, however, were not significant for Grimes and barely so for Jonathan.

2. The pressure test of both Grimes and Jonathan was considerably higher at the same stage of maturity in 1935 than in 1934, and hence, even though weekly differences were found significant for the Jonathan variety in 1934, little value can be placed on the pressure test as a measure of maturity for these varieties.

3. An inverse relation between fruit size and pressure test was indicated at all stages, but the pressure test of a single size groups decreased throughout the season at approximately the rate of a random sample from the tree.

4. The pressure test of the Grimes variety was higher than that of the Jonathan variety in each year.

5. The electrical maturity tester readings did not show a significant trend during the harvest period for either variety in either year, and therefore, seem of little value as an index of maturity.

6. The electrical maturity tester readings showed a downward trend during the harvest period with the Grimes variety, but no consistent trend was noted in the case of the Jonathan variety.

7. There was no significant difference between the electrical maturity tester readings for Grimes and Jonathan.

8. Temperature was shown to have a marked effect on the electrical maturity tester readings.

9. Ground color changes in the Grimes variety were very slow during the harvest period, and were decidedly affected by the cultural conditions under which the trees were grown. The weekly changes were too small to be of value as an index of maturity, and the wide difference,due to cultural conditions, further excludes this character as an index.

10. The development of red color of Jonathan fruit seemed to be dependent upon climatic factors to a large extent, and to be well correlated with edible quality after storage; a twenty-five per cent red color development was found necessary before fruit developed characteristic quality after storage at thirty-two degrees F.

11. The pressure test decreased regularly throughout the storage period, and the early pickings had the highest rate of decrease. All tended to come to a common value at the end of the storage period, but the pickings, in general, retained their original rank.

12. The electrical maturity tester readings showed a slight decrease during the storage period, but there was no correlation between picking date and the final value obtained.

13. The ground color of Grimes fruit increased slowly throughout the storage period.

14. Chemical analyses for carbohydrate fractions and total nitrogen showed no correlation with maturity

at harvest, except, possibly the starch content of Jonathan fruit.

15. The reducing substance content of Grimes and Jonathan fruit remained practically constant throughout the harvest period, and showed a slight increase throughout the storage period. The reducing substances content of Jonathan was greater than that of Grimes.

16. The sucrose content of both Grimes and Jonathan was low at the time of the first harvest, increased greatly during the first weekly interval, and more slowly until the last harvest date, at which time it showed a decrease. The sucrose content of both varieties tended to come to a constant level during the storage period, which resulted in an increase in sucrose content of the early pickings, and a decrease for the later pickings. The sucrose content of Grimes was higher than that of Jonathan.

17. Total sugars tended to follow the sucrose curve during the harvest period. During storage, total sugars tended to come to a constant level of about sixty-two per cent for Grimes and seventy per cent for Jonathan. In both cases this resulted in an upward trend in total sugars during the storage period.

18. The starch content of Grimes decreased from seven per cent to about two and one-half per cent in the first five weekly pickings, but showed an increased value at the time of the last harvest. The starch con-

tent of Jonathan was about six per cent at the time of the first harvest, and decreased rapidly throughout the weekly intervals, obtaining a value of less than one per cent at the fourth harvest. By the sixth picking date only 0.2 per cent starch was present in the Jonathan fruit.

19. Starch decreased rapidly in storage in both Grimes and Jonathan varieties, the values being below 0.5 per cent in nearly all cases at the time of the first storage sample. At the end of the storage period Grimes still showed slight traces of starch, but only two pickings of Jonathan showed any starch content at the end of the storage period, and then only traces.

20. Total nitrogen content of both Grimes and Jonathan averaged between 0.45 and 0.50 per cent on the dry weight basis, and although there was considerable variation, there was no seasonal trend apparent. The total nitrogen content remained practically constant throughout the storage period.

21. None of the factors measured was sufficiently correlated with the maturation processes of the Grimes variety to serve as picking index, and the results obtained seem to indicate the factors affecting the ability of this variety to stand up in storage are most important in relation to time of harvest.

22. Red color development was closely associated with edible quality after storage of Jonathan fruit, and the results show that at least twenty-five per cent red

color development is necessary if characteristic quality is to be obtained. The starch content of Jonathan fruit was found to change rapidly during the ripening period, and further investigation may show this to be correlated with quality after storage.

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APPENDIX

TABLE IX -- Average Pressure Test, in Pounds, of Grimes Fruit from Six Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During Storage, 1934.

