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Predicting Harvest Date Windows for Apples

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Contents

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Harvest Date and Quality

An effective marketing program for apples requires the delivery of product at sufficiently high and consistent quality levels to both satisfy customer demands and generate repeat sales. While each market may define quality differently, the components of apple quality are always measured in terms of appearance, taste, and fruit internal condition.

Harvest date is an important factor affecting apple quality after storage.

Apples harvested too early are frequently very firm after storage, but small, green in appearance, acid-tasting or lacking in flavor, and likely to develop storage scald and/or bitter pit, two storage disorders associated with immaturity at harvest. If the harvest is delayed too long, harvest drop and the development of water core may become problems. After storage, late-picked apples: (1) have a short shelf life, (2) frequently are dull in appearance, (3) taste overripe and mealy, (4) may have developed flesh senescent breakdown, and (5) because they are soft, are highly susceptible to grading and transit bruising.

Harvest Windows for Storage Apples

The "harvest window" is that period in days when the apples should be picked for storage. It opens when the apples reach the stage of development that will assure good fruit quality after storage and closes when the picking date is too late to assure good fruit quality after storage. The harvest window for a geographic area spans the expected calendar dates of best harvest for the apples in that area and is usually limited to about seven days. McIntosh is used here to illustrate the harvest window concept.

Table 1 shows typical poststorage data for apples picked from one block of trees on a series of calendar dates and kept in air at 32°F until the end of the regular storage period. Early picked apples were green in color and acid-flavored. Late-picked apples were dull in appearance and tasted overripe. The fruit with the best panel scores for appearance and eating quality combined were picked on September 23, 26, and 30, the harvest window for that block in that season. The best harvest date, September 26, was in the middle of that period.

Table 1. Panel evaluation scores for McIntosh apples picked from the same trees on several dates and stored in air at 32°F until January.

	Taste Panel Evaluation Scores for Quality		
Harvest date	*Fruit appearance*	*Eating quality*	*Combined score*
September 16	**8**	**14**	**22**
September 19	**9**	**19**	**28**
September 23	**16**	**19**	**35**
September 26	**17**	**20**	**37**
September 30	**20**	**16**	**36**
October 3	**15**	**13**	**28**
October 7	**12**	**11**	**23**

Table 2. Fruit characteristics on September 26 and poststorage panel estimates of best harvest dates for storage of McIntosh from six farms in Sodus, N.Y.

	Fruit characteristics on September 26		*Poststorage panel estimate*
Farm	*Firmness (lb.)*	*Red color (%)*	*for best harvest date*
A	**16.2**	**85**	**October 1**
B	**15.0**	**90**	**October 1**
C	**14.9**	**90**	**September 30**
D	**14.8**	**75**	**September 28**
E	**14.6**	**66**	**September 29**
F	**14.4**	**50**	**September 30**

Table 3. September 24 firmness and poststorage taste panel estimates of best harvest dates for McIntosh grown on four farms in the Lake Ontario area.

	Niagara County	*Orleans County*	*Monroe County*	*Wayne County*
September 24 firmness (lbs.)	**13.3**	**16.1**	**14.0**	**15.5**
Best Harvest Date*	**Sept. 28**	**Sept. 27**	**Sept. 26**	**Sept. 26**

* Based on poststorage taste panel scores for samples picked on Sept. 13, 16, 21, 24, 28, Oct. 1, 5.

Table 4. Harvest windows for best harvest dates of McIntosh apples.

	Hudson Valley		*Lake Ontario area*	
Crop year	*No. of farms*	*Harvest window*	*No. of farms*	*Harvest window*
1960	**3**	**Sept. 16-18**	**4**	**Sept. 23-29**
1961	**4**	**Sept. 28-Oct. 2**	**4**	**Oct. 4-7**
1962	**4**	**Sept. 18-21**	**4**	**Sept. 22-25**
1963	**3**	**Sept. 24-25**	**5**	**Sept. 25-30**
1964	**4**	**Sept. 24-26**	**5**	**Sept. 26-28**
1965	-	- - - - -	**4**	**Sept. 26-Oct. 5**
1966	**3**	**Sept. 28-Oct. 1**	**3**	**Sept. 30-Oct. 1**
1967	**4**	**Sept. 24-28**	**4**	**Sept. 26-Oct. 2**
1968	**4**	**Sept. 18-25**	**4**	**Sept. 24-30**

Best harvest dates in another season are shown in Table 2 for McIntosh grown on six farms in the Town of Sodus. Panel evaluations of apples from these six farms indicated that the best storage McIntosh in Sodus that season were picked in the four-day harvest window September 28–October 1.

The best harvest dates for McIntosh grown on four farms in the Lake Ontario area were September 27 ± 1 day in another season, as shown in Table 3. Fruit characteristics of apples sampled a few days prior to the best harvest dates exaggerated the remarkably small among-orchard variation in best harvest dates shown in Tables 2 and 3. (See Picking Inside the Harvest Window.)

Table 4 summarizes a large McIntosh harvest-maturity study in the Hudson Valley and Lake Ontario areas. Although there were significant among-year and among-area differences in the calendar dates of the best harvest, the harvest windows for best harvest dates were usually no longer than one week for any given season in either area.

Compared to McIntosh, there is less among-season variation in calendar dates of best harvest for Empire, Delicious, Crispin/Mutsu, and Idared apples (Table 5, next page). In the Lake Ontario area, the normal harvest windows for these apple varieties are:

Empire, October 5-9;

Delicious, October 5-15;

Crispin/Mutsu, October 13-19;

Idared, October 15-22.

Forecasting Harvest Windows

This section discusses methods for forecasting harvest windows for McIntosh, Empire, Delicious, Crispin/Mutsu, and Idared. When the harvest windows for these varieties have been determined, harvest windows for other storage varieties can be predicted from the harvest sequence shown in Table 6.

Apple growers should forecast their harvest window dates well before picking to permit scheduling of harvest labor, distribution of empty bins in the orchard, proper timing of preharvest stop-drop hormone sprays, and final preparation of harvest, packing, and storage equipment and facilities.

Apple varieties harvested before Jonamac are usually marketed immediately and therefore should not be picked until they are almost ready to be eaten directly out-of-hand from the tree. The harvest windows for these early varieties can usually be determined by the seasonal earliness or lateness of other fruits and apple varieties (see Table 6) that ripen earlier.

Table 5. October dates of best harvest for apples in the Lake Ontario area.

Empire		*Delicious*		*Crispin/Mutsu*		*Idared*	
1972-84		*1960-76*		*1973-76*		*1965-76*	
Date	*Tests*	*Date*	*Tests*	*Date*	*Tests*	*Date*	*Tests*
Oct. 1-4	**5**	**Oct. 1-4**	**1**	**pre Oct. 13**	**0**	**Oct. 13-14**	**2**
Oct. 5-9	**18**	**Oct. 5-15**	**12**	**Oct. 13-19**	**9**	**Oct. 15-22**	**25**
Oct. 10-11	**2**	**Oct. 16-25**	**1**	**post Oct. 19**	**0**	**Oct. 23-28**	**8**

Table 6. Normal harvest sequence of apple varieties.

Jerseymac	***McIntosh***	***Jonagold***
Tydeman	***Cortland***	***Law Rome***
Empress	***Liberty***	***Golden Delicious***
Paulared	***Macoun***	***Crispin/Mutsu***
Jonamac	***Freedom***	***Idared***
Elstar	***Spartan***	***Rome Beauty***
Gala	***Empire***	***Braeburn***
	Delicious	***Fuji***

McIntosh

The procedure below can be used to estimate the last day of picking for CA storage. McIntosh apples picked later than that date should not be placed in CA storage.

