QUALITY OF THE 2001 CROP OF WASHINGTON APPLES:

A REPORT TO THE WASHINGTON TREE FRUIT INDUSTRY

Eugene Kupferman
Jake Gutzwiler
Nancy Buchanan
Chris Sater

Washington State University
Tree Fruit Research and
Extension Center
1100 N. Western Ave.
Wenatchee, WA 98801

Email: Kupfer@wsu.edu

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ABSTRACT

This is the second part of a two-year study investigating apple quality characteristics and the variability of fruit packed by packinghouses in Washington State.

This survey includes a significant amount of fruit of the newer varieties (Braeburn, Pink Lady® brand, Cameo and Jonagold). It includes an estimation of apple edible quality (firmness, soluble solids and acidity) and fruit temperature at time of packing on nine varieties. Firmness evaluations were performed using traditional destructive technology (penetrometer) as well as nondestructive acoustical firmness.

Acidity levels and firmness changed a great deal during the season while soluble solids levels changed the least. Acidity declined the most in Granny Smith, Pink Lady® brand and Fuji as compared to other varieties. Low acidity levels and poor sugar/acid ratios result in bland flavor. This is typical of Red Delicious and Fuji at the end of the season.

Braeburn, Golden Delicious and Jonagold apples had the widest range in individual apple firmness. Six percent of all Red Delicious apples were below 12 lbf at the time of packing.

Quality varied over time to different degrees dependent upon variety. With most varieties, apples early in the packing season were firm, high in acidity and low in soluble solids. These factors changed slowly as fruit was packed out of regular storage. In December, fruit firmness and acidity increased as CA rooms were opened and over time both quality parameters declined.

However, all varieties did not behave in the same way. The firmness of Braeburn and Cameo declined during the packing season more than other varieties. Gala apples held firmness throughout the packing season. Golden Delicious apples lost firmness dramatically following regular storage more than out of CA. Firmness of Red Delicious was not related to packing date with both firm and soft apples available year-round. To provide higher and more consistent quality the industry should consider shortening the length of time it takes to obtain CA certification from 60 days to 45 days for both Red Delicious and Golden Delicious or raise grade standards for both firmness and SS.

The quality of apples from the 2001 crop packed between January and the end of the packing season was superior to the quality from the 2000 crop in most attributes. The largest difference in fruit quality between the two years was in Fuji and the least was in Gala.

Internal apple temperature at time of packing ranged from 34 ºF to 90 ºF. External temperature ranged from 44 ºF to 87 ºF.

The quality of apples was also related to packinghouse and is tabulated within the report.

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1. INTRODUCTION

This is the second part of a two-year study investigating apple quality characteristics and the variability of fruit packed by packinghouses in Washington State.

The Grade and Pack Committee of the Washington State Horticultural Association requested we initiate a survey of the quality of Washington grown apples. Funding was obtained from the Tree Fruit Research Commission. The survey is intended to provide data for the development of standards based on edible quality. Samples of apples were obtained at the time of packing from cooperating packinghouses throughout the packing season.

This report describes the methods used and the results of sampling the major Washington apple varieties from the 2001 harvest with comparisons to the 2000 crop.

1.1 METHODS

1.1.1 Sampling methodology

Sampling for the 2001 packing season began on August 6, 2001 and continued through September 18, 2002. Sampling consisted of 25-apple samples taken from 35 different packing lines, located in three different regions of Eastern Washington. Nineteen packinghouses in Yakima were routinely sampled, seven in Wenatchee and nine north of Wenatchee. None of the fruit sampled had been treated with AgroFresh™ (MCP).

Fruit were sampled directly from the packing line at a location immediately before being placed on trays. Variety and fruit size sampled were dependent on the packing schedule. Apples sampled were between sizes 125 and 72. The number of samples of each variety is shown in Table 1. After December, selected packers were contacted prior to sampling to determine packing schedules of Braeburn, Cameo and Pink Lady® brand apples to increase sample numbers of these varieties. As a result, sample numbers of each variety are not an accurate estimation of the volume of fruit being packed.

Table 1. Number of samples of each variety, 2001 crop year.

Variety	No. of Samples
Braeburn	31
Cameo	12
Fuji	75
Gala	83
Golden Delicious	83
Granny Smith	34
Jonagold	14
Pink Lady® brand	9
Red Delicious	138
Other (data not reported)	5
	489

The information collected at the packinghouse on each lot of fruit consisted of:

- Storage type (storage temperature, O_2 and CO_2 levels)
- CA room opening dates
- Grower/lot numbers and orchard locations
- Flesh temperature of five apples (determined with a PT-2 thermocouple thermometer; Ryan Instruments, Redmond, Washington)
- External temperature of five apples (determined with a non-contact infrared thermometer by Ryan Instruments, Redmond, Washington)

Fruit were taken to the WSU-TFREC Postharvest lab and analyzed for the following quality characteristics:

- Non-destructive acoustical firmness measurement (AWETA Acoustical Firmness Sensor; Nootdorp, the Netherlands)
- Destructive firmness measurement (Fruit Texture Analyzer, Güss Manufacturing; Strand, South Africa)
- Soluble solids (SS) levels (Palette Digital Refractometer; Atago, Tokyo, Japan)
- Titratable acidity (TA) level (Titrino Automatic Titrator; Metrohm, Herisau, Switzerland).

While the attributes of flavor, aroma and juiciness are important factors in acceptability, it was not possible to determine these factors in an accurate and efficient manner given the volume of fruit examined.

1.1.2 Description of the firmness instruments

The acoustical firmness was measured using the AWETA Acoustic Firmness Sensor. This instrument delivers a slight impact to the apple surface, sending vibrations through the apple which are sent back to the device through a miniature hearing aid. The sonic vibration detected (which is based on the return vibration of a sphere) is then converted to a numeric value. Round apples produce the most accurate results.

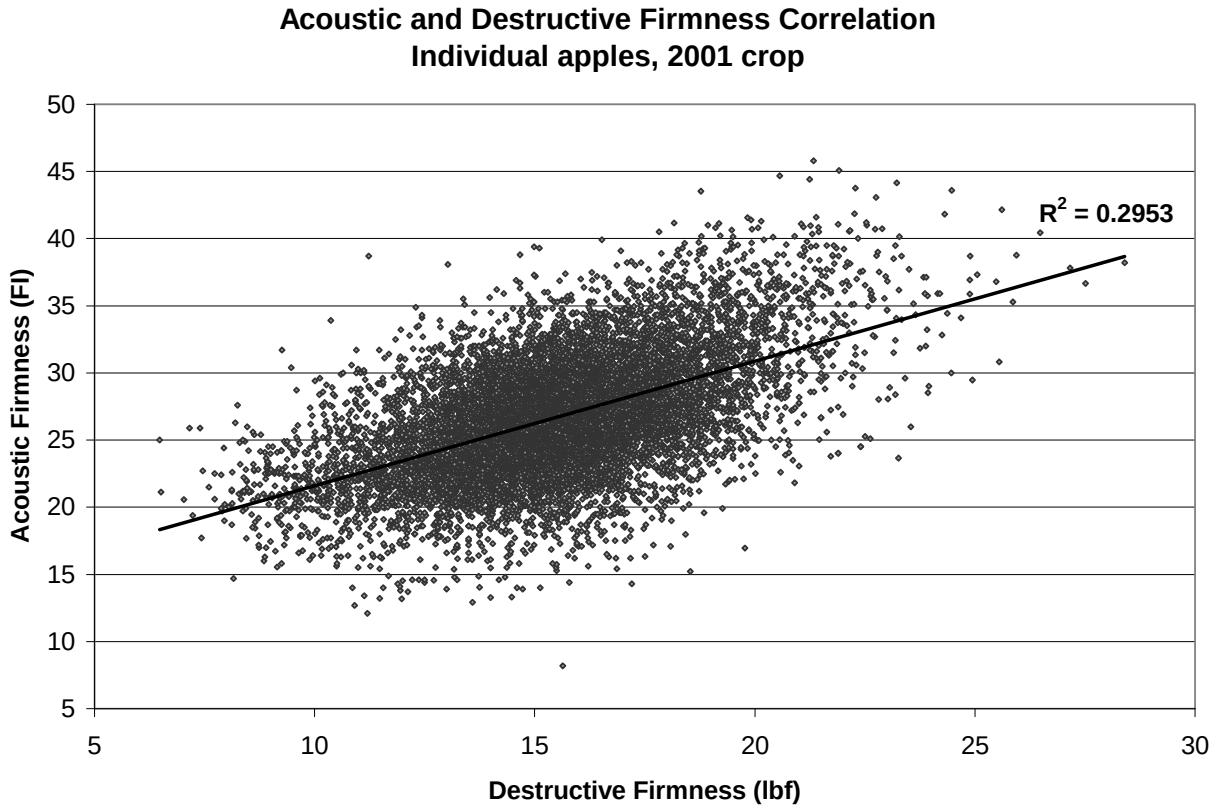
The acoustical firmness of each apple was measured on three locations around the circumference. The average of the three readings was reported as the acoustical firmness value for the apple.

The destructive firmness was measured using the Fruit Texture Analyzer, an automated Magness-Taylor penetrometer instrument. The Magness-Taylor method determines the amount of force (pounds-force [lbf]) required to overcome the resistance of the cell walls as the probe penetrates fruit flesh. The Fruit Texture Analyzer is more consistent than a manually compressed penetrometer (e.g., Effegi) because probe speed and depth are regulated by the machine. Although the Magness-Taylor method is the industry standard, it only determines firmness at a single point for each measurement. For this survey, the destructive firmness was measured at two points on each apple (on the shoulders between the sun and shade sides), and the average was reported.