		At Harvest 1934			End of November		End of December	
Harvest Date.	Fruit Size Group	Number of Fruit in Each Size Group.	Pressure Test in Pounds.	Weighted Average of Pressure Test.	Pressure Test in Pounds.	Weighted Average of Pressure Test.	Pressure Test in Pounds.	Weighted Average of Pressure Test.
	Large							
August 23.	Medium	1580	22.26 ±.21*	23.28	16.26	16.90	15.55	16.12
	Small	2331	23.97 ±.46		17.34		16.51	
	Large							
August 30.	Medium	2030	20.11 ±.19	20.55	15.19	15.48	14.62	14.89
	Small	1392	21.18 ±.16		15.91		15.28	
	Large							
September 6.	Medium	1556	19.44 ±.26	19.94	15.86	16.22	14.72	15.34
	Small	1714	20.40 ±.26		16.54		15.90	
	Large	504	18.27 ±.52		15.40		13.44	
September 13	Medium	1681	19.14 ±.37	19.13	15.97	16.05	14.48	14.36
	Small	512	19.94 ±.22		16.93		14.47	
	Large	1394	18.09 ±.51		14.04		12.30	
September 20	Medium	1070	18.80 ±.26	18.40	14.64	14.30	13.65	12.87
	Small	52	19.38 ±.09		14.84			
	Large	1803	17.30 ±.24		14.08		13.04	
September 27	Medium	505	18.28 ±.18	17.51	14.84	14.24	13.32	13.10
	Small							

*Standard Error.

Fisher's t test for significance of differences of means of small samples was used throughout in testing the significance of differences between samples.

TABLE X -- Average Pressure Test, in Pounds, of Grimes Fruit from Five Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During Storage, 1935.

At Harvest 1935					End of November		End of December	
Harvest Date.	Fruit Size Group	Number of Fruit in Each Size Group.	Pressure Test in Pounds.	Weighted Average of Pressure Test.	Pressure Test in Pounds.	Weighted Average of Pressure Test	Pressure Test in Pounds.	Weighted Average of Pressure Test.
August 24.	Large Medium Small	101 1750 96	20.18 ± .26 21.76 ± .38 24.70 ± .60	21.82	16.07	16.07	15.06 16.34	16.27
August 31.	Large Medium Small	198 1697 189	19.61 ± .11 20.95 ± .33 23.61 ± .71	21.06	14.52 16.19 17.77	16.17	15.82	15.82
September 7.	Large Medium Small	291 1365 55	19.14 ± .13 20.40 ± .27 24.42 ± .31	20.31	14.97 15.81	15.66	14.93	14.93
September 14	Large Medium Small	214 433 1	20.92 21.90	21.58	15.70 16.80	16.44	13.45 15.05	14.52
September 21	Large Medium Small	31 658 66	17.25 18.10 21.38	18.35	15.50	15.50	12.82	12.82

TABLE XI — Average Pressure Test, in Pounds, of Jonathan Fruit from Six Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During Storage, 1934.

At Harvest 1934					End of November		End of January	
Harvest Date.	Fruit Size Group	Number of Fruit in Each Size Group.	Pressure Test in Pounds.	Weighted Average of Pressure Test.	Pressure Test in Pounds.	Weighted Average of Pressure Test.	Pressure Test in Pounds.	Weighted Average of Pressure Test.
August 23.	Large							
	Medium	1671	17.68 ± .14	18.08	13.81	13.92	11.69	12.30
	Small	1222	18.62 ± .17		14.08		13.14	
August 30.	Large	536	16.01 ± .23		14.22		10.74	
	Medium	1322	16.68 ± .13	16.64	13.57	13.86	11.30	11.41
	Small	972	16.94 ± .14		14.05		11.94	
September 6.	Large	506	15.30 ± .11		13.00		11.12	
	Medium	713	15.63 ± .19	15.74	13.41	13.43	10.87	11.13
	Small	1396	15.96 ± .16		13.59		11.26	
September 13	Large	840	14.51 ± .18		12.86		10.84	
	Medium	1066	14.98 ± .09	14.91	13.21	13.21	11.23	11.11
	Small	534	15.24 ± .19		13.74		11.29	
September 20	Large	1218	13.72 ± .13		12.54		10.28	
	Medium	809	13.95 ± .09	13.87	12.88	12.68	10.88	10.52
	Small	218	14.46 ± .12					
September 27	Large	811	13.63 ± .05		12.21		10.11	
	Medium	1204	13.94 ± .11	13.87	12.95	12.65	10.72	10.47
	Small	109	14.90 ± .10					

TABLE XII -- Average Pressure Test, in Pounds, of Jonathan Fruit from Five Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During Storage, 1935.

At Harvest 1935					End of November		End of December	
Harvest Date.	Fruit Size Group	Number of Fruit in Each Size Group.	Pressure Test in Pounds.	Weighted Average of Pressure Test.	Pressure Test in Pounds.	Weighted Average of Pressure Test.	Pressure Test in Pounds.	Weighted Average of Pressure Test.
August 29.	Large	260	16.42 ± .19		12.94		11.42	
	Medium	1350	18.00 ± .27	17.93	14.11	14.08	13.20	12.91
	Small	145	20.02 ± .37		15.88			
September 6.	Large	418	15.76 ± .14		12.60		11.76	
	Medium	1151	17.06 ± .11	16.80	13.66	13.38	12.57	12.35
	Small	59	18.96 ± .03					
September 12	Large	373	15.12 ± .23		12.30		11.50	
	Medium	1152	16.53 ± .25	16.29	13.31	13.06	12.44	12.21
	Small	39	20.40					
September 19	Large	733	14.88 ± .26		12.96		11.92	
	Medium	497	16.14 ± .08	15.39	13.64	13.23	12.07	11.98
	Small	15						
September 26	Large	282	15.78		13.95		12.80	
	Medium	233	16.80	16.24	13.92	13.94	14.07	13.37
	Small	7						

TABLE XIII -- Average Electrical Maturity Tester Readings in Milliamperes x 100, of Grimes Fruit from Six Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During Storage, 1934.