1. Record the date of full bloom—the day on which bee activity was heaviest and at least 80 percent of the flowers were fully open with anthers shedding pollen on the north side of the trees.

Example: May 16

2. Add 3 days to the May date of bloom. (The calculations are based on the number of days past April 27.)

Example: May 16
+ 3
19 the number for full bloom (FB) you will use in the formula

3. Compute the average mean temperature (MT-30) for the 30-day period following bloom.

Table 7. Mean numbers of days between starch-iodine index numbers (SI) and suggested ranges in starch-iodine index numbers for CA storage.

McIntosh		*Empire*		*Delicious*		*Idared*	
1986-90		*1988-90*		*1988-90*		*1988-90*	
SI change	*Days*	*SI change*	*Days*	*SI change*	*Days*	*SI change*	*Days*
3.0-4.0	**5.7**	**2.6-3.0**	**5.8**	**1.6-2.0**	**8.9**	**1.6-2.8**	**8.9**
4.0-5.0	**5.7**	**3.0-3.5**	**4.6**	**2.0-2.8**	**5.8**	**2.8-3.5**	**5.5**
5.0-6.0	**5.6**	**3.5-4.5**	**6.9**	**2.8-3.5**	**4.7**	**3.5-4.0**	**5.6**
6.0-7.0	**3.6**					**4.0-6.0**	**6.2**
suggested range in starch-iodine index numbers for CA storage							
5.0-6.0		**4.5-5.5**		**2.8-3.5**		**2.8-3.5**	

Example:

average maximum for 30-day period = 73.3°F

average minimum for 30-day period = 50.7°F

average mean for the 30-day period = 62.0°F

4. Select the length-of-season formula for your area. The length-of-season is the number of days from full bloom to the last day of picking for CA storage.

Geographic area	*Length-of-season formula*
Hudson Valley	205.04 - 0.16FB - 1.08MT-30
Central New York	201.53 - 0.16FB - 1.08MT-30
Lake Ontario	201.56 - 0.16FB - 1.08MT-30
Champlain Valley	197.73 - 0.16FB - 1.08MT-30

Example: for Ithaca, select the 'Central New York' formula,

length-of-season = 201.53 - 0.16FB - 1.08MT-30

5. Enter the computed FB (19) and MT-30 (62.0) data into the formula.

Example: days = 201.53 - (0.16 x 19) - (1.08 x 62.0) = 201.53 - (3.04) - (66.96)
= 201.53 - (3.04 + 66.96)
= 201.53 - 70.00
= 131.53 or 132 days

The formula predicts the last day for picking CA McIntosh in Ithaca should be May 16 + 132 days = September 26 (see Appendix A).

The following steps will predict the harvest window for CA McIntosh in a geographic area:

1) Use full-bloom and temperature data for several McIntosh orchards to calculate their predicted last dates for picking for CA.
2) The harvest window for CA McIntosh closes on the average date calculated in the previous step.
3) The start-date for McIntosh picking should be sufficiently early to finish picking for CA before the window closes.
4) The dates of the predicted harvest window must be verified by fruit maturity tests made in the orchard before the opening of the predicted harvest window. These tests are discussed in the next section.

Other varieties

The actual harvest windows for Empire, Delicious, Crispin/Mutsu, and Idared are normally about one week long. That is, the harvest window extends about three days on either side of the best harvest date for any given variety grown in any given geographical area in any given season. The ranges in best harvest dates in the Lake Ontario area are shown in Table 5. (In the Hudson Valley the best harvest dates are frequently, but not always, *five to seven days earlier* than the dates shown in Table 5.) Apples picked during the first half of the harvest window are normally stored in CA; those picked in the second half are normally stored in air at 32°F or sold at harvest.

The best harvest dates for Empire were October 1–ll in 25 harvest maturity tests conducted in the Lake Ontario area from 1972 to 1984 (Table 5). In 18 of these tests, the poststorage evaluations indicated the best apples for storage were picked October 5–9. Early bloom was usually followed by an early best harvest date, and late bloom by a best harvest date near the end of the October 1–11 period.

Table 5 shows that the best harvest dates for Delicious normally occur October 5–15. October 10 is a good predicted best harvest date for Delicious in the Lake Ontario area, if bloom is within a week of normal. If bloom is more than a week earlier than normal, best harvest dates will probably be earlier than normal, but never less than 135 days or more than 150 days after bloom. If bloom is more than a week later than normal, the best harvest will probably be later than normal, but almost never after October 15, the date frequently associated with the beginning of severe water core. Starkrimson (Bisbee) Delicious usually reaches harvest maturity a few days later than most other strains of Delicious.

Nine maturity tests with Crispin/Mutsu in the Lake Ontario area showed the best harvest dates for that variety were in the narrow window of October 13-19. At harvest, the appearance of apples in lightly and heavily cropped blocks frequently suggested a greater spread of best harvest dates. To test this observation, apples were harvested from heavily cropped trees on M106 rootstocks and from a neighboring block of same-age, lightly cropped trees on the same rootstock. The poststorage panel evaluations indicated that small, green, soft apples from the heavily cropped trees and the larger, firmer, yellow apples from the lightly cropped trees both had best harvest dates that fell within the October 13-19 window (Fig. 1). October 16 is the predicted best harvest date for Crispin/Mutsu in the Lake Ontario area in most seasons.

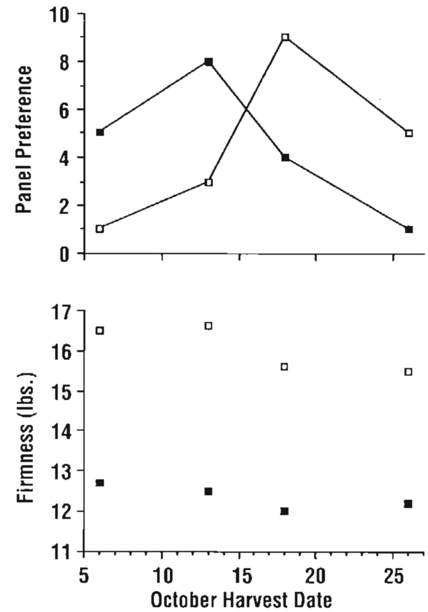

Figure 1. *Poststorage flesh firmness and panel preference scores for Crispin/Mutsu apples picked on four dates from similar trees that were lightly cropped (open squares) and heavily cropped (shaded squares).*

Best harvest dates for Lake Ontario area Idared apples were October 13–28 in 35 tests, with more than two-thirds occurring October 15–22 (Table 5). Thus, October 19 is a good predicted harvest date for Idared. This date can be modified by a rule-of-thumb applicable to most storage varieties: For each two-three days departure from the normal bloom date, there will be a one-day departure from the normal harvest date.

Verifying Harvest Window Predictions

Although the calendar, weather data, and the ripening of other fruits can be used to predict harvest windows in advance of the harvest period, it is essential to make fruit ripening measurements before harvest to verify or, if necessary, to adjust the predicted dates of best harvest in a geographical area. In the past, several fruit ripening indexes were suggested: flesh firmness, red or green color of the skin, flesh color, seed color, soluble solids content of the juice, taste, harvest drop, fruit internal ethylene concentration, and starch-iodine index. Figure 2 illustrates some of these changes that occurred in four Rhode Island Greening blocks in Wayne County.