The destructive penetrometer measurement is isolated to a small area of the apple while the acoustical firmness is a measure of the entire fruit. The acoustical firmness method produces consistent results at multiple locations on the same apple, while the destructive firmness method may produce measurements from the same fruit that can vary by 4 lbf.

Although both acoustic and destructive firmness measurements have been found to correlate with liking and firmness as determined by sensory panel, they are not directly correlated to each other. When plotted against each other the correlation between the acoustic and destructive firmnesses is significant, but the level of correlation is low. Figure 1 shows the relationship of acoustic and destructive firmness for all apples sampled in the 2001 crop.

Figure 1. Acoustic and destructive firmness correlation, 2001 crop.



1.2 TEMPERATURE

Internal apple temperatures were measured with a temperature probe inserted approximately 1 cm inside the fruit flesh. Internal temperatures, less susceptible to short-lived external stimuli than external temperatures, averaged 44.7 ºF to 56.9 ºF for all varieties (Table 2). The vast majority of fruit was within a range of 50 ºF to 55 ºF. The lowest internal temperatures measured on the packingline were in Golden Delicious, a variety that is not warmed for waxing. Internal temperatures were within 1 to 2 ºF of those encountered last year.

The external temperature of apples was measured with a non-contact infrared thermometer in the packinghouse. The average external temperatures of the nine varieties sampled were between 60.3 ºF and 67.6 ºF (Table 2). The highest external temperature average was observed in Red Delicious apples, and is associated with hot water in dump tanks to heat fruit prior to waxing.

The lowest average external temperature was in Cameo (60.3 ºF) but because Cameo was sampled only in a few locations it may be more related to packinghouse than an indication of industry-wide treatment of this variety.

Table 2. Average apple internal and external temperature by variety, 2001 crop.

Average Apple Internal Temperature									
	Braeburn	**Cameo**	**Fuji**	**Gala**	**Golden**	**Granny**	**Jonagold**	**Pink Lady®**	**Red**
Average	**50.7 b**	**44.7 c**	**52.8 b**	**54.2 ab**	**53.2 ab**	**53.8 ab**	**54.3 ab**	**56.9 a**	**54.6 ab**
Min	37	36	40	40	34	40	43	43	39
Max	65	57	78	84	75	78	74	72	90

Average Apple External Temperature									
	Braeburn	**Cameo**	**Fuji**	**Gala**	**Golden**	**Granny**	**Jonagold**	**Pink Lady®**	**Red**
Average	**63.8 c**	**60.3 d**	**64.2 c**	**66.3 abc**	**66.2 abc**	**64.8 bc**	**67.3 ab**	**64.8 c**	**67.6 a**
Min	46	56	48	48	49	54	54	59	44
Max	80	65	78	84	83	87	79	77	83

2. APPLE QUALITY

The quality characteristics of each variety are discussed in the following sections. The quality discussion for each variety includes histograms showing the acoustic and destructive firmness of individual apples held in regular atmosphere (RA) and controlled atmosphere (CA) storage. This is done to show the range in firmness of the population of Washington apples after removal from each respective type of storage at time of packing.

In addition to individual apple firmness data, graphs are presented based on sample averages. The term 'sample' refers to 25 apples taken from the packingline. All data reported for samples are averages of quality components (average firmness, average SS, etc.). Graphs show the changes in acoustical firmness, destructive firmness, SS and TA of samples over the season. The relationship of each characteristic to time of packing is shown by correlation.

Correlation is the numerical relationship between two variables indicating whether or not there is a uniform increase or decrease in one variable (acoustical firmness, destructive firmness, SS or TA) in relation to the decrease or increase of another variable (time, in this study). Correlation coefficient, typically noted as 'r', is a number between 1 and -1, noting the strength of a correlation. As r approaches 1 or –1, the correlation becomes stronger and, as it approaches 0 there is less likelihood that the two variables are related. In interpreting correlations, a common practice is to determine the r^2 value. This value may be interpreted as the proportion of variance in one variable that can be explained by variation in the other variable. *Only the significant correlations between each quality parameter and date of packing are shown in the figures for each variety.*

Comments on trends in quality:
Acoustic firmness declined in RA storage especially in Braeburn, Cameo, Golden Delicious and Granny Smith; but not in fruit stored in CA. Destructive firmness declined with packing date most steeply in fruit from RA storage. The most severe declines were seen in Golden Delicious and Braeburn. More gradual declines were seen in Fuji and Granny Smith. Firmness of CA stored apples did not decline dramatically, but in most cases the softest fruit was sampled from CA storage.

Soluble solids rose only slightly in RA stored fruit over time in Golden Delicious, Fuji, Granny Smith and Red Delicious. They did not rise over time in CA samples. Fruit with the lowest SS were found in RA samples.

Titratable acidity declined most steeply in RA stored Golden Delicious, Granny Smith and Pink Lady® brand apples. There was some slight decline in acidity over time in Braeburn, Fuji and Jonagold from RA storage. Of all quality measures acidity was the most uniform between samples at any one sampling date.

Multiple samples from a packinghouse:
In the tables displaying fruit quality information, some values are highlighted in **bold**, indicating averages are comprised of five or more lots of fruit. Values not highlighted indicate a small number of lots from a specific packer.

2.1 BRAEBURN QUALITY—2001 CROP

A total of 749 apples (31 samples) of Braeburn were sampled from the 2001 crop.

2.1.1 Individual apples

Fruit firmness varied by storage regime. Both acoustic and destructive firmness values of individual fruit were higher in Braeburn apples packed from RA than from CA storage (Figure 2).

2.1.2 Apple samples

Acoustic and destructive firmness of fruit samples decreased over time in RA storage, but not following CA storage (Figure 3). The averages and ranges of acoustic and destructive firmness are presented in Table 3.

The concentration of soluble solids was higher in CA samples that in RA samples, but there was no increase in soluble solids relative to time of packing in fruit stored in CA (Figure 4). The acidity in Braeburn apples stored in RA declined rapidly in the weeks following harvest and the decline continued at a less severe rate until the supply of RA-stored apples was depleted. During the packing of CA-stored Braeburn, the acidity was not related to time of packing (Figure 4).

2.1.3 Packinghouse information

Fruit were of similar quality from the two packinghouses in which five or more samples of Braeburn were obtained (Table 3).

Table 3. Summary of Braeburn quality attributes by packinghouse.

Packinghouse	No. of samples	Temperature (ºF)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
a	2	64	66	12.3	0.636	19.2	36.7
b	1	—	62	12.0	0.570	22.4	37.7
c	3	53	61	12.7	0.487	17.7	31.1
d	2	47	66	12.6	0.493	15.2	27.9
f	1	—	70	10.9	0.567	18.7	35.3
j	**6**	**54**	**66**	**12.6**	**0.518**	**15.6**	**30.7**
k	1	51	74	13.7	0.617	13.8	31.6
n	2	46	70	12.6	0.575	19.0	31.8
o	**6**	**50**	**57**	**12.7**	**0.511**	**15.5**	**29.9**
q	1	—	80	10.4	0.618	19.7	33.7
r	1	50	67	11.3	0.544	18.8	31.4
s	1	—	54	12.4	0.551	18.6	33.0
u	3	50	65	12.2	0.647	18.4	34.2
v	1	38	53	13.0	0.585	18.7	33.6
Average and range of all Braeburn samples.							
Average of samples	**51**	**64**		**12.4**	**0.547**	**17.2**	**31.9**
Range of samples	37 to 65	46 to 80		10.4 to 13.7	0.392 to 0.718	11.1 to 24.1	24.5 to 38.3

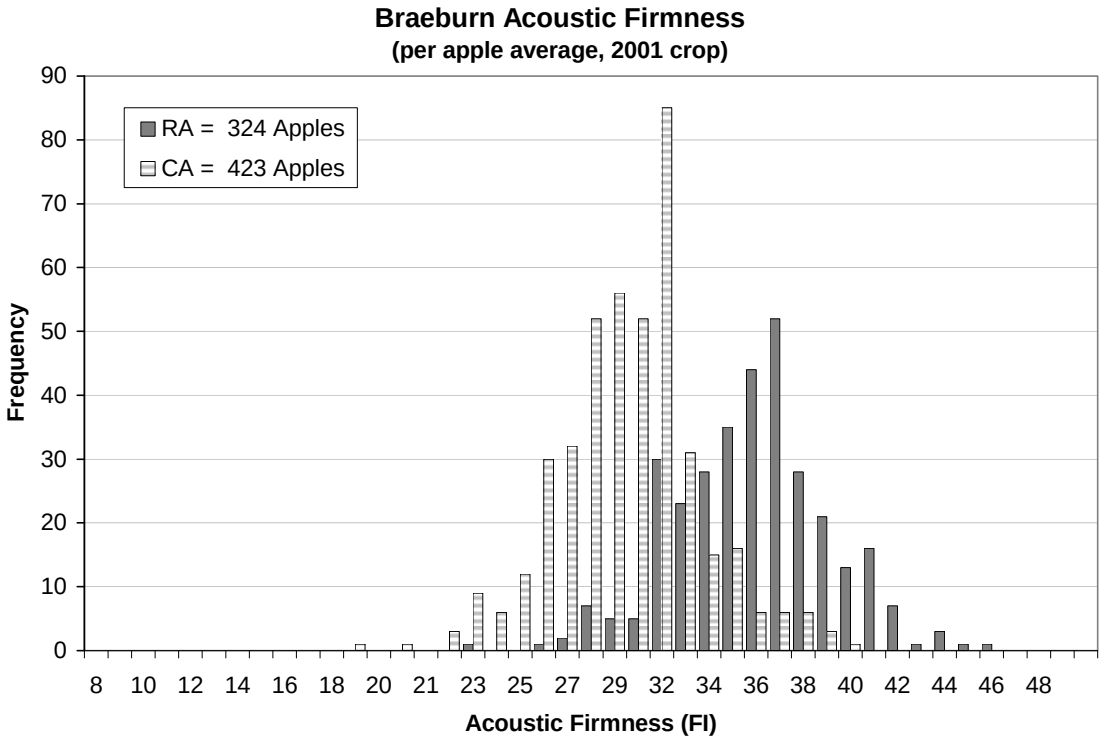
Numbers in **bold** type indicate packinghouse averages are comprised of five or more lots of fruit.