		At Harvest 1934			End of November		End of December	
Harvest Date.	Fruit Size	Number of Fruit in Each Size Group.	Electrical Maturity Tester Readings Milliamps. x 100	Weighted Average E.M.T. Readings.	Electrical Maturity Tester Readings Milliamps. x 100	Weighted Average E.M.T. Readings.	Electrical Maturity Tester Readings Milliamps. x 100	Weighted Average E.M.T. Readings.
	Large							
August 23.	Medium	1580			14.80		12.90	13.13
	Small	2331			14.81	14.81	13.28	
	Large							
August 30.	Medium	2030	16.27 ± .58	15.81	14.65	14.54	13.60	13.45
	Small	1392	15.14 ± .31		14.38		13.22	
	Large							
September 6.	Medium	1556	15.21 ± .44	15.67	15.20	15.04	13.27	13.18
	Small	1714	15.64 ± .40		14.90		13.10	
	Large	504	14.49 ± .10		15.48		12.90	
September 13	Medium	1681	14.71 ± .18	14.59	14.26	14.61	12.22	12.31
	Small	512	14.29 ± .19		14.90		12.05	
	Large	1394	14.56 ± .20		13.91		12.99	
September 20	Medium	1070	14.31 ± .37	14.47	14.30	14.08	12.54	12.79
	Small	52	15.20 ± .11					
	Large	1803	12.93 ± .16		13.76		13.72	
September 27	Medium	505	13.15 ± .18	12.98	13.68	13.74	13.49	13.67
	Small							

TABLE XIV -- Average Electrical Maturity Tester Reading in Milliamperes x 100, of Grimes Fruit from Five Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During Storage, 1935.

	At Harvest 1935				End of November		End of December	
Harvest Date.	Fruit Size	Number of Fruit in Each Size Group.	Electrical Maturity Tester Readings Milliamps x 100	Weighted Average E.M.T. Readings.	Electrical Maturity Tester Readings Milliamps x 100	Weighted Average E.M.T. Readings.	Electrical Maturity Tester Readings Milliamps x 100	Weighted Average E.M.T. Readings.
	Large	101	29.80 ±.54				15.66	
August 24.	Medium	1750	29.25 ±.19	29.29	15.44	15.44	15.61	15.61
	Small	96	29.29 ±.48					
	Large	198	27.06 ±.51		15.72			
August 31.	Medium	1697	26.97 ±.49	27.04	16.03	15.89	12.64	12.64
	Small	189	27.68 ±.82		14.80			
	Large	291	29.84 ±.47		15.20			
September 7.	Medium	1365	30.26 ±.37	30.17	15.04	15.08	11.79	11.79
	Small	55	29.58 ±.81					
	Large	214	27.12		14.90		10.87	
September 14	Medium	433	27.43	27.33	14.95	14.93	11.43	11.24
	Small	1						
	Large	31	22.48	23.40				
September 21	Medium	658	23.47		15.35	15.35	11.92	11.92
	Small	66	23.15					

TABLE XV -- Average Electrical Maturity Tester Readings in Milliamperes x 100, of Jonathan Fruit From Six Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During the Storage Period, 1934.

	At Harvest 1934.				End of November		End of January	
Harvest Date.	Fruit Size	Number of Fruit in Each Size Group.	Electrical Maturity Tester Readings Milliamps. x 100.	Weighted Average E.M.T. Readings.	Electrical Maturity Tester Readings Milliamps. x 100.	Weighted Average E.M.T. Readings.	Electrical Maturity Tester Readings Milliamps. x 100.	Weighted Average E.M.T. Readings.
August 27.	Large							
	Medium	1671			14.71	14.32	14.33	13.96
	Small	1222			13.79		13.46	
September 3.	Large	536	16.10 ± .35		15.59		13.32	
	Medium	1322	15.66 ± .25	15.39	15.37	15.18	13.58	13.29
	Small	972	14.64 ± .36		14.71		12.87	
September 10	Large	506	15.18 ± .28		15.37		13.68	
	Medium	713	15.51 ± .26	15.25	14.57	14.43	13.42	13.29
	Small	1396	15.15 ± .21		14.27		15.09	
September 17	Large	840	15.60 ± .10		15.46		14.70	
	Medium	1066	15.04 ± .24	15.26	14.65	14.92	13.76	13.73
	Small	534	15.15 ± .44		14.59		12.16	
September 24	Large	1218	14.98 ± .51		14.83		13.60	
	Medium	809	14.79 ± .55	14.85	13.97	14.49	13.04	13.38
	Small	218	14.30 ± .46					
October 1	Large	811	16.04 ± .49		13.74		14.96	
	Medium	1204	15.54 ± .42	15.69	13.68	13.70	13.42	14.04
	Small	109	14.75 ± .38					

TABLE XVI — Average Electrical Maturity Tester Readings in Milliamperes x 100, of Jonathan Fruit from Five Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During Storage, 1935.