All apple ripening indexes are imperfect measurements of fruit harvest maturity and are frequently difficult to interpret. Seasonal climatic factors, as well as such orchard factors as nutrition and cropping level, frequently influence apple ripening indexes but do not affect harvest maturity dates.

On any given date there are always among-orchard variations in apple ripening indexes. These variations, which are associated with differences in orchard nutrition, cropping level, etc., can be minimized by making fruit ripening measurements in several orchards to determine average values for an area. By making fruit ripening measurements on several dates, it is possible to determine if the current season is earlier or later than a previous season. This is illustrated in Figure 3, which shows averages for several Empire orchards in the Lake Ontario area. The starch-iodine indexes plotted in the top graph show that Empire in 1990 ripened about five days earlier than in 1989. The ethylene data plotted in the bottom graph show Empire ripened much later in 1984 than in 1977.

Although ethylene measurements are more precise than measurements of starch-iodine index, under commercial orchard and storage conditions the latter is the preferred fruit maturity index because:

(1) Ethylene measurements require a gas chromatograph, which is an expensive piece of laboratory equipment.

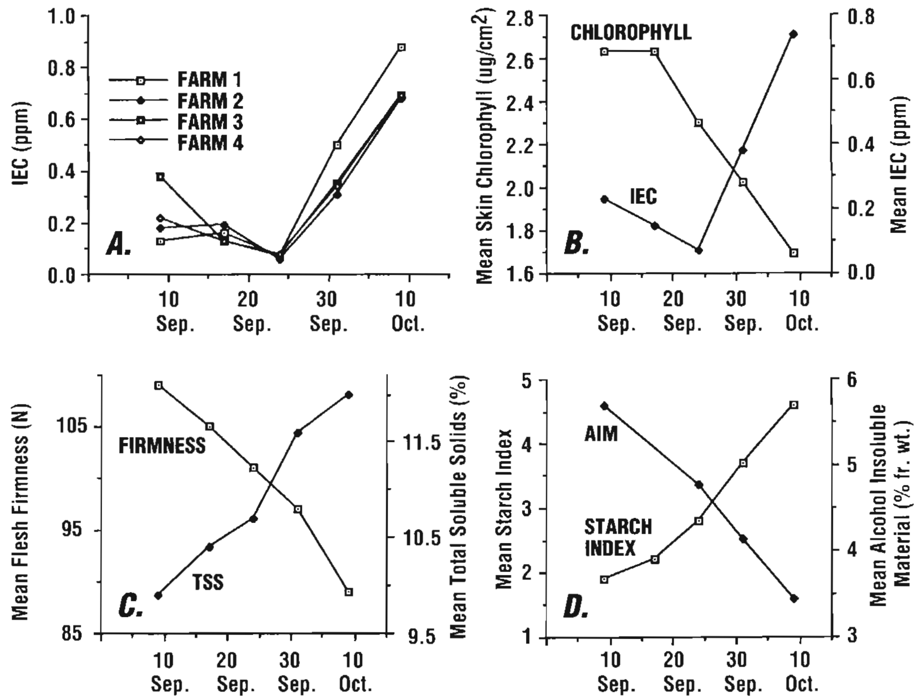

Figure 2. *Some apple maturity indexes for Rhode Island Greening apples from four Wayne County farms in 1987. **A** Internal ethylene concentration (IEC) for each farm. **B** Mean IEC and skin chlorophyll content for the four farms. **C** Mean flesh firmness and total soluble solids (TSS) for the four farms. **D** Mean starch index and flesh content of alcohol insoluble material (AIM) for the four farms.*

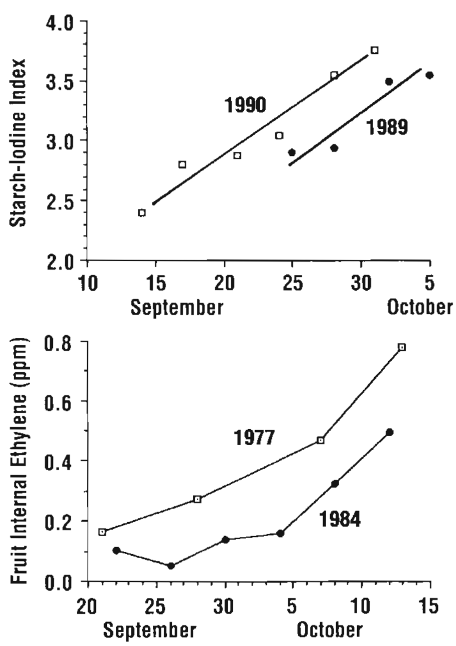

Figure 3. *(Upper) Mean starch-iodine index for several Lake Ontario Empire orchards in two seasons. (Lower) Mean fruit internal ethylene concentration for several Lake Ontario area Empire orchards in two seasons.*

(2) Ethylene measurements take more time.

(3) Changes in starch-iodine indexes occur earlier than changes in fruit internal ethylene and therefore allow earlier prediction of the opening of harvest windows in a given area. The procedure for measuring starch-iodine indexes is outlined in detail on the starch-iodine index chart (see centerfold).

Although there are among-season and among-orchard variations in elapsed days between starch-iodine indexes, the mean numbers of elapsed days shown in Table 7 can be used to estimate the opening dates of harvest windows for several varieties. For example, if the mean starch-iodine index for McIntosh in an area is 4.0, then the the harvest window for CA storage McIntosh will probably open in five or six days.

McIntosh

Starch-iodine index measurements should begin no later than four weeks before the predicted last date of picking for CA. Measurements should be taken at no more than seven-day intervals until some apples have begun to move from starch-iodine index 3.0 to 3.5. From then on, the measurements should be taken twice each week until the average for the area indicates the harvest window has opened (starch-iodine index 5.0).

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Generic Starch-Iodine Index Chart for Apples

As sugar is produced in apple leaves, it is transported to the fruits where it is chemically changed to starch and stored. The stored starch is slowly changed back to sugar during the period of fruit maturation. The starch-iodine index chart is based on the percentage of stained tissue. The slow disappearance of starch can be observed by periodically collecting apples (see Sampling Procedure) and staining the starch (see Making the Measurements). The pattern of starch disappearance is not the same in all varieties. While some varieties such as Delicious store starch in the core tissue, others such as McIntosh do not. Several examples are presented in the chart to illustrate the variability of the starch staining patterns in the flesh.

Preparation of Iodine Solution

Fresh iodine solution should be prepared at the beginning of each harvest season and stored in an amber bottle or a clear glass bottle wrapped with aluminum foil. The solution is very poisonous. The bottle should be properly labeled and kept away from children and pets. Test apples should be discarded in a way that will not permit them to be eaten by people, pets, or wildlife. Induce vomiting and consult a physician if test apples are accidentally ingested.

The following recipe can be used by a pharmacist or chemist to make the iodine solution:

1. Dissolve 8.8 grams of potassium iodide in 30 ml of warm water. Gently stir the solution until potassium iodide is dissolved.
2. Add 2.2 grams of iodine crystals. Shake the mixture until the crystals are thoroughly dissolved.
3. Dilute with water to make 1.0 liter of iodine solution.

Sampling Procedure

1. Sample once or twice each week, beginning three or four weeks before the expected opening of the harvest window.
2. Select test trees that are representative of the orchard block in crop load and tree vigor.
3. Avoid sampling from trees at the ends of rows and from outside portions of outside rows.
4. Tag the sampling trees and return to them each time samples are collected and tested.
5. Sample from different sides of the trees and from areas within easy reach, but not from shaded tree interiors.
6. Select apples that have typical size and color for the tree. Avoid apples that are obviously and atypically advanced in ripening.
7. Collect at least ten apples per sample, with no more than two apples per tree.