2.1.4 Historical perspective for Braeburn

The quality attributes of the 2000 and 2001 Braeburn crops are shown in Table 4.

Table 4. Comparison of Braeburn quality attributes in 2000 and 2001.

		2000 Crop	2001 Crop
Firmness (lbf)	average range	**15.3** (12 to 18)	**17.2** (11 to 24)
Soluble solids (%)	average range	**13.1** (12 to 15)	**12.4** (10 to 14)
Acidity (%)	average range	**0.45** (0.23 to 0.52)	**0.55** (0.39 to 0.72)
Number of samples		13	31



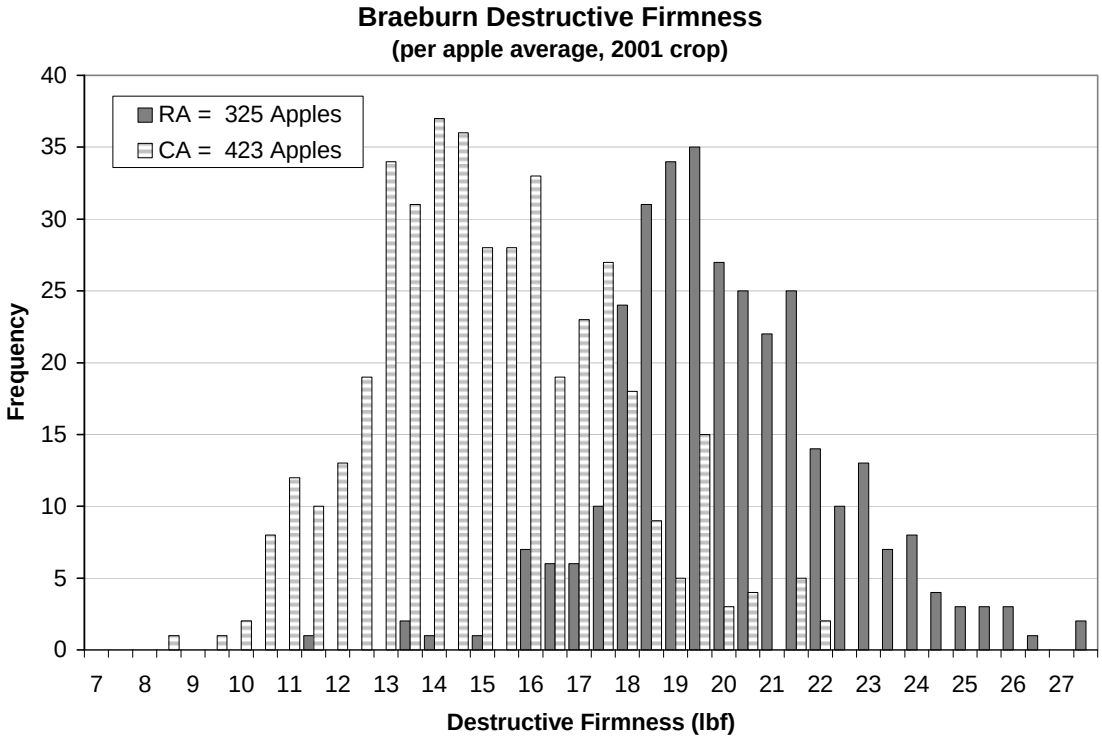


Figure 2. Braeburn acoustic and destructive firmness based on individual apples, 2001 crop.

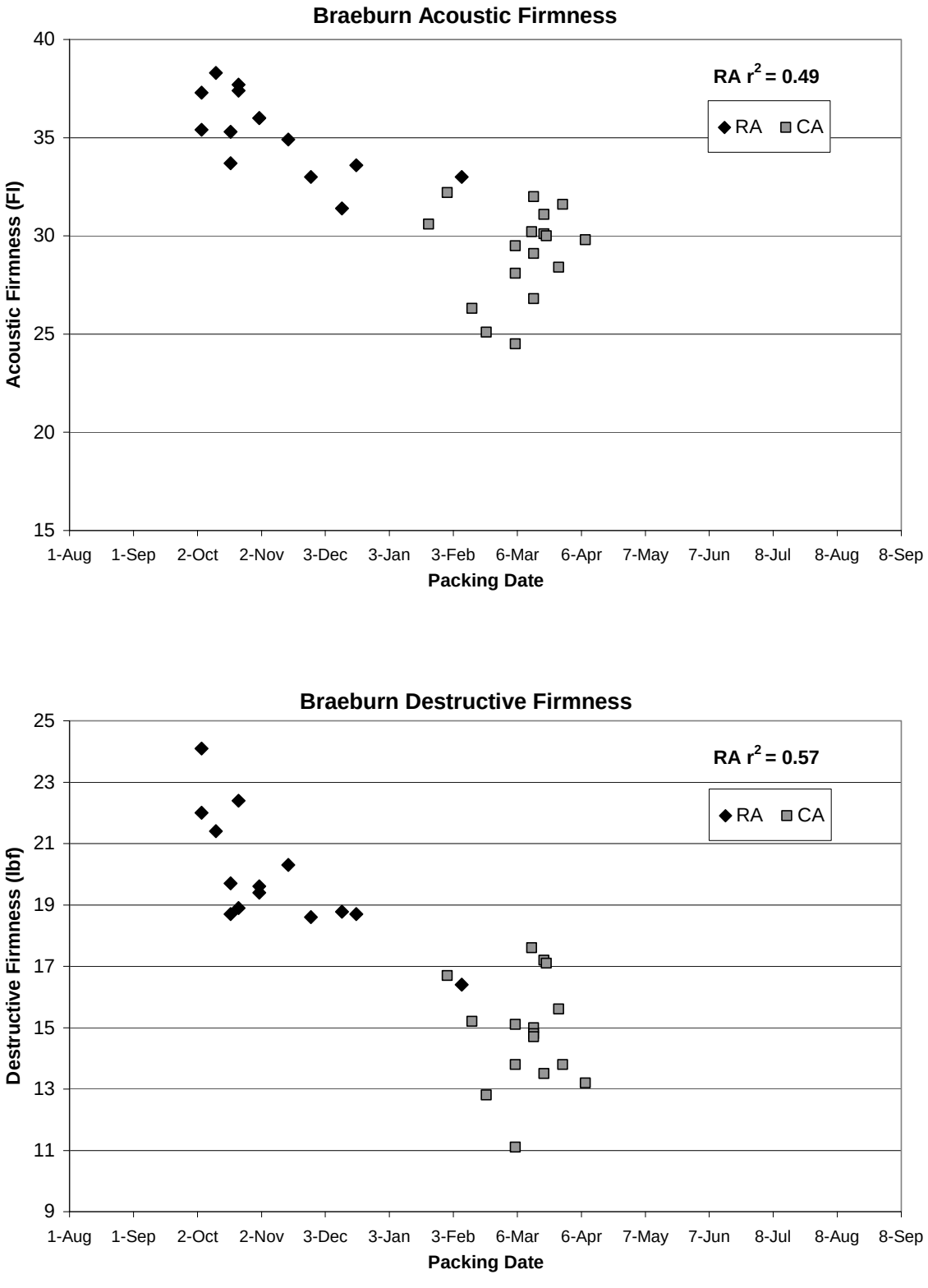
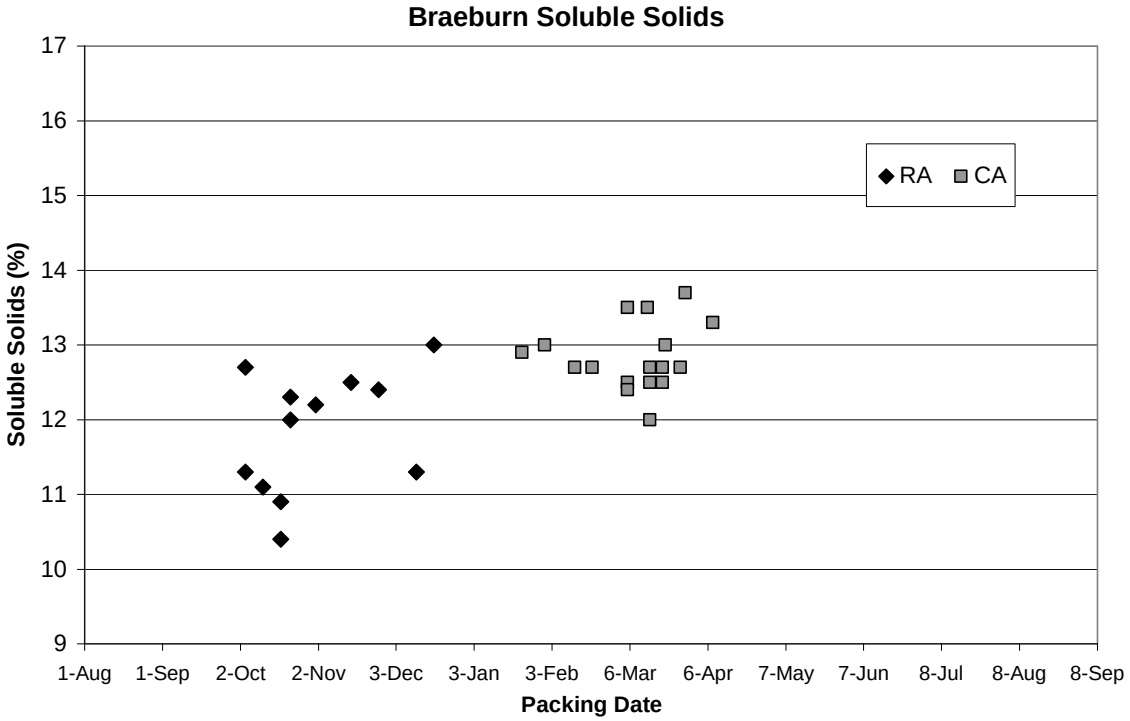


Figure 3. Braeburn sample average acoustic and destructive firmness by week, 2001 crop.