		At Harvest 1935			End of November		End of December	
Harvest Date.	Fruit Size	Number of Fruit in Each Size Group.	Electrical Maturity Tester Readings Milliamps x 100	Weighted Average E.M.T. Readings.	Electrical Maturity Tester Readings Milliamps x 100	Weighted Average E.M.T. Readings.	Electrical Maturity Tester Readings Milliamps x 100	Weighted Average E.M.T. Readings.
August 29.	Large	260	24.68 ± .39		16.76		13.22	
	Medium	1350	24.51 ± .53	24.72	15.47	15.47	12.91	12.96
	Small	145	26.73 ± .85		13.13			
September 6.	Large	418	28.05 ± .42		15.36		12.37	
	Medium	1151	28.00 ± .43	27.99	15.71	15.62	12.30	12.32
	Small	59	27.28 ± .39					
September 12	Large	373	26.58 ± .40		17.17		13.16	
	Medium	1152	26.75 ± .54	26.67	15.31	15.76	11.62	12.00
	Small	39	25.22					
September 19	Large	733	27.72 ± .46		16.07		13.60	
	Medium	497	26.69 ± .61	27.30	14.94	15.61	11.41	12.72
	Small	15						
September 26	Large	282	27.23		14.90		14.47	
	Medium	233	27.17	27.20	15.48	15.16	13.51	14.06
	Small	7						

TABLE XVII — Development of Ground Color, after the Magness and Diehl Color Chart, of Grimes Fruit from Six Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals, 1934.

At Harvest 1934				
Harvest Date.	Fruit Size Group	Number of Fruit in Each Size Group	Ground Color.	Weighted Average of Ground Color.
August 23.	Large			
	Medium	1580	1.39 ± .09	1.45
	Small	2331	1.49 ± .12	
August 30.	Large			
	Medium	2030	2.12 ± .03	2.14
	Small	1392	2.16 ± .04	
September 6.	Large			
	Medium	1556	1.66 ± .04	1.61
	Small	1714	1.57 ± .09	
September 13	Large	504	1.92 ± .06	
	Medium	1681	1.90 ± .05	1.90
	Small	512	1.88 ± .02	
September 20	Large	1394	2.22 ± .06	
	Medium	1070	2.15 ± .09	2.19
	Small	52		
September 27	Large	1803	2.22 ± .04	
	Medium	505	2.19 ± .04	2.21
	Small			

TABLE XVIII — Development of Ground Color, after the Magness and Diehl Color Chart, of Grimes Fruit from Five Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals and During Storage, 1935.

At Harvest 1935					End of November		End of December	
Harvest Date.	Fruit Size Group	Number of Fruit in Each Size Group.	Ground Color	Weighted Average of Ground Color.	Ground Color	Weighted Average of Ground Color.	Ground Color	Weighted Average of Ground Color.
August 24.	Large	101					2.75	
	Medium	1750			2.26	2.26	2.49	2.50
	Small	96						
August 31.	Large	198	2.04 ± .11		2.48			
	Medium	1697	2.05 ± .07	2.05	2.30	2.34	2.93	2.93
	Small	189	2.02 ± .11		2.52			
September 7.	Large	291	1.79 ± .09		2.50			
	Medium	1365	1.95 ± .05	1.94	2.59	2.57	3.30	3.30
	Small	55	1.87 ± .16					
September 14	Large	214	2.78		3.28		3.95	
	Medium	433	2.62	2.67	2.80	2.96	3.72	3.80
	Small							
September 21	Large	31	2.63					
	Medium	658	2.78	2.80	2.75	2.75	3.18	3.18
	Small	66	3.05					

TABLE XIX — Development of Red Color, in Per cent, of Jonathan Fruit from Six Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals, 1934.