Making the Measurements

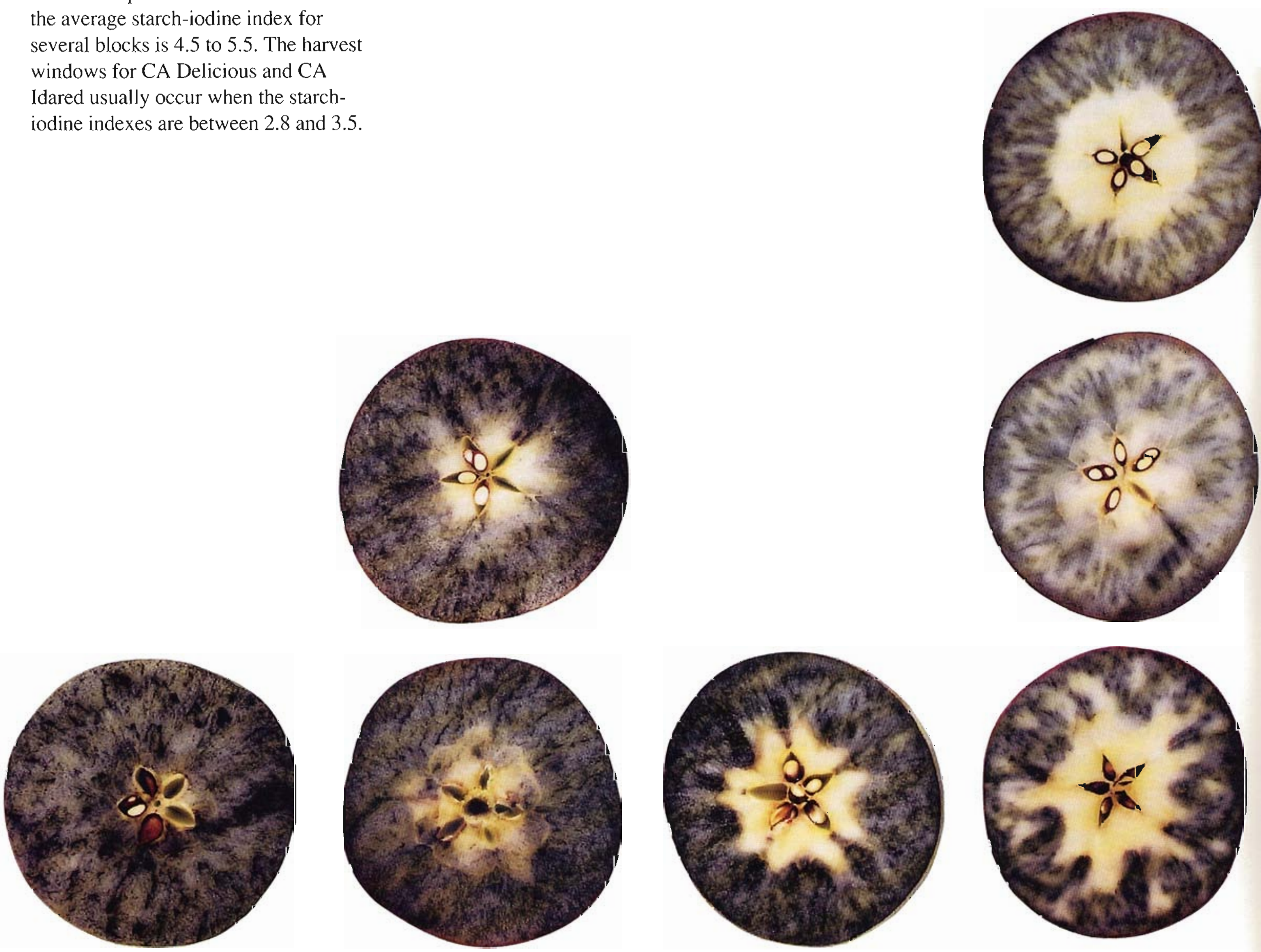
1. Test the apples as soon after collection as possible—no more than 24 hours after collection.
2. Cut the apples in half through the equator. Cutting the apples close to the stem or to the calyx cavity will affect the resulting starch pattern.
3. Apply the iodine solution to one cut surface of one of the halves of each apple. This may be done by holding the apple halves by their stems and then dipping them into the iodine solution, or by placing the apple halves together, cut surface up, and spraying them with iodine solution held in a small, plastic sprayer bottle.
4. Wait at least one minute for the starch patterns to completely develop.
5. Arrange the apples in ascending or descending order, according to the percentage of the tissue that is strained.
6. Compare the pattern of each stained apple-half with the pictures on the chart. Choose the picture that most closely represents the pattern on the stained apple-half or the two pictures that bracket the stained apple-half. If the stained apple-half is bracketed by two pictures, estimate the starch-iodine index to the nearest tenth. For example, if the stained apple-half is between starch-iodine index 3 and 4, but is closer to 3 than 4, it should be recorded at 3.2, 3.3, or 3.4, depending upon the closeness to 3.
7. Calculate the average to the nearest one-tenth of an index number.

Evaluating Test Results

The first changes in the starch-iodine index are the earliest indicators of the approaching harvest season. Permanent records of starch-iodine index measurements for each variety can be used to estimate the earliness or lateness of this season in comparison with other, previous seasons.

Since the starch-iodine index may be influenced by orchard factors that do not influence fruit maturity, the starch-iodine index cannot be used to predict exact harvest dates for individual blocks. For example, apples from lightly cropped trees will stain darker than apples from heavily cropped trees, indicating delayed maturation. However,the darker stain of the apples from the lightly cropped trees is not due to a difference in fruit maturity, but rather a greater amount of total starch at the beginning of the period of fruit maturation. One could attempt to estimate the influence of cropping and other nonmaturity factors on the starch-iodine index, but it is easier to overcome these difficulties by collecting and testing samples from several orchard blocks. The average starch-iodine index is then used to estimate the advancement of fruit maturity in the sampling area.

McIntosh should be picked for CA storage as the average starch staining in flesh tissue changes from 60 and 40 percent; i.e., at starch-iodine index 5 and 6. Empire are usually at the best stage of fruit development for CA harvest when the average starch-iodine index for several blocks is 4.5 to 5.5. The harvest windows for CA Delicious and CA Idared usually occur when the starch-iodine indexes are between 2.8 and 3.5.