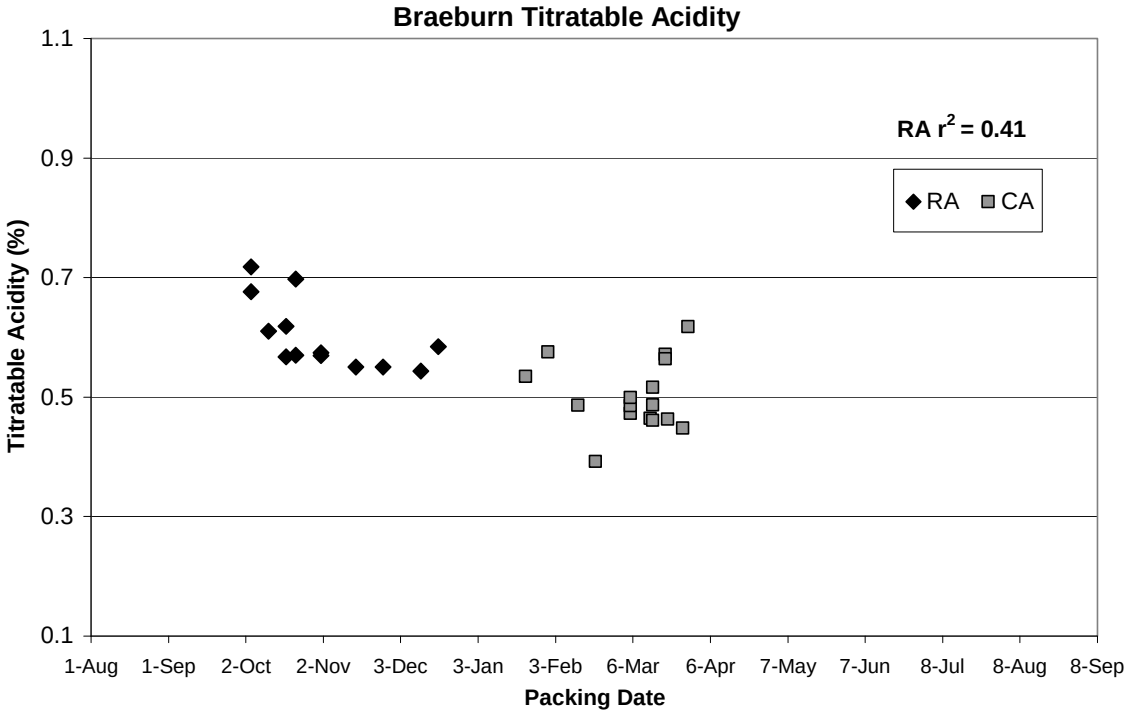


Figure 4. Braeburn sample average SS and TA by week, 2001 crop.

2.2 CAMEO QUALITY—2001 CROP

A total of 300 apples (12 samples) of Cameo were taken from the 2001 crop.

2.2.1 Individual apples

The acoustical firmness values for RA stored fruit ranged between 21and 30 FI, without a strong peak, while the values for CA fruit peaked at 25 FI (Figure 5). The destructive firmness values of individual apples from RA storage had a strong peak at 14.5 lbf. In contrast, CA-stored fruit destructive firmness varied between 11.0 and 20.0 lbf with no clear peak.

2.2.2 Apple samples

Both acoustic and destructive firmness declined with packing date (Figure 6). The decline in both firmness values over time was slightly stronger in RA-stored fruit than CA-stored fruit. The sample average and range of acoustic and destructive firmness are presented in Table 5.

Sample SS and titratable acidity declined throughout the RA packing season (Figure 7). Soluble solids concentrations from CA storage samples declined with packing date. Titratable acidity of CA-stored fruit was not related to packing date. The sample averages and ranges of Cameo SS and acidity are presented in Table 5.

2.2.3 Packinghouse information

Five or more samples of Cameo were taken from only one packinghouse (Table 5).

Table 5. Summary of Cameo quality attributes by packinghouse.

Packinghouse	No. of samples	Temperature (°F)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
c	**8**	**50**	**62**	**13.8**	**0.360**	**14.5**	**24.0**
n	1	—	56	13.7	0.454	17.3	27.5
q	1	36	56	13.9	0.442	17.3	26.9
u	2	41	62	13.6	0.436	13.4	25.8
Average and range of all Cameo samples.							
Average of samples	**45**	**60**		**13.7**	**0.388**	**14.9**	**24.8**
Range of samples	36 to 57	56 to 65		12.5 to 15.3	0.295 to 0.465	12.5 to 17.3	22.8 to 27.5

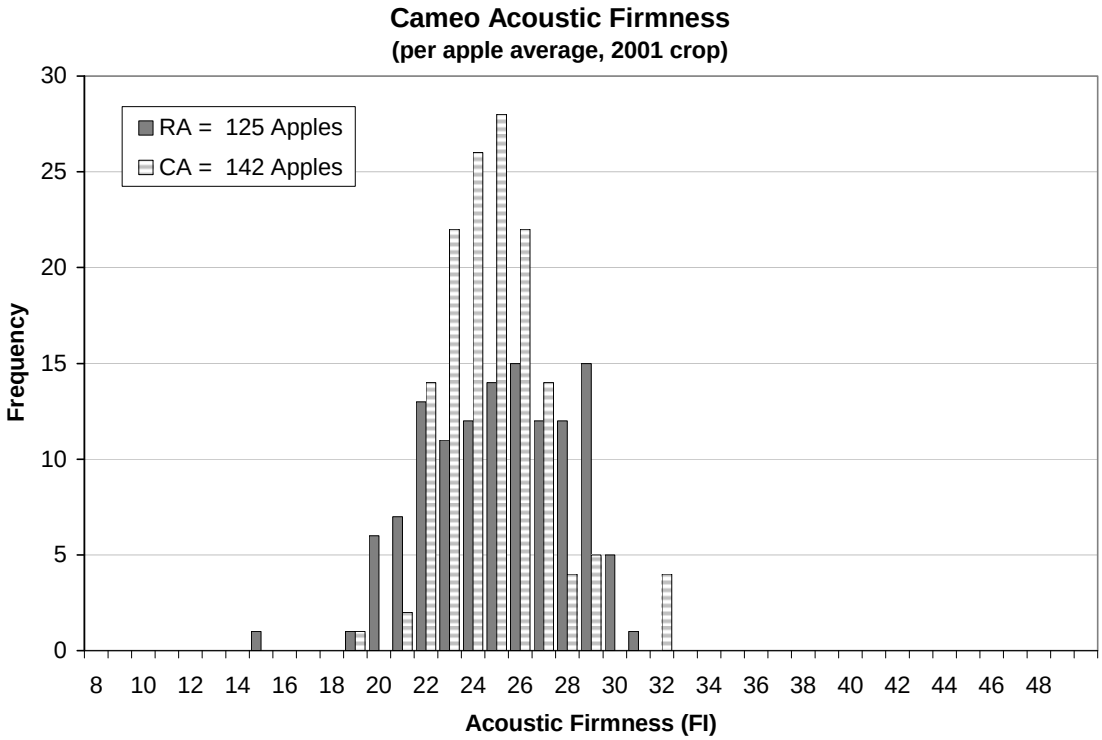
Numbers in **bold** type indicate packinghouse averages are comprised of five or more lots of fruit.

2.2.4 Historical perspective for Cameo

The quality attributes of the 2000 and 2001 Cameo crops are shown in Table 6.

Table 6. Comparison of Cameo quality attributes in 2000 and 2001.

