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MATURITY AND STORAGE STUDIES WITH APPLES IN RELATION TO THE SUBSEQUENT DEVELOPMENT OF EDIBLE AND KEEPING QUALITIES

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INTRODUCTION

The stage of maturity* at which an apple is harvested is most important in determining its subsequent life. Of the numerous factors influencing the quality of many varieties of apples during storage and subsequent handling, perhaps none so largely pre-determines the development of proper flavor and freedom from many physiological diseases as the proper stage of maturity at harvest.

Formerly, during years of export demand for apples, consumer preference for small sized apples and the better prices received from early sales led growers to sell certain varieties, especially Jonathan and Grimes Golden, at an immature stage. Such fruits prematurely harvested often reached their destination in an unattractive and unpalatable condition.

For grower and consumer protection, grade standards for U.S. No. 1 apples demanded that the fruits should be of such maturity at harvest to insure the proper completion of the ripening process during subsequent handling. Since this stage of maturity was more clearly defined by the subsequent storage quality than by any known index used during the harvest period, the general judgment of maturity at harvest by the grade inspectors sometimes led to friction between the Inspection Service and the growers. If there were available some reliable harvest index that would

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*The term "mature" or "maturity" is used in these studies in reference to those ripening processes in progress while the fruit remains on the tree. "Ripening" refers to those same changes after the fruit is picked.

reflect differences in fruit maturity resulting from differences in growth status of the orchards concerned, as well as accurately forecast keeping qualities of the fruits, then the development of proper shipping and storage quality could be assured to the ultimate benefit of both the grower and the consumer.

Prior to the inauguration of this study, previous work at Maryland (25,28) showed several commonly accepted maturity measurements either to fail in forecasting differences in keeping qualities, or to be unreliable in determining small differences in fruit maturity. Included in these trials upon Jonathan and Grimes were the pressure test, the electrical maturity test, the index figure test, ground color changes, percentage of blush on Jonathan and quantitative and qualitative starch determinations. Only the starch tests and color development showed sufficiently high correlations with storage quality of Jonathan to prove worthy of further test. The qualitative starch test had an additional advantage in that it was simple and easily enacted and understood.

The purpose of the maturity studies with Jonathan herein reported has been to test the qualitative starch method under the range of Maryland conditions. Taken into consideration during a three-year period have been nutritional level or growth status of the trees, and such orchard practices or conditions which might be considered to influence the time of fruit maturity.

Since Hesse and Hitz (26) have shown premature harvest of Grimes Golden not to reflect as much in poor flavor development as in storage wastage caused by wilt and superficial scald, the control of this wastage is the primary reason for proper maturity at harvest. If control measures for wilt and scald, other than harvest at exactly the proper stage of maturity, could be used commercially, this variety could flow into trade and storage channels at earlier and longer periods than are now employed.

Golden Delicious is a variety of apple highly valued for its dessert qualities. Unfortunately the epidermis of this variety is not particularly efficacious in protecting against moisture loss, and in the course of commercial handling, this variety often loses considerable turgidity. If this moisture loss could be prevented or reduced, the fruit might enjoy a more enviable position in the fruit industry. The purpose of the waxing studies herein reported has been to study the effects of wax emulsions in controlling storage wilt of Grimes Golden and Golden Delicious apples picked at progressive harvest dates.

LITERATURE REVIEW

Since apple maturity as influencing storage quality, and as influenced by nutritional levels and growth status of the orchard, have long been studied, a voluminous amount of literature has accumulated. Because there are available several publications or reports (25,26,28) which have discussed this literature, only that considered pertinent to the subject is here considered.

Of the many tests to guage apple maturity those which appeared more promising for Maryland conditions were reported by Hesse and Hitz (25,26,28). They concluded that only the starch-iodine test, when compared with the pressure test, the electrical maturity test, the index number test and blush changes yielded results worthy of further or complete trial.

The method of determining the starch content in halved apple fruits by exposure to iodine was first used by Bigelow, Gore and Howard (5) in noting the starch changes in certain summer varieties. Although they stated the starch loss to be very uneven in the varieties they studied, more significant is their detailed description of the pattern of starch loss in the apple. Askew (2) used this qualitative method to follow starch behavior during growth and ripening of Jonathan and Dunn's Favorite. Although he noted the location of starch loss in maturing fruits, he did not suggest the method for use as an index of maturity.

Although this qualitative method has been tested in various apple-producing sections, not all of the conclusions have been in agreement. As an indication of proper time of picking, Smith (50) found the test beneficial in the control of bitter pit in certain English varieties. Using the method, he was able to guage harvests at sufficiently late stages to preclude the development of the disease.

In agreement with Smith's work, denoting successful application of the qualitative starch test as an indication of maturity, is the work of Davis and Blair (12) with McIntosh and Fameuse. With both varieties starch hydrolysis showed a definite pattern, as revealed on halved apples dipped in a prepared iodine solution. Based on different stages of the hydrolysis as shown by photographs, they prepared a standard for the proper harvest stage of those two varieties. However, they mention that fruits of apparently the same stage at harvest may not behave alike in storage. This was thought possibly due to different nutritional levels of the tree.

Hinton (27), following an extensive study of this index with English varieties, found that fruits grown under different cultural conditions, but showing the same starch content at harvest, behaved differently in storage. This result and the observation that apples from cultivated plots lost starch more rapidly than those from grassed plots led to the conclusions that an accurate maturity index would take into account the ripening rate, as shown by the starch test, and the content of dry matter and sugars as indicated by the sucrose-hexose ratio. From studies in conjunction with these he did not find catalase and oxidase activity, pressure test, weight and size changes, nitrogen content, acid hydrolyzable materials, sucrose and reducing sugars to have any additional roles as possible indices of maturity.

Studies of the method with New Zealand varieties led Tiller (55) to conclude that the qualitative starch test was unsatisfactory. His complaint against the test was due to the high variability between fruits within samples of Jonathan and Cox Orange. He suggested that the variation might prove so great as to mask the effect of the time factor upon starch hydrolysis.

Eaves (17) reported little success in attempting ".....to correlate maturity by means of the starch test with fertilizer application." Development of scald in storage served as the criterion for the determination of best maturity.

Since well-colored fruits have often been found less susceptible to certain physiological diseases commonly associated with immaturity, development of overcolor has often been used to guage proper time of harvest. Brooks, Cooley and Fisher (7), Plagge, Maney and Pickett (44), Ramsay et. al. (46) and others (17,18,51) have found superficial scald less prevalent on well-colored fruits and upon blushed cheeks of fruits with less color. Verner (57) however, considered the influence of color upon scald as only coincidental with maturity. He found immature fruits of high color to scald worse than fruits of later pickings with less color. Although scald, bitter pit (50) and soft scald (44) have often been encountered less on well-colored fruits, studies of red color development under various conditions by numerous workers have invariably led to the conclusion that this is not a satisfactory index of maturity.

Among growers and apple dealers particularly, it has been thought that the fertilizer and cultural practices may affect fruit quality. At one time fruits from orchards which were known to have been fertilized with nitrogen suffered a loss of premium on the market due to the belief of a detrimental effect of the fertilizer upon shipping and keeping quality. Of the reported research almost all has been unanimous in reporting no commercially significant differences in storage quality, providing fruits were at the same level of maturity at harvest. From an extensive study of the effect of nitrogen and potassium fertilizers upon firmness and keeping quality, Degman and Weinberger (14) reported ".....it has been impossible to find any direct influence of nitrogen on firmness or keeping quality....." on apples in Maryland. They did find an increased percentage of total nitrogen in the fruits from the nitrated trees, which, although accompanied by a higher respiration rate in storage did not cause greater breakdown. They emphasize that their conclusions are based upon apples of equal size, color and maturity and suggest the nitrogen application, unless used in conjunction with good orchard practices might have an adverse effect upon those characteristics. Gourley and Hopkins (22) reported nitrogen applications to be followed by fruits of increased size, less color and greater susceptibility to scald. Respiration rate of fruits in storage was not influenced by nitrogen application nor could Jonathan breakdown be induced by the fertilizer treatment. Overley and Overholser (40) agree with Degman (13) that comparable Jonathan samples from nitrated and check trees do not show differences in their softening rate or keeping quality. However, they point out that nitrogen application causes larger sized apples under most conditions and that these larger fruits were found softer and more susceptible to Jonathan breakdown and soft scald. Here again the effect of nitrogen is indirect in that the differences in keeping quality of the fruits are attributed to differences in amount or vigor of foliage. These results indicating the small influence of nitrogen on keeping quality are in agreement with the work of

Knowlton and Hoffman (32) on varieties of the Winesap group and with that of Magness and Overley (37) on Jonathan, and others (1,4,21,33,48).

Although nitrogen applications may in some instances increase color (1), it is generally agreed by many workers (17,22,37,40,41) that in most cases nitrogen applications are accompanied by a retardation in development of color. Although an increased total nitrogen content of the fruits might also be present, the decreased color has seldom been directly attributed to the nitrogen content. Recently, Magness et. al. (34) found a relationship between nitrogen content of twigs and leaves and fruit color which they believed indicative of a retarding influence of nitrogen. From analysis of twigs of one hundred and five young, bearing Rome trees receiving nitrogen at different times during the year, a regression of -51.6 of color on nitrogen content of twigs was computed. On eleven trees which had received soluble nitrogen just after petal fall or immediately following cessation of terminal elongation, they found a "relatively high" nitrogen content and a color value not only below the group average but also "below the expected color based on the nitrogen content of the leaves." The poorer color of this group was attributed to a direct nitrogen influence rather than to greater growth and shading. They suggest, however, that young trees are most responsive to nitrogen application and that, although this nitrogen-color relationship probably has wide application, the exact duplication of results might be prevented by various orchard conditions.

In connection with studies attempting to increase the color development of apples Dustman and Duncan (16) have recently identified the red pigment as idaein, a glycoside yielding cyanidin and galactose upon hydrolysis. To determine the effect of certain thiocyanate compounds upon color formation, they sprayed apple trees with soluble forms of these materials.

For fall varieties, spraying with .05-2.0 percent solutions in August caused an improvement in both red and yellow color. The increased ground color, resembling that of more mature fruit, was suggested to be of possible value in reducing storage losses from superficial scald.

Although many workers have indicated that nitrogen may delay fruit maturity (13,37,40), the only factual evidence is presented by Verner (57). Using scald development in storage as a measure of fruit maturity at harvest, he emphasized that the increase of overcolor was only coincidental with maturity in determining subsequent scald development. He stated that the percent scald on Yorks, ".....picked on October 14 from the fertilized trees was no greater than in the fruit picked one week earlier from the check trees, despite the fact that there was still great contrast in color development."

There is considerable evidence that trees receiving nitrogen respond with increased fruit size (1,4,14,32,33,57). Most of the workers have also reported an increased nitrogen content in the fruit from treated trees, which may have an influence upon keeping quality. Wallace (58) found grassed plots in England to yield fruits of a lower nitrogen content and longer storage life than fruits from cultivated plots. Haynes and Archbold (23) found in English varieties that samples of high nitrogen and lowered carbohydrate content to have a decreased storage life. Aldrich (1) says that the nitrogen content can be increased slightly without a deleterious effect upon storage quality, but explains this as probably due to a higher amount in the seeds rather than in the flesh of the fruits. Gourley and Hopkins (21) and Lagasse (33) found increases of 100 and 18 percent in nitrogen content of fruit respectively, to have no detrimental effect upon storage quality, and Lagasse further states that the increase in the nitrogen content of the seeds was insignificant.

Degman (13,14) reported an increased nitrogen content of fruit which was proportional to the amount of nitrogen applied. Although he found an increased amount of starch and total carbohydrates accompanying the higher nitrogen content in York, the opposite was true with Stayman Winesap. The higher nitrogen content was not reflected in poorer keeping quality. Gourley and Hopkins (21) found a "somewhat higher" total sugar content in samples from check and low nitrogen trees. Wallace (58) showed an increased percentage of dry matter from his cultivated plots which also had the higher nitrogen content. The influence of nitrogen treatment may or may not, through its influence upon total dry matter influence a qualitative test of starch content such as the test used in this study.

With Grimes Golden the chief storage disorder following premature picking is the more frequent occurrence of certain physiological diseases in storage. The limits of the harvest season in which this variety will develop standard storage quality are wider than for the Jonathan variety (25,28). If, by some treatment previous to cold storage, Grimes apples could be protected against excessive moisture loss, the picking season could be considerably extended to the ultimate benefit of the commercial grower.

Magness and Diehl (35) found that respiration, the rate of softening, ground color changes and other ripening processes in winter varieties of apples could be retarded by coating apples with oils and paraffines to reduce the permeability of the epidermis. The degree of retardation was directly proportional to the quantity of the coating material. They found, however, that with the heavier coatings undesirable flavors, resulting from anerobic respiration, were common. They concluded that coatings of such materials sufficiently concentrated to significantly retard the ripening process would cause undesirable flavors in stored fruit. Smock (52) used a water soluble wax with a carnauba-paraffin base on Gravenstein and Yellow Newtown and concluded that waxing apples and pears was not satisfactory under all conditions. After the fruits were waxed, the physiological changes taking place over a relatively short period at high temperatures were measured. The wax emulsions, used at full manufacturer's concentrations, reduced the ripening processes, but there always resulted an unpalatable flavor caused by anerobic respiration. He suggested, however, that waxing might be applicable if greater dilutions and lower storage temperatures were used. He observed considerably less wilt and a reduced scald on some of the waxed samples.

Miller, Neilson and Bandemer (38) in an experiment of a preliminary nature found undesirable breakdown in apples dipped in paraffin. However, fruits dipped in a paraffin wax, emulsified with ammonium linoleate supplemented with bentonite or ball clay, had a reduced shrinkage when compared with check fruits. No off flavors, scald or breakdown resulted from the waxing treatment.

Although "Dowax" at various dilutions reduced shrivelling, Jones and Richey (30) found the emulsions to leave an objectionable deposit and to shorten the storage life of Grimes and Gano. The shortened storage life resulted from a "burning" caused by the wax.

Platenius (45) measured the thickness of dry wax films which were obtained when vegetables were dipped in various miscible waxes. He found the wax coating to be very thin, averaging one to two microns, which, he concluded, did not seriously affect natural gaseous exchange.

Hitz and Haut (29), using the same carnuaba-paraffin wax used by Smock (52) and at the greater dilutions suggested by him, found that with Grimes Golden apples, waxing reduced the weight loss during storage and also the number of fruits graded out because of wilt after 21 weeks of cold storage. It was found, however, that waxing fruits immediately after picking apparently increased the susceptibility of those apples to scald as compared with unwaxed samples of the same storage treatment.

Smock (53) in 1939 reported that carnuaba-paraffin waxes of a slightly different formula from the wax used previously, materially reduced the wilt of apples in storage, especially when fruit was held under conditions of low humidities. The effect of the wax upon scald was seemingly dependent upon fruit maturity, and he remarks, ".....when the fruit was picked at the time of commercial harvest, it (the wax) never significantly increased the amount of scald at any concentration."

Fisher and Britton (19), although making no mention of the difficulty of maintaining extremely high humidities in commercial storages, as well as preventing the growth of certain fungi, reported that during the storage period, storage humidity was a more important factor than waxing with a carnuaba-paraffin wax in determining weight loss in storage. However, during the period after removal from cold storage, waxed samples had an average daily weight loss of fifty-six percent of the unwaxed fruits. Generally, the waxing treatment increased scald and reduced the rate of respiration. Further evidence of a retarded ripening process was indicated by the delay of mealiness of Delicious, coreflush in McIntosh and Jonathan spot in Jonathan, all generally associated with over-ripeness in these varieties.

Even though it were feasible to employ high relative humidities to prevent moisture loss during storage, there is little possible control of humidity during the period after fruit leaves storage and before it is consumed. Smock (53), Claypool (10) and Hitz and Haut (29) have suggested that during this period, when low humidities are often encountered, waxing may prove extremely beneficial in preventing moisture loss.

Claypool (10) suggested that the benefit of waxing fruits results from a reduction in moisture loss, thereby maintaining good condition and eating quality for a longer period. He found waxes to improve the keeping quality or appearance of pears, apples, peaches, nectarines, and cherries.

Prior to the use of oil paper and wraps in controlling scald, the loss from this disorder was tremendous. Brooks, Cooley and Fisher (7) found the severity of attack to be influenced by many conditions or factors of which proper harvest maturity was very important. Plagge, Maney, and Pickett (44), for control of scald, recommended that fruit be picked in a mature stage, graded, packed with oiled paper or wraps and stored immediately at a temperature of 35 - 36°F. promptly after picking. They reported any delay in cold storage to be detrimental to scald control. Brooks, Cooley, and Fisher (7) considered any delay in storage to adversely influence scald development, but they mention cases when less scald was found on delayed samples of Grimes Golden, especially if the fruits were well ventilated during the period of delay. Their recommendations for scald control (8) do not show delayed storage to be of benefit in any variety.

Eaves and Hill (18) did report considerably less scald development on immature McIntosh which had been held above cold storage temperatures for two weeks before cold storing.

There is the same lack of agreement in the effect of delaying cold storage on other physiological disorders of apples. Plagge and Maney (43) found delayed storage would both increase and decrease soggy breakdown of Grimes Golden in storage, depending upon the fruit maturity at harvest. Compared with immediate storage, Brooks and Harley (9) found a 3-6 day delay period to double the amount of a similar low temperature breakdown of

Jonathan in storage. Conversely, this latter disorder was lessened by delayed storage in the work of Trout and Tindale (56).

Although parasitical rots and diseases are increased by delaying fruit before cold storage, (24,44,46,48) and Jonathan and Baldwin Spot may be more severe (44,48), Rasmussen (47) found a five-day delay to reduce wastage at the end of storage of New England McIntosh. He adds, however, that apples so treated would probably not last as long on the retail stands as apples placed in cold storage sooner. A longer delay period, two weeks, was found to adversely affect the storage life of varieties of the Pacific Northwest by Ramsey, et. al. (46).

Perhaps the best explanation of the influence of delay before cold storage upon the development of certain physiological disorders is given in results secured by Kidd and West (31). They state that with maturity, apples approach a climateric in respiratory activity. The more nearly complete this climateric the less was the scald attack. Delaying storage on apples, which had been picked before their climateric, was found beneficial in reducing scald. Storing apples at the peak of the climateric was found to increase their susceptibility to low temperature breakdown. Thus it can be seen that the influence of delay before storage may possibly be a function of the respiratory activity at time of picking, and that the results secured from delayed storage dependent upon relative stage of fruit maturity.

MATERIALS AND METHODS

General Methods

For both the maturity and waxing studies, storage behavior and the development of optimum edible quality during cold storage served as standards for evaluating the efficacy of any given treatment. The storage room was cooled by diffusion-type storage equipment with Freon used as the refrigerant. Storage temperatures approximating 32°F. were maintained. The samples were packed in oiled paper, and when placed in storage, were packed in one-half bushel open hampers which were placed in open orchard lug boxes to facilitate stacking.

The determination of storage quality was similar in all studies. After a storage period varying from twenty to twenty-two weeks, the fruits were graded for rots, wilt and scalded fruit, counts being made of the number of fruits falling in each class. Fruits showing physiological breakdown were counted as rots, but in a separate category from parasitical rots. Fruits were considered wilted when the wilt was apparent either by sight or by a characteristic feel when handled. Scalded fruit, whenever the disorder was sufficiently heavy, was divided into "slight and severe" categories. All scald was considered slight until enough of the surface, approximately fifty percent, was covered to seriously influence the marketability of the fruit. A scald value was determined by formula to weigh the degree of severity: $\frac{1 \times \text{slight scald} + 2 \times \text{severe scald}}{\text{Total number of fruits in sample}}$.

Methods Incident to the Qualitative Starch Index Studies with Jonathan

The qualitative starch test as a maturity index is based upon the reaction between starch and iodine. It is well known that as the apple matures there is a decrease in the starch content. To follow this change twenty apples were halved transversely. One-half of each apple was rinsed in water and placed, cut surface down, in a shallow dish of IKI solution at a concentration of 0.25 grams of iodine and 1 gram of potassium iodide per hundred cubic centimeters of water. The halved apples were allowed to remain in the solution for one minute. After removal they were allowed to dry approximately five minutes before comparison with the pattern chart, Figure 1, adapted for Jonathan from the Davis and Blair (12) chart for Fameuse and McIntosh.

In addition to the qualitative starch test observations were made upon ground color and percent blush.

Field Plots and Methods Used in 1938 Studies

Since Auchter (3) had shown there was little cross-transfer of nitrogen in apple trees, it was thought half-tree nitrogen applications might reveal closer differences in tree nutrition than could otherwise be obtained.

Jonathan trees furnishing fruits for the maturity studies were located in commercial orchards at Colesville and Frederick, Md. At Colesville six trees of approximately twenty-five years old and of relatively uniform size and vigor were selected. Fertilizer was applied to whole and half trees as shown in Table I. At Frederick four trees of comparable growth and vigor were selected. Fertilizer treatment of these trees is also shown in Table I. In both orchards rainfall within a few days of application was sufficient to make the materials available.