At Harvest 1934

Harvest Date.	Fruit Size Group	Number of Fruit in Each Size Group.	Per cent Red Color.	Weighted Average of Red Color.
August 27.	Large			
	Medium	1671	3.63 ± 1.0	3.77
	Small	1222	3.95 ± 1.5	
September 3.	Large	536	5.72 ± 1.2	
	Medium	1322	5.97 ± 1.9	6.75
	Small	972	8.37 ± 1.6	
September 10	Large	506	7.28 ± .56	
	Medium	713	7.52 ± .53	6.85
	Small	1396	6.36 ± 1.9	
September 17	Large	840	11.41 ± 1.7	
	Medium	1066	9.41 ± .90	10.00
	Small	534	8.96 ± .86	
September 24	Large	1218	39.95 ± 1.6	
	Medium	809	34.13 ± 2.2	37.63
	Small	218		
October 1.	Large	811	53.15 ± 1.3	
	Medium	1204	39.67 ± 4.7	45.10
	Small	109		

TABLE XX -- Development of Red Color, in Per Cent, of Jonathan Fruit from Five Random Trees by Size Groups and Weighted Average for the Size Groups at the Weekly Harvest Intervals, 1935.

At Harvest 1935				
Harvest Date.	Fruit Size Group	Number of Fruit in Each Size Group.	Per Cent Red Color.	Weighted Average of Red Color.
August 29.	Large Medium Small	260 1350 145	7.23 ± 1.2 8.34 ± 1.5 8.66 ± 2.1	8.20
September 6.	Large Medium Small	418 1151 59	16.63 ± 1.2 16.82 ± 2.2 14.20 ± 1.0	16.68
September 12	Large Medium Small	373 1152 39	29.66 ± 6.9 27.30 ± 5.2 26.88	27.85
September 19	Large Medium Small	733 497 15	52.45 ± 3.2 39.15 ± 5.8	47.08
September 26	Large Medium Small	282 233 7	64.75 45.00	55.81

TABLE XXI — Per Cent Composition on the Dry Weight Basis by Trees and Size Groups and Average for the Size Groups of Certain Chemical Constituents of Grimes Fruit at the Weekly Harvest Intervals, 1934.

Harvest Date.	Fruit Size Group.	Tree Nos.	Total Solids By Tree	Total Solids Average	Per Cent Water By Tree	Per Cent Water Average	Reducing Substances By Tree	Reducing Substances Average	Sucrose By Tree	Sucrose Average	Total Sugars By Tree	Total Sugars Average	Starch By Tree	Starch Average	Total Nitrogen By Tree	Total Nitrogen Average
August 23.	Medium	26	18.41		81.59		45.35		0		42.83		6.53		.67	
		2	17.46	17.93	82.44	82.07	31.42	38.38	16.27	8.14	47.69	45.26	8.55	7.54	.69	.68
	Small	26	18.44		81.56		34.43		8.75		43.18		4.90		.60	
		2	18.16	18.30	81.84	81.70	39.73	37.08	3.43	6.09	43.16	43.17	7.62	6.26	.54	.57
August 30.	Medium	4	16.42		83.58		35.45		18.91		54.36		3.35		.45	
		27	18.26	17.34	81.74	82.66	33.85	34.65	17.57	18.24	51.42	52.89	6.49	5.06	.47	.46
	Small	4	16.72		83.28		36.15		17.60		53.57		4.47		.46	
		27	18.10	17.41	81.90	82.59	34.45	35.30	17.45	17.52	52.90	53.24	9.74	7.10	.49	.48
September 6.	Medium	22	18.38		81.62		37.55		26.05		63.60		8.82		.46	
		33	18.38	18.38	81.62	81.62	38.46	38.00	20.77	26.41	59.23	61.42	3.33	6.07	.44	.45
	Small	22	19.18		80.82		36.14		24.09		60.23		4.77		.42	
		33	18.94	19.06	81.06	80.94	38.36	37.25	19.45	21.77	57.81	59.02	4.31	4.54	.39	.40
September 13.	Large	19	16.04		83.96		33.10		32.66		65.76		5.26		.41	
		28	17.08	16.56	82.92	83.44	30.79	31.94	26.80	29.73	57.59	61.68	4.25	4.76	.40	.40
	Medium	19	16.25		83.75		42.30		22.23		64.53		4.06		.36	
		28	17.41	16.83	82.59	83.17	29.89	36.10	29.99	26.11	59.88	62.20	2.11	3.08	.45	.40
	Small	19	16.63		83.37		32.74		29.58		62.32		5.49		.38	
		28	17.68	17.16	82.32	82.84	36.06	34.40,	21.06	25.32	57.12	59.72	5.45	5.47	.39	.38
September 20.	Large	11	17.30		82.70		34.95		22.28		57.23		2.98		.48	
		18	16.46	16.88	83.54	83.12	38.85	36.90	29.49	25.88	68.34	62.78	2.97	2.98	.52	.50
	Medium	11	16.18		83.82		32.86		37.53		70.39		.97		.38	
		18	17.34	16.76	82.66	83.24	30.48	31.67	31.96	34.74	62.44	66.42	1.80	1.38	.37	.38
September 27.	Large	30	16.77		83.33		37.34		18.97		56.31		3.74		.69	
		20	17.91	17.34	82.09	82.66	34.14	35.74	20.99	19.98	55.31	55.81	4.56	4.15	.62	.66
	Medium	30	16.57		83.43		35.86		19.48		55.44		3.30		.67	
		20	17.24	16.90	82.76	83.10	36.97	36.46	18.92	19.20	55.89	55.66	4.33	4.82	.70	.68

TABLE XXII -- Per Cent Composition on the Dry Weight Basis by Trees and Size Groups and Average for the Size Groups of Certain Chemical Constituents of Grimes Fruit After Storage from the Time of Harvest to the End of November, in Relation to the Time of Harvest, 1934.