		2000 Crop	2001 Crop
Firmness (lbf)	average range	**15.3** (12 to 18)	**14.9** (12 to 17)
Soluble solids (%)	average range	**13.4** (13 to 14)	**13.7** (12 to 15)
Acidity (%)	average range	**0.32** (0.24 to 0.44)	**0.39** (0.30 to 0.46)
Number of samples		5	12



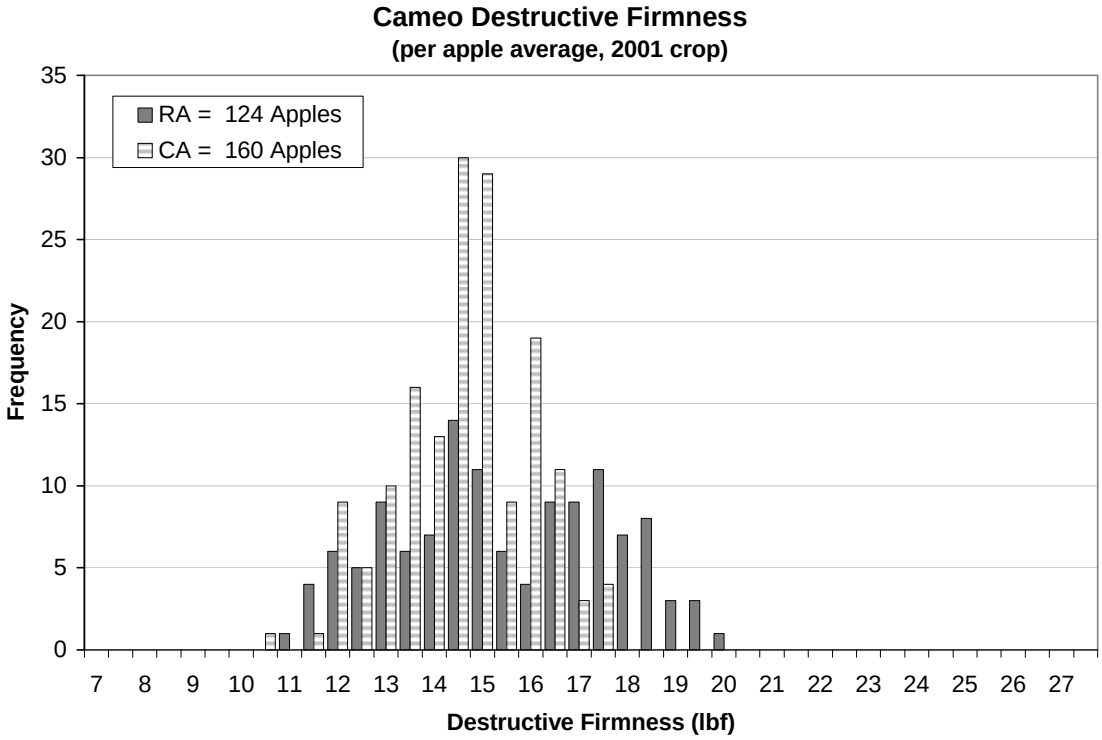


Figure 5. Cameo acoustic and destructive firmness based on individual apples, 2001 crop.

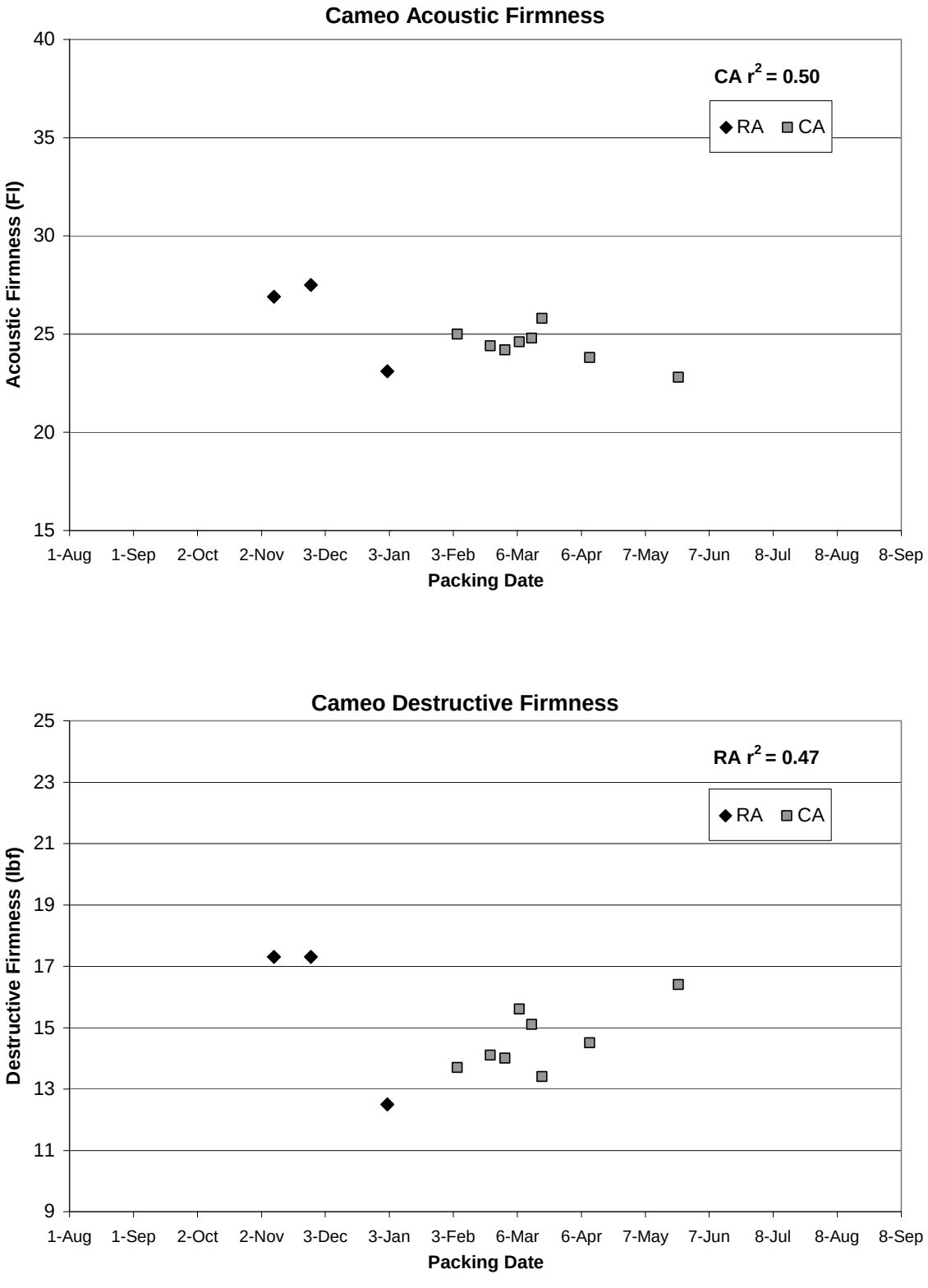
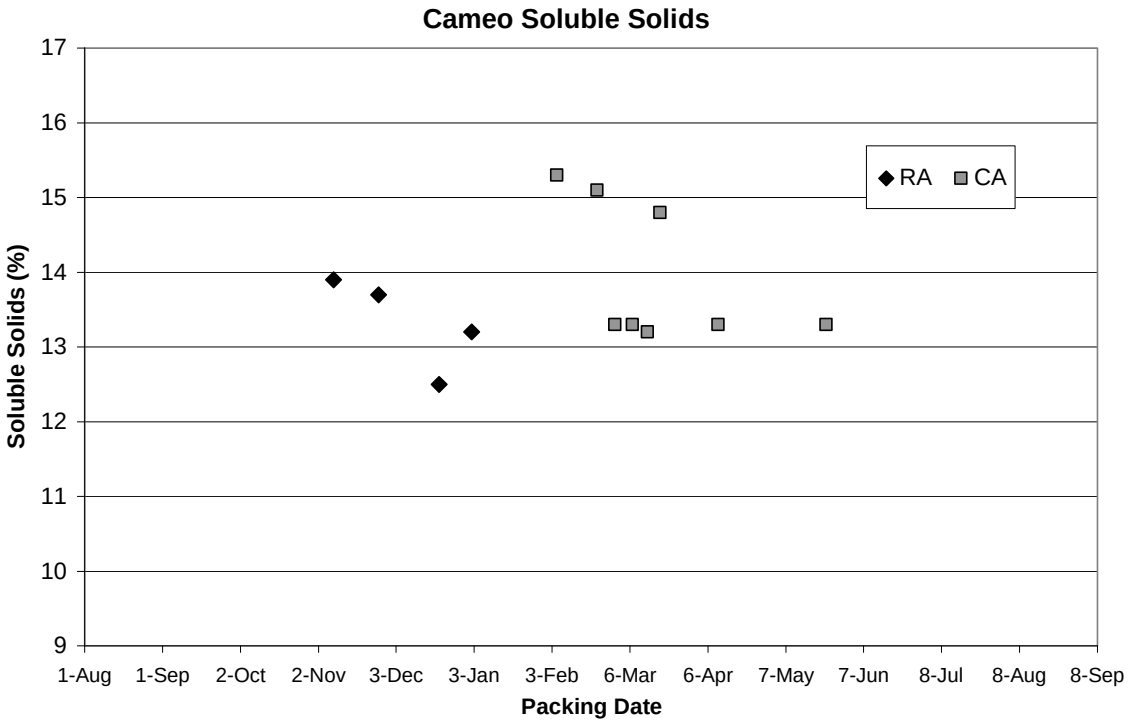


Figure 6. Cameo sample average acoustic and destructive firmness by week, 2001 crop.