Figure 1. Stages of starch conversion in Jonathan as shown by starch IKI reaction.

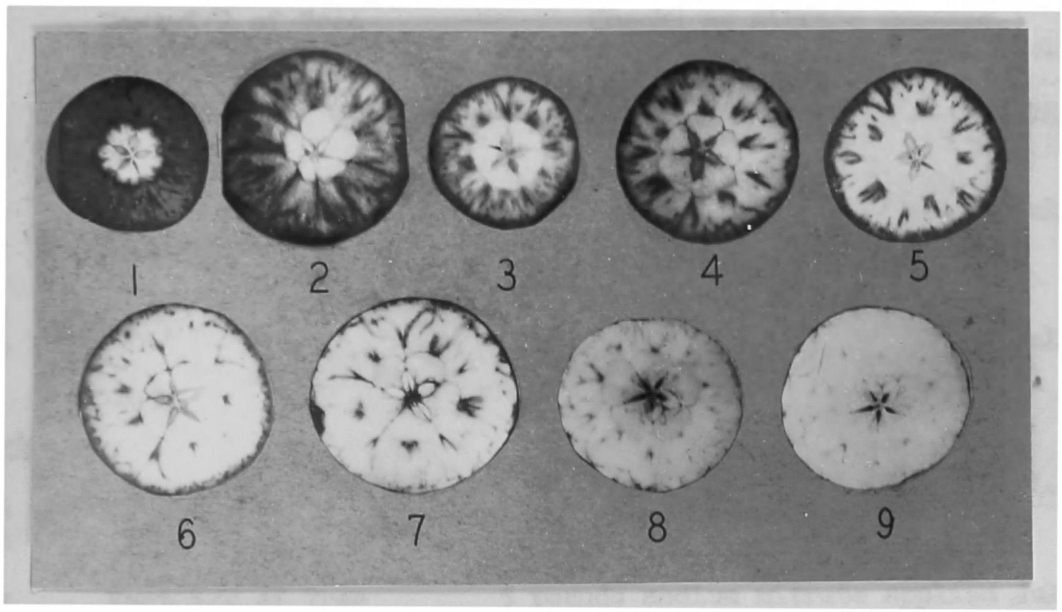


Figure 1

TABLE I

Fertilizer Treatment of Trees Used as Source of Samples for Maturity Studies on Jonathan. Colesville and Frederick Orchard. 1938.

Blocks	Tree	Fertilizer Treatment
Colesville Orchard		
A	East 1/2 of Tree	Check; no nitrate applied
A	West 1/2 of Tree	5 pounds sodium nitrate applied July 31
B	Whole Tree	10 pounds sodium nitrate applied July 31
B	Whole Tree	Check; no nitrate applied
C	Whole Tree	10 pounds sodium nitrate applied July 31
C	Whole Tree	Check; no nitrate applied
D	North 1/2 of Tree	Check; no nitrate applied
D	South 1/2 of Tree	5 pounds sodium nitrate applied July 31
Frederick Orchard		
A	Whole Tree	10 pounds sodium nitrate applied July 31
A	Whole Tree	Check; no application
B	East 1/2 of Tree	5 pounds sodium nitrate applied July 31
B	West 1/2 of Tree	Check; no application
C	East 1/2 of Tree	Check; no application
C	West 1/2 of Tree	5 pounds sodium nitrate applied July 31

Samples for the starch studies were selected twice weekly beginning on August 23 at Frederick and August 24 at Colesville. Samples for storage studies were begun at the same time and were continued at weekly intervals thereafter until four samples had been taken from the Colesville plots and five from the Frederick plots. To aid randomization of sampling a greater quantity of fruits was picked from all parts of the tree than was necessary for the tests. The apples for the tests were then picked at random from the harvested sample.

To test any possible influence of red color or light upon starch conversion and to possibly indicate a correlation between starch content and blush, approximately sixty fruits on each of five trees were enclosed with black muslin bags on August 5. On four different picking dates five fruits were removed from each tree and tested for starch content which was in turn compared to the starch content of the closest adjoining uncovered fruit. At the final picking sufficient bagged fruits remained to allow for a storage sample.

For determination of the nitrogen content of the fruit, thirty representative fruits were selected from each tree under treatment at the time of the final harvest. In preparing for analysis a thin slice was taken from each apple and a sufficiently sized portion of that slice was used to obtain two fresh weight samples of twenty grams each, which was composed of approximately equal portions from each of the thirty apples. These duplicate portions were used for nitrogen determinations. To preserve nitrogen samples until time of determination each twenty-gram sample was sealed in a tin can containing 160 cubic centimeters of hot ninety-five percent alcohol with a small amount of calcium carbonate added. At the time the determinations were made, the contents were filtered and after repeated washings with alcohol, the filtrate was evaporated to almost dryness and total nitrogen determined by the Kjeldahl method. The residue was ground to pass through a forty-mesh screen with a Wiley micro-mill. Total nitrogen content was obtained on one gram of this screened residue by the Kjeldahl method. This method was adopted from Hesse's (25) method with similar material. Nitrogen figures are expressed as the absolute amount in the extract and the amount in one gram of the residue.

Field Plots and Methods Used in 1939 Studies

Studies in 1939 were confined primarily to the Frederick orchard. Jonathan trees comparable in size and vigor and bearing good crops were selected. Tree treatment is given in Table II.

Sampling methods were the same as in 1938, except that four weekly storage samples only were made. Samples for the qualitative starch test in Jonathan were taken twice weekly from August 28 until September 25. Samples for storage studies were selected weekly during the same period.

The 1938 method of obtaining representative samples for nitrogen determinations was again used. However, instead of preserving in alcohol, the duplicate samples from fruits collected September 14, and which had been used for determination of dry weight, were saved and stored in a dry place. At the time the nitrogen determinations were made, the samples were re-dried to a constant weight of within 0.05 grams. The dried sample was ground to forty mesh fineness and stored in a dessicator until used. Total nitrogen was determined on one gram of this material by the Murneek and Heinze (39) modification of the official Kjeldahl-Gunning-Arnold method.

Field Plots and Methods Used in the 1940 Studies

As synthetic growth substances provide a means of prolonging the time fruits can remain on the trees, their use offered an opportunity to study the qualitative starch test over a wider range of fruit maturity. The recent report by Dustman and Duncan (16) suggested that over-color might be

TABLE II

Fertilizer Treatment in 1939 and Fertilizer and Orchard Treatment in 1940 for Jonathan Trees used as Source of Fruit for Maturity Studies.

Frederick Orchard. 1939.

Tree No.	1939 Treatment	1940 Treatment
A_1	10# $NaNO_3$ 7/31	10# $NaNO_3$ 8/1
A_2	Check	0.1% Na thiocyanate 8/12
A_3	5# $NaNO_3$ 7/31, 8/15	10# $NaNO_3$ 8/1; 0.1% Na thiocyanate 8/12; "Fruitone" 9/15
B_1	5# $NaNO_3$ 7/31, 8/15	Check
B_2	Check	0.1% Na thiocyanate 8/12; "Fruitone" 9/15
B_3	10# $NaNO_3$ 7/31	10# $NaNO_3$ 8/1; 0.1% Na thiocyanate 8/12
C_1	Check	"Fruitone" 9/15
C_2	10# $NaNO_3$ 7/31	10# $NaNO_3$ 8/1; "Fruitone" 9/15
C_3	5# $NaNO_3$ 7/31, 8/15	
D_1	10# $NaNO_3$ 7/31	
D_2	5# $NaNO_3$ 7/31, 8/15	
D_3	Check	Check
E_1	Check	
E_2	5# $NaNO_3$ 7/31, 8/15	
E_3	10# $NaNO_3$ 7/31	

increased with sprays of sodium thiocyanate. It was also desirable to know if the starch test would indicate fruit on trees sprayed with thiocyanate to be more mature at any harvest period than similar unsprayed trees, and it was hoped that perhaps the increase in coloration might facilitate scald control, as suggested in the literature (7,16,44).

To take advantage of any cumulative effect of nitrogen treatments, the same trees of the Frederick orchard were used again in 1940. In Table II are presented the 1939 treatments and the 1940 treatments of the same trees.

The thiocyanate treatment consisted of spraying the designated trees with a 0.1 percent solution of sodium thiocyanate solution on August 12. Approximately ten gallons of the solution were applied to each tree.

The synthetic hormones to delay harvest drop were applied in the form of the commercial preparation, "Fruitone", used at the rate of two-fifths pounds per hundred gallons of water. The trees were sprayed by the grower September 14-16 at the rate of ten gallons per tree.

With Jonathan, storage samples and samples for the starch test were taken once weekly. Sampling commenced September 6 and continued through September 26 allowing a total of four storage samples.

In 1940 a supplementary test was conducted to determine the influence of widely varying orchard conditions upon the accuracy of the starch test in forecasting maturity. These studies were comprised of fifteen Jonathan orchards in Western Maryland where variable fertilizer treatment, tree age, general tree vigor and crop sizes prevailed. To provide an index of the growth status of the trees from which the samples were taken in each case, terminal growth from at least ten growing points from five to ten trees was measured. On three picking dates, at weekly intervals, a sufficiently large sample of fruit was picked from each orchard to furnish fruits for the starch test and for studies of subsequent storage behavior.

All storage samples were packed with oiled paper in one-half bushel open hampers and stored as previously described. The samples were graded during the last week of January and again in the third week of February. Storage after the January grading was in a storage room held at 50°F. Palatability tests were also made at the February examination.

Methods Incident to the Waxing Studies with Grimes Golden and Golden Delicious

Preliminary work in 1936 and 1937 (29) at this station had indicated that waxing apples with Brytene 489A to be of value in prolonging storage life, especially from the standpoint of retarding dessication. A more complete study was undertaken to determine the effects of the wax treatment upon weight loss, ripening, storage disorders and general keeping quality of Grimes Golden and Golden Delicious, varieties which are known to wilt badly under some conditions of growth and storage.

Orchard sampling methods were similar each year. On each sampling date fruits were selected at random from a great many trees. Cleaning these samples in a commercial flotation-type washer or in a brush cleaner further randomized the samples. After cleaning, the fruits were placed in one-half bushel open hampers in which they remained during the pre-ripening and waxing treatments and until they were graded at the end of the cold storage periods.

The same method of applying the wax to the apples was used each year. The apples to be waxed were in one-half bushel hampers, and the whole was immersed in the wax solution made at a concentration of one part of the commercially prepared wax to two parts of water. The dipped fruits were allowed to drain and dry overnight before they were placed in storage.

Ten apples were selected from each basket, marked with India ink and weighed. This made it possible to follow the weight changes throughout the pre-ripening and storage periods.

The term "pre-ripening" is hereafter used to designate a treatment of delayed storage whereby the apples were stored in a closed 60°F. room before waxing or cold storing. The length of the pre-ripening period varied in different years.

Cold storage temperatures and conditions have been previously described.

Grading methods at the end of the storage period were the same as those used with the maturity samples, and have been previously described. To remove the effect of unequal storage periods upon the changes following harvest, each sample was examined at a pre-determined number of weeks from the harvest date of that sample rather than at the same date.

Methods Used in the 1938 Waxing Studies

Included in the 1938 studies were samples of Grimes Golden from the Frederick orchard and samples of Golden Delicious collected from a commercial orchard near Ashton, Md. All samples from each orchard were picked once weekly with the exception of the last sampling of Golden Delicious. Because this orchard had been harvested before the time of the last sampling, and the apples placed in common storage by the grower, the samples selected were taken from the storage. Samples at six weekly harvest dates, commencing August 16, were taken from the Frederick orchard, and four from the Golden Delicious orchard commencing August 30. About four bushels of fruits were picked from at least ten trees. After cleaning, these four bushels from each orchard, on each harvest date, were divided into eight equal lots. Four of the eight lots were waxed with Brytene 489A, one lot receiving wax the same day of picking, and the other lots after one, two or three weeks of pre-ripening respectively. After the wax had dried, the samples were placed in cold storage. One of the remaining four lots was placed in cold storage on the same day of picking, and the remaining lots after one, two or three weeks of pre-ripening respectively, to serve as checks to the waxing treatments.

During the storage periods, changes in weight loss were followed by weighing the ten previously marked fruits at five, twelve and twenty-one weeks from harvest and again after the fruits had been exposed to 60°F. for three weeks following the period in cold storage. Samples were graded twenty-one weeks from harvest and again following the exposure to 60°F. or twenty-four weeks from harvest.

Methods Used in the 1939 Waxing Studies

The 1938 results indicated waxing to be beneficial in retarding wilt, but that a week of pre-ripening was necessary before scald could be adequately controlled. In 1939 it was deemed desirable, therefore, to investigate the efficacy of shorter pre-ripening periods upon scald development. It was also believed important to determine whether comparable results could be expected with apples packed in the regular commercial bushel baskets.

To test the shorter pre-ripening periods, approximately eight or nine bushels of fruit were picked from the Grimes trees of the Frederick orchard. On the weekly sampling dates commencing August 14, and continuing until six samples had been picked, the fruits were picked from several trees so that representative samples could be selected for each picking. After the fruits had been cleaned in a brush cleaner, they were divided into sixteen equal lots. Duplicate lots were waxed on the day of picking and after two, four or seven days of pre-ripening. After drying the samples were placed in cold storage. Duplicate check lots were placed in cold storage at the same periods.

Weight changes were followed by weighing ten marked fruits in each lot at various intervals, namely, at the time of harvest, after the pre-ripening treatment or at time of waxing, and when removed from cold storage twenty-two weeks from harvest.

The test of waxing fruits in commercial packages was made on Grimes Golden and Golden Delicious. The Grimes Golden were obtained from the University orchard at Beltsville, Md. at two picking dates. After picking they were cleaned, sorted, and sized so that the apples used were of a two and one-half inch minimum diameter. Enough fruit to furnish twenty packed baskets was picked on September 6 and September 14 and divided into ten equal lots. Duplicate baskets were waxed following picking and after four, seven or fourteen days of pre-ripening. After the fruits had dried they were packed in bushel baskets and placed in cold storage. Duplicate unwaxed check baskets were placed in cold storage after the same periods of pre-ripening. Grading methods were similar to those previously described except that wastage and good fruits were weighed rather than counted.

The test with Golden Delicious was essentially the same. Thirty cleaned, graded and packed baskets of fruit were obtained from a co-operative packing house on September 20. They had been picked two or three days previously and were slightly immature. The baskets to be waxed were unpacked, waxed and repacked according to the pre-ripening schedule previously described for Grimes Golden. Grading methods after cold storage were also the same. In addition two baskets waxed the day of selection, and two unwaxed check baskets were left in the pre-ripening room for six weeks and then graded.

Methods Used in the 1940 Waxing Studies

The 1939 results indicated that, under harvest or storage conditions favoring scald development, the pre-ripening periods previously found beneficial in reducing scald did not always give adequate control. Since an increased ground color, of the type indicating a greater fruit maturity, had been found sometimes beneficial in reducing scald (7), it was desirable to know the effect of the increased ground color resulting from thiocyanate sprays (16) upon the subsequent scald development of waxed apples. The fruit was picked from the Grimes Golden trees of a "Fruitone"-nitrogen-thiocyanate experiment with treatments similar to those used in the maturity studies with Jonathan in 1940. Table III shows the 1939 and 1940 treatments on this block of trees. To remove any possible effect of the "Fruitone"-nitrogen treatments upon the representativeness of the sample, equal amounts were selected from each tree of the treatment and were segregated only by the thiocyanate treatment. Since the experimental trees were of a combination of the three treatments mentioned, any influence of nitrogen or "Fruitone" would have been represented equally in samples selected on the basis of thiocyanate treatment. On each of four harvest dates, approximately three bushels of fruit were picked from the four trees sprayed with thiocyanate and from four unsprayed trees receiving otherwise the same treatments.

After cleaning in a brush cleaner, the fruits of the two lots were divided into six equal parts, and packed in one-half bushel open hampers. One hamper from the thiocyanate lot and one from the unsprayed lot were waxed the day of harvest, and other lots were waxed after four and seven days of pre-ripening. Check hampers from both lots were given the same pre-ripening treatments as the waxed fruits.

TABLE III

Fertilizer Treatment in 1939 and Fertilizer and Orchard Treatment in 1940 of Grimes Golden Trees used as Source of Fruit for Waxing Studies in 1940. Frederick Orchard.

Tree No.	1939 Treatment	1940 Treatment
A_1	5# $NaNO_3$ 7/31, 8/15	10# $NaNO_3$ 8/1; 0.1% Na thiocyanate 8/12; "Fruitone" 9/15
A_2	Check	Check
A_3	10# $NaNO_3$ 7/31	10# $NaNO_3$ 8/1; 0.1% Na thiocyanate 8/12
B_1	5# $NaNO_3$ 7/31, 8/15	10# $NaNO_3$ 8/1; 0.1% Na thiocyanate 8/12; "Fruitone" 9/15
B_2	Check	0.1% Na thiocyanate 8/12
B_3	10# $NaNO_3$ 7/31	10# $NaNO_3$ 8/1
C_1	Check	"Fruitone" 9/15
C_2	10# $NaNO_3$ 7/31	
C_3	5# $NaNO_3$ 7/31, 8/15	
D_1	5# $NaNO_3$ 7/31, 8/15	
D_2	Check	Check
D_3	10# $NaNO_3$ 7/31	
E_1	Check	
E_2	10# $NaNO_3$ 7/31	
E_3	5# $NaNO_3$ 7/31, 8/15	

Methods of following weight changes and grading methods were as previously described. After the grading twenty-one weeks from storage, the samples were held in a room at approximately 50°F. for two weeks, and then re-graded as in previous experiments.

RESULTS

Results Incident to the Maturity Studies on Jonathan

The results of progressive harvest dates, nitrogen treatments, color changes,"Fruitone" and thiocyanate sprays upon the reliability of the qualitative starch test as a maturity index for Jonathan as indicated by the development of edible and keeping qualities during subsequent cold storage are hereinafter presented for each of the years under study.

Results of the 1938 Studies

Table IV reveals that on successive harvest dates at the Colesville orchard there was a progressively improved palatability of storage samples, which had been forecast by the concomitant increased starch conversion at the successive times of harvest. From the table it is evident that good edible quality did not develop in storage if the samples had not reached a starch test of approximately five prior to harvest. There was a decreased wastage, excepting the last harvest, with the higher readings of the starch test. Since throughout the experiment the primary cause of storage wastage was wilt and the increased wilt of late pickings had been adequately explained by Clements (11), the test showed effectiveness in forecasting storage quality. The table also reveals, however, that the difference in wastage which samples from two different trees might develop in storage was not always in proportion to the difference those samples might show in starch content at time of harvest.

Although the nitrate application increased total nitrogen content of fruit, Table V, the mean difference did not prove of statistical significance.

TABLE IV

Starch Test and Percent Blush at Eight Sampling Dates and Development of Waste and Palatability in Storage for Samples from Nitrated and Check Trees. Colesville. 1938.

Harvest Date	Starch Test		Percent Blush		Total Waste		Palatability*	
	NO_3	Check	NO_3	Check	NO_3	Check	NO_3	Check
Aug. 17	1	1	6	5				
Aug. 24	1.6	1.5	25.0	31.2	60.8	54.0	1.0	1.0
Aug. 27	2.0	2.8	21.0	30.2				
Aug. 31	3.0	3.1	32.5	38.2	49.5	54.8	1.5	1.7
Sept. 3	3.6	4.7	40.2	48.2				
Sept. 7	5.1	5.1	52.2	47.5	44.0	37.5	2.1	2.3
Sept. 9	6.4	5.6	55.2	54.9				
Sept. 15		7.0		59.4	53.9	53.0	2.5	2.5

* 1 - Poor; 2 - Good; 3 - Excellent

TABLE V

Effect of Nitrogen Application in Late July Upon Total Nitrogen Content, Color Formation, Starch Loss, and Keeping Quality of Jonathan. Colesville and Frederick Orchards. 1938.

Measurement	Number of Comparisons	Mean of NO_3 Blocks	Mean of Check Blocks	Mean Difference	Sum of Squares	"t" Value	"t" Value for Sign. 5%
Colesville Orchard							
NO_3 Content	4	0.747	0.652	.0945	0.1571	.98	3.18
Blush	28*	33.18	36.46	3.27	4174.00	1.447	2.052
Starch Content	28	3.27	3.42	0.146	34.11	.0693	2.052
Storage Waste	16**	52.25	49.81	2.44	4871.00	0.546	2.131
Frederick Orchard							
Blush	27a/	32.89	30.96	1.93	1298.00	1.47	2.056
Starch Content	30b/	3.05	2.95	0.1	6.52	1.18	2.045
Storage Waste	15c/	60.4	49.2	11.27	2899.00	5.18	2.14

* 7 Sampling dates; ** 4 Sampling dates; a/ 9 Sampling dates; b/ 10 Sampling dates; c/ 5 Sampling dates.

The same table reveals that the effect of nitrate application upon the starch test, color and storage wastage was also insignificant.