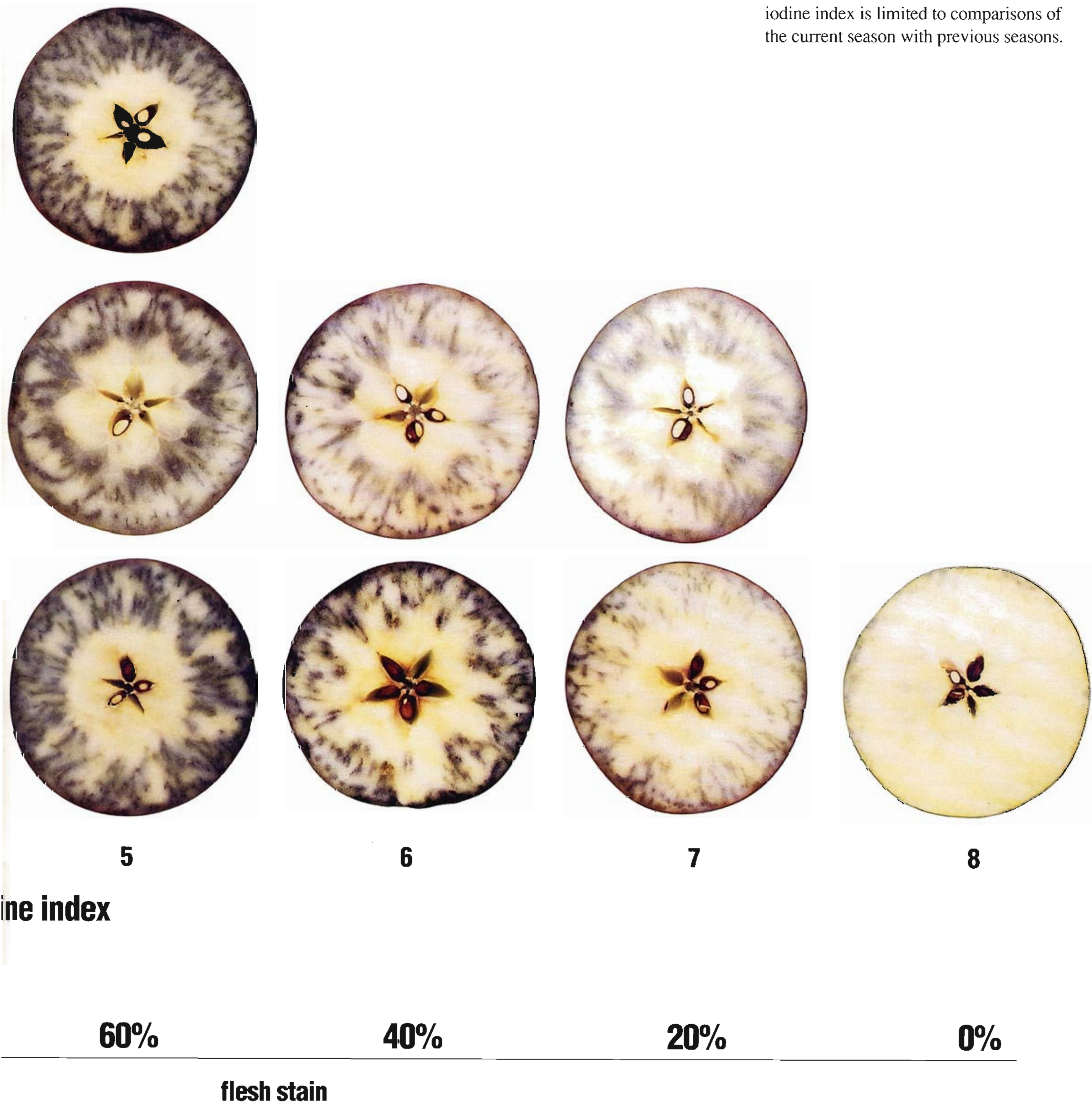
1 2 3 4

100% 50% 0% starch-i

core stain

100% 80%

Starch-iodine indexes for the harvest windows of other varieties have not yet been determined. If you do not have these four varieties to estimate the harvest windows for intervening varieties, the usefulness of the starch-iodine index is limited to comparisons of the current season with previous seasons.



Cortland

The harvest window for CA Cortland is usually immediately after the CA McIntosh harvest window closes, and before McIntosh are picked for air storage.

Empire

Starch-iodine index measurements for Empire should begin about September 15. Twice-weekly measurements will permit reasonably accurate comparisons with previous seasons (see Fig. 3). Limited observations suggest that CA Empire should be picked when the average starch-iodine index is between 4.5 and 5.5.

Delicious

Delicious are usually harvested for CA storage when the average starch-iodine index for an area ranges 2.8-3.5. They should not be picked until the grass-like flavor has left the skin, the chlorophyll has left the flesh, and the fruit has lost its raw-potato flavor and attained at least a suggestion of characteristic apple flavor. Delicious harvest for CA should end no later than 155 days after full bloom and no later than October 15, the date normally associated with the development of severe water core.

Idared

Limited observations indicate Idared should be picked for CA when the average starch-iodine for the area is between 2.8 and 3.5. They should not be picked before the bitter flavor has disappeared from the skin, since that will remain after picking. The harvest window for CA Idared opens shortly after the bitter flavor has left the skin.

Picking Inside the Harvest Window

It is commonly believed that fruit ripening measurements at harvest can be used to predict the storage life of a block of apples. Observations in New York indicate that apples picked before or after the harvest window for the area do not normally have the post-CA storage quality of apples that were picked within the window. When apples are picked inside the harvest window for the area, however, the poststorage quality is determined by orchard factors, not by fruit maturity or picking date. This important point is illustrated with the following four examples:

1. McIntosh for storage were sampled on five dates from eight Niagara/Orleans County blocks at three- to four-day intervals, beginning September 3. The average starch-iodine indexes for these eight blocks indicated the harvest window opened on September 7 (starch-iodine of 5.0). Harvested apples were stored in air at 32°F until mid-November, when they were removed from storage, held at room temperature for a week, and then evaluated for best harvest dates by a panel of eight judges. The best harvest dates and fruit characteristics on those dates are shown in Table 8. On the best harvest dates there appeared to be great variations in fruit maturity; i.e., fruit internal ethylene concentration (0.08–0.62 ppm), flesh firmness (13.4–15.9 pounds), total soluble solids (10.4–12.8 percent) and starch-iodine index (3.8–5.8). But there was very little variation in calendar dates of best harvest (September 11 ± 2 days).

   The apparent among-block spread in fruit maturity is shown graphically for four of the blocks in Figure 4. The two blocks with the earliest ethylene rise (G and H) actually had slightly later best harvest dates than the two blocks characterized by later rise in ethylene (A and D). Although ethylene analyses indicated that the apples on Farm H were ripening two weeks earlier than apples on Farm D, panel scores showed that harvest maturity dates were similar in these two blocks.

2. Apples were collected from the four Orleans County Empire orchard blocks at four-day intervals beginning

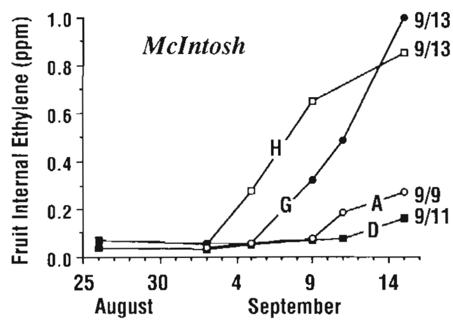


Figure 4. *Rise of fruit internal ethylene concentrations in four Niagara County McIntosh orchards (Farms A, D, G, and H in Table 8). September dates at right indicate panel evaluations of best harvest dates for samples held at room temperature for one week after removal from 32°F air storage until mid-November.*

Table 8. Fruit characteristics on the best harvest dates for 32°F air storage of McIntosh from eight Niagara and Orleans counties farms. Panel evaluations of best harvest dates were made after storage removal in mid-November plus one week at room temperature.

Farm	*Best harvest date September*	*Fruit internal ethylene ppm*	*Flesh firmness lbs.*	*Total soluble solids %*	*Starch iodine index*
A	9	0.08	13.4	10.4	3.8
B	9	0.56	15.9	12.0	4.8
C	10	0.50	15.3	12.8	4.9
D	11	0.08	15.4	12.2	5.8
E	11	0.13	14.2	12.2	5.1
F	13	0.22	15.7	12.4	5.6
G	13	0.48	14.6	12.3	5.6
H	13	0.62	14.1	12.2	5.4

September 26. Some of the apples from each farm on each sample date were tested for internal ethylene and the remainder were placed in CA storage. The harvest window for the area was predicted to be October 5-9 because the bloom date was average and other apple varieties were ripening on schedule. The fruit internal ethylene analyses indicated there was a two-week spread in ripening dates of the apples from the four farms (Fig. 5). However, the poststorage fruit quality scores for the four farms indicated the best harvest dates, October 4 and 8, were not related to the ethylene analyses at harvest.