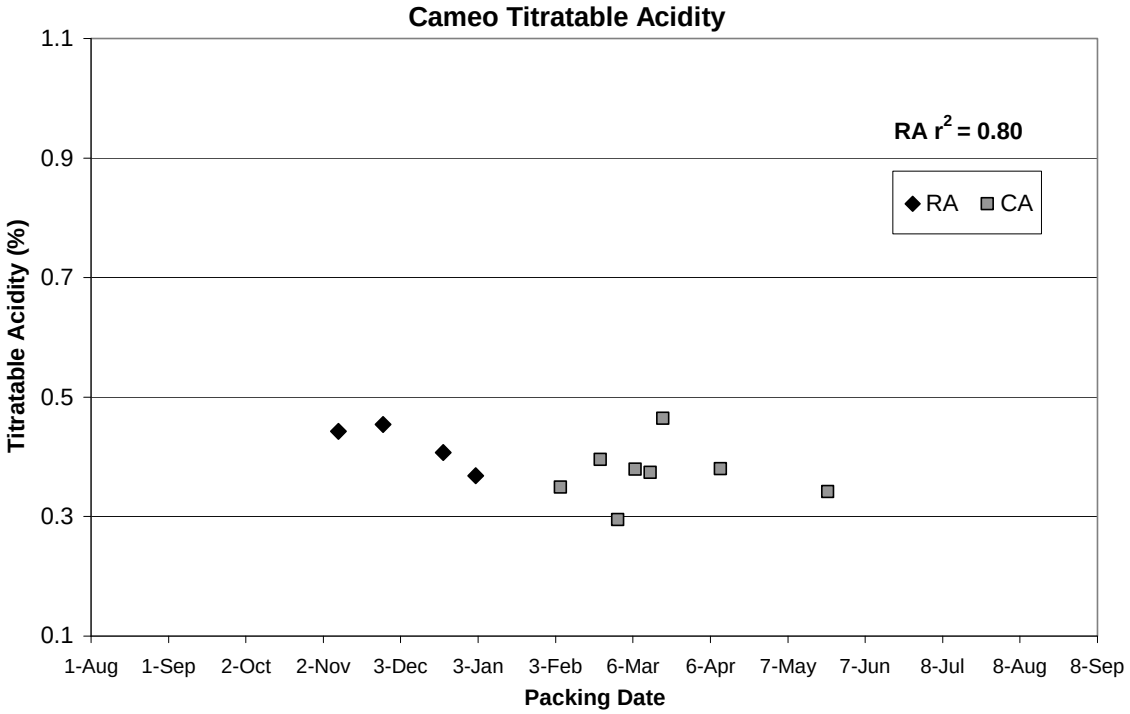


Figure 7. Cameo sample average SS and TA by week, 2001 crop.

2.3 FUJI QUALITY—2001 CROP

A total of 1737 apples (75 samples) of Fuji were taken from the 2001 crop.

2.3.1 Individual apples

There was very little difference in acoustic and destructive firmness of RA and CA-stored Fuji (Figure 8). Destructive firmness values were heavy-tailed to the right, indicating a trend for higher firmness apples. Only one of the 1737 apples sampled measured below 12 lbf.

2.3.2 Apple samples

There was a great deal of variability in firmness at every packing date for Fuji apples. Values for destructive firmness of samples showed a stronger relationship with packing date than acoustical firmness (Figure 9). The average and range of acoustic and destructive firmness are presented in Table 7.

Fuji SS showed a weak relationship to the date of packing out of CA or RA storage (Figure 10). Values for SS were high but variable ranging from 12.4 to 16.1 (Table 7).

The seasonal change in acidity is the most telling quality measurement in Fuji (Figure 10). Acidity steadily declined over the course of the entire season at a very consistent rate. Acidity in CA-stored Fuji was lower than that of RA-stored fruit, and 21% of samples from CA were below 0.210%. The sample average and range of acidity for Fuji are presented in Table 7.

2.3.3 Packinghouse information

The average destructive firmness of Fuji apples sampled from most packinghouses was near 16 lbf, although there was some variation. For example, Fuji sampled from packinghouse 'u' was below the general range (Table 7). Acid levels of Fuji from frequently sampled packinghouses were variable, ranging from 0.239% to 0.393%.

Table 7. Summary of Fuji quality attributes by packinghouse.

Packinghouse	No. of samples	Temperature (°F)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
a	**5**	**57**	**64**	**14.6**	**0.393**	**16.3**	**29.0**
b	4	57	62	14.0	0.380	18.2	30.5
c	**12**	**56**	**65**	**13.9**	**0.276**	**16.1**	**30.1**
d	**9**	**51**	**64**	**14.0**	**0.374**	**16.1**	**29.6**
e	1	78	71	14.4	0.382	16.9	32.2
g	1	40	65	13.5	0.279	15.4	28.5
k	1	—	—	13.4	0.279	12.6	30.1
l	**9**	**55**	**67**	**14.5**	**0.362**	**16.0**	**29.5**
n	3	46	59	14.6	0.364	16.0	27.9
o	**8**	**55**	**65**	**14.5**	**0.322**	**16.5**	**32.2**
q	3	53	64	14.3	0.251	16.2	29.5
r	3	52	65	13.6	0.339	16.0	30.6
s	4	52	66	14.5	0.331	15.5	26.4
u	**7**	**49**	**66**	**14.6**	**0.248**	**14.5**	**29.5**
v	**5**	**46**	**56**	**14.2**	**0.239**	**15.6**	**29.3**
Average and Range of all Fuji samples.							
Average of samples		**53**	**64**	**14.2**	**0.318**	**16.0**	**29.8**
Range of samples		40 to 78	48 to 78	12.4 to 16.1	0.169 to 0.455	12.4 to 19.7	24.7 to 36.8

Numbers in **bold** type indicate packinghouse averages are comprised of five or more lots of fruit.

2.3.4 Historical perspective for Fuji

We sampled Fuji apples during the packing of the 1992, 1993, 2000 and 2001 crops. Firmness, acidity and soluble solids were significantly lower in the 2000 crop (Table 8). Most packers and growers will agree that the edible quality of Fuji apples in 2000 was not exceptional.

Table 8. Comparison of Fuji quality attributes over the past 10 years.

		1992 Crop	1993 Crop	2000 Crop	2001 Crop
Firmness (lbf)	average	**16.9**	**16.5**	**15.1**	**16.0**
	range	(14 to 19)	(11 to 23)	(12 to 20)	(12 to 20)
Soluble solids (%)	average	**14.9**	**14.6**	**13.7**	**14.2**
	range	(13 to 17)	(13 to 17)	(12 to 16)	(12 to 16)
Acidity (%)	average	**0.41**	**0.34**	**0.26**	**0.32**
	range	(0.23 to 0.65)	(0.23 to 0.46)	(0.12 to 0.42)	(0.17 to 0.46)
Number of samples		84	36	93	75

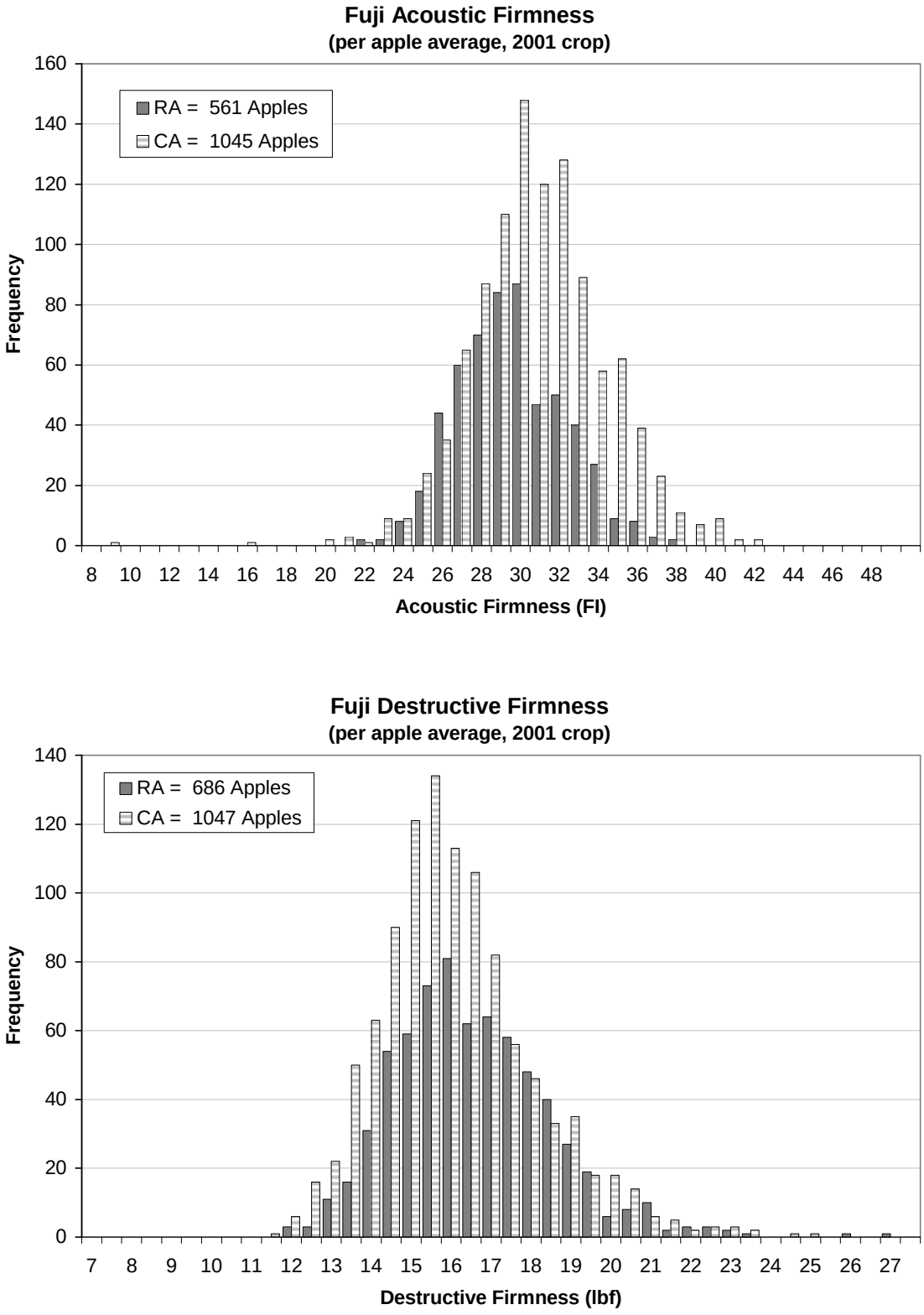


Figure 8. Fuji acoustic and destructive firmness based on individual apples, 2001 crop.