Harvest date was more instrumental in determining development of palatability than was the nitrogen treatment, Table IV. The difference that resulted from the nitrogen treatments were almost too small to be discerned by the judges. This was also true with texture, aroma, and appearance, those somewhat immeasurable factors important in determining a suitable or pleasant flavor.

The results at the Frederick orchard largely substantiated the results in the Colesville orchard, Table V. The insignificant differences in blush and starch content are interesting because both were contrary to those shown at Colesville. Compared with the check trees, samples from the nitrated trees showed the higher blush and the greater starch conversion. Also contrary to the insignificant influence of nitrogen upon keeping quality at the Colesville orchard was the significant increase in wastage from the nitrated trees at Frederick. This increased waste was also due primarily to the increased percentage of fruit graded out for wilt.

As revealed in Table VI, there was at the Frederick orchard also a progressively improved palatability with successive harvest dates accompanied by a greater starch conversion at each harvest. However, fair palatability developed in storage samples of the Frederick orchard when the starch test at harvest was approximately three. The best flavor did not develop unless samples had a starch test of approximately four at time of harvest.

The development of wastage in storage was apparently uncorrelated with harvest date and also the starch test at time of harvest. The progressively greater starch conversion accompanying successive picking dates was not reflected in improved keeping quality in storage. It has been previously mentioned that wilt was the primary cause of wastage in storage.

TABLE VI

Starch Test and Color at Progressive Sampling Dates and the Development of Wastage and Palatability in Storage of Samples from Nitrated and Check Trees of the Frederick Orchards. 1938.

Date	Average Starch Test		Percent Color		Total Waste		Relative Palatability*	
	NO_3	Check	NO_3	Check	NO_3	Check	NO_3	Check
8/23	1.0	1.1	9.3	7.3	64.6 ± 7.5	57. ± 5.7	1.0	1.0
8/26	1.4	1.3	20.0	14.0				
8/30	1.2	1.3	21.0	19.0	50.0 ± 6.2	40. ± 3.0	1.7	1.5
9/2	1.9	1.7	30.0	20.0				
9/6	3.1	2.6	38.0	39.0	57.0 ± 4.1	47. ± 5.5	2.5	2.2
9/9	3.0	3.4	46.0	46.0				
9/13	4.0	3.7	59.0	65.0	66.0 ± 4.1	48. ± 2.6	3.0	3.0
9/16	5.5	5.4						
9/21	8.2	8.5	72.0	62.0	65.0 ± 3.5	55. ± 7.5	3.0	3.0

* 1 - Poor; 2 - Good; 3 - Excellent

The results of bagging fruits revealed rather clearly that color development had little relationship to starch loss in Jonathan. Table VII shows the inconsistent differences in starch content of bagged and unbagged fruits.

Table VII

Comparison of the Relative Starch Content in Bagged Jonathan Apples with the Closest Adjoining Unbagged Fruits at Four Harvest Periods. Frederick Orchard. 1938.

Harvest Date	No. Comparisons	Mean Bagged	Mean Not Bagged	Mean Difference	"t" Value	"t" Nec. for Sign.
Sept. 2	24	4.25	3.83	.42	.936	2.06
Sept. 9	26	5.04	4.81	.23	.546	2.06
Sept. 16	28	5.18	5.82	.64	2.36	2.05
Sept. 21	20	8.55	8.34	.21	.789	2.09

In only one case was there a significant difference in starch test between bagged and unbagged fruits. The one exception indicated a greater starch conversion due to bagging. The bagged fruits developed a high ground color, whereas ground color of the unbagged fruits was mostly masked by the over-color. Although the relatively small storage samples in this case would not justify final conclusions, no difference in keeping quality was observed between bagged and unbagged samples picked and put in storage September 21. The palatability of the bagged fruit was equal to the unbagged fruits in the opinion of the judges sampling both.

The 1938 studies at the Colesville orchard revealed the qualitative starch test to be effective in forecasting storage quality, measured by the development of wastage and palatability. With samples from the Frederick orchard, storage wastage, caused primarily by wilt, was apparently uncorrelated with the starch test at harvest. Improved palatability was found on samples which had shown the highest starch tests at harvest, but the development of fair palatability was at a lower starch test than were the Colesville samples. In neither orchard were the nitrate applications significantly influencing the starch test or the development of blush. Bagging fruits did not retard rate of starch conversion.

Results of the 1939 Studies

The studies of this year were somewhat enhanced by storage conditions favoring scald development. During the last part of December the refrigerating machinery ceased operation and before being discovered, conditions prevailed which are generally regarded as optimum for scald development. When the machinery ceased operation, there was no forced ventilation of the fruit and the temperature of the room reached 45° or 50°F. for a period of a week or ten days. Since both the experimental and other fruit from different orchards stood in the same cold storage room, and all showed scald to a degree far in excess of the normal year, it is assumed that the scald attack was due to those abnormal conditions just described. The apples were graded only once, twenty-two weeks from harvest, and were held in cold storage until that time.

Table VIII illustrates the development of scald in storage from the first three picking dates, the only samples on which scald developed on Jonathan, and the starch content and percent blush of the samples on those harvest dates. Although there was a progressively increased starch conversion with successive harvest dates and a similar decrease of scald attack with progressive harvest dates, the variability in the scald attack was not forecast by the starch test at harvest.

In the same table, the development of blush, although shown in 1938 to have no direct influence upon maturity, did have more significance in determining scald attack in 1939. Those samples which had developed at least forty percent over-color before harvest never developed a scald

TABLE VIII

Percent Blush, Starch Test and Scald Value at Time of Grading for the First Three Harvest Dates of Frederick Jonathan, 1939.

Plot	Split Application: 5# July 31; Aug.15 % Blush	Starch	Scald Value	10# NO_3 July 31 % Blush	Starch No.	Scald Value	No Application % Blush	Starch No.	Scald Value
Aug. 31									
A	26	1.7	96.9	16	1.6	38.4	30	1.6	70.7
B	19	1.4	129.4	20	1.2	95.3	22	1.4	86.4
C	15	1.6	64.7	26	1.4	80.3	38	1.7	82.7
D	24	1.8	101.4	31	1.8	101.6	37	1.2	29.9
E	32	1.1	89.6	23	2.7	100.0	35	1.1	53.0
Sept. 7									
A	48	4.4	—	45	3.2	3.2	39	3.6	9.1
B	32	4.2	72.0	39	3.3	16.1	33	3.8	14.1
C	18	3.6	17.8	39	4.2	7.5	40	3.6	7.8
D	27	3.0	28.3	50	3.4	5.0	52	3.6	—
E	47	3.4	9.7	51	4.2	—	30	3.4	5.7
Sept. 14									
A	65	5.0	—	76	4.7	—	56	5.6	—
B	38	5.4	—	63	5.0	—	64	5.2	—
C	52	5.1	—	60	4.9	—	80	4.1	—
D	60	5.2	5.3	62	3.5	—	79	5.2	—
E	68	4.6	—	43	5.8	—	61	4.3	—
	Mean three Harvest Dates		41.0			29.8			23.0

value of over ten in storage. In early pickings, however, where scald was severe, it was observed that the scalded portion often extended into the blushed cheek of the fruit. On the samples of September 7 harvest, the fruit from the A, B and E blocks receiving the split nitrate applications had an average blush of forty-eight, thirty-two and forty-seven percent, respectively. In each case seventy percent of the fruits examined had forty percent of the fruit surface covered with red color at the time of harvest. Yet the amount of scald developing on each sample differed materially on that date, and was higher than on the B sample of September 14, having thirty-eight percent average blush with only half of them with forty percent or more blush. This would indicate that the value attributed to increased color as scald preventive is only coincidental with an increased fruit maturity.

The number of apples graded out for wilt and rot at the time of the storage examination in these 1939 studies was insignificant. However, it is probably accounted for by the fact that these apples were not stored at 60°F. following the period of cold storage, as was employed in 1938. Such storage at high temperature favors the development these disorders. Because of the relative unimportance of disorders other than scald, the scald value in these tests is a general index of the keeping quality.

The nitrogen content showed a relationship with severity of scald. On averages of each treatment, scald and percent total nitrogen in samples selected for nitrogen determinations showed a close relationship which indicated a greater scald attack on fruits of a higher nitrogen content. Certainly there was a greater prevalence of scald on samples from the nitrated trees, with the split application showing the greatest effect.

The mean difference in scald value for the three storage examinations which developed scald was greater between the samples of the split application of nitrogen and the single application than between the latter and the check receiving none. This is interesting in view of the results the determination for total nitrogen discussed later. Although the means showed this relationship between nitrogen content and scald development, comparisons from individual trees with the amount of scald developing on storage samples from those trees did not always show the association.

The data in Table IX indicate that the application of nitrogen in the form of sodium nitrate to the trees increased the nitrogen content of the fruit tissue in samples from the treated trees. The only significant increase, however, was due to the split application of five pounds July 31 and five pounds August 15. Ten pounds of sodium nitrate applied approximately seven weeks before samples were taken for nitrogen analysis did not increase the nitrogen content of the fruits significantly over that of check trees. Analysis of variance showed significance existing between treatments, plots and the interaction, plots X treatment. The significant differences are evident from Table IX. The significant interaction indicated variability within the plots and the variable response to the fertilizer treatment.

The increased nitrogen content in samples from the nitrated trees was not associated with any significant change in starch content. Throughout the whole test period, the change in starch content accompanying successive harvest dates was the only significant starch change taking place. Table X shows the starch content over the test period, and the differences necessary between means for significance as calculated by analysis of variance are given in Table XI.

Also shown in the same tables are the changes in blush that were necessary for statistical significance. As with the starch content there

TABLE IX

Total Nitrogen (Fresh Weight Basis) of Apples Collected Sept. 14 from Trees Receiving Either Ten Pounds of Sodium Nitrate July 31 or Five Pounds July 31 and Five Pounds Aug. 15 (Split) and from Check Trees Receiving No Nitrate. Frederick Jonathan, 1939.

Plot	Check		Split		10# July 31		Plot
	Rep.	Rep.	Rep.	Rep.	Rep.	Rep.	Mean
A	.0335	.0330	.0355	.0333	.0355	.0364	.0342
B	.0301	.0286	.0327	.0338	.0342	.0340	.0322
C	.0252	.0250	.0350	.0363	.0319	.0304	.0306
D	.0344	.0346	.0350	.0353	.0305	.0291	.0315
E	.0342	.0341	.0317	.0370	.0257	.0283	.0318
Mean of Treatment	.03127		.0436		.0316		
Nec. for sign. Between Treat.	5%		.0011				
	1%		.00158				
Nec. for sign. Between Plots	5%		.0015				
	1%		.00203				

"F" Value: Plots 7.79**; Treatment 20.6**; Replicate .44

** Significant at 1% Level.

TABLE X

Percent Blush and Starch Content, as Indicated by the Qualitative Starch Test, Averaged from Five Plots of Three Nitrogen Fertilizer Treatments Throughout the Experimental Period. Frederick Jonathan Orchard, 1939.

	Split 5# July 31 5# Aug. 15		10# July 31		Check		Mean	
Date	Blush	Starch Test	Blush	Starch Test	Blush	Starch Test	Blush	Starch Test
Aug. 28	10	1.3	12	1.4	15	1.4	12.5	1.4
Aug. 31	23	1.5	23	1.7	32	1.4	26.3	1.6
Sept. 4	19	3.0	24	2.9	28	3.4	23.1	3.1
Sept. 7	34	3.7	45	3.7	39	3.6	39.3	3.7
Sept. 11	33	4.8	42	4.4	45	4.4	38.8	4.6
Sept. 14	57	5.1	61	4.7	68	4.9	61.8	4.9
Sept. 25	86	6.7	85	6.7	90	6.5	86.9	6.6
Mean	37.5	3.72	41.5	3.66	44.7	3.67		

TABLE XI

Means, and Differences Necessary Between Means for Significance of Plots, Fertilizer Treatment and Dates for Data in Table X

Starch

Plot		Mean	Fertilizer Treatment	Mean	Dates	Mean
A		3.80			Aug. 28	1.4
B		3.76	Split	3.72	Aug. 31	1.6
C		3.70	10# July 31	3.66	Sept. 4	3.1
D		3.52	Check	3.67	Sept. 7	3.7
E		3.65			Sept. 11	4.6
					Sept. 14	4.9
					Sept. 25	6.6
Dif. Nec.	5%	.30		.23		.36
for Sign.	1%	.40		.31		.48
"F" Value		1.11		.26		216.60*

Percent Blush

Plot		Mean	Fertilizer Treatment	Mean	Dates	Mean
A		42.7			Aug. 28	12.5
B		35.7	Split	37.5	Aug. 31	26.3
C		40.8	10# July 31	41.5	Sept. 1	23.1
D		43.0	Check	44.7	Sept. 7	39.3
E		44.0			Sept. 11	38.8
					Sept. 14	61.8
					Sept. 25	86.9
Dif. Nec.	5%	4.66		3.61		5.51
for Sign.	1%	6.17		4.78		7.30
"F" Value		3.99**		8.02**		168.2**

** Significant at 1% Level

were significant changes due to successive harvest dates. Only one block, namely B, averaged a significantly lower color throughout the season. This block also showed a high scald value for the harvest dates on which scald developed and samples for nitrogen analysis from this block showed one of the highest mean total nitrogen contents.

The trend of significance for the effect of nitrate application upon color was the same as that for nitrogen content. Table XI shows that a significant retardation of color followed only the split application of sodium nitrate. The retardation following the single application did not differ significantly from the check, and samples of both had a significantly higher blush than samples from the trees receiving the split application. A similar trend in total nitrogen content has been previously discussed. Again, the differences existing between means of percent blush were comparable to the differences existing between means of scald value for the nitrogen treatments, Table VIII.

The 1939 results with Jonathan disclosed, therefore, that the split application of sodium nitrate caused a significantly increased total nitrogen content in samples of those trees receiving the split application in comparison with trees receiving only one application or check trees. This significant increase in nitrogen content had no influence upon the starch readings, but did cause a retardation of color of the same order of significance as in total nitrogen content. Accompanying the greater nitrogen content and color retardation was a higher scald value on samples from the nitrated trees. The mean differences were comparable.

Results of the 1940 Studies

Table XII shows the progressive changes in starch content, percentage blush and percentage of good apples remaining after the second storage

TABLE XII

Mean of Starch Content, Percent Blush and Percent Good Fruits in Storage Samples at the Second Storage Examination of Jonathan for Three Harvest Dates and for Individual Trees at the Last Harvest Date. Frederick Orchard, 1940.

Date	Tree	Starch Test	Percent Blush	Percent Good Fruit
Sept. 6	(mean 8 trees)	1.5	26.8	44.3
Sept. 13	(mean 9 trees)	2.5	63.7	61.6
Sept. 20	(mean 8 trees)	3.3	84.8	61.5
Sept. 26	(mean 9 trees)	5.5	91.2	70.6
	A_1	6.4	94.0	60.0
	A_2	4.4	95.0	54.5
	A_3	5.0	85.0	70.4
	B_1	6.2	97.0	83.3
	B_2	6.2	87.0	71.1
	B_3	4.5	89.5	87.5
	C_1	5.8	90.0	78.2
	C_2	5.7	92.0	68.1
	D_3	5.4	91.0	62.0

examination for all picking dates. As in previous years, there was progressively improved keeping quality accompanying samples of successive harvest dates, which was forecast by a progressively greater starch conversion at time of harvest. The best keeping quality was in the lots of the last harvest and which was forecast by a starch test of approximately five at time of harvest.

The starch test did not forecast the variations in keeping quality of samples from individual trees on the last harvest date. The starch test and keeping qualities of samples of this harvest date have been included in Table XII to show the apparently uncorrelated variability in both the starch test and the keeping quality. A comparison of trees A_2 and B_3 will illustrate this lack of association. Storage samples of these two low starch tests, practically at the same stage at harvest, in one case showed the least wastage of all samples and in the other case, the greatest wastage. Another indication was the poorer keeping qualities of some samples showing the highest amount of starch conversion prior to harvest.

As determined by the author with occasional additional aid, there were no differences in palatability of samples of the same date. Samples of the early harvest dates did not equal the palatability of the last harvest samples, which were rated excellent as compared to small samples gathered even later in the season. On samples of the last harvest dates, those samples with the low starch test were rated of equal palatability with samples of the higher starch tests. It is significant, however, that a starch test of approximately five was reached before pleasant palatability developed in storage.

Table XIII

Mean Effects of Orchard Treatments Upon Percentage of Good Apples at the End of the Experimental Period, and "t" Values of Determining Their Significance. Frederick Jonathan. 1940.

Treatment	Mean of Treatment	Mean Difference	Sum of Squares	"t" Value	"t" Nec. for 5% Sign.
Thiocyanate	58.4	.61	724.3	.35	2.13
Check	59.0				
Nitrate Appl.	57.1	3.11	8194.5	.54	2.13
Check	60.2				
"Fruitone"	61.1	5.53	8540.0	1.01	2.13
Check	55.5				

Table XIII reveals that the effect of the various orchard treatments upon keeping quality, as measured by the percentage of good apples remaining after the second storage examination, was insignificant. Using paired comparisons to determine mean differences and their significance allowed four comparison of any one treatment on each picking date or a total of sixteen comparisons. In no case did the difference yield "t" values of five percent significance.

The results of the orchard treatments of nitrate fertilization and spraying the trees with sodium thiocyanate and "Fruitone" are presented in Tables XIV and XV. As in previous years, date of harvest significantly influenced the starch test readings, and the nitrate treatment showed no significant effect. The "Fruitone" sprays also showed no effect upon the starch test. The significant retardation of starch conversion by the thiocyanate sprays was unexpected in view of the inconsistent effect of the sprays upon fruit color. This treatment, as well as the nitrate and "Fruitone" treatments had no significant effect upon fruit color, Tables XIV and XV.

TABLE XIV

Starch Test and Percentage Blush of Samples from Jonathan Trees Receiving Various Treatments of Nitrate Fertilization and Sprays of Sodium Thiocyanate and "Fruitone". Frederick Orchard, 1940.

Date	10 lbs Nitrogen				No Nitrogen			
	Thiocyanate		No Thiocyanate		Thiocyanate		No Thiocyanate	
	"Fruitone"	No "Fruitone"	"Fruitone"	No "Fruitone"	"Fruitone"	No "Fruitone"	"Fruitone"	No "Fruitone"
Starch Content								
Sept. 6	1.2	1.4	1.6	2.4	1.6	1.1	1.7	1.4
Sept. 13	2.3	2.9	2.2	3.1	2.5	2.0	2.6	2.5
Sept. 20	2.4	2.8	3.1	4.1	3.6	2.6	3.9	3.9
Sept. 26	5.0	4.5	5.7	6.4	6.2	4.4	5.8	6.2
Mean*	2.72	2.90	3.12	4.00	3.50	2.52	3.50	3.50
Percentage Blush								
Sept. 6	27.5	26.5	25.0	35.5	11.2	43.2	28.5	17.2
Sept. 13	61.5	56.7	74.5	85.0	78.0	76.7	60.9	66.0
Sept. 20	86.0	65.7	90.0	86.7	82.7	92.7	91.5	82.7
Sept. 26	85.0	90.0	92.0	94.0	87.0	95.0	90.0	97.0
Mean**	65.0	59.7	70.4	75.3	64.7	76.9	67.7	65.7

* Necessary for significance between these means: 5%, 0.59; 1%, 0.80

** Necessary for significance between these means: 5%, 10.9; 1% 14.8

TABLE XV

Means of Starch Content and Percentage Blush with Differences Necessary to Determine Significance of the Experimental Factors in Table XIV

Starch Content

Treatment		Mean of Starch Content
Date of Harvest		
Sept. 6		1.55
Sept. 13		2.50
Sept. 20		3.30
Sept. 26		5.52
Dif. Nec.	5%	0.42
for Sign.	1%	0.57
"F" Value		142.60**
Thiocyanate Sprayed		2.91
Not Sprayed		3.54
Dif. Nec.	5%	0.295
for Sign.	1%	0.40
"F" Value		19.8**
10# $NaNO_3$		3.19
No Nitrogen		3.25
Dif. Nec.	5%	0.295
for Sign.	1%	0.40
"F" Value		0.12
"Fruitone"		3.21
No "Fruitone"		3.23
Dif. Nec.	5%	0.295
for Sign.	1%	0.40
"F" Value		0.0

Percent Blush

Treatment		Mean of Percentage Blush
Date of Harvest		
Sept. 6		26.8
Sept. 13		63.7
Sept. 20		84.8
Sept. 26		91.2
Dif. Nec.	5%	7.98
for Sign.	1%	10.86
"F" Value		367.7**
Thiocyanate Sprayed		66.59
Not Sprayed		69.78
Dif. Nec.	5%	5.62
for Sign.	1%	7.59
"F" Value		1.52
10# $NaNO_3$		67.6
No Nitrate		68.7
Dif. Nec.	5%	5.62
for Sign.	1%	7.59
"F" Value		.20
"Fruitone"		66.96
No "Fruitone"		69.41
Dif. Nec.	5%	5.62
for Sign.	1%	7.59
"F" Value		.88

** Significant at 1% Level

In Table XVI the grading results of the samples from Western Maryland indicate that most orchards, if not picked prematurely, were at the earliest limits of the mature stage at the time of commercial harvest. With only one exception, those samples which had the highest starch conversion test at time of harvest kept best in storage and developed the greatest palatability. Excepting the sample from the Wharton orchard, all storage samples which showed a keeping quality of ninety percent or more good at the first storage examination, had starch tests at harvest of four or more. Samples which had starch tests only slightly under four, generally had figures close to ninety percent good at the first storage examination. Those samples with the lowest starch test showed the greatest wastage and were most lacking in palatability. The one notable exception to a starch test of four forecasting good keeping quality in storage was the sample from the Hixon orchard. Although the starch test of this lot was relatively high at time of harvest, the keeping quality was relatively poor; nevertheless the palatability of this sample was the best of any orchard.