3. Fruit internal ethylene analyses at harvest indicated the apples from two Empire orchard blocks in the Albion area were ripening on similar dates (bottom of Fig. 6). If fruit maturity at harvest was an important factor influencing keeping quality, then we would expect the apples from the two orchard blocks to have similar quality after storage. The asterisks in the top portion of Figure 6 show the best harvest dates were similar in both orchard blocks; the keeping quality of the apples from the two blocks, however, was quite different. All the flesh firmness values for apples from one orchard block were higher than those from the other orchard block. This indicated that differences in storage keeping quality were caused by orchard factors, not differences in maturity at harvest.

4. In a Columbia County orchard nutrition experiment, Empire leaf samples were collected and analyzed in August so that individual trees could be selected for fruit maturity and storage tests. In this study, a spread in leaf potassium was desired because previous tests had shown that an early rise in fruit ethylene was associated with high levels of leaf potassium. Apples from six trees were tested in 1986, eight trees in 1987, and ten trees in 1988. Three tests were run each year: 1) fruit internal ethylene concentration at harvest, 2) mineral analyses of leaves and apple flesh, and 3) storage quality of the fruit. The only consistent (at least two of the three seasons) relationships found between leaf or fruit mineral analyses and fruit ripening dates were the relationships between leaf magnesium, potassium, and boron, shown at the bottom of Table 9. An early rise in fruit ethylene production was associated with low leaf magnesium, high leaf potassium, and high leaf boron. Poststorage evaluations of the fruit did not reveal any consistent relationships between leaf or fruit mineral content and fruit condition. Thus, although orchard nutrition appeared to influence apple ripening (ethylene initiation) dates, orchard nutrition did not change best harvest dates for storage.

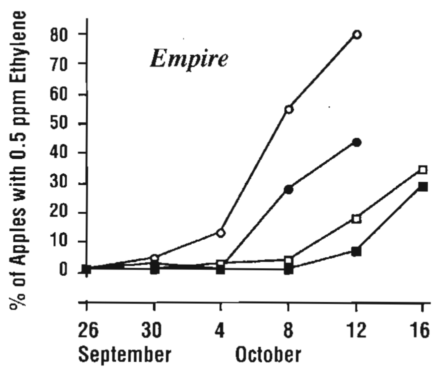


Figure 5. *Percentages of Empire apples with more than 0.5 ppm internal ethylene. Apples sampled from four farms on six dates.*

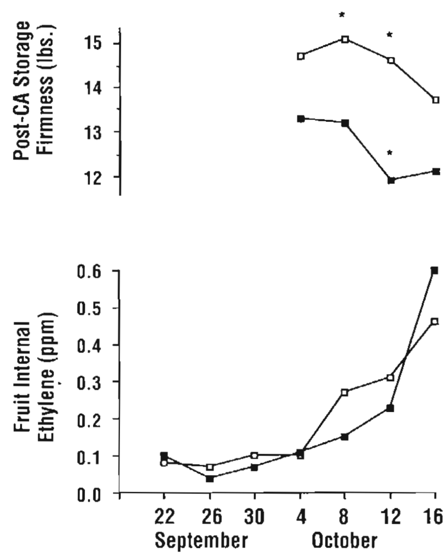


Figure 6. *Fruit internal ethylene concentrations at harvest and post CA-storage flesh firmness of Empire apples sampled from two orchard blocks in the Albion area. Asterisks show panel evaluations of best harvest dates.*

These and several other experiments, tests, and commercial storage survey studies indicated the order of picking blocks within the harvest window can be sequenced by factors other than fruit maturity; e.g., convenience, fruit size, color, drop, etc.

Segregating Lots for Long-term CA Storage

Fruit internal ethylene at harvest

Storage operators in other fruit growing areas have reported using fruit internal ethylene measurements as a means for estimating the storage potential of apples. New York State surveys with Empire, picked in the harvest window, showed that fruit internal ethylene at harvest could not be used to estimate potential storage keeping quality.

Empire apple orchards were surveyed in eastern and western New York in three seasons to determine if fruit internal ethylene analyses could be used to segregate the lots for short- and long-term storage. All the orchards in a given area and given season were picked in a one- or two-day period. Samples of apples from each orchard were analyzed for internal ethylene at harvest. The apples were firmness tested and scored for flesh senescent breakdown after storage (Tables 10 and 11).

In 1985, eastern New York apples with the lowest internal ethylene concentrations at harvest were the most firm after storage (Table 10). There was, however, no relationship between fruit internal ethylene concentration at harvest and poststorage firmness in the other five tests shown in Table 10. Again, this may be attributable to the overriding effect of orchard factors that influence the keeping quality of apples picked inside the harvest window.

Table 9. Summary of the orchard nutritional effects on the ethylene rise of Empire apples in a Hudson Valley orchard nutrition experiment.

Crop year	*Mineral Analysis*	*Fruit Ca*	*Leaf Ca*	*Leaf Mg*	*Leaf K*	*Leaf B*
		Percent dry weight				*ppm*
1986	**max.**	**0.031**	**1.56**	**0.52**	**1.04**	**54**
	min.	**0.024**	**1.17**	**0.37**	**0.60**	**31**
	mean	**0.027**	**1.42**	**0.42**	**0.89**	**38**
1987	**max.**	**0.037**	**1.67**	**0.48**	**1.14**	**36**
	min.	**0.029**	**1.09**	**0.34**	**0.40**	**27**
	mean	**0.032**	**1.34**	**0.42**	**0.68**	**31**
1988	**max.**	**0.033**	**1.80**	**0.44**	**1.40**	**38**
	min.	**0.019**	**0.80**	**0.28**	**0.56**	**2**
	mean	**0.027**	**1.30**	**0.37**	**0.93**	**31**
		Relationship (r) between nutrient level and ethylene rise[1]				
1986		**ns**	**ns**	**+0.85**	**-0.94**	**-0.83**
1987		**ns**	**ns**	**ns**	**ns**	**-0.70**
1988		**ns**	**+0.74**	**+0.72**	**-0.70**	**ns**

(1) ns = no significant relationship; + indicates the higher the nutrient, the later the ethylene rise; - indicates the higher the nutrient, the earlier the ethylene rise.

Table 10. Mean fruit internal ethylene concentration at harvest of Empire apples from eastern and western New York that were separated into three flesh firmness groups after storage.

			Poststorage flesh firmness group		
			Least firm	*Average*	*Most firm*
Crop year	*Area*	*No. of farms*	*Internal ethylene (ppm) at harvest**		
1985	**West**	**20**	**0.20a**	**0.20a**	**0.18a**
	East	**13**	**0.43b**	**0.47b**	**0.20a**
1986	**West**	**19**	**0.26a**	**0.33a**	**0.34a**
	East	**17**	**0.40a**	**0.53a**	**0.38a**
1987	**West**	**27**	**0.16a**	**0.15a**	**0.13a**
	East	**30**	**0.15a**	**0.20a**	**0.17a**

* Numbers in a row followed by the same letter are not significantly different (0.05).