Harvest Date.	Fruit Size Group.	Tree Nos.	Total Solids By Tree	Total Solids Average	Per Cent Water By Tree	Per Cent Water Average	Reducing Substances By Tree	Reducing Substances Average	Sucrose By Tree	Sucrose Average	Total Sugars By Tree	Total Sugars Average	Starch By Tree	Starch Average	Total Nitrogen By Tree	Total Nitrogen Average
August 23.	Medium	2	18.02		81.98		32.45		24.69		57.14		0.38		.37	
		26	18.77	18.40	81.60	81.60	32.91	32.68	23.70	24.20	56.61	56.88	0.69	0.54	.49	.43
	Small	2	24.36		75.64		24.81		23.06		47.87		0.21		.27	
		26	18.35	21.36	81.65	78.64	33.68	29.24	29.88	26.47	63.56	55.72	0.21	0.21	.41	.34
August 30.	Medium	4	16.52		83.48		44.86		23.98		67.88		0.65		.36	
		27	18.28	17.40	81.72	82.60	41.11	42.98	24.95	23.98	66.06	66.96	0.22	0.43	.34	.35
	Small	4	16.77		83.23		42.83		24.01		66.84		0.40		.36	
		27		16.77		83.23		42.83		24.01		66.84		0.40		.36
September 6.	Medium	22	18.88		81.12		39.25		20.14		59.39		4.74		.36	
		33	18.25	18.56	81.75	81.44	43.56	41.40	21.51	20.82	65.07	62.22	0.22	2.48	.36	.36
	Small	22	19.04		80.96		35.52		23.36		58.88		1.57		.35	
		33	18.22	18.63	81.78	81.37	43.34	39.43	22.19	22.78	65.53	62.21	0.53	1.05	.35	.35
September 13.	Large	19														
		28	17.21	17.21	82.79	82.79	31.99	31.99	30.92	30.92	62.91	62.91			.34	.34
	Medium	19	16.74		83.26		42.41		22.26		65.03		1.06		.34	
		28	17.30	17.02	82.70	82.98	31.32	36.86	31.23	26.74	62.55	63.60	0.96	1.01	.35	.34
	Small	19	17.23		82.77		31.36		33.48		65.09		1.26		.39	
		28		17.23		82.77		31.36		33.48		65.09		1.26		.39
September 20.	Large	11	16.84		83.16		37.59		19.31		56.90		3.76		.31	
		18	17.14	16.99	82.86	83.01	37.05	37.32	20.71	20.01	57.76	57.33	0.16	1.96	.24	.28
	Medium	11	16.98		83.02		37.15		21.84		58.99		0.38		.25	
		18	17.02	17.00	82.98	83.00	38.72	37.96	19.76	20.80	58.53	58.76	0.08	0.23	.20	.22
September 27.	Large	30	15.64		84.36		39.87		21.35		61.22		1.21		.63	
		20	17.71	16.68	82.29	83.32	35.86	37.86	19.69	20.52	55.55	58.38	2.86	2.03	.63	.63
	Medium	30	16.17		83.83		35.99		18.24		54.23		1.35		.66	
		20	16.48	16.32	83.52	83.68	36.02	36.00	19.33	18.78	55.35	54.78	1.20	1.27	.76	.71

TABLE XXIV — Per Cent Composition on the Dry Weight Basis by Trees and Size Groups and Average for the Size Groups of Certain Chemical Constituents of Jonathan Fruit at the Weekly Harvest Intervals, 1934.