Of the samples showing a starch test of four, all developed at least a "good-excellent" palatability in storage, althought this same degree of palatability was also developed by some samples which had varyingly lower starch tests at harvest. It should be pointed out, however, that for the development of comparable edible qualities in storage, there was a wide range in the starch test at time of harvest.

The relationship of tree vigor, as indicated by terminal growth, to stage of maturity of the fruits, judged by starch and storage tests, is of interest. All the samples from trees having less than six inches average terminal growth had comparable starch tests at harvest and showed similar keeping and edible qualities in storage, excepting the Wharton

TABLE XVI

Fertilizer Treatment and Other Data Pertaining to Jonathan Trees Furnishing Samples for Maturity Studies in 1940; the Maturity Measurements at Time of Commercial Harvest and Storage Quality as Evidenced by Percentage Good Apples at Two Storage Examinations and the Development of Palatability of Samples Selected at the Indicated Dates

Orchard	Fertilizer Treatment	Age of Trees	Terminal Growth	Gen'l Tree Vigor	Crop	Date of Comm. Harvest	Date of Test	Blush %	Starch No.	Percent Good 19 wks	Percent Good 23 wks	Palatability 23 wks
Wishard	10-6-4. spring Manure	25-30	11.5	Ave.	Ave.	9/23	9/19	57	3.6	89.2	18.4	2.0
Lookout	4# NO_3 spring	20-25	6.1	Ave.	Light Good	9/15	9/16	78	4.6	90.1	39.2	2.5
Hixon	None	35-40	1.0	Poor	Few	9/18	9/18	98	4.4	74.3	15.3	3.0
Taylor	4# NO_3 split*	30-35	5.2	Ave.	Few	9/19	9/18	72	3.6	61.4	15.7	2.25
Rinehart	4# NO_3 split*	30-35	11.4	High	Ave.	9/17	9/18	76	3.9	88.0	10.0	2.0
Sweeney	5# NO_3 spring; None before	25	2.3	Good	Good	9/16	9/17	93	4.7	91.9	38.7	2.5
Henderson	3# NO_3 spring	35	11.0	Good	Ave.	9/19	9/17	71	3.6	89.0	34.5	2.5
Ridgefield	3# NO_3 spring	25	9.4	Fair	Good	9/15	9/10	44	1.6	48.1	3.7	2.0
Wharton	None. Cover Disced in July	25	5.6	Fair	Good	9/17	9/17	90	2.8	92.4	58.4	2.0
Scott	4# NO_3 Fall	20	9.4	Good	Good	9/18	9/18	90	3.8	71.6	16.9	1.2
Cohill		25	8.5	Good	Few	9/18	9/18	45.5	4.7**	51.3	3.7	2.0
Elberta #1	200# P. on cover	5	13.2	Good	Good	9/19	9/17	85.2	3.0	71.1	15.5	2.5
Elberta #2	200# P. on cover	35	7.5	Ave.	Ave.	9/17	9/17	76.0	3.4	63.8	19.1	2.25
D.E. Rinehart	6# NO_3spring	12		Good	Ave.	9/22	9/19	79	4.9	90.9	27.2	2.5
Gardenhour	5-6# Cyan. Fall	25	6.8	Ave.	Ave.	9/22	9/19	72	2.8	77.3	30.6	2.75

* Two pounds fall; two pounds spring ** Not tested immediately

orchard. However, many trees averaging over six inches of terminal growth yielded fruit as mature as that from trees under this figure. None of the samples from orchards averaging over ten inches of terminal growth had starch test of four or above at time of harvest or ninety percent good when removed from storage, although some orchards closely approached those levels. None of the samples testing four or more at harvest or having ninety percent good at the first examination were from orchards of the greatest terminal growths. Those characteristics accompanying the most vigorous growth apparently retarded maturity, and the difference was shown by the starch test on samples selected at the approximate time of commercial harvest.

The development of blush showed no apparent relation with storage quality or palatability. On samples collected at approximately the same date, there was a color retardation on the more vigorous trees. Again, using six inches of terminal growth as the criterion, those trees of the lower classification yielded the greatest number of samples of the higher color percentages.

The correlation of starch content and blush in samples of the various orchards over the harvest season, as well as the variability in color percentages of samples of the same or similar starch tests, is illustrated in Figure 2. The same range in starch conversion was evident for each color division. The correlation values are interesting only in their variable values at the different harvest dates. The low "r" value of the first date was probably due to the limitations of the qualitative method in accurately measuring starch content at the high starch levels.

Figure 2. Dot chart of starch test and percent blush on the individual apples comprising the maturity test for fifteen Jonathan orchards in Western Maryland at three sampling dates. 1940. "r" values: first sampling date, +0.13; second sampling date, +0.64; third sampling date, +0.74; for all samples +0.51.

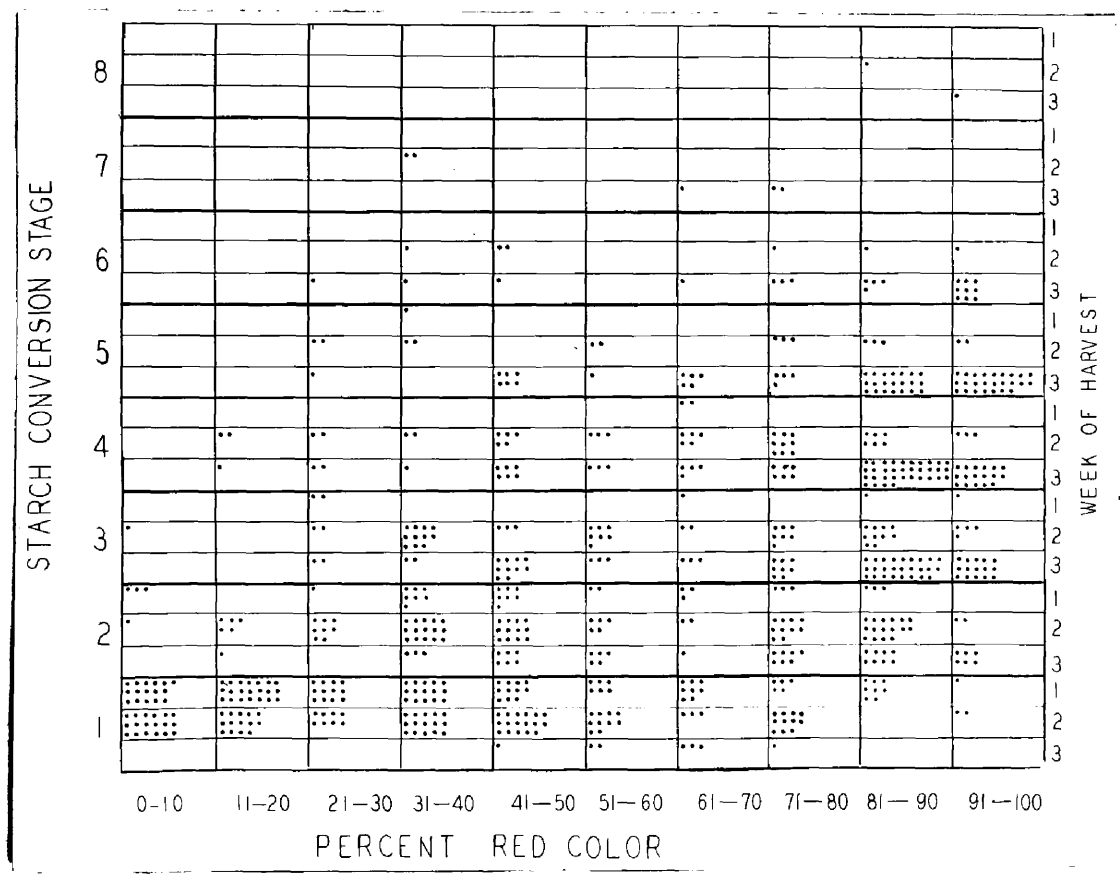

STARCH CONVERSION STAGE
8
7
6
5
4
3
2
1
WEEK OF HARVEST
1
2
3
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
PERCENT RED COLOR

Figure 2

Results Incident to the Waxing Studies with Grimes Golden

The results of waxing, pre-ripening, date of harvest and thiocyanate spray treatments upon (a) weight loss during the storage periods, (b) storage wilt, (c) the development of scald, (d) ground color changes and (e) palatability are hereinafter presented for each of the years comprising the studies.

Results of the 1938 Studies

In Table XVII, summarizing the data in Appendix Table I, it is revealed that all waxed samples had less weight loss at the end of the cold storage period, twenty-one weeks from harvest, than the unwaxed samples of otherwise the same treatment. Averaging the weight changes in waxed samples of all pre-ripening periods at all harvest dates, the waxed samples showed a reduction in weight loss of 22.0 grams per thousand grams original weight when compared with check unwaxed samples. A difference of 7.86 grams denoted significance at the 1% level. The influence of pre-ripening periods upon the weight losses at the end of the cold storage period were insignificant, although the mean weight loss of samples pre-ripened more than one week was greater than the loss on samples placed in cold storage without pre-ripening. The greatest difference attributed to the pre-ripening treatment was 6.5 grams per thousand where differences of 8.2 grams were necessary for 5% significance. The table also shows that dates of harvest were significantly influencing weight loss by the end of the cold storage period. The greatest significance was in the greater weight loss of the last two harvest dates over the losses of the first three.

Table XVIII shows the effect of the experimental factors upon weight loss of samples stored at 60°F. for three weeks after their removal from cold storage. The data indicate that the waxing retained its effectiveness

TABLE XVII

Means of Weight Losses, in Grams per Thousand Grams Original Weight, at Time of Removal from Cold Storage, Twenty-one Weeks from Harvest, of Grimes Golden Given Various Treatments at Six Harvest Dates and Differences Necessary for Significance Between Means as Calculated by Analysis of Variance. Frederick Orchards. 1938.

Treatment		Mean	Treatment		Mean
Waxing Treatment			Date of Harvest		
Waxed		49.2	Aug. 14		56.6
Not Waxed		71.2	Aug. 23		51.7
			Aug. 30		48.8
Dif. Nec.	5%	5.83	Sept. 6		60.0
for Sign.	1%	7.86	Sept. 13		70.9
			Sept. 23		73.3
No. Weeks Pre-ripened					
0		57.6			
1		56.6			
2		64.1			
3		62.6			
Dif. Nec.	5%	8.2	Dif. Nec.	5%	9.80
for Sign.	1%	11.1	for Sign.	1%	13.6

TABLE XVIII

Means of Weight Losses, in Grams per Thousand Grams Original Weight, During the Post Storage Period of 60°F. for Three Weeks for Samples of Grimes Golden Given Various Treatments at Six Harvest Dates and Differences Necessary for Significance Between Means as Calculated by Analysis of Variance. Frederick Orchards. 1938.

Treatment		Mean	Treatment		Mean
Waxing Treatment			Date of Harvest		
Waxed		15.6	Aug. 14		15.1
Not Waxed		20.2	Aug. 23		14.0
			Aug. 30		14.4
Dif. Nec.	5%	1.24	Sept. 6		17.7
for Sign.	1%	1.66	Sept. 13		20.5
"F" Value		56.9**	Sept. 23		25.6
No. Weeks Pre-ripened					
0		20.0			
1		17.9			
2		17.3			
3		16.3			
Dif. Nec.	5%	1.75	Dif. Nec.	5%	2.15
for Sign.	1%	2.35	for Sign.	1%	2.88
"F" Value		6.7**	"F" Value		31.11**

** Significant at 1% Level

in retarding weight loss during this period. The difference of 4.6 grams per thousand grams original weight was significant at the one percent level. The data also reveal that during this period the pre-ripened samples lost less weight than samples placed in cold storage without pre-ripening. Where the pre-ripening period was two or more weeks, the losses were significantly less than the non-pre-ripened samples. The later harvest dates showed a significantly greater loss than the earlier dates during this period also.

Table XIX, summarizing the data in Appendix Table II, shows that for the entire experimental period, including cold storage and the three weeks storage at 60°F., the reduction in weight loss of waxed samples of all pre-ripening treatments at all harvest dates over the check unwaxed samples averaged 27.1 grams per thousand grams original weight. A difference of 8.2 grams denoted high significance. The insignificant influence of pre-ripening periods upon the total weight loss over the entire experimental period indicates that the significantly increased loss in samples of the longer pre-ripening periods during the three weeks at 60°F. did no more than to level values so that the net differences at the end of the experiment were even smaller than at the time of removal from cold storage. The greatest difference did not reach five percent significance.

The significant increases in weight loss accompanying harvest dates are most evident in this table.

Figures 3 and 4 show wastage from various causes on the Frederick Grimes at the twenty-one weeks grading, when taken from cold storage, and the three weeks period at 60°F. Only the good apples of the twenty-one weeks examination were put in the 60° room, and Figure 4 shows the amount of wastage on those apples. The reduction in number of fruits discarded for wilt as the result of the wax treatments is evident. Also noteworthy

TABLE XIX

Means of Total Weight Losses, in Grams per Thousand Grams Original Weight, at the End of the Storage Periods, Twenty-four Weeks from Harvest, of Grimes Golden Given Various Treatments at Six Harvest Dates and Differences Necessary for Significance Between Means as Calculated by Analysis of Variance. Frederick Orchard. 1938.

Treatment		Mean	Treatment		Mean
Waxing Treatment			Date of Harvest		
Waxed		64.8	August 14		72.0
Not Waxed		91.9	August 23		66.1
			August 30		63.4
Dif. Nec.	5%	6.08	Sept. 6		77.8
for Sign.	1%	8.2	Sept. 13		91.8
			Sept. 20		99.1
No. Weeks Pre-ripened					
0		78.0			
1		74.8			
2		81.3			
3		79.2			
Dif. Nec.	5%	8.59	Dif. Nec.	5%	10.5
for Sign.	1%	11.6	for Sign.	1%	14.2

Figure 3. Grimes Golden 1938. Percent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of harvest followed by cold storage for twenty-one weeks from date of picking.

Figure 4. Grimes Golden 1938. Percent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of harvest, followed by cold storage for twenty-one weeks from date of picking and thereafter held at 60°F. for three weeks, to simulate market conditions after storage.

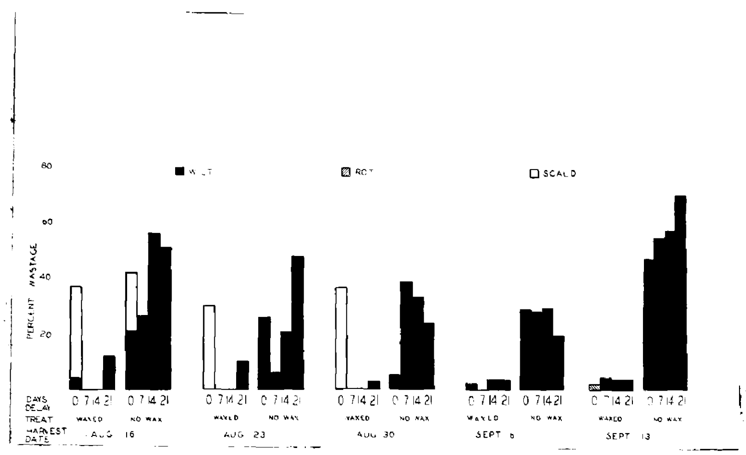


Figure 3

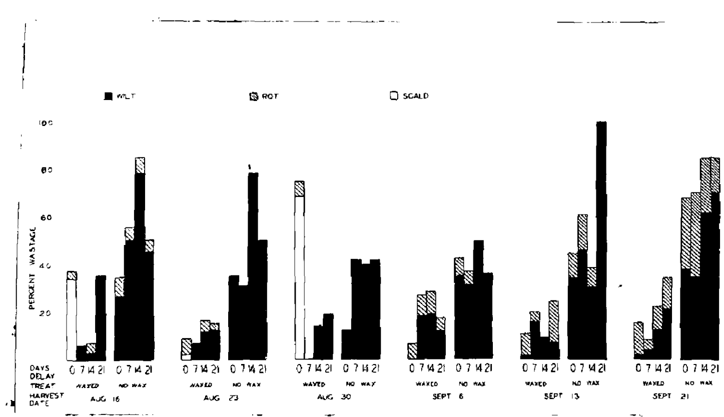


Figure 4

was the greater discard, with only few exceptions, for the unwaxed samples of no pre-ripening treatment in comparison with the discard of the waxed samples of the longer pre-ripening periods. The longer pre-ripening periods were generally accompanied by a greater wastage, caused primarily by wilt. The wax treatment, however, retarded wilt so that in the waxed samples the differences in wilt caused by pre-ripening were insignificant. With all samples wilt decreased as the apples became more mature with progressive harvest dates, except for the last picking.

All three factors of the experiment, wax treatment, pre-ripening period and date of harvest influenced scald. At the earliest pickings, waxing increased scald development, especially if no pre-ripening was employed. On the first harvest scald developed on both the waxed and unwaxed samples receiving no pre-ripening treatments. For the following two harvest periods scald developed only on the fruits waxed and placed in cold storage without pre-ripening. The fourth (September 6) and the fifth (September 13) harvest dates developed no scald. With the harvest dates on which samples developed scald, pre-ripening one week before waxing or placing in cold storage precluded any scald attack.

Rot development, shown in Figure 4, was significantly greater on samples of the last harvest date when compared with some earlier dates. None of the other experimental factors were important in determining the development of rot.

Observations were made on ground color through the storage periods. The changes in ground color during this period are shown in Table XX as averaged for the waxing and pre-ripening treatments. Until the limits of the color changes on the Magness chart (36) had been reached, date of harvest was unimportant in determining the rate of change. The table indicates that the greatest change in ground color during the three weeks

TABLE XX

Changes in Ground Color of Grimes Golden During Pre-ripening, Cold Storage and for the Entire Experimental Periods, Including the Post Storage Period at 60°F., Twenty-one to Twenty-four Weeks from Harvest. Averaged for All Harvest Dates of Frederick Orchard. 1938.

Treatment		Change in Ground Color			
Weeks Pre-ripened	Waxing	During Pre-ripening	Total Change 12 wks from picking	Total Change 21 wks from picking	Total Change 24 wks from picking
0	Waxed		.5	.8	1.4
0	Not waxed		1.4	1.8	2.4
1	Waxed	.3	.6	1.2	1.7
1	Not waxed	.3	1.7	2.0	2.3
2	Waxed	1.0	1.8	2.0	2.1
2	Not waxed	1.0	2.2	2.3	2.5
3	Waxed	1.8	2.2	2.3	2.5
3	Not waxed	1.8	2.3	2.5	2.8

period at 60°F. following cold storage was in the fruits showing least previous change. This was mostly due to the limitations of the chart. Although an advanced stage of five was estimated, the color intensities beyond stage four were no more than estimates.

The data in Table XX also show the inhibiting effect of the wax treatment upon color change and the increased coloration caused by the pre-ripening treatments. During cold storage the most attractive apples were those which were yellowed by the pre-ripening treatment and then waxed. They maintained a bright yellow, smooth finish for a longer period than did the unwaxed fruits. Date was an important factor in this respect in that the same stage of yellow color was reached with less pre-ripening on the later picking dates. By the end of the cold storage period the unwaxed samples of the longer pre-ripening periods, especially of the late pickings, were of a very intense yellow color. For any given picking date those waxed with no pre-ripening, or pre-ripened one week, and the unwaxed,non-pre-ripened samples were the greenest of the fruits. After three weeks at 60°F. the unwaxed samples were at the advanced yellow stage. Those apples waxed with no pre-ripening or only one week's pre-ripening were at the most attractive stage of coloration, but the coloration was uneven. The inhibiting effect of the wax prevented a uniform coloration, unless the color had largely developed before the wax was applied.

Palatability tests were in general agreement with the ground color studies. Those apples of the greatest attractiveness were most palatable. At the end of the cold storage period, those apples retaining the greenest color, regardless of previous treatment were undesirable because of an immature, sour flavor, whereas those showing the more advanced yellowing were superior. After the three weeks' period at 60°F., however, these latter samples were mostly in an over-ripe stage for best flavor, being mealy and tasteless. The waxed samples of the shorter pre-ripening treatments, which were greenest when removed from cold storage were of the best flavor and color after this three weeks' period.