Although flesh senescent breakdown after storage is often associated with advanced maturity at harvest (for example, Farm C in Fig. 7), and high internal ethylene is associated with advanced maturity at harvest, there were no significant relationships between fruit internal ethylene at harvest and flesh senescent breakdown after storage in this survey (Table 11, next page). The explanation for this is in Figure 7, which shows that advanced maturity at harvest is not always associated with high incidences of flesh senescent breakdown (Farm A in Fig. 7), and picking at early maturity does not always assure freedom from this storage disorder (Farm B in Fig. 7).

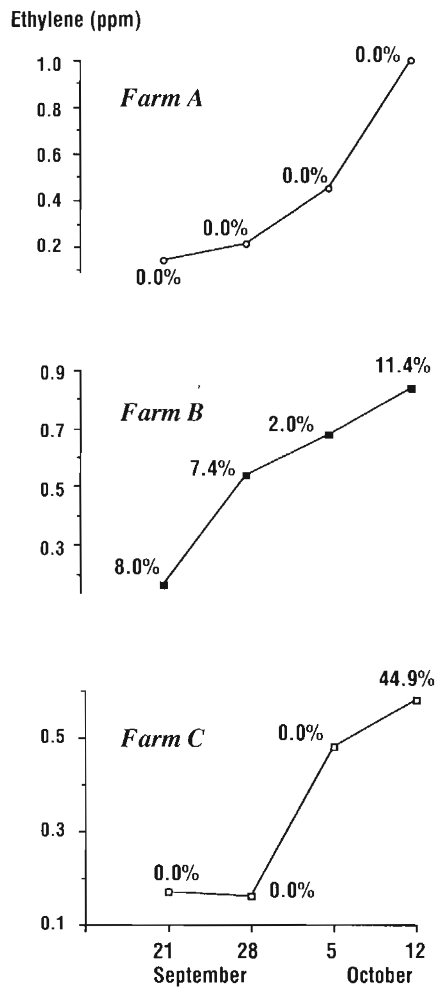


Figure 7. *Harvest rise of fruit internal ethylene in three Lake Ontario area Empire orchards and the subsequent incidences of poststorage senescent breakdown, shown as percentage of affected fruits.*

Early picked apples that show obvious signs of accelerated ripening before the harvest window opens should be excluded from controlled atmosphere (CA) storage. Late-picked apples, those with very high internal ethylene because they were harvested after the harvest window for the area has closed, cannot be expected to store well and should be excluded from CA storage. The Empire survey indicated that fruit internal ethylene concentration at harvest cannot be used to estimate potential storage keeping quality, when the apples are picked inside the harvest window.

Table 11. Mean fruit internal ethylene concentration at harvest of Empire apples from eastern and western New York that were later separated into three groups based on incidences of poststorage senescent breakdown.

			Incidence of senescent breakdown		
			None	*1-10%*	*>10%*
Crop year	*Area*	*No. of farms*	*Internal ethylene (ppm) at harvest**		
1986	**West**	**19**	**0.23a**	**0.43a**	**0.36a**
	East	**17**	**0.40a**	**0.44a**	**0.38a**
1987	**West**	**28**	**0.13a**	**0.13a**	**0.16a**
	East	**29**	**0.18a**	**0.16a**	**0.23a**

* Numbers in a row followed by the same letter are not significantly different (0.05).

Fruit firmness at harvest

Orchard factors that result in hard apples at harvest, usually impart good keeping quality to the apples. For example, the apples in Table 12 were picked within the 1990 Lake Ontario McIntosh harvest window and stored at a local CA facility. The wide spread in post-CA firmness was closely associated with, and could have been predicted by, the firmness measurements at harvest (Fig. 8). There are exceptions, however, to the general relationship between firmness before and after storage. For example, compared with other strains of McIntosh, the spur strains soften more quickly and Marshall Mac softens more slowly in storage. Also, records may show that apples from some blocks retain their firmness better, or develop more storage disorders, than comparable apples from other blocks, regardless of firmness at harvest. When records of this type are available, firmness measurements may be redundant when segregating orchard lots of apples for long- and short-term storage.

###

Table 12. Harvest and poststorage firmness of McIntosh apples stored in one CA room at a Lake Ontario storage facility.

		Flesh firmness measurement	
Storage lot #	*September harvest date*	*Harvest (lbs.)*	*After storage (lbs.)*
1	**11**	**16.5**	**13.2**
2	**11**	**16.5**	**13.6**
3	**12**	**14.5**	**10.6**
4	**14**	**13.8**	**10.0**
5	**14**	**15.5**	**13.3**
6	**18**	**14.9**	**12.3**
7	**18**	**15.3**	**12.1**
8	**18**	**16.5**	**13.5**
9	**19**	**16.5**	**13.2**

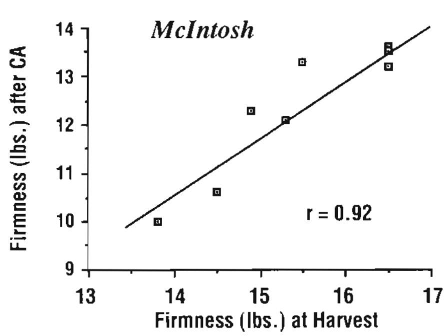


Figure 8. *The relationship between firmness at harvest and post-CA firmness of McIntosh apples picked in the harvest window.*

Appendix A.

Days Between April-May Bloom and September-October Harvest

April/May bloom	*122*	*124*	*126*	*128*	*130*	*132*	*134*	*136*	*138*	*140*	*142*	*144*	*146*
April 26	8/27	8/29	8/31	9/2	9/4	9/6	9/8	9/10	9/12	9/14	9/16	9/18	9/20
28	8/29	8/31	9/2	9/4	9/6	9/8	9/10	9/12	9/14	9/16	9/18	9/20	9/22
30	8/31	9/2	9/4	9/6	9/8	9/10	9/12	9/14	9/16	9/18	9/20	9/22	9/24
May 2	9/2	9/4	9/6	9/8	9/10	9/12	9/14	9/16	9/18	9/20	9/22	9/24	9/26
4	9/4	9/6	9/8	9/10	9/12	9/14	9/16	9/18	9/20	9/22	9/24	9/26	9/28
6	9/6	9/8	9/10	9/12	9/14	9/16	9/18	9/20	9/22	9/24	9/26	9/28	9/30
8	9/8	9/10	9/12	9/14	9/16	9/18	9/20	9/22	9/24	9/26	9/28	9/30	10/2
10	9/10	9/12	9/14	9/16	9/18	9/20	9/22	9/24	9/26	9/28	9/30	10/2	10/4
12	9/12	9/14	9/16	9/18	9/20	9/22	9/24	9/26	9/28	9/30	10/2	10/4	10/6
14	9/14	9/16	9/18	9/20	9/22	9/24	9/26	9/28	9/30	10/2	10/4	10/6	10/8
16	9/16	9/18	9/20	9/22	9/24	9/26	9/28	9/30	10/2	10/4	10/6	10/8	10/10
18	9/18	9/20	9/22	9/24	9/26	9/28	9/30	10/2	10/4	10/6	10/8	10/10	10/12
20	9/20	9/22	9/24	9/26	9/28	9/30	10/2	10/4	10/6	10/8	10/10	10/12	10/14
22	9/22	9/24	9/26	9/28	9/30	10/2	10/4	10/6	10/8	10/10	10/12	10/14	10/16
24	9/24	9/26	9/28	9/30	10/2	10/4	10/6	10/8	10/10	10/12	10/14	10/16	10/18
26	9/26	9/28	9/30	10/2	10/4	10/6	10/8	10/10	10/12	10/14	10/16	10/18	10/20
28	9/28	9/30	10/2	10/4	10/6	10/8	10/10	10/12	10/14	10/16	10/18	10/20	10/22
30	9/30	10/2	10/4	10/6	10/8	10/10	10/12	10/14	10/16	10/18	10/20	10/22	10/24

Days from bloom to calendar dates shown in the table

Appendix B.