Harvest Date.	Fruit Size Group.	Tree Nos.	Total Solids		Per Cent Water		Reducing Substances		Sucrose		Total Sugars		Starch		Total Nitrogen	
			By Tree	Average	By Tree	Average	By Tree	Average	By Tree	Average	By Tree	Average	By Tree	Average	By Tree	Average
August 27.	Medium	8	15.76		84.24		48.08		2.34		50.51		4.31		.49	
		34	16.24	16.00	83.76	84.00	49.29	48.68	0.13	1.28	49.42	49.96	7.12	5.72	.52	.50
	Small	8	16.18		83.82		50.02		0		49.97		8.60		.52	
		34	16.32	16.25	83.68	83.75	38.76	44.39	11.63	5.86	50.39	50.18	5.56	7.08	.46	.49
September 3.	Large	3	15.91		84.09		44.54		20.33		64.87		4.74		.39	
		16	16.14	16.03	83.86	83.97	33.67	39.11	27.32	23.82	60.99	62.93	4.96	4.86	.49	.44
	Medium	3	16.79		83.21		35.15		25.89		62.04		3.98		.48	
		16	16.86	16.82	83.14	83.18	40.60	37.88	18.44	22.16	59.04	60.54	5.31	4.81	.44	.46
	Small	3	17.00		83.00		44.59		15.56		60.15		1.61		.57	
		16	17.00	17.00	83.00	83.00	44.49	44.54	16.78	16.17	61.27	60.71	6.05	3.83	.57	.57
September 10.	Large	1	15.89		84.11		45.57		19.25		64.82		1.43		.35	
		11	15.32	15.61	84.68	84.39	46.36	45.96	19.75	19.50	66.11	65.46	1.67	1.56	.62	.48
	Medium	1	15.80		84.20		44.92		15.32		60.24		1.98		.40	
		11	15.35	15.58	84.65	84.42	45.13	45.02	16.42	15.87	61.55	60.90	1.34	1.65	.39	.40
	Small	1	16.23		83.77		43.74		16.02		59.76		0.37		.38	
		11	15.20	15.72	84.80	84.28	47.50	45.62	13.85	14.94	61.35	60.56	1.00	0.68	.58	.48
September 17.	Large	5	15.50		84.50		48.33		20.23		68.56		2.33		.37	
		36	15.60	15.55	84.40	84.45	49.68	49.00	21.95	21.09	71.63	70.10	0.12	1.22	.56	.46
	Medium	5	15.18		84.82		49.77		20.80		70.57		0.11		.52	
		36		15.18		84.82		49.77		20.80		70.57		0.11		.52
	Small	5	15.91		84.09		50.81		23.26		74.07		0.18		.51	
		36	14.39	15.15	85.61	84.85	56.86	53.84	19.26	21.26	76.12	75.10	2.20	1.19	.48	.50
September 24.	Large	4	15.09		84.91		36.69		32.69		69.38		0.52		.32	
		35	16.26	15.68	83.74	84.32	46.23	41.46	27.73	30.21	73.96	71.67	0.13	0.33	.33	.32
	Medium	4														
		35	15.61	15.61	84.39	84.39	48.15	48.15	16.39	16.39	64.54	64.54	0.34	0.34	.29	.29
	Small	4	15.64		84.36		51.95		10.07		62.02		0.62		.55	
		35	15.84	15.74	84.16	84.26	50.59	51.27	22.40	16.24	72.99	67.50	0.09	0.36	.55	.55
October 1.	Large	22	16.75		83.25		45.76		21.89		67.65		0.13		.37	
		32	16.26	16.50	83.74	83.50	44.07	44.92	24.51	23.20	68.58	68.11	0.30	0.22	.34	.36
	Medium	22	15.47		84.53		51.52		9.91		60.43		0.31		.38	
		32	16.12	15.80	83.88	84.20	44.21	47.86	26.13	13.02	70.34	65.38	0.11	0.21	.38	.33

TABLE XXV -- Percent Composition on the Dry Weight Basis by Trees and Size Groups and Weighted Average for the Size Groups of Certain Chemical Constituents of Jonathan Fruit after Storage from the Time of Harvest to the End of November, in Relation to the Time of Harvest, 1934.

Harvest Date.	Fruit Size Group.	Tree Nos.	Total Solids By Tree	Total Solids Average	Per Cent Water By Tree	Per Cent Water Average	Reducing Substances By Tree	Reducing Substances Average	Sucrose By Tree	Sucrose Average	Total Sugars By Tree	Total Sugars Average	Starch By Tree	Starch Average	Total Nitrogen By Tree	Total Nitrogen Average
August 27.		8	16.26		83.74		44.54		18.36		62.90		.81		.34	
	Medium	34	16.16	16.21	83.84	83.79	49.00	46.77	18.84	18.60	67.84	65.37	.38	.59	.58	.46
		8	16.46		83.54		48.01		20.08		68.09		.49		.58	
	Small	34	16.54	16.50	83.46	83.50	49.14	48.58	16.33	18.20	65.47	66.78	.96	.72	.34	.46
September 3.		3	16.71		83.29		52.65		18.06		70.71		.95		.50	
	Medium	16	17.01	16.86	82.99	83.14	45.54	49.10	8.48	13.72	54.02	62.37	.50	.72	.62	.56
		3														
	Small	16	17.65	17.65	82.35	82.35	47.15	47.15	18.73	18.73	65.88	65.88	1.15	1.15	.66	.66
September 10.		1	15.96		84.04		47.11		16.94		64.05		0.20		.58	
	Large	11	13.43	14.70	86.57	85.30	58.80	52.96	16.89	16.92	75.69	69.88	0.04	0.12	.46	.52
		1	15.02		84.98		48.05		18.72		66.77		0.10		.37	
	Medium	11	15.48	15.25	84.52	84.75	50.26	49.16	16.28	17.50	66.54	66.66	0.04	0.07	.32	.34
		1	15.41		84.59		49.34		4.08		53.42		0.19		.41	
	Small	11	15.73	15.57	84.27	84.43	49.04	49.19	15.56	9.82	64.60	59.01	0.07	0.13	.33	.37
September 17.		5	14.70		85.30		49.41		16.56		65.97		0.95		.38	
	Large	36		14.70		85.30		49.41		16.56		65.97		0.95		.38
		5	15.50		84.50		51.93		20.15		72.08		0.37		.51	
	Medium	36	16.22	15.86	83.78	84.14	50.42	51.18	14.79	17.47	65.03	68.65	0.37	0.37	.38	.44
		5														
	Small	36	15.84	15.84	84.16	84.16	52.05	52.05	18.79	18.79	71.02	71.02	0	0	.52	.52
September 24.		4	14.96		85.04		48.60		18.92		67.52		0.07		.32	
	Large	35	15.47	15.22	84.53	84.78	34.33	41.46	34.56	26.74	68.69	67.93	0.04	0.06	.38	.35
	Medium	4	15.40		84.60		52.94		19.16		72.10		0		.51	
		35	15.64	15.52	84.36	84.48	35.01	43.98	30.38	24.78	65.39	68.76	0.20	0.10	.33	.42
October 1.		22														
	Large	32	16.24	16.24	83.76	83.76	52.36	52.36	25.32	25.32	77.68	77.68	0.04	0.04	.57	.57
		22	17.45		82.55		50.54		19.79		70.33		0.07		.57	
	Medium	32	16.13	16.79	83.87	83.21	48.57	49.56	10.01	14.90	58.58	64.46	0.07	0.07	.53	.55