Summarizing, these studies with Grimes showed waxing retarded weight loss and wilt, but increased the susceptibility of the samples to scald. The data further show, however, this difficulty with scald was alleviated by pre-ripening samples for one week without detrimental effect. The waxing treatment slowed the rate of ripening, as indicated by ground color and palatability tests, and because of this, apples can be ripened to an attractive yellow stage, and if waxed, can be held at that stage for longer periods than unwaxed samples.

With Golden Delicious waxing also significantly retarded weight loss twenty-one weeks after picking, as shown by the data presented in Table XXI. The retardation of weight loss in waxed samples averaged for all pre-ripening treatments from all picking dates amounted to 27.0 grams per thousand grams original weight. A difference of 8.04 grams per thousand denoted significance at the one percent level.

The pre-ripening periods had a greater influence upon total weight loss in Golden Delicious than in Grimes; pre-ripening the fruit more than two weeks resulted in a significantly greater weight loss at the end of the cold storage period. The data in Table XXI show also that weight losses became greater as the harvest date progressed. Samples of the last picking lost a significantly greater amount than did those of the first two pickings.

The effect of waxing Golden Delicious upon the subsequent development of wilt in storage is indicated in Figure 5. It is evident that waxing reduced wilt, especially on those samples of the shortest pre-ripening periods. As far as keeping quality over a long storage period is concerned

TABLE XXI

Weight Loss, in Grams per Thousand Grams Original Weight, at Time of Removal from Cold Storage, of Golden Delicious Given Various Treatments at Four Harvest Dates, and the Means of Weight Losses with Differences Necessary for Significance as Calculated by Analysis of Variance. Ashton Orchard. 1938.

Number Weeks Pre-ripened	Weight Change Grams per 1000 grams Original Weight: Waxed	Not Waxed	Number Weeks Pre-ripened	Weight Change Grams per 1000 grams Original Weight: Waxed	Not Waxed
Aug. 30			Sept. 7		
0	67.4	94.3	0	58.5	86.4
1	73.6	92.3	1	75.4	119.1
2	75.6	93.4	2	69.2*	94.2
3	79.2	102.2	3	74.7	92.6
Sept. 15			Sept. 24		
0	77.9	107.9	0	70.3	104.6
1	72.2	100.0	1	79.5	115.5
2	78.1	102.0	2	82.5	109.2
3	89.3	114.5	3	102.5	128.9

* Filled in by formula for missing data (42)

Treatment		Mean of Wt. Loss	Treatment		Mean of Wt. Loss
Waxing Treatment			Harvest Date		
Waxed		76.6	Aug. 30		84.75
Not Waxed		103.6	Sept. 7		83.8
Dif. Nec.	5%	5.92	Sept. 15		92.7
for Sign.	1%	8.04	Sept. 24		99.1
"F" Value		91.10**			
No. Weeks Pre-ripened					
0		83.4			
1		90.4			
2		88.0			
3		99.0			
Dif. Nec.	5%	8.38	Dif. Nec.	5%	8.38
for Sign.	1%	11.4	for Sign.	1%	11.4
"F" Value		4.05**	"F" Value		6.4**

** Significant at 1% Level

Figure 5. Golden Delicious 1938. Percent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of harvest followed by cold storage for twenty-one weeks from date of picking.

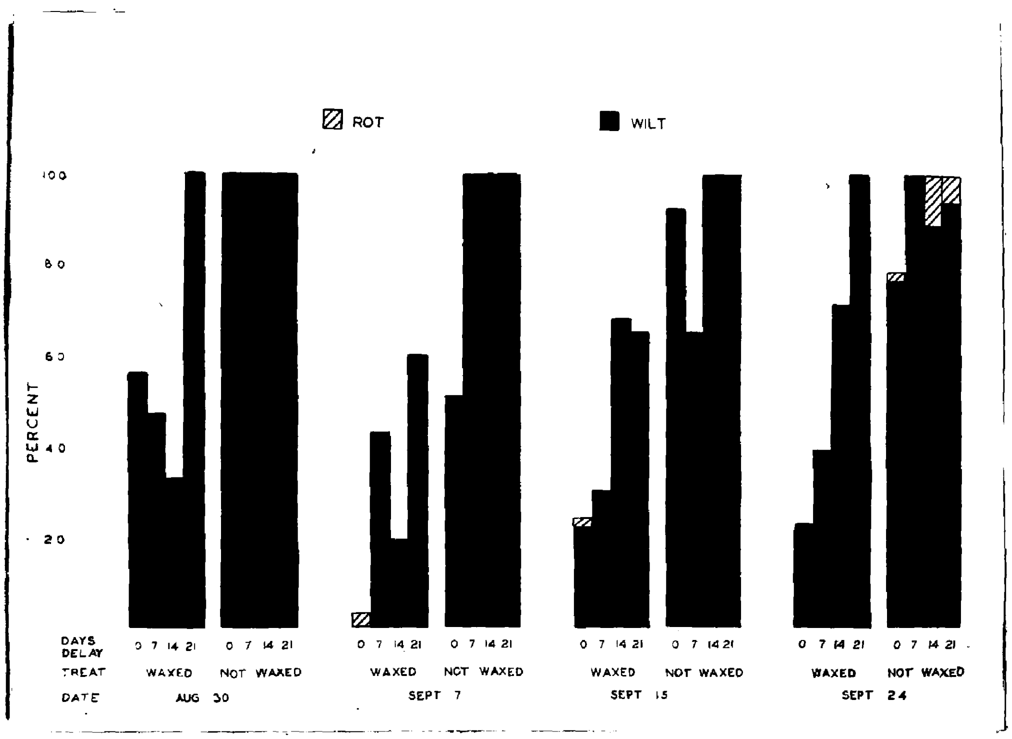

ROT
WILT
100
80
60
40
20
PERCENT
DAYS DELAY
0 7 14 21
0 7 14 21
0 7 14 21
0 7 14 21
0 7 14 21
0 7 14 21
0 7 14 21
0 7 14 21
TREAT
WAXED
NOT WAXED
WAXED
NOT WAXED
WAXED
NOT WAXED
WAXED
NOT WAXED
DATE
AUG 30
SEPT 7
SEPT 15
SEPT 24

Figure 5

there seems little advantage to pre-ripening Golden Delicious before cold storage, since it appears from the data that the development of rot was independent of any experimental treatment, and this variety was not susceptible to scald.

Ground color changes of Golden Delicious were measured by the ground color chart (36) and are presented in Table XXII. Averaging all harvest dates, the change in ground color for each week of pre-ripening was about one-half of a stage. Thus, samples picked at stage two were at stage three and one-half after three weeks of pre-ripening. In cold storage the waxing retarded ground color change, and at the end of the cold storage period, twenty-one weeks from harvest, the waxed samples of the short pre-ripening periods averaged about one-half to three-fourths of a stage less color than unwaxed samples of otherwise the same treatment. Regardless of the waxing treatment, samples pre-ripened three weeks had almost the same ground color at the end of the cold storage period. They were of an intense yellow-orange color which was difficult to determine because of the lack of standards. This advanced color was not attractive.

There was a progressive increase in ground color associated with dates. These relative differences were maintained during subsequent treatment until intensity of color made measurements difficult. The most attractive apples throughout the period in cold storage were those picked at approximately the time of commercial harvest and pre-ripened one week. At the time of removal from cold storage, twenty-one weeks from harvest, apples given no pre-ripening treatment were at a less attractive greener stage and those of the longer pre-ripening treatments were of a too deep yellow color, especially those not waxed.

Following the twenty-one weeks examination some fruits of each lot were held at 60°F. for two weeks, and observations were made on ground

TABLE XXIII

Changes in Ground Color, Averaged for All Picking Dates, of Golden Delicious During Pre-ripening and Cold Storage and Total Changes From Harvest at the Time of Removal From Cold Storage, Twenty-one Weeks From Harvest. Ashton Orchard. 1938.

No. Weeks Pre-ripened	Waxed 0	Waxed 1	Waxed 2	Waxed 3	Not Waxed 0	Not Waxed 1	Not Waxed 2	Not Waxed 3
During Pre-ripening	0	.3	1.2	1.4	0	.3	1.2	1.4
During Cold Storage Period	.5	.6	.5	.6	1.2	1.0	.75	.7
Total Change	.5	.9	1.7	2.0*	1.2	1.3	1.95*	2.1*

* Final ground color on samples was of an intense yellow beyond the limits of the Magness (36) Chart.

color at the end of this period. The ground color changes were very rapid. The waxed apples not pre-ripened were uneven in coloration, both as regards to different apples within the lot and different sections of the surface of individual fruits. Unwaxed fruits of the same pre-ripening treatment developed a normal uniform color, especially those of the last two harvest dates. Fruits of any given harvest date, which had been pre-ripened for one week and then waxed were still attractive at the end of this period while the unwaxed fruits of the same pre-ripening treatment were approaching the unattractive deep yellow color.

The palatability tests at the time of removing the fruits from storage indicated that Golden Delicious should be mature at harvest before proper palatability will develop in storage. Samples of the first two pickings never developed a pleasant or even suitable palatability even after the pre-ripening treatments. On the last two harvest dates those samples waxed without pre-ripening had a sour or alcoholic taste, which was unpalatable. Those unwaxed samples receiving no pre-ripening had the characteristic slightly green taste of cold storage Golden Delicious which is not quite as pleasant as that developed in a short time after such fruits are removed from cold storage. The pre-ripening treatment of one week apparently improves the palatability of both the waxed and unwaxed samples. The majority of the judges considered the unwaxed apples receiving one week of pre-ripening to be the best flavored of all those tested. Although samples of longer pre-ripening periods had suitable flavor, the majority of the judges placed them below the samples just mentioned possibly because of greater toughness accompanying the greater wilt.

After the two weeks at 60°F., these apples were again tested for palatability. Those fruits waxed and stored immediately were rated as best. There was no evidence of a sour or alcoholic taste. The samples which rated second best were those waxed after one week of pre-ripening. During this period at 60°F. storage, both the waxed and unwaxed samples of the longer pre-ripening periods developed excessive wilt or over-ripeness, and did not compare in quality with the samples just mentioned.

Results of the 1939 Studies

The primary object of the 1939 studies was to determine whether scald control of Grimes could be attained with pre-ripening treatments of less than one week's duration. The treatments were inadvertently placed to a very severe test by the storage conditions so favorable to scald development as described in connection with the results of the maturity studies in 1939.

The efficacy of the waxing treatment in retarding weight loss and wilt is shown by the data presented in Table XXIII, which is a condensed form of the data presented in Appendix Table III, and in Figure 6 respectively.

The analysis of variance for weight loss at the end of the cold storage period, twenty-two weeks from picking, showed three significant interactions, dates X pre-ripening period, dates X waxing treatment and pre-ripening X waxing, Appendix Table III. These significant values indicate that waxing and pre-ripening did not show the same effect on every date and that waxing did not always have the same effect on the pre-ripened samples. The significance of these interactions is a measure of variability of response to the treatments and is not considered of interest except to note that the response was variable. The variability influenced the determination of significance of some treatments. Using analysis of variance for the main effects only, i.e. leaving some significant interactions in error, the pre-ripening treatments were not significant in determining the weight loss at the end of twenty-two weeks. Moreover, no

TABLE XXIII

Means of Weight Loss, in Grams per Thousand Grams Original Weight, at the Time of Removal from Cold Storage, Twenty-two Weeks After Harvest, of Grimes Golden Given Various Treatments at Time of Harvest and Differences Necessary for Significance Between Such Means. Frederick Orchard. 1939.

Treatment		Mean	Treatment		Mean
Waxing Treatment			Date of Harvest		
Waxed		45.8	August 21		65.9
Not Waxed		75.1	August 28		76.1
*Dif. Nec.	5%	4.56	Sept. 4		46.2
for Sign.	1%	6.12	Sept. 11		53.4
**Dif. Nec.	5%	1.65	*Dif. Nec.	5%	6.4
for Sign.	1%	2.21	for Sign.	1%	8.61
No. Days Pre-ripened			**Dif. Nec.	5%	2.36
			for Sign.	1%	3.17
0		56.0	Replication		
2		63.3			
4		62.3	1		61.3
7		59.9	2		59.5
*Dif. Nec.	5%	6.4	**Dif. Nec.	5%	1.65
for Sign.	1%	8.61	for Sign.	1%	2.21
**Dif. Nec.	5%	2.36			
for Sign.	1%	3.17			

* From Analysis of Variance for Main Effects Only.
**From Analysis of Variance with Certain Significant Interactions Removed from Error.

Figure 6. Grimes Golden 1939. Percent wilt of waxed and unwaxed fruit when given various pre-ripening treatments at time of harvest followed by cold storage for twenty-two weeks from date of picking.

Figure 7. Golden Delicious 1939. Percent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of commercial packing and followed by cold storage until January, 1940.

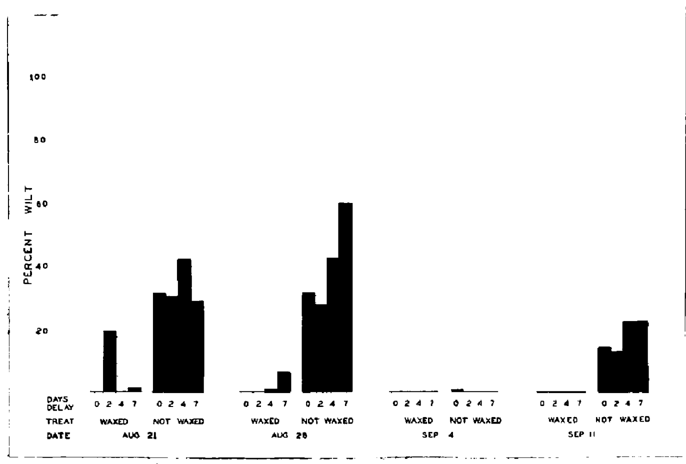


Figure 6

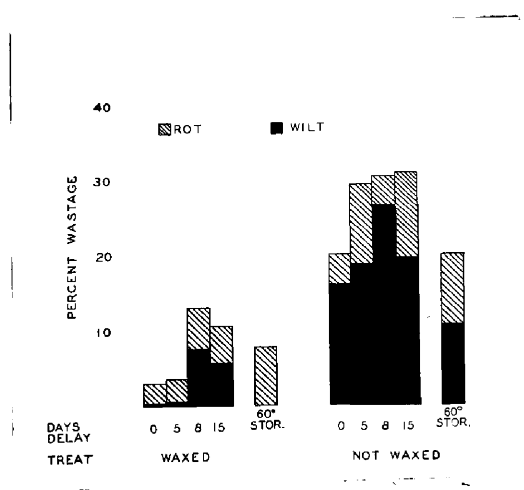


Figure 7

date differed significantly from any other date. Reducing the error variance by removing the significant interactions reduced the differences necessary for significance so that certain significant differences were seen in pre-ripening treatment and each date differed significantly. In view of the large differences in weight loss resulting from the waxing treatment, the small differences resulting from the various pre-ripening treatments were probably without commercial importance. This view is substantiated by the differences shown in wilt resulting from the waxing and pre-ripening treatments in Figure 6. Except for the September 4 harvest, the differences resulting between waxed and unwaxed samples were larger than differences resulting from the pre-ripening treatment. Only on the unwaxed samples of August 28 did pre-ripening increase wilt to such extent to prove of possible commercial interest.

The weight changes of samples at different dates corresponded closely with the amount of wilt at grading. The samples of September 4 showed the least weight loss and the least wilt and other positive interrelationships between these two were evident. The low percentage of wilt from the September 4 picking, compared with samples picked one week earlier and one week later, may indicate that there is only a relatively short time during harvest that wilt can be controlled without supplementary measures.

The influence of waxing upon the subsequent development of scald is clearly evident from the results presented in Table XXIV. With only one exception, the waxed samples on any picking date or with any pre-ripening treatment, had a higher scald value than comparable unwaxed samples. Considering only means of duplicates, this amounted to a mean difference of 38.3. Computing differences resulting between all waxed samples and all unwaxed samples yielded a "t" value of 3.91. A "t" value of 2.947 denoted significance at the one percent level.

TABLE XXIV

Scald Values* Upon Removal from Cold Storage, 22 Weeks After Picking, for Waxed and Unwaxed Samples of Grimes Golden at Four Different Harvest Dates and Pre-ripening Periods. 1939.

	Waxed				Not Waxed				Mean
Days Pre-ripened	0	2	4	7	0	2	4	7	
Date of Harvest August 21	192	141	180	176	163	131	145	72	150.0
August 28	175	189	149	142	158	128	77	2	127.5
September 4	196	181	90	90	194	148	82	95	134.5
September 11	191	183	158	120	184	159	120	82	149.6
Mean	188.5	173.5	144.2	132	174.7	141.5	106.0	62.7	

Mean: Waxed 159.6; Not Waxed 121.2

* Scald Value: $\frac{2 \times \text{No. Severe Scald} + 1 \times \text{No. Slight Scald}}{\text{Total No. Fruits in Sample}}$

Although some scald developed on every lot of fruit, its severity lessened with the longer pre-ripening periods. For any picking date those samples pre-ripened for two, four or seven days developed less scald than those samples stored the day of harvest. This held true regardless of the waxing treatment. The average scald value of those apples pre-ripened one week was less than one-half of the average scald value of the samples placed in storage without pre-ripening. In fact, the rate of scald reduction accompanying pre-ripening was comparable on both waxed and unwaxed samples. Comparing only means of the pre-ripening columns, it is interesting that the reduction of scald value accompanying pre-ripening, although proceeding at approximately the same rate in both waxed and unwaxed samples, was about two days more advanced in the samples not waxed.

Of special note was the reduced average scald value of samples pre-ripened one week before waxing compared with the samples placed in storage without pre-ripening or waxing. Scald was more effectively controlled by pre-ripening one week and then waxing than by placing the fruits in cold storage without pre-ripening and without waxing.

Summarizing, the data have shown that wilt was reduced by the waxing treatment to such an extent that samples pre-ripening one week had a fewer number of wilted fruits than unwaxed samples stored immediately. Furthermore, the same relationship to treatment also held true for the development of scald. Therefore, since rots developed in no pronounced trend, the smallest amount of wastage developed on those samples pre-ripened one week, waxed and placed in storage.

Observations of ground color changes largely substantiated the 1938 results with this variety. Samples pre-ripened two and four days, especially for the first two picking dates had color changes much like the samples stored immediately without pre-ripening.

The results with the commercially packed Golden Delicious, as indicated in Figure 7, show a reduction in wilt on waxed samples which has commercial importance. The influence was evident both in cold storage samples and on some samples left at the pre-ripening temperature for six weeks, indicated as "common storage" in Figure 7.

The data in Figure 8 show the effect of the waxing and various pre-ripening periods upon the storage behavior of Grimes Golden packed in commercial packages. On samples picked September 6, very little wilt developed in approximately twenty-two weeks after picking. It is evident, however, that the pre-ripening treatments reduced scald development on both the waxed and unwaxed samples. On samples picked September 14, the waxing treatment was effective in reducing wilt. Contrary to the effect of the waxing and pre-ripening treatments upon scald development in previous work with samples packed in open hampers, was the reduced scald development in the waxed samples and the failure of the pre-ripening periods of less than two weeks to materially reduce scald severity on the unwaxed samples picked September 14. This may possibly be a function of aeration during pre-ripening which is discussed later.

Although ground color changes were not closely followed, it was observed that the pre-ripening materially improved the ground color in both varieties. The appearance of the fruit in cold storage was enhanced by pre-ripening and waxing. With Golden Delicious, however, the practicability of pre-ripening for more than one week is limited by the increased wastage which would result following long periods of storage.

Results of the 1940 Studies

The results of the weight loss determinations at the time of removal of Grimes Golden from cold storage, twenty-one weeks from harvest, and

Figure 8. Grimes Golden 1939. Percent wastage of waxed and unwaxed fruit when given various pre-ripening treatments at time of commercial packing and followed by cold storage until January, 1940.