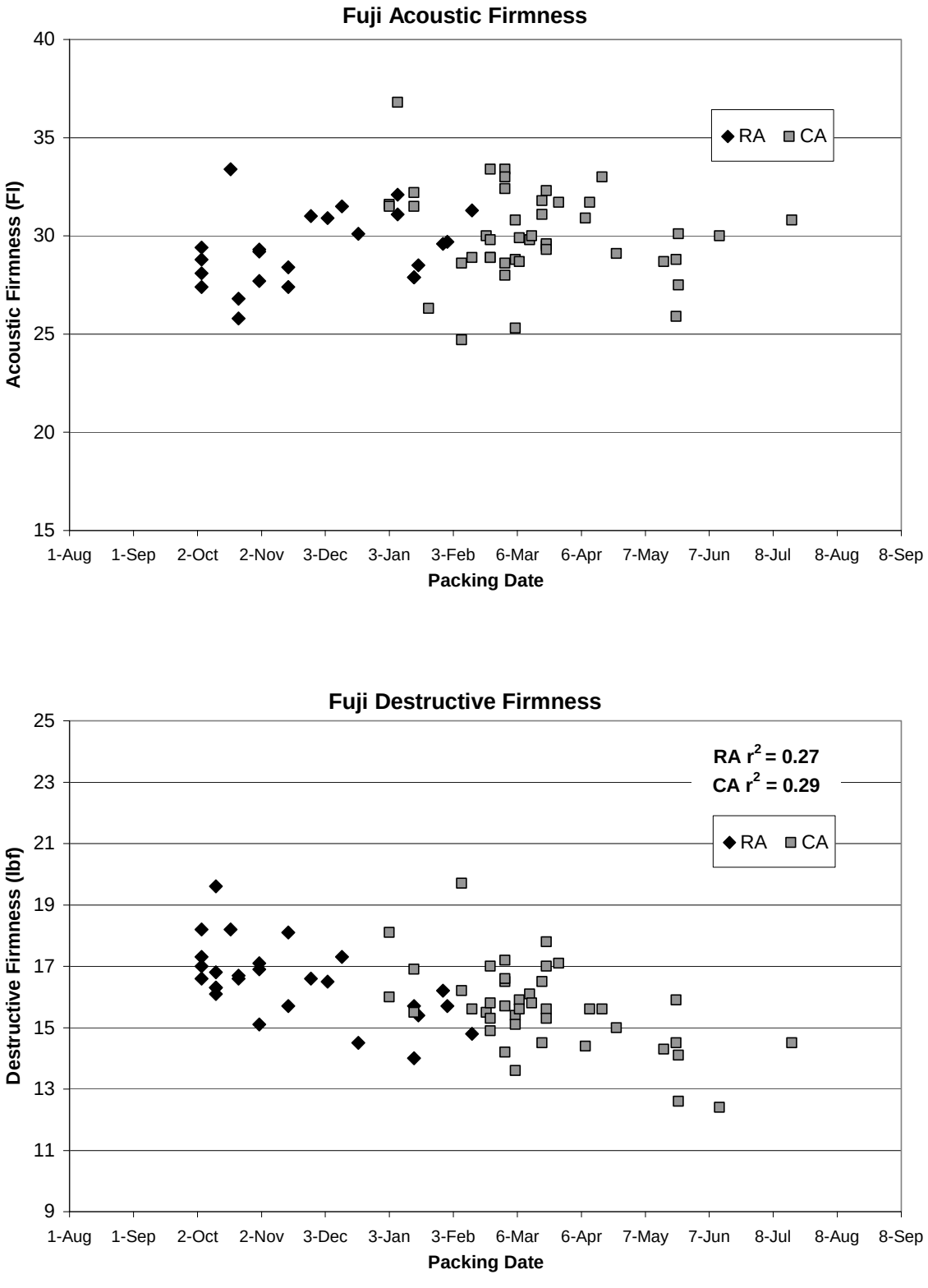
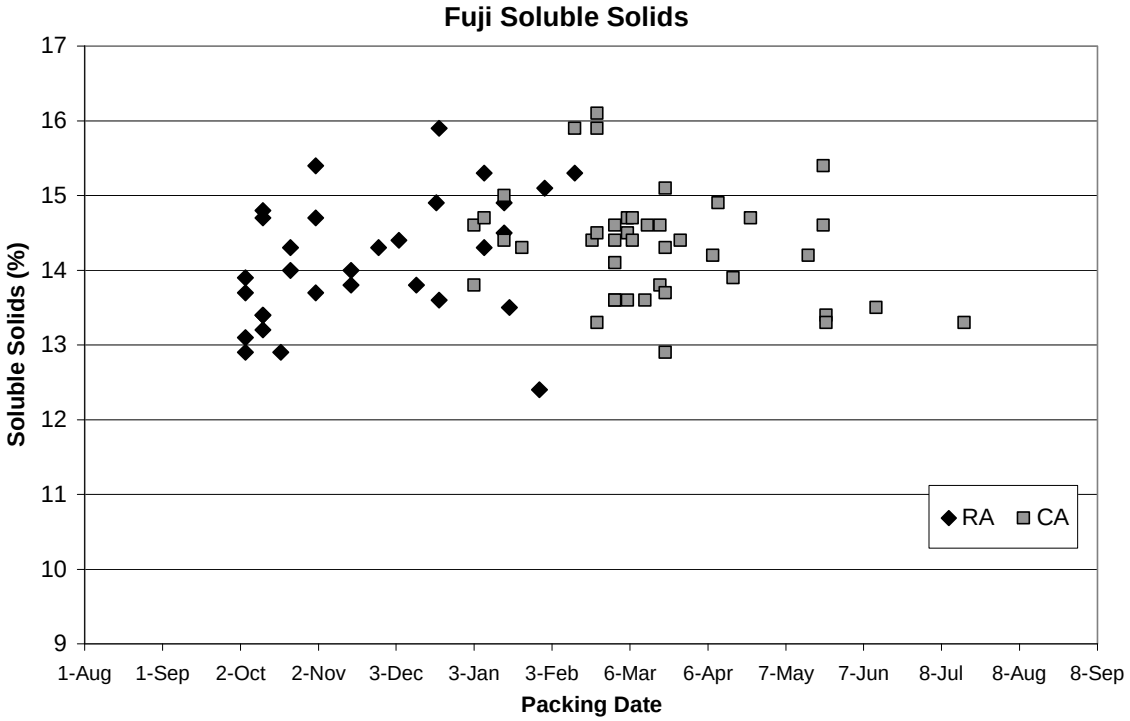


Figure 9. Fuji sample average acoustic and destructive firmness by week, 2001 crop.



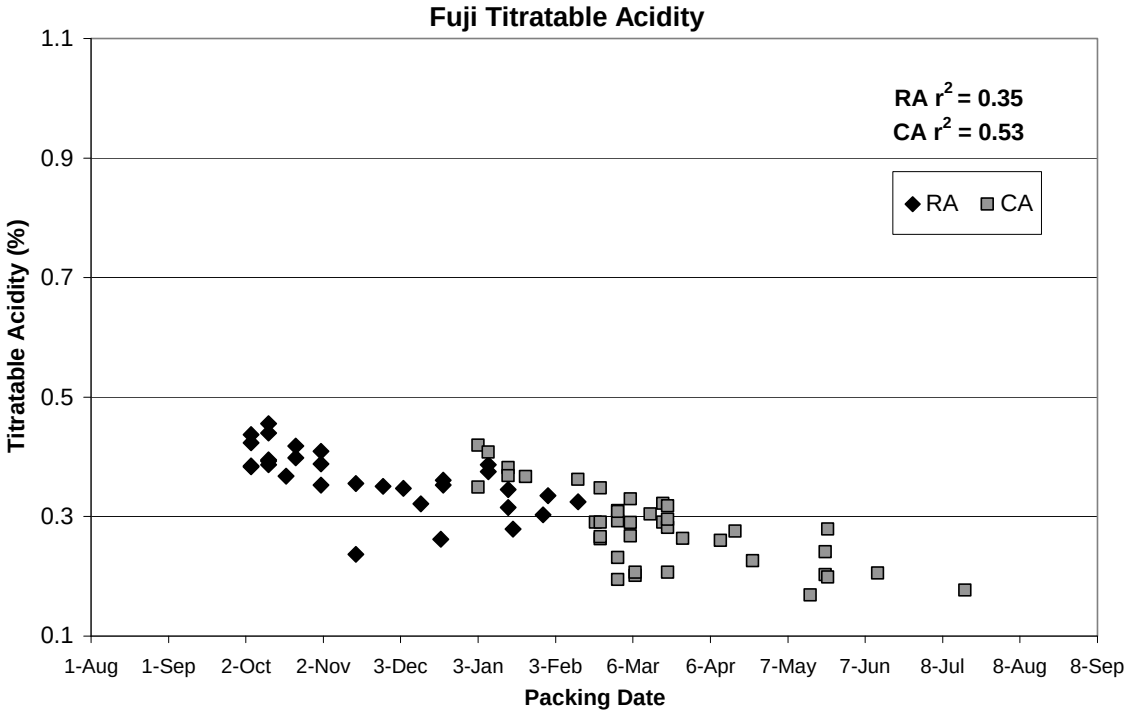


Figure 10. Fuji sample average SS and TA by week, 2001 crop.