TABLE XXVI -- Per Cent Composition on the Dry Weight Basis by Trees and Size Groups and Weighted Average for the Size Groups of Certain Chemical Constituents of Jonathan Fruit after Storage from the Time of Harvest to the End of January, in Relation to the Time of Harvest, 1934.

Harvest Date.	Fruit Size Group.	Tree Nos.	Total Solids		Per Cent Water		Reducing Substances		Sucrose		Total Sugars		Starch		Total Nitrogen	
			By Tree	Average	By Tree	Average	By Tree	Average	By Tree	Average	By Tree	Average	By Tree	Average	By Tree	Ave.
August		8	16.13		83.87		51.02		17.33		68.35		0		.48	
27.	Medium	34	16.76	16.44	83.24	83.56	52.61	51.82	14.04	16.14	67.55	67.96	0	0	.54	.51
		3	16.86		83.14		58.44		6.52		64.96		.13		.43	
	Medium	16		16.86		83.14		58.44		6.52		64.96		.13		.43
September																
3.		3	17.51		82.49		57.35		14.34		71.69		.46		.41	
	Small	16	17.00	17.26	83.00	82.74	55.77	56.56	13.58	13.96	69.35	70.52	0	.23	.46	.44
		1	16.04		83.96		54.25		17.30		71.55		.10		.50	
	Large	11		16.04		83.96		54.25		17.30		71.55		.05		.50
September																
10.		1	16.23		83.77		55.08		16.62		71.70		0		.43	
	Medium	11	16.02	16.12	83.98	83.86	56.18	55.63	15.06	15.84	71.24	71.47	0	0	.41	.42
		1	16.23		83.77		52.81		14.15		70.33		0		.44	
	Small	11	16.07	16.15	83.93	83.85	54.88	53.84	16.52	15.34	71.40	69.18	0.04	0.02	.42	.43
		5	15.51		84.49		55.77		14.35		70.12		0		.56	
	Large	36		15.51		84.49		55.77		14.35		70.12		0		.56
September																
17.		5	14.95		85.05		55.40		16.86		72.26		0		.52	
	Medium	36	16.01	15.48	83.99	84.52	54.64	55.03	16.63	16.74	71.27	71.77	0	0	.50	.51
		5														
	Small	36	15.14	15.14	84.86	84.86	61.45	61.45	13.38	13.38	74.83	74.83	0	0	.50	.50
		4	15.66		84.34		57.46		15.80		73.26		0		.44	
	Large	35	16.64	16.15	83.36	83.85	51.92	54.69	16.66	16.23	68.58	70.92	0	0	.44	.44
September																
24.		4	15.70		84.30		58.17		14.94		73.11		0		.44	
	Medium	35	15.83	15.76	84.17	84.24	58.44	58.30	14.06	14.50	72.50	72.80	0	0	.47	.46
		22	18.03		81.97		49.25		17.79		67.04		0		.44	
	Large	32	15.95	16.99	84.05	83.01	52.97	51.11	17.67	17.73	70.64	68.84	0	0	.49	.46
October																
1.		22	18.29		81.71		49.50		18.28		67.78		0		.46	
	Medium	32	16.47	17.38	83.53	82.62	53.90	51.70	16.67	17.48	70.57	69.18	0	0	.46	.46

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