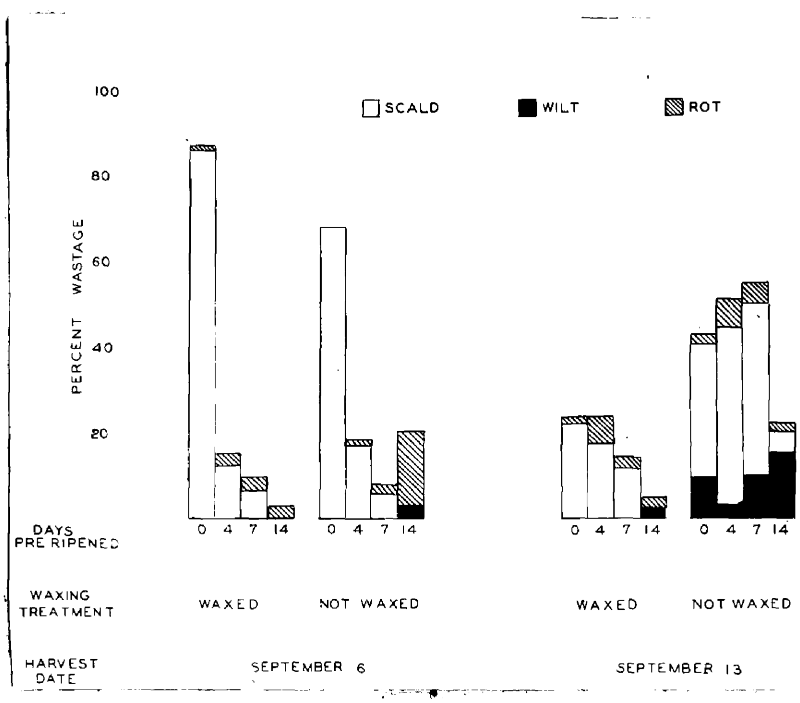

100
80
60
40
20
PERCENT WASTAGE
SCALD
WILT
ROT
DAYS PRE RIPENED
0 4 7 14
0 4 7 14
0 4 7 14
0 4 7 14
WAXING TREATMENT
WAXED
NOT WAXED
WAXED
NOT WAXED
HARVEST DATE
SEPTEMBER 6
SEPTEMBER 13

Figure 8

after the post period of storage at 50°F. for two weeks, are shown in Tables XXV and XXVI respectively. As in previous years, the waxed fruits of all treatments lost significantly less weight than unwaxed fruits having otherwise the same treatment. At the end of the cold storage period, the mean retardation of weight loss amounted to 31.1 grams per thousand grams original weight and only 4.77 grams were necessary to show significance at the one percent level, Table XXV. After the post storage period, the mean difference was 35.6 grams per thousand, where a difference of 5.96 grams denoted high significance, Table XXVI. In Figure 9 the reduction in wilt resulting from the wax treatment is shown. It is evident that waxing reduced wilt regardless of other treatments employed. When the whole experimental period was considered, the average percent wilt in all waxed samples was less than one-tenth the wilt in the unwaxed samples.

Table XXV also shows that, at the time of removal from cold storage, the average weight loss of all samples pre-ripened one week was significantly greater than the non-pre-ripened samples. However, this significant difference of nine grams per thousand grams original weight does not have the commercial importance of the thirty-one grams decrease attributed to the waxing treatments during the same storage period. Furthermore, as shown by the small insignificant differences attributed to the pre-ripening treatment in Table XXVI, those samples given no pre-ripening lost more weight during the post storage period at 50°F. than did the pre-ripened samples. Therefore, pre-ripening was not important in determining weight loss when the entire experimental period is considered. In Figure 9, showing percentage wilt graded out over the entire experimental period, samples pre-ripened one week had a slightly greater amount than samples not pre-ripened. Using paired comparisons on the data in Appendix Table IV to test the statistical significance of this difference, a "t" value of

TABLE XXV

Weight Loss, in Grams per Thousand Grams Original Weight, at the Time of Removal from Cold Storage, Twenty-one Weeks from Harvest, of Grimes Golden Given Various Orchard and Harvest Treatments with the Treatment Means and Differences Necessary to Show Significance Between Such Means.

1940.

Dates / Lot	Sept. 6	Sept. 13	Sept. 20	Sept. 26	Mean
TWA	44.2	41.8	42.7	54.3	45.8
TWB	59.3	42.1	41.6	53.1	59.0
TWC	59.3	57.2	57.7	59.4	58.4
TA	80.8	78.5	88.0	87.9	83.8
TB	73.0	79.3	98.2	80.0	82.6
TC	82.0	89.5	84.8	95.1	97.8
WA	43.6	33.3	40.9	51.5	42.3
WB	56.0	55.5	43.8	48.5	51.0
WC	56.5	58.7	57.9	56.9	57.5
A	76.9	79.7	73.5	75.7	76.4
B	80.8	73.0	81.0	79.9	78.7
C	79.5	79.5	89.4	76.3	81.2

Treatment		Mean of Weight Loss
Harvest Date		
Sept. 6		66.0
Sept. 13		64.0
Sept. 20		66.6
Sept. 26		68.2
Dif. Nec.	5%	5.02
for Sign.	1%	6.74
"F" Value		.98
Days of Pre-ripening		
0		62.1
4		65.3
7		71.2
Dif. Nec.	5%	4.35
for Sign.	1%	5.84
"F" Value		9.28**

Treatment		Mean of Weight Loss
Thiocyanate Treatment		
Trees sprayed .1% Na Thiocyanate		67.91
Trees not sprayed		64.5
Dif. Nec.	5%	3.55
for Sign.	1%	4.77
"F" Value		3.70
Waxing Treatment		
Samples Waxed		50.7
Samples Not Waxed		81.8
Dif. Nec.	5%	3.6
for Sign.	1%	4.77
"F" Value		312.7**

** Significant at 1% Level
T=Samples were taken from trees sprayed with .1% Na Thiocyanate Aug. 12.
W=Samples waxed before placing in cold storage.
A=Sample placed in cold storage day of Harvest.
B=Sample placed in cold storage after 4 days of pre-ripening at 60°F.
C=Sample placed in cold storage after 7 days of pre-ripening at 60°F.

TABLE XXVI

Weight Loss, in Grams per Thousand Grams Original Weight, for the Entire Experimental Period, Twenty-three Weeks from Harvest, of Grimes Golden Given Various Orchard and Harvest Treatments with the Treatment Means and Differences Necessary to Show Significance Between Such Means. 1940.

Dates / Lot	Sept. 6	Sept. 13	Sept. 20	Sept. 26	Mean
TWA	61.9	73.2	68.4	77.0	70.1
TWB	74.8	71.8	59.6	75.7	70.5
TWC	73.0	81.8	82.3	76.0	78.3
TA	111.0	135.0	135.3	122.7	126.2
TB	98.0	124.2	137.0	110.4	117.4
TC	107.4	134.7	118.8	128.3	122.3
WA	61.0	72.2	68.4	69.8	67.8
WB	70.5	87.1	63.7	66.7	72.0
WC	73.0	85.2	76.8	72.6	76.9
A	107.7	136.8	118.3	104.3	116.8
B	106.7	121.4	118.2	107.6	113.5
C	103.8	122.2	125.4	102.2	113.4

Treatment		Mean of Weight Loss
Harvest Date		
Sept. 6		87.4
Sept. 13		103.8
Sept. 20		97.7
Sept. 26		92.8
Dif. Nec.	5%	6.55
for Sign.	1%	8.76
"F" Value		9.27**
Days of Pre-ripening		
0		95.2
4		93.3
7		97.7
Dif. Nec.	5%	5.66
for Sign.	1%	7.57
"F" Value		1.24

Treatment		Mean of Weight Loss
Thiocyanate Treatment		
Trees sprayed .1% Na Thiocyanate		97.4
Trees not sprayed		93.4
Dif. Nec.	5%	4.63
for Sign.	1%	6.19
"F" Value		3.10
Waxing Treatment		
Samples waxed		72.6
Samples not waxed		118.2
Dif. Nec.	5%	4.63
for Sign.	1%	6.19
"F" Value		470.90**

* Significant at 5% Level ** Significant at 1% Level
T = Samples were taken from trees sprayed with .1% Na Thiocyanate Aug. 12.
W = Samples waxed before placing in cold storage.
A = Samples placed in cold storage day of Harvest.
B = Samples placed in cold storage after 4 days of pre-ripening at 60°F.
C = Samples placed in cold storage after 7 days of pre-ripening at 60°F.

Figure 9. Grimes Golden 1940. Percent wilt at the time of removal from cold storage, twenty-one weeks from harvest, and for a post storage period of 50°F. for two weeks, twenty-three weeks from harvest, for fruits given various orchard and harvest treatments.

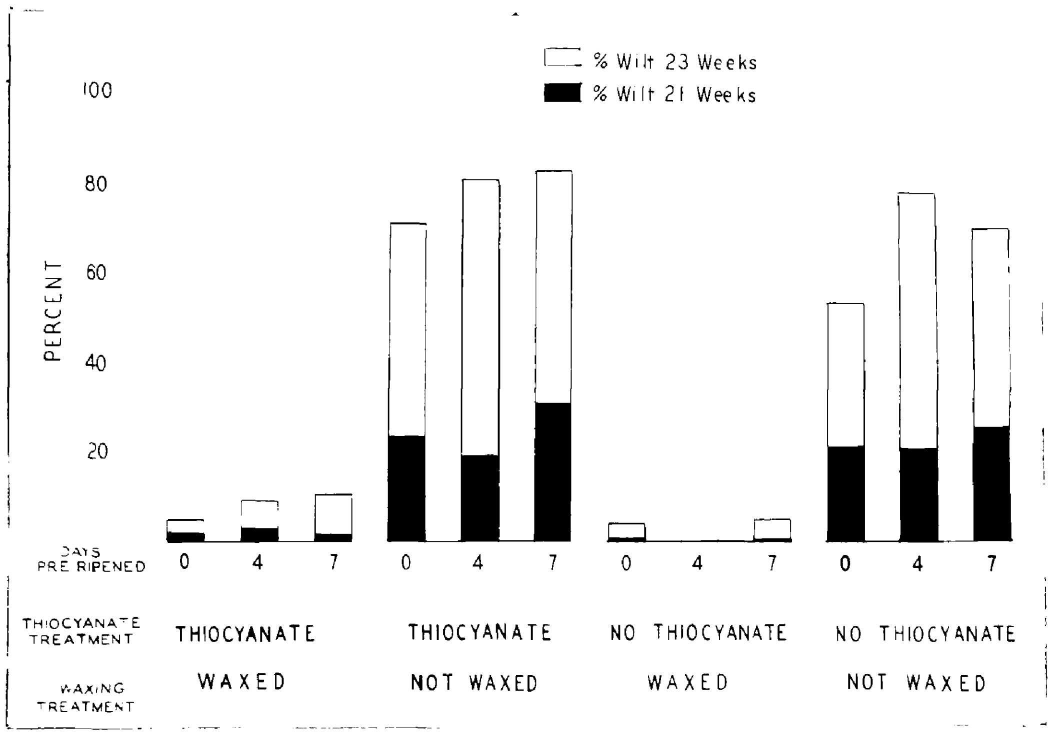

% Wilt 23 Weeks
% Wilt 21 Weeks
PERCENT
100
80
60
40
20
DAYS PRE RIPENED
0
4
7
0
4
7
0
4
7
0
4
7
THIOCYANATE TREATMENT
THIOCYANATE
THIOCYANATE
NO THIOCYANATE
NO THIOCYANATE
WAXING TREATMENT
WAXED
NOT WAXED
WAXED
NOT WAXED

Figure 9

2.74 was obtained. This "t" value, from a mean difference of 8.41, was less than the value of 2.94 necessary for significance at the one percent level. It was above the five percent level of significance, however. Since samples given the four-day pre-ripening period had a mean value for percentage wilt which was intermediate with the values of no pre-ripening and seven days pre-ripening, it is evident that pre-ripening had no highly significant effect on wilt when the entire experimental period was considered.

The samples from the trees sprayed with sodium thiocyanate showed a greater weight loss during the twenty-one weeks period than did the samples from unsprayed trees, but Table XXV reveals the difference to be of no statistical significance. Although the difference was slightly greater following the post storage period for two weeks at 50°F., as shown in Table XXVI, it still lacked statistical significance. This slightly greater weight loss in the samples from the thiocyanate sprayed trees was, nevertheless, reflected in greater wilt, Figure 9. Using paired comparisons, from the data in Appendix Table IV, to evaluate the statistical significance of the mean difference 8.3 percent wilt developing during the entire experimental period, a "t" value of 2.91 was obtained. A "t" value greater than 2.79 indicated significance at the one percent level. Thus, an insignificant difference in weight loss was reflected in a significant increase in percentage wilt resulting from the treatment.

At the twenty-one weeks examination there were no significant differences in weight loss due to harvest dates, Table XXV. The data in Table XXVI reveal that after the post storage period some dates were showing significant effects upon weight loss when the entire experimental period was considered. A comparison of data in Table XXVI with the grading results in Appendix Table IV shows no apparent relationship between wilt and weight loss as far as dates were concerned. In fact, the samples of the September 13 picking showed a significantly higher mean weight loss than two of the three other harvest dates, but had the second lowest mean wilt development, averaging all treatments.

On every picking date those samples which had been waxed had a higher scald value at the end of the experimental period than did the corresponding unwaxed samples. Using paired comparisons from Table XXVII to test the mean difference of 25.1 in scald value, a "t" value of 3.65 was obtained. A "t" value of 2.81 denoted high significance.

On every picking date those samples from trees sprayed with Na thiocyanate had higher average scald values than samples collected from the trees not sprayed with the thiocyanate. Using paired comparisons from Table XXVII to test the mean difference of 17.2 in scald value, a "t" value of 4.98 was obtained. A "t" value of 2.81 denoted high significance.

With all treatments in Table XXVII averaged, the more advanced maturity of the later picking dates was accompanied by a reduction in scald value. The scald value of the last harvest period was little more than one-fourth that of the first harvest date.

There was a reduced scald value on samples given the pre-ripening treatments, Table XXVII. The mean difference of 28.1 between the average scald value of the non-pre-ripened samples and those pre-ripened one week yielded a "t" value of 5.03 compared to a value of 2.94 necessary for high significance. Pre-ripening four days reduced scald compared to no-pre-ripening. The mean difference of 15.3 yielded a "t" value of 2.72 which was between the 5% and 1% levels of significance. The difference between four and seven days of pre-ripening was comparable.

The effect of the various treatments upon keeping quality is most clearly summarized in Figure 10. This illustration shows a lower percentage

TABLE XXVII

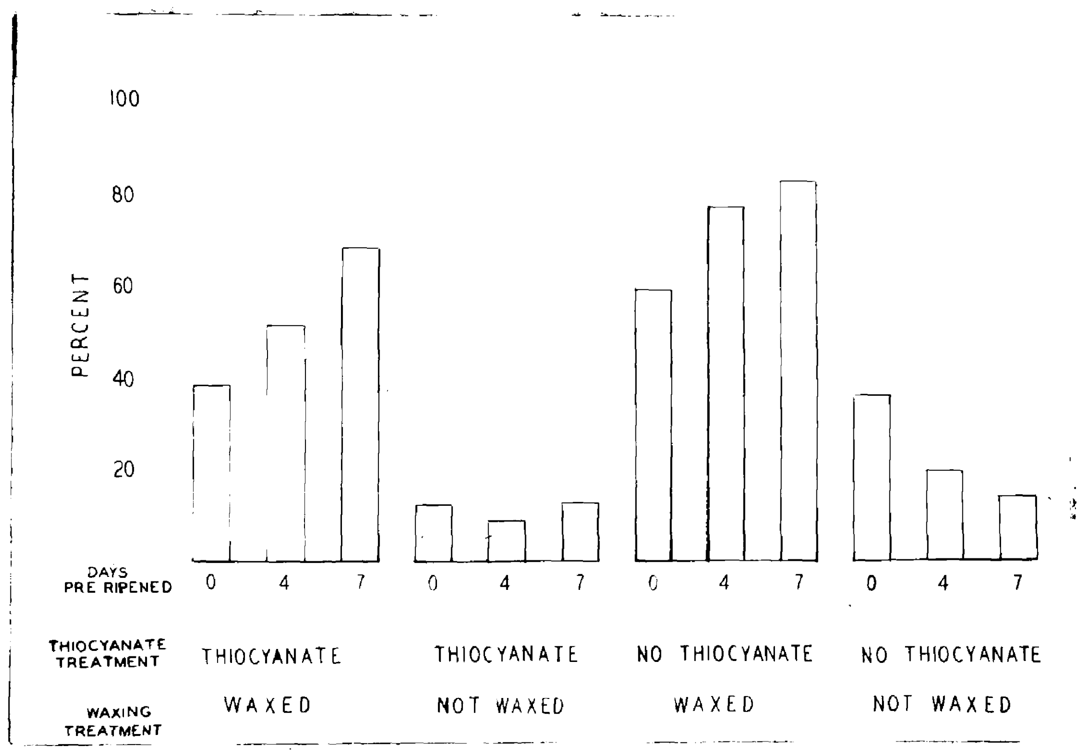
Scald Values* at the End of the Experimental Period for Grimes Samples Picked at Four Harvest Dates and Given Different Orchard and Harvest Treatments. Frederick Grimes. 1940.

	Sept. 6	Sept. 13	Sept. 20	Sept. 26	Mean
TWA	117	68.4	60.8	44.0	72.6
TWB	40	65.1	70.2	5.2	45.1
TWC	40	37.3	7.2	0	21.1
TA	3	44.0	42.1	17.6	26.7
TB	7.6	23.3	33.7	1.8	16.6
TC	5.4	0	0	0	1.4
WA	78.2	36.1	24.3	17.3	38.9
WB	35.5	8.4	31.8	0	18.9
WC	26.0	9.8	2.8	0	9.6
A	0	3.7	15.0	9.8	7.1
B	0	0	13.8	0	3.4
C	0	0	3.0	0	1.0
Mean	29.4	24.7	25.3	8.0	

T = Samples from trees sprayed with .1% Na Thiocyanate Aug. 12
W = Samples Waxed before placing in cold storage.
A = Samples pre-ripened 0 days before cold storage.
B = Samples pre-ripened 4 days before cold storage.
C = Samples pre-ripened 7 days before cold storage.

* Scald Value: $\frac{\text{2 x No. Severe Scald + 1 x No. Slight Scald}}{\text{Total No. of Apples in Sample}}$

Figure 10. Grimes Golden 1940. Percent good fruit remaining in samples when given various orchard and harvest treatments followed by cold storage for twenty-one weeks from date of picking and thereafter held at 50°F. for two weeks, to simulate market conditions after storage.



100
80
60
40
20
PERCENT
DAYS PRE RIPENED
0
4
7
0
4
7
0
4
7
0
4
7
THIOCYANATE TREATMENT
THIOCYANATE
THIOCYANATE
NO THIOCYANATE
NO THIOCYANATE
WAXING TREATMENT
WAXED
NOT WAXED
WAXED
NOT WAXED

Figure 10

of good apples on the unwaxed samples. This was due mainly to the wilt in those samples. The samples from the thiocyanate sprayed trees had a lower percentage of good apples because of the greater number of scalded and wilted fruits on these samples compared to the waxed samples from the unsprayed trees. The higher percentages of good apples associated with the increased length of pre-ripening on the waxed samples was the result of greater scald control obtained with the four- and seven-day pre-ripening treatments, as well as the fact that the increased wastage from wilt associated with the pre-ripening periods was not equal to the resultant increased scald control. The relatively small amount of scald on the unwaxed samples allowed wilt to be of greater importance in determining the number of apples discarded from these samples. Where increased scald control was not considered, greater wastage occurred with the increased length of pre-ripening. On the samples from the thiocyanate sprayed trees, where scald development was greater than on unsprayed trees, the scald control accompanying the pre-ripening periods of four and seven days just about equaled the increased wilt accompanying these pre-ripening periods. Therefore, the differences in percent good apples of samples from the thiocyanate sprayed trees given the different pre-ripening periods did not differ markedly. The reduced number of good apples associated with four-and seven-day pre-ripening periods of the unwaxed samples from the trees receiving no thiocyanate was due to the reduced scald on these samples. In this case the percentage of good fruits was largely determined by the amount of wilt, which was greatest when the fruits were preripened.

The results illustrated in Figure 10 substantiated the conclusions of previous years that the best keeping quality was found in waxed samples pre-ripened one week before waxing and placing in cold storage.

The results of spraying with Na thiocyanate to increase ground color were not clearly evident. By mid-September a difference in tree appearance could be discerned. Especially on the south sides of the trees, where sun exposure was greatest, the apples on the sprayed trees had the deep yellow shade and red tints reported by Dustman and Duncan (16). In the shaded sections of the trees the coloration was not so pronounced. In many of these sections the fruit coloration was no greater than on the unsprayed trees. As shown in Appendix Table V, the fruits of the September 6 harvest from both the sprayed and unsprayed trees were at the same ground color stage, as measured by the Magness, et. al. color chart (36), although some fruits of the sprayed trees appeared of deeper yellow. Samples from sprayed trees were considered half a stage more advanced at the September 13 harvest and a quarter of a stage more advanced at the September 20 picking. On the last picking date the increased coloration of the more mature fruit from all trees erased any effect of the thiocyanate treatment.

Table XXVIII presents a condensation of the data in Appendix Table V to show the relative effects of the treatments upon ground color change. The data show that the wax inhibited ground color change slightly. The mean reduction over the entire experimental period for the waxed samples over the corresponding unwaxed samples was less than one-half stage. The difference might have been somewhat larger, but some changes in ground color were very difficult to measure since stages beyond four were estimated.