Harvest Drop of McIntosh

Because it can be a serious economic problem, harvest drop of McIntosh has been closely observed for many years. Harvest drop frequently occurs earlier in orchards with shallow soils, and in orchards with low magnesium, high potassium, and high boron. Early harvest drop may also be associated with overcropping and/or heavy summer pruning if leaf-fruit ratios are reduced below 20:1. Harvest drop can also be accelerated by heavy infestations of mites, tentiform leaf miners, and other insects that significantly reduce the photosynthate produced by the leaves. The effects of these orchard factors which appear to accelerate drop will be more apparent in dry seasons than in seasons with adequate or more-than-adequate rainfall (irrigation).

Growing season temperatures also influence drop of McIntosh apples. In hot growing seasons, for example, the period between bloom and drop of sound apples is shorter than in cool growing seasons (Fig. B-1). As the concentration of ethylene increases in McIntosh apples before or during the normal harvest period, heightened fruit internal ethylene stimulates fruit abscission (drop). The higher the daily temperatures, the shorter will be the interval between ethylene rise and fruit drop (Table B).

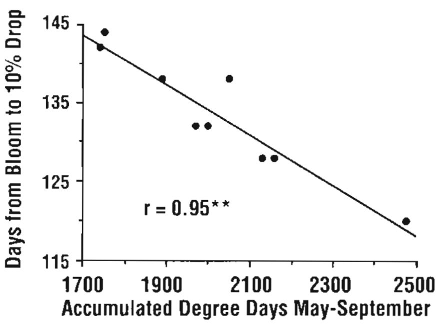
While most apple growers cannot measure fruit internal ethylene to estimate when drop may occur, they can easily estimate starch-iodine indexes, which are usually in the 3.5–4.5 range when fruit internal ethylene rises (Fig. B-2). Therefore, if the starch index in a McIntosh block is 3.5 today, indicating that ethylene may start to increase, and the weather forecast for the next week is for mean daily temperatures of 60°–65°F, drop of sound apples will probably begin

Table B. Relationship between mean daily temperatures and elapsed days between start of the ethylene rise and abscission of McIntosh apples.

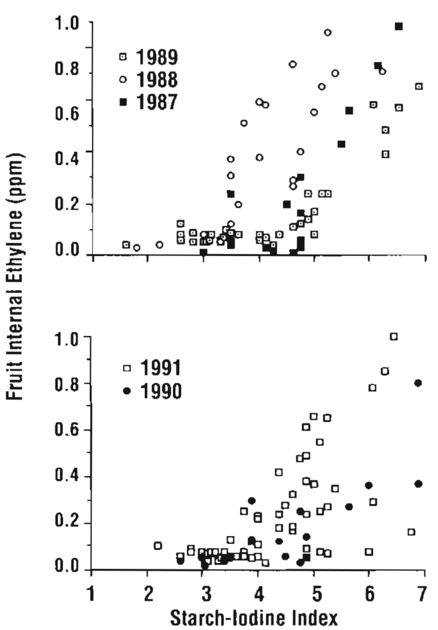
Mean daily temp.(°F)	*Days from start of ethylene rise to abscission*
40	25
45	18
50	13
55	9
60	7
65	5
70	4

Source: Christopher S. Walsh, 1977.

in about six days (see Table 1). If the crop will not to be picked until two weeks from today, the grower should revisit the block in one week to determine if drop has started; if so, it would indicate that naphthalene acetic acid (NAA) should be applied. Use starch indexes to indicate when drop will probably begin, but do not apply NAA until drop has actually started. (Consult current pest management recommendations and product labels for specific application directions.)



Appendix Figure B-1. *Relationship between accumulated degree days (daily mean temperature minus 50°F) during the growing season and the number of days from full bloom to 10 percent drop of sound McIntosh apples. (Courtesy of the late M.B. Hoffman, Cornell University.)*



Appendix Figure B-2. *Relationship between internal ethylene concentration and starch-iodine index for McIntosh apples in the Lake Ontario area 1987-91. Each point on the graph represents the mean for ten apples.*

Appendix C.

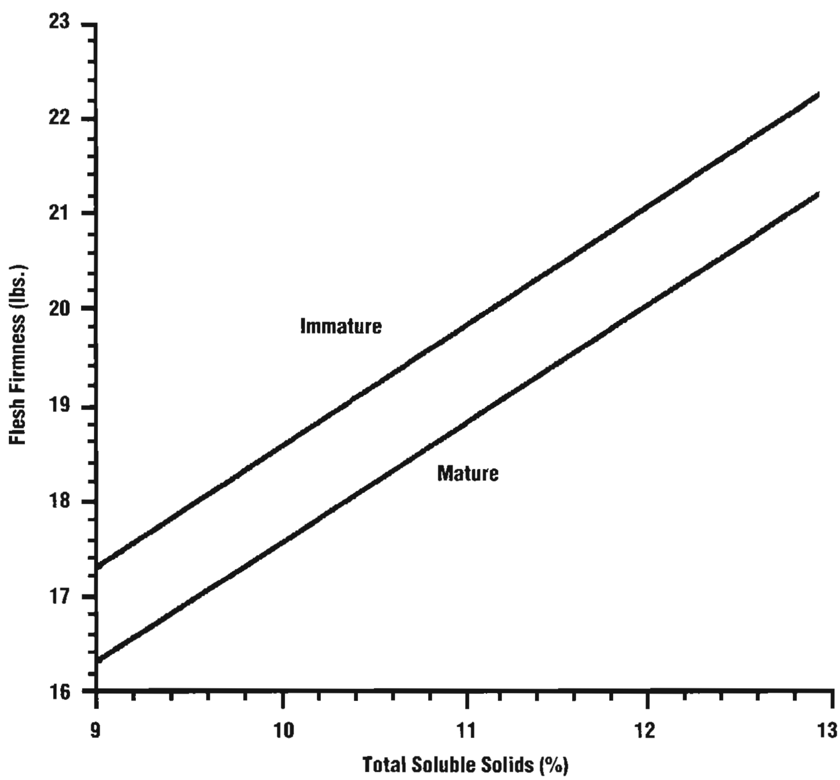
Earliest Acceptable Harvest for Delicious

Research to determine if objective measurements would indicate the earliest acceptable harvest dates for Delicious apples was conducted during several seasons in the Hudson Valley and Lake Ontario areas.

Apples that did not have acceptable eating quality at harvest and did not develop it during a one-week holding period at room temperature were considered to be immature. Apples that had acceptable eating quality at harvest, or if not acceptable at harvest but did develop it during a one-week holding period at room temperature, were considered to be sufficiently mature for early market harvest.

The taste panels that determined "acceptable eating quality" found that very firm apples (20-pound test) were acceptable if the soluble solids were high, and that apples with low soluble solids required less firmness to be acceptable. This relationship is shown in Figure C, where apples with firmness-soluble solids intersects below the lower maturity index line were found to be mature, as defined above. Apples with firmness-soluble solids intersects above the lower maturity index line were immature.

Measurements in eight seasons showed that apples plotting between the two maturity index lines were immature, but became mature and therefore ready to pick for early sales after an additional week on the tree.



Appendix Figure C. *Maturity index lines for Delicious strains other than Starkrimson. See text for explanation.*

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