2.4 GALA QUALITY—2001 CROP

A total of 1892 apples (83 samples) of Gala were taken from the 2001 crop.

2.4.1 Individual apples

Acoustic firmness values peaked at 25 FI for RA and 24 FI for CA (Figure 11). The distribution of destructive firmness values for Gala apples was heavy to the center, with more values near 14.0 and 14.5 lbf (Figure 11). Destructive firmness of fruit stored in RA was higher than fruit stored in CA. There were few outlying low-firmness values, with only 1% of all apples below 11 lbf destructive firmness.

2.4.2 Apple samples

The decline in firmness with packing date was more severe when measured destructively than acoustically (Figure 12). The decline in firmness was more apparent in RA than in CA-stored fruit (Figure 12). The average and range of acoustic and destructive firmness values are presented in Table 9.

Soluble solids levels in Gala were not associated with the date of packing out of RA storage and only slightly associated with the date of packing in CA-stored fruit (Figure 13).

Acidity levels were not associated with date of packing. The sample averages and ranges of Gala SS and acidity are presented in Table 9.

2.4.3 Packinghouse information

The quality of Gala apples in the 2001 packing season was relatively uniform and of high quality throughout the year.

Table 9. Summary of Gala quality attributes by packinghouse.

Packinghouse	No. of samples	Temperature (ºF)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
a	**7**	**62**	**68**	**12.5**	**0.334**	**14.8**	**23.5**
b	2	42	57	13.2	0.398	13.4	23.9
c	**18**	**49**	**63**	**13.2**	**0.372**	**15.2**	**24.1**
d	2	68	78	12.7	0.400	16.6	24.6
e	1	—	60	14.4	0.353	12.8	21.7
g	**6**	**56**	**66**	**13.6**	**0.361**	**14.9**	**24.0**
j	4	58	73	12.6	0.350	17.0	23.2
l	**7**	**50**	**67**	**13.5**	**0.382**	**15.1**	**25.8**
m	**7**	**55**	**72**	**13.5**	**0.367**	**15.1**	**24.6**
n	**5**	**48**	**66**	**13.8**	**0.350**	**14.2**	**21.6**
o	**9**	**59**	**65**	**13.4**	**0.374**	**14.3**	**23.5**
r	**8**	**59**	**68**	**13.9**	**0.376**	**14.6**	**24.1**
s	2	59	72	13.0	0.446	15.7	24.2
u	1	60	63	14.9	0.337	15.2	27.1
v	4	44	59	13.0	0.334	14.4	22.4
Average and range of all Gala samples.							
Average of samples	**54**		**66**	**13.3**	**0.366**	**15.0**	**23.8**
Range of samples	40 to 84		49 to 84	11.3 to 14.9	0.266 to 0.454	12.2 to 18.5	18.6 to 28.1

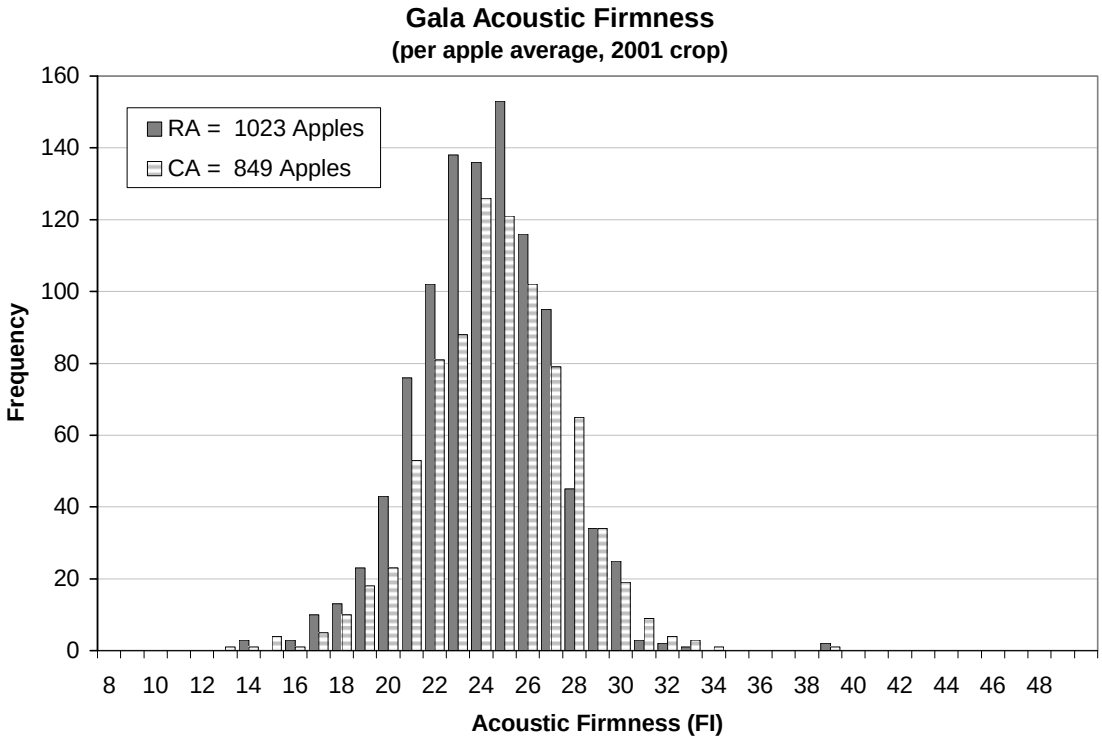
Numbers in **bold** type indicate packinghouse averages are comprised of five or more lots of fruit.

2.4.4 Historical perspective for Gala

Gala apples were sampled during the packing of the 1992, 1993, 1995, 2000 and 2001 crops (Table 10).

Table 10. Comparison of Gala quality attributes over the past 10 years.

		1992 Crop	1993 Crop	1995 Crop	2000 Crop	2001 Crop
Firmness (lbf)	average	**16.1**	**16.7**	**15.2**	**14.6**	**15.0**
	range	(14 to 18)	(13 to 20)	(12 to 18)	(8 to 16)	(12 to 19)
Soluble solids (%)	average	**13.0**	**13.1**	**13.9**	**13.3**	**13.3**
	range	(11 to 16)	(11 to 16)	(12 to 16)	(10 to 15)	(11 to 15)
Acidity (%)	average	**0.53**	**0.42**	**0.30**	**0.33**	**0.37**
	range	(0.32 to 0.82)	(0.32 to 0.56)	(0.22 to 0.38)	(0.23 to 0.42)	(0.27 to 0.45)
Number of samples		180	100	210	55	83



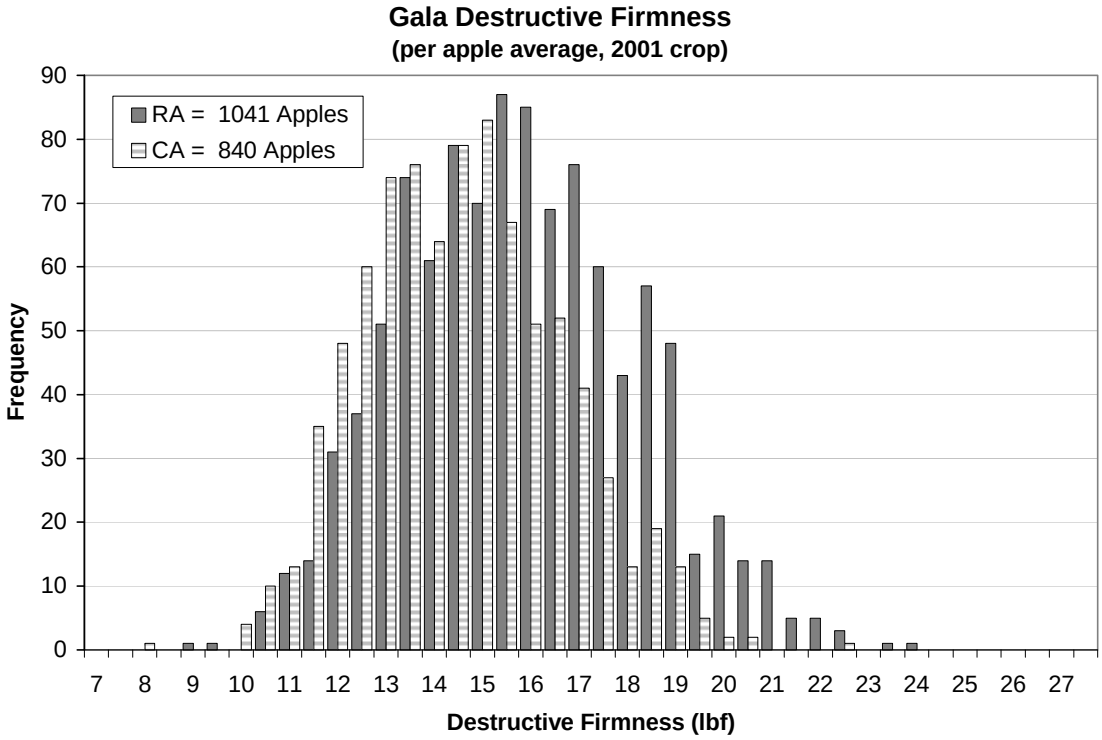