Data in Appendix Table V also show the effect of pre-ripening upon ground color. At the end of the experiment the increased coloration of pre-ripened samples over the non-pre-ripened samples having otherwise the same treatment, averaged about one-half stage. Here again, the changes may not have been accurately recorded because of the difficulty in measuring

TABLE XXVIII

Changes in Ground Color Averaged for the Four Harvest Dates to Show the Relative Effects of Certain Orchard and Harvest Treatments Upon Ground Color of Waxed and Unwaxed Grimes at the End of the Cold Storage Period, 21 Weeks After Harvest, and After the Post Storage of 2 Weeks Exposure to 50° F. 1940.

Lot	Sept. 6		Sept. 13		Sept. 20		Sept. 26		Average	
	21 wks	23 wks	21 wks	23 wks	21 wks	23 wks	21 wks	23 wks	21 wks	23 wks
TWA	1.0	1.75	.50	1.25	—	1.25	1.0	1.25	.83	1.38
TWB	1.5	2.0	.50	1.50	.75	1.25	1.25	2.0	1.0	1.7
TWC	1.5	2.25	1.25	1.75	1.75	2.0	—	2.0	1.5	2.0
TA	1.5	2.5	1.0	2.0	.75	1.75	1.0	1.5	1.1	1.9
TB	—	2.75	1.25	2.25	1.0	2.0	1.75	1.75	1.3	2.2
TC	—	3.25	.75	2.25	2.0	2.0	1.75	2.25	1.2	2.4
WA	1.25	2.0	.75	2.0	.25	1.75	.75	1.25	.75	1.75
WB	—	—	1.0	2.25	.50	1.5	1.25	1.50	.92	1.75
WC	—	2.25	1.0	2.25	2.0	2.25	1.25	2.25	1.4	2.25
A	—	—	1.25	2.5	.75	2.0	1.25	1.50	1.1	2.0
B	—	—	—	2.75	.75	2.0	1.75	2.25	1.25	2.25
C	—	2.75	2.0	2.75	.75	2.0	1.75	2.25	1.5	2.4

the ground color beyond stage four on the chart. But the table does indicate that ground color can be increased by a pre-ripening treatment.

The most attractive apples throughout the storage period were those pre-ripened seven days. The apples of especially the later pickings were highly colored when pre-ripened. When these apples were waxed, they remained attractive in appearance during both the cold storage period and the post storage period of two weeks at 50°F. At the end of the post storage period the unwaxed samples were often of such intense color as to be unattractive in appearance.

DISCUSSION

Previous studies (26) of the reliability of various maturity indices studied under Maryland conditions indicated the qualitative starch test to be the only one worthy of further test for possible commercial use in Maryland. Although many of the other indices tested by Hesse and Hitz (26) showed a general relationship with fruit maturity, they failed to reliably forecast differences in keeping or edible quality during subsequent storage.

In the studies herein reported, considering the results of each year and averaging all treatments, the starch test generally showed good correlation with fruit maturity. In every case there was an increased starch conversion with progressive harvest dates; also accompanying successive harvest dates was an increased palatability development during storage and generally an improved keeping quality. For every year and under all experimental factors, the samples picked on harvest dates showing the highest starch conversion had also the highest quality after storage.

To prove reliable, however, an index of maturity should record small differences between trees or orchards resulting from differences in growth status or nutritional level. The most direct method of modifying tree nutritional level has been by the use of nitrogen application to the tree.

The influence of nitrogen application upon keeping quality has been thoroughly studied in Maryland by Degman (13) and elsewhere by other workers (4,17,21,23,32,33,40,43,57,58). Most of the work is consistent in reporting no influence of nitrogen upon keeping quality, providing the fruit is of the same size and at the same stage of maturity at harvest. It has been regarded by these same workers, however, that nitrogen applications do retard maturity, and that there may be a decreased keeping quality as a result of premature harvesting. Nitrogen effects upon keeping qualities, coloration and palatability of samples at comparable harvest dates were employed in the studies herein reported only to test the efficacy of the qualitative starch test in measuring the differences in maturity resulting from the influence of tree nutritional level.

In these studies, application of sodium nitrate to trees near the last of July did not always significantly increase the nitrogen content of the fruit tissue. The application caused an increase in the nitrogen content of the fruit tissue in 1938 and in 1939, but only the split application of five pounds July 31, 1939 and five pounds August 15, 1939 showed a statistically significant increase. In neither year did ten pounds of nitrate applied July 31 or August 1 cause significant changes in total nitrogen content of the fruit tissue. In 1939 the samples from trees receiving the split application of nitrate differed significantly both from the check trees and from the trees receiving nitrate in the single ten-pound application July 31. Since the method of preparing the nitrogen samples precluded the possibility of seeds being included in the samples for nitrogen determination, the increase was in the fruit tissue. An increased nitrogen content of the seeds rather than in fruit tissue was offered as a possible explanation by Aldrich (1) to those cases where slight increases in the nitrogen content of whole fruits showed no influence upon keeping quality. The results of these present studies are in agreement with those of Gourley and Hopkins (21) and Lagasse (33) in that the increased nitrogen content was in the fruit tissue.

The influence of the nitrate application upon color development was significant only where the nitrogen application caused a statistically significant increase in nitrogen content of the fruit. That was only with split application of nitrate in 1939. Aldrich (1) found that an increase in total nitrogen content of fruit tissue resulting from application of four pounds of sodium nitrate per tree August 19 caused retardation of color on Stayman and York. From results of ten-pound applications on August 1, Fletcher (20) concluded that nitrogen application after cessation of terminal growth had no effect upon fruit color, although he made no nitrogen analysis of fruit tissue. Rainfall records indicate, however, that the nitrates became available shortly after application. Gourley and Hopkins (21) reported an increased nitrogen content in fruit tissue from August applications, and although they also reported a reduced coloration, the extent of the reduction is not mentioned nor evidence presented. Magness, et. al (34) found that July 11 application greatly reduced red color at harvest on fruits from young trees of the Rome Beauty variety. The nitrogen application caused an approximately nineteen percent increase in nitrogen content of the leaves, but no analysis was made on fruit tissue. Other reports, although not always accompanied by chemical analyses, indicate a retarding influence upon color from nitrogen applications (32,37,40,41,57).

The results reported in these studies indicate that when nitrate applications after cessation of terminal growth are followed by significant increases in nitrogen content of the fruit, there is a retardation of color.

Since the qualitative starch method indicated no differences in starch content resulting from nitrate applications, even when the treatment significantly reduced coloration, the suggestion of Magness et. al. (34) that the influence is probably direct is substantiated here where nitrogen analysis was made on fruit tissue.

Nitrate applications influenced keeping quality only on samples of the Frederick orchard in 1938 and 1939. In 1939 the mean development of scald was proportionally in the same direction as was the influence of nitrate application upon blush and total nitrogen content of the fruit. It was apparent that the increased scald on samples from the nitrated trees was proportionally equivalent to the reduced coloration. Many workers (7,17,18,44,48,51) have observed this apparent relationship between coloration and scald. Only Verner (57) has suggested both to be coincidental with fruit maturity. In these studies such was indicated in the bad scald year of 1939. In the results it was pointed out that highly colored samples of one picking date showed more scald than less colored samples of the picking date one week later. This one illustration indicates the relationship between color and scald development is not always direct, but that in certain cases, both are correlated with a maturity factor. Another indication of joint correlation of color and scald development with a maturity factor was the entire absence of scald on any of the bagged fruit placed in storage. Although these samples were always picked late in the season, the entire absence of scald on these samples refutes the possibility of a direct relationship between scald and color.

With the exception of scald development in 1939 and total wastage in Frederick Jonathan of 1938, the wastage in storage was not influenced by the nitrogen treatments. Plagge et. al. (43,44) and others have reported certain other storage physiological diseases to be influenced by tree vigor, but because of the relative unimportance of these disorders in determining waste in these studies, they are reported only as rots.

Neither the "Fruitone" nor the thiocyanate treatment in 1940 influenced keeping quality.

Verner (57) reported a detrimental effect of nitrogen application upon quality and palatability, stating that especially with Black Twig, ".....it was possible.....for a blindfolded person to segregate many mixed lots of apples from nitrated and non-nitrated trees into these two classifications merely by the sense of smell." The flavor was also superior in samples from the check trees. In the studies herein reported it was impossible to detect any differences in flavor that could be attributed to the nitrogen treatment. On samples from the Frederick orchard, in which the effect of nitrate applications was studied, the differences in flavor were noticeably different only on different harvest dates. Without fail, the later the date of harvest the more pleasing was the aroma and flavor when the samples were removed from cold storage. At any harvest date differences between samples from nitrated and non-nitrated trees were too small to detect.

In weighing the efficiency of the qualitative starch method in determining maturity at harvest, some variable results must be considered. In the orchards of the fertilizer experiments where data on starch changes were obtained on individual trees, in none of the three years did the test forecast the differences in keeping quality between the samples from the different trees. Certain of the data have indicated that these differences in keeping behavior were the result of the influence of nitrogen in retarding fruit maturity. Although there is no criterion available to determine what effect relative differences in nitrogen content of the fruit might have upon this retardation, it is considered significant that where nitrogen application caused statistically significant increases in fruit nitrogen content, there was significantly less color and a proportionally greater comparable scald development in storage. In no instance did the starch test indicate any such differences in maturity. Additional data indicating the relative unimportance of starch content at harvest in determining storage wastage was the influence of the thiocyanate sprays upon starch content in 1940. In this case the samples from the sprayed trees averaged a significantly higher starch content which was not reflected in poorer keeping quality in storage.

However, in 1938 it was found that a test of five indicated best palatability in storage, and even though keeping quality could not be accurately forecast in either 1939 or 1940, there was a progressive change in starch conversion with the advance of harvest dates. In 1940 most samples showed a test of five or more on the last harvest date, and also the best average keeping quality and palatability in storage. In the study of this index on a group of Western Maryland orchards in 1940, it was, in the majority of cases, well correlated with the development of wastage and palatability in storage. Although tests of five had not been attained by the time of commercial harvest, those samples of the highest tests generally had the best keeping quality in storage and the best palatability when removed from storage.

Many of the disadvantages of the test as an index of storage quality may result from its variability. Tiller (55) reported the extreme variability between samples prevented its accurate use. Davis and Blair (12), Hinton (27) and Hitz (28) found a variable storage response to samples averaging the same starch content at harvest. In the figure giving the correlation coefficients between percentage blush and starch test on apples tested in the Western Maryland orchards in 1940, it was emphasized that there was a great difference in starch content of samples showing the same blush. This same variability was evident in the twenty readings making up the average starch test of any tree for any date. It was not unusual for a sample of twenty apples though, to have a range five or six stages which would yield a relatively high standard deviation and coefficient of variability. For example, Tree A_3 of the September 26 sampling in the Frederick orchard in 1940 had at least one of the twenty apples falling into eight of the numbered stages and more than two fruits in each of six stages. For that tree on that particular picking date the standard deviation was 1.79, and the coefficient of variability was 35.8 percent. The average starch reading on twenty apples from each of nine trees was 5.5 on that particular date. The coefficients of variability for the starch readings on each of the nine trees making up the average ranged from 14.0 to 35.8 percent and averaged 23.4 percent. Due to the method of sampling, this variability in starch test is considered a measure of the variability between individual fruits on the tree.

This variability may be the basic cause of failure in any attempted method of indicating fruit maturity. The necessity for studies to clarify this variability is indicated. Dorsey and McMann (15) found two hundred pounds of fruit per tree to be the smallest sample to accurately represent size differences between eight trees of the Jefferis variety. For the commercial use of any index by the grower or the Federal-State Inspection Service, such large samples would not be economically feasible. A better approach than large samplings would seem to be a study of the correlation between the maturity test and keeping and edible qualities of the individual fruits.

If the maturity test and storage test could be made on the same fruits, then the influence of each stage of maturity upon storage quality would not be hidden by variability, and it would not be necessary to assume a similarity between fruits which various measurements have proven non-existent.

A definition of mature fruits was given by Hesse (25): ".....that stage 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." Because of the very broadness of the definition, the ultimate measure of fruit maturity most frequently relied upon has been the development of optimum edible and keeping qualities of the fruits in storage. This method, however, is subject to criticism because storage conditions will largely determine the "quality and appearance" after storage. One illustration will emphasize the point: In 1939 the storage conditions favored scald development. There is little doubt that the picking of September 7 with an average starch content of 3.7 and an average blush of 39.3 was more mature than the fruits of September 6 picking in 1940 with an average starch content of 1.5 and an average blush of 26.8. Yet the appearance of the September 7 picking of 1939 was more unattractive at the end of the storage period because of an average scald value of 13.1, compared to no scald development of a less mature sample of 1940.

Throughout the experiment, with 1939 excepted, wilt was one of the most common causes of wastage. Clements (11) has suggested that wilt may be largely a function of the sealing of lenticels at the time of maturity. He found that during the final period that the apple remains on the tree, certain growth conditions may cause breakage of the sealed lenticels and greater water loss would be observed in storage. The importance of storage humidity in controlling storage wilt has been emphasized many times (19,49,53). This cause of wastage, greatly influenced by the storage atmosphere or epidermal layers of the fruit, was a measure extensively used to judge the efficiency of maturity index such as measuring the starch content at the time of harvest. It would seem, with growth conditions influencing such factors as russeting and degree of lenticel sealing, and thus, the amount of wilt, and with varying storage conditions also affecting it, that wilt development would be sufficiently independent of the starch content at harvest so that the latter could not be expected to reliably forecast storage wilt, especially in successive seasons. Since other variables are therefore operative, only insofar as wilt development might be correlated with maturity and this, in turn, indicated by the starch test, could it be hoped that the test would forecast the degree to which wilt would develop. Yet, wilt was an important cause of wastage, and must, as such, be considered in storage studies.

The results of these studies herein reported show the qualitative starch test to be a reliable index of the development of edible quality in subsequent storage, and, therefore, it satisfies the requirements for a standard of maturity for use by the Inspection Service, since, as has been previously mentioned, the grade requirements demand only that the apples be of such maturity at harvest to insure the completion of the ripening process during subsequent handling. However, since factors other than the optimum maturity may influence storage behavior, as previously mentioned, it does not necessarily forecast under all conditions, the storage life of the fruit. Notwithstanding this, a general association between maturity as indicated by the starch test, and subsequent storage behavior has been found in these studies.

Hesse (25) and Hitz (28) concluded that the chief disadvantage of picking Grimes Golden prematurely was the tendency of this variety to wilt under such conditions. Undesirable or insipid flavors resulting from premature pickings were not as apparent as with other varieties. It has been suggested that if the wilt in prematurely picked samples could be controlled, the harvest season on this variety might be extended.

In preliminary experiments Hitz and Haut (29) found that waxing apples with a miscible wax, Brytene 489A, would largely control wilt, but that the wax treatment immediately after harvest increased the severity of scald in storage.

The results of the studies herein reported have shown waxing to have a highly significant influence upon weight loss and wilt development in storage. For the three years, the weight losses, at the times Grimes Golden samples were removed from cold storage, for all unwaxed samples averaged fifty-six percent (27.4 grams per thousand grams original weight) greater than waxed samples receiving otherwise the same treatment. In Golden Delicious the difference amounted to thirty-five percent (27.0 grams per thousand grams original weight). For the entire experimental period, including the post storage periods at higher temperatures the difference in Grimes Golden amounted to fifty-three percent (36.3 grams per thousand grams original weight). On all harvest dates and at all pre-ripening periods the waxed samples showed less waste from wilt than the unwaxed samples of otherwise the same treatment. The wax treatment reduced wilt during the period the apples were in cold storage and during the period of 50-60°F. storage, simulating conditions found in trade outlet channels. Other work (10,30,38,52,53) has shown that the wax treatment will reduce weight loss during storage. Fisher and Britton (19), while attributing to the wax great value in reducing weight loss under conditions of low humidity, found storage humidity to be more important in controlling moisture loss while the fruits were in storage. The influence of high storage humidities in controlling wilt in storage have been signified by Smock (52,53) and others (6,44,49). The difficulty of maintaining high relative humidities, above 80-85%, under cold storage conditions renders such storage conditions economically unsound. And, in addition, many molds capable of growth at 32°F. find the high atmospheric moisture ideal for growth (54). The ability of the wax to reduce weight loss and wilt under usual storage humidity conditions is a distinct advantage of the wax treatment. Even at a relative humidity of 85% Fisher and Britton (19) found the average daily weight loss of several varieties of unwaxed apples to be over one and one-half times greater than waxed samples, all stored at 70°F.

Under the cold storage conditions of these studies, the reduction in weight loss was important because of its relation to wastage from wilt in storage. Smock (53) has suggested that at a weight loss of approximately five percent, visible shriveling or wilt becomes evident upon the fruits. Therefore, any reduction of weight loss in the proximity of that level may be considered beneficial in reducing the amount of wilt. At the end of the period in cold storage the average percentage of original weight loss on all waxed samples was approximately five and for unwaxed samples seven to eight percent. At the end of the period of exposure to higher temperatures following cold storage, the differences were still greater. These differences, although not of great magnitude, were important in determining the amount of wilt because of values equal to or greater than the level at which wilting has been shown to occur (53).

Although the wax treatments were highly efficient in reducing weight loss and wastage from wilt, the waxing also increased the amount of scald on the samples. At all harvest dates on which scald developed, excepting the commercially packed Grimes of September 14 in 1939, all waxed samples had a higher scald value than the unwaxed samples. This is not in agreement with the conclusions of Smock (53) who used different concentrations in studying the effect of the same waxes upon scald development. He found that at some concentrations, one of which was the concentration reported here, scald could be reduced. He concluded that with Rhode Island Greening, the effect of waxing on scald was a function of fruit maturity and the nature and concentration of the wax. Fisher and Britton (19) found waxing to induce "a type of scald not observed on the checks."

Regardless of the waxing treatment, pre-ripening was found to reduce the scald development on all Grimes Golden samples held in cold storage. Every year of experimentation, pre-ripening one week reduced the severity of scald attack in both waxed and unwaxed fruits. In 1938 this amount of pre-ripening was sufficient to preclude scald development on any harvest date, and in 1939 and 1940 pre-ripening for that period reduced scald severity to a level below or comparable with the development on unwaxed samples of no pre-ripening which is the commercial procedure.

This method of reducing scald has not found general support in the literature. Brooks, Cooley and Fisher (8) recommend immediate cold storage for best scald control. Plagge, Maney and Pickett (44) also concluded that scald was greater on samples delayed one week, but their data revealed, especially with prematurely picked Grimes, a delay in storage of one week actually reduced scald. Even on Grimes picked at later dates the difference in scald between those samples stored immediately and those delayed one week was less than one percent. The increase in scald after two weeks delay was much greater. Probably based on these two recommendations, many of the general bulletins discussing storage of apples, such as the one recently published by Smock (54), have recommended immediate storage of apples for scald control regardless of the maturity factor.

In agreement with the results of these studies are those of Eaves and Hill (18) who found a delayed storage decreased scald on immature McIntosh and of Kidd and West (31) who found at certain stages of maturity that a delay before storage was beneficial in reducing scald on Bramely Seedling. Also there have been brought to the writer's attention certain instances in the commercial industry where a delay in storage has reduced scald. One such instance will serve as an illustration. In 1938 a large commercial packing house packed two car-loads of Yorks from the same orchard on the same day. One car was shipped immediately upon completion of loading and the fruits were in cold storage not longer than two days after picking. Due to negligence somewhere along the line, the other car did not reach storage until about one week after loading. Observation at nearly the end of the storage season revealed the fruits of the first car had scalded to such an extent in storage that a reduction in price was taken. Fruits of the second car were in a bright condition with no scald apparent at the time of observation. Judging by the appearance of the ground color on samples from the first car and by the amount of blush on samples from both cars, the fruits were rather immature at time of harvest.

Throughout these studies pre-ripening in only one instance failed to be beneficial in reducing the amount of scald. Since many of the changes in constituents of picked apples are similar to the changes taking place while the apples are maturing on the trees, but possibly at a faster rate, it is difficult to explain the reports of increased scald accompanying delay before cold storage unless it is a function of aeration during the period of delay. If the cause of scald is considered to be an accumulation of certain aromatic esters and gases in the epidermal layers of the fruit (7), the high temperatures of the delay period possibly allow a higher relative accumulation of these materials than in the low temperatures of cold storage over a longer period of time. Such lack of aeration might be found where the pre-ripening treatment was given in unventilated storage rooms, particularily if packed to approximate capacity with fruit, but obviously such conditions need not prevail to make pre-ripening a feasible operation under commercial conditions. Brooks, Cooley and Fisher (7) recognized this point and declared that delayed storage in a closed, unventilated room or refrigerator car would likely cause scald in storage later. Moreover, these authors state: "If it is possible to give good aeration during the delay, the results may be distinctly beneficial...... especially if it (the fruit) is rather immature." Nevertheless, in another publication (8), they do not recommend delayed storage, or pre-ripening, under any condition of maturity, harvest or aeration. Although in these studies scald development was materially reduced or precluded on samples pre-ripened in a closed, unventilated room, this is probably not necessarily in disagreement with the preceding discussion because the room was not filled to capacity. Since the number of fruits in the pre-ripening room at any one time was relatively small, very likely there was sufficient diffusion of the noxious materials from the fruits packed in open hampers into the storage atmosphere not heavily laden with the gases. It would seem that the container and liners would offer less opportunity for the diffusion of the noxious materials from apples packed in commercial packages.

It is possible that such may partially explain the ineffectiveness of the pre-ripening treatments of less than two weeks to reduce the severity of scald on the samples of the September 14, 1939 picking that were packed in commercial packages. However, the fact that all pre-ripening periods had an influence upon scald severity of the September 6 picking indicates that factors other than aeration were important. The 1939 test of the effect of the experimental factors upon scald development was a very severe test in that storage conditions prevailed which are considered ideal for scald development. The great retardation of scald on the samples pre-ripened two weeks would indicate that under the storage conditions of 1939, less than two weeks pre-ripening was insufficient to preclude the development of scald. On the September 14 picking all waxed samples showed less scald development than the unwaxed samples. This effect has been mentioned by Smock (53) but is not substantiated by other results in this study.

In controlling scald the importance of harvesting at a mature stage was evident throughout the experiment.

Although there were differences in significance during any period of storage, the influence of the pre-ripening treatment upon weight loss was comparable each season. During the period the fruits were in the pre-ripening room, they lost more weight than fruits of the same harvest dates in cold storage. When the pre-ripened fruits were placed in cold storage after the pre-ripening period, they lost weight less rapidly than the non-pre-ripened samples of otherwise the same treatment. This difference in rate of weight loss was not sufficient for pre-ripened and check samples to show comparable amounts of loss at the end of the period in cold storage, twenty to twenty-two weeks from harvest. Generally, however, it was sufficiently high that, at least for samples of Grimes pre-ripened not over one week, the differences in weight loss over the entire experimental period were not significant, and in some cases the pre-ripened samples showed less weight loss than the non-pre-ripened samples. In all cases the waxed samples pre-ripened one week showed less weight loss than unwaxed samples placed in cold storage without pre-ripening. This difference was reflected in the amount of wilt developing in each category.

Magness and Diehl (35), Smock (52,53), Fisher and Britton (19), and Hitz and Haut (29) have shown that covering the fruits with a wax coating retarded ripening as indicated by ground color changes, respirations rates or both. This same retardation, based upon ground color changes, was evident in this experiment. This suggests one commercial application in which some growers have shown interest. The sales appeal of yellow varieties is enhanced when the fruits show a bright yellow color rather than the dull green so typical of these varieties on the market. If the fruits can be pre-ripened to a bright yellow color and waxed, the retardation of ripening by the wax treatment should hold them at this attractive stage for a longer period than unwaxed fruits ripened to the yellow color. Of additional benefit is the sheen furnished the fruits by the wax coating.

A disadvantage of waxing non-pre-ripened Grimes Golden and Golden Delicious of an intense green color was the splotched and uneven coloration when the fruits were exposed to ripening temperatures after cold storage. However, if apples were pre-ripened one week before waxing, there resulted an attractive ground color which was maintained during the post storage period simulating the period between storage and consumer in the commercial method of distribution.

Summarizing, the effect of the experimental factors on the keeping qualities of Grimes Golden showed that waxing would markedly retard weight loss and wilting, but that waxing without pre-ripening would increase the severity of scald. Scald control was enhanced by any pre-ripening treatment. Since waxing effectively controlled the development of wilt and since pre-ripening for one week either significantly reduced scald or precluded it entirely without significantly affecting the development of wilt, the higher percentage of good apples obtained at the end of the experimental period in every year was in lots having that treatment.

In one case to the author's knowledge waxing has been used on a commercial scale for apples. Figures 11 and 12 show waxing equipment in the Byrd packing house at Berryville, Virginia. The apples to be waxed were diverted from the grader and run through a mist or spray of the wax. To facilitate packing of the fruits after waxing, the waxed fruits were passed through a warm air blast from fans blowing through small steam heated coils. This commercial concern reported the more attractive appearance and longer market life of waxed apples when removed from storage to be of definite advantage in selling. Wholesalers distributing the waxed fruits found the fruit to be most attractive to retailers and that this fruit was ordered in preference to regularly packed fruit as long as the supply lasted.

SUMMARY AND CONCLUSIONS

The purpose of the maturity studies with Jonathan was to determine the efficacy of the qualitative starch method as a maturity index for time of proper picking. The waxing studies were inaugurated to test the effect of wax emulsion, Brytene 489A, upon wilt development in Grimes Golden and Golden Delicious.

Storage samples were collected once weekly prior to and extending through the time of commercial harvest for these varieties. Determination of the effectiveness of the starch index or waxing treatment was made by comparison of the keeping and edible qualities after approximately five months of cold storage.

In the maturity studies with Jonathan, midsummer applications of sodium nitrate at the rate of ten pounds per trees were made to study the efficacy of the maturity index method in revealing differences in fruit

Figure 11. Commercial waxing equipment in use during the 1940 packing season at the H.F. Byrd packing house, Berryville, Va. Apples are diverted from grader belt at (A), enter chamber (B) where wax is sprayed on fruits, and then fruits pass through chambers (C) where fans blow warm air over it to facilitate drying.

Figure 12. Commercial waxing equipment in use during the 1940 packing season at the H.F. Byrd packing house, Berryville, Va. Rear view showing drying chambers (C), small steam coils (E) and fruit returning to the grader belt at (D) after having passed through the chambers.

maturity resulting from a modified growth status of the trees. In 1940 a sodium thiocyanate spray was applied to Jonathan trees in studying the relation of the improved color with fruit maturity, as indicated by the amount of starch conversion. Also in 1940 the starch test was used to determine Jonathan maturity in fifteen Western Maryland orchards, varying in vigor, age and fruitfulness. Storage and test samples were collected at weekly intervals from these orchards.

The qualitative starch test showed a good relationship with the general improvement in keeping and edible qualities of samples associated with successive harvest dates. Considering all seasons and all orchards, the samples picked on dates when the highest average starch tests were found, developed the best edible quality in storage. When the starch test at harvest averaged "four" or "five" on storage samples, good palatability developed, and storage wastage generally was reduced. Although this result was most apparent on weekly sampling dates from the same orchard, the index indicated the differences in maturity of samples picking at approximately the same date from different orchards in Western Maryland in 1940, which was later revealed by the storage behavior of those samples.

However, at harvest dates approximating time of commercial harvest in the Frederick orchard over a three-year period and in the Colesville orchard in 1938, the method did not forecast accurately the variability in keeping qualities in individual samples from different trees. Neither did it exactly forecast the differences in keeping qualities resulting from a modified growth status of the trees. This was most marked in those cases where measurements of blush development, total nitrogen content of fruit tissue and storage wastage indicated that nitrogen applications had retarded fruit maturity, and in the failure of the retarded starch conversion resulting from the thiocyanate sprays in 1940 to be

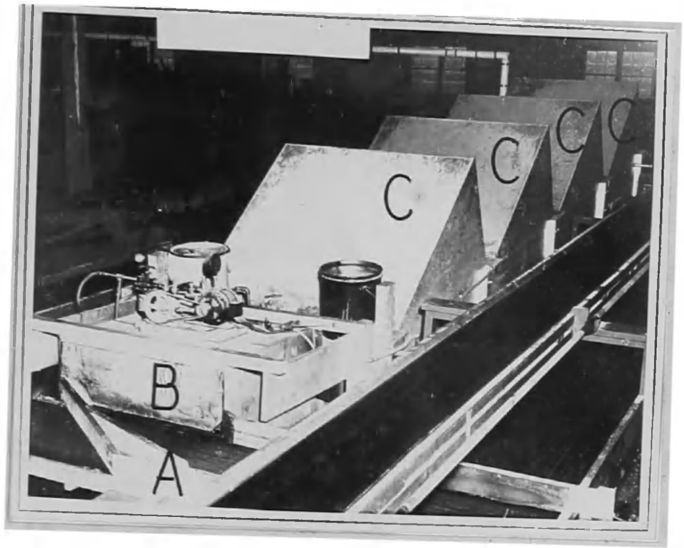


Figure 11

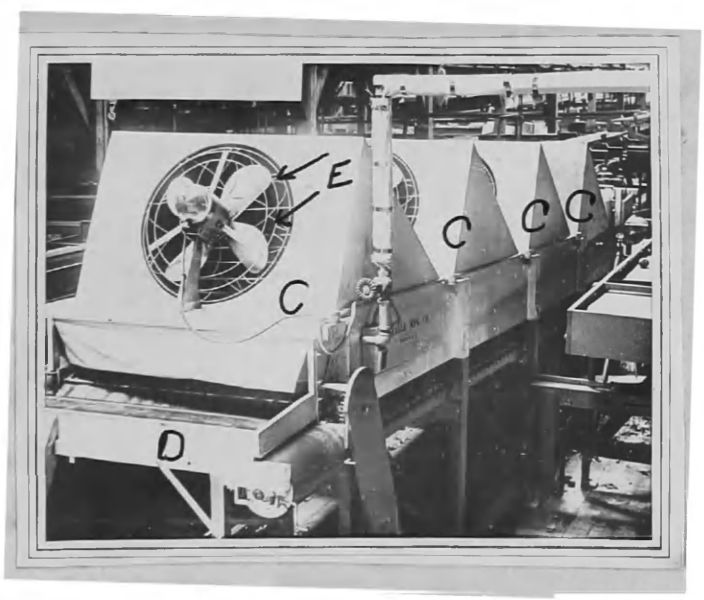


Figure 12

reflected in differences in keeping or edible qualities in storage. The range in the maturity status of individual fruits as well as the influence of growth and storage conditions upon the development of storage wilt, an important cause of wastage, is suggested as a possible explanation for the failure of the index to more accurately reveal this variability in keeping quality.

In the waxing studies weight loss, keeping quality, changes in ground color and development of palatability were studied on waxed and unwaxed Grimes Golden and Golden Delicious picked on progressive harvest dates and given pre-ripening treatments varying in length in successive seasons. Also, the 1940 studies included a test of thiocyanate sprays, as a method of increasing the ground color at harvest, and in turn to determine the effect of such ground color on storage scald of Grimes Golden.

These studies showed the waxing treatment to be highly significant in reducing weight losses of Grimes Golden during cold storage and the post storage period at 50 or 60°F. At the time the samples were removed from cold storage, twenty-one or twenty-two weeks from harvest, the unwaxed Grimes of all harvest dates and pre-ripening treatments for the three years, averaged a fifty-six percent greater weight loss than comparable waxed samples. For the entire experimental storage period, extending over twenty-four weeks from harvest, including a post storage period at 50 to 60°F., the difference, averaged for two years, amounted to fifth-three percent. In the Golden Delicious studies in 1938, the unwaxed samples had lost thirty percent more weight than waxed samples when removed from cold storage. These differences in weight loss were important in determining the amount of storage wilt because of values equal to or greater than the level at which wilting occurs. Moreover, this importance was shown by the greater reduction in storage wilt accompanying the wax treatments, a reduction in wilt sufficient to have marked commercial significance.

Although the wax treatments were highly effective in reducing weight loss and storage wilt, waxing also increased severity of superficial scald. However, exposing the fruits to 60°F. in a closed room for one week (pre-ripening) either reduced or precluded the attack of scald on both waxed and unwaxed fruits. Samples waxed after one week of pre-ripening had scald values comparable to or below those values for unwaxed samples placed in cold storage without pre-ripening. With progressive harvest dates the more mature fruits showed a proportional reduction in scald. The thiocyanate spray in 1940, although increasing the ground color slightly on two harvest dates, also increased the severity of scald.

The waxing treatment was found to retard the rate of ground color change. Fruits which were waxed without pre-ripening did not show the normal development of yellow color during cold storage or during the post storage period. Fruits which had been pre-ripened one week before waxing had a brighter color at the end of the post storage period.

The highest percentage of good apples remaining after a storage period simulating conditions that fruits encounter in normal distribution channels following cold storage, were those fruits pre-ripened one week and then waxed. They showed less wilt and scald and were brighter in appearance than fruits handled by methods comparable to those now used in the apple industry.

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APPENDIX

APPENDIX TABLE I

Weight Loss, in Grams per Thousand Grams Original Weight, at the Time of Removal from Cold Storage, Twenty-one Weeks from Harvest, of Grimes Golden Given Various Treatments at Harvest and Analysis of Variance to Show Significance of the Main Effects. Frederick Orchard. 1938.

Waxing	Waxed				Not Waxed			
No. Weeks Pre-ripened	0	1	2	3	0	1	2	3
Date of Harvest								
August 16	43.6	42.2	51.7	71.6	61.8	54.5	68.9	58.7*
August 23	41.0	42.9	43.3	52.1*	59.6	54.1	64.4	56.3*
August 30	36.3	36.3	44.1	48.6*	57.6	54.6	54.7	58.5
Sept. 6	43.4	49.0	54.4*	49.7	81.5	66.9	75.8*	59.7
Sept. 13	43.6	52.5	56.1	55.6	86.6	75.9	109.1	88.0
Sept. 23	49.7	51.1	62.7	60.3	87.2	99.4	83.6	92.2

* Filled in by formula for missing data (42)

Analysis of Variance

Source	D/F	Sum Squares	Variance	"F" Value
Total	41	13422.3		
Wax	1	5803.6	5803.6	59.16**
Pre-ripen	3	480.5	160.2	1.6
Dates	5	3999.4	799.9	8.2**
Error	32	3138.8	98.1	

APPENDIX TABLE II

Total Weight Loss, in Grams per Thousand Grams Original Weight, for the Entire Experimental Period, Twenty-four Weeks from Harvest, of Grimes Golden Given Various Treatments at Harvest and Analysis of Variance to Show Significance of the Main Effects. Frederick Orchards. 1938.

Waxing	Waxed				Not Waxed			
No. Weeks Pre-ripened	0	1	2	3	0	1	2	3
Date of Harvest								
August 16	57.4	55.6	65.1	86.7	79.9	70.6	86.6	74.3*
August 23	54.8	53.6	53.9	61.9*	78.9	71.1	81.8	72.6*
August 30	48.8	48.1	56.7	58.9*	75.3	74.1	71.8	73.3
Sept. 6	63.0	66.6	67.0*	62.9	106.4	86.3	94.2*	74.8
Sept. 13	62.4	69.6	72.9	71.6	113.9	99.0	130.6	114.4
Sept. 23	76.1	74.2	86.0	81.4	119.4	129.1	108.8	117.5

* Filled in by formula for missing data (42)

Analysis of Variance

Source	D/F	Sum Squares	Variance	"F" Value
Total	41	20661.8		
Wax	1	8788.6	8788.6	82.5**
Pre-ripen	3	262.1	87.4	.82
Dates	5	8203.6	1640.7	154 .1**
Error	32	3407.5	106.5	

APPENDIX TABLE III

Weight Loss, in Grams per Thousand Grams Original Weight, at the Time of Removal from Cold Storage, Twenty-two Weeks from Harvest, for Grimes Golden Given Various Treatments at Time of Harvest and Analysis of Variance to Show Significance of the Main Effects and Certain Interactions. Frederick Orchard. 1939.

Waxing Treatment	W A X E D								N O T W A X E D							
Days of Pre-ripening	0		2		4		7		0		2		4		7	
Harvest Date																
August 21	38.0	41.0	55.0	45.0	64.0	53.0	46.0	50.0	74.0	79.0	102.0	85.0	81.0	75.0	87.0	80.0
August 28	48.0	47.0	54.0	55.0	55.0	52.0	56.0	55.0	97.0	78.0	90.0	115.0	102.0	116.0*	103.0	95.0
Sept. 4	43.0	39.0	39.0	38.0	40.0	40.0	38.0	37.0	54.0	50.0	57.0	52.0	53.0	58.0	51.0	51.0
Sept. 11	42.0	35.0	45.0	45.0	39.0	40.0	46.0	44.0	63.0	68.0	70.0	67.0	70.0	60.0	60.0	60.0

*Filled in by formula for missing data (42)

Analysis of Variance

Source	D/F	Sum of Squares	Variance	"F"	"F" Value for Main Effects Only
Total	62	27188			
Dates	3	8441	2814	263**	34.5**
Pre-ripening	3	518	173	16.1**	2.12
Waxing	1	13777	13777	1287.6**	169.0**
Replicates	1	51	51	4.8*	.62
Da x Pre-rip.	9	407	45	4.2**	
Da x W.	3	2409	803	75.0**	
W x Pre-rip.	3	1166	389	36.3**	
Error	39	419	10.7		

* Significant at 5% Level ** Significant at 1% Level

APPENDIX TABLE IV

Percentage Wilt When Removed from Cold Storage, Twenty-one Weeks After Harvest, and Total Percentage Wilt Twenty-three Weeks After Harvest of Grimes Samples Given Various Orchard and Harvest Treatments Before Storage. 1940.

Dates	Sept. 6		Sept. 13		Sept. 20		Sept. 26		Mean	
Lot	21 wks	23 wks	21 wks	23 wks	21 wks	23 wks	21 wks	23 wks	21 wks	23 wks
TWA	2.1	2.1	0	4.1	5.7	15.9	0	0	2.0	5.5
TWB	10.9	25.4	1.5	7.5	0	2.7	0	0	3.1	8.9
TWC	6.0	26.0	0	8.0	0	9.0	0	0	1.5	10.8
TA	22.0	72.0	17.3	72.0	25.3	72.2	29.4	68.6	23.5	71.2
TB	0	82.0	36.3	89.6	23.7	75.0	16.9	75.4	19.2	80.5
TC	49.1	89.0	30.0	85.5	28.5	92.2	14.8	61.7	30.6	83.6
WA	0	0	0	1.7	1.3	14.8	0	0	0.3	4.1
WB	0	0	0	0	0	0	0	0	0	0
WC	2.1	13.0	0	1.6	0	2.8	0	23.0	0.5	4.9
A	50.8	84.7	13.2	49.0	19.1	58.9	0	19.6	20.8	53.0
B	33.3	93.3	11.1	59.2	30.7	87.6	57.0	69.2	20.2	77.3
C	36.1	80.8	31.3	70.5	28.7	81.8	6.0	46.0	25.5	69.8
Mean	17.7	47.4	11.7	37.4	13.7	42.8	6.1	28.6		

T = Samples from trees sprayed with Na thiocyanate.
W = Samples Waxed before placing in cold storage.
A = Samples pre-ripened 0 days before placing in cold storage.
B = Samples pre-ripened 4 days before placing in cold storage.
C = Samples pre-ripened 7 days before placing in cold storage.

APPENDIX TABLE V

Original Ground Color, and Changes in Ground Color at the End of the Cold Storage Period, 21 Weeks After Time of Picking, and After a Two Weeks Post Storage Period at 50°F., 23 Weeks After Picking of Waxed and Unwaxed Grimes Given Various Orchard and Harvest Treatments in 1940.

Date / Lot	Original Ground Color	Ground Color Change 21 wks	Ground Color Change 23 wks	Final Ground Color	Date / Lot	Original Ground Color	Ground Color Change 21 wks	Ground Color Change 23 wks	Final Ground Color
Sept. 6					Sept.20				
TWA	1.25	1.0	1.8	3.0	TWA	2.25		1.25	3.5
TWB	1.25	1.5	2.00	3.25	TWB	2.25	.75	1.25	3.5
TWC	1.25	1.5	2.25	3.5	TWC	2.25	1.75	2.0	4.25
TA	1.25	1.5	2.5	3.75	TA	2.25	.75	1.75	4.00
TB	1.25		2.75	4.00	TB	2.25	1.0	2.0	4.25
TC	1.25		3.25	4.5	TC	2.25	2.0	2.0	4.25
WA	1.25	1.25	2.0	3.25	WA	2.0	.25	1.75	3.75
WB	1.25				WB	2.0	.50	1.5	3.5
WC	1.25		2.25	3.5	WC	2.0	2.0	2.25	4.25
A	1.25				A	2.0			
B	1.25				B	2.0	.75	2.0	4.00
C	1.25		2.75	4.00	C	2.0	.75	2.5	4.5
Sept.13					Sept.26				
TWA	2.25	.50	1.25	3.5	TWA	2.25	1.0	1.25	3.5
TWB	2.25	.50	1.50	3.75	TWB	2.25	1.25	2.0	4.25
TWC	2.25	1.25	1.75	4.0	TWC	2.25		2.0	4.25
TA	2.25	1.0	2.0	4.25	TA	2.25	1.0	1.5	3.75
TB	2.25	1.25	2.25	4.50	TB	2.25	1.75	1.75	4.0
TC	2.25	.75	2.25	4.5	TC	2.25	1.75	2.25	4.5
WA	1.75	.75	2.0	3.75	WA	2.25	.75	1.25	3.5
WB	1.75	1.0	2.25	4.0	WB	2.25	1.25	1.50	3.75
WC	1.75	1.0	2.25	4.0	WC	2.25	1.25	2.25	4.5
A	1.75	1.25	2.5	4.25	A	2.25	1.25	1.50	3.75
B	1.75		2.75	4.5	B	2.25	1.75	2.25	4.5
C	1.75	2.0	2.75	4.5	C	2.25	1.75	2.25	4.5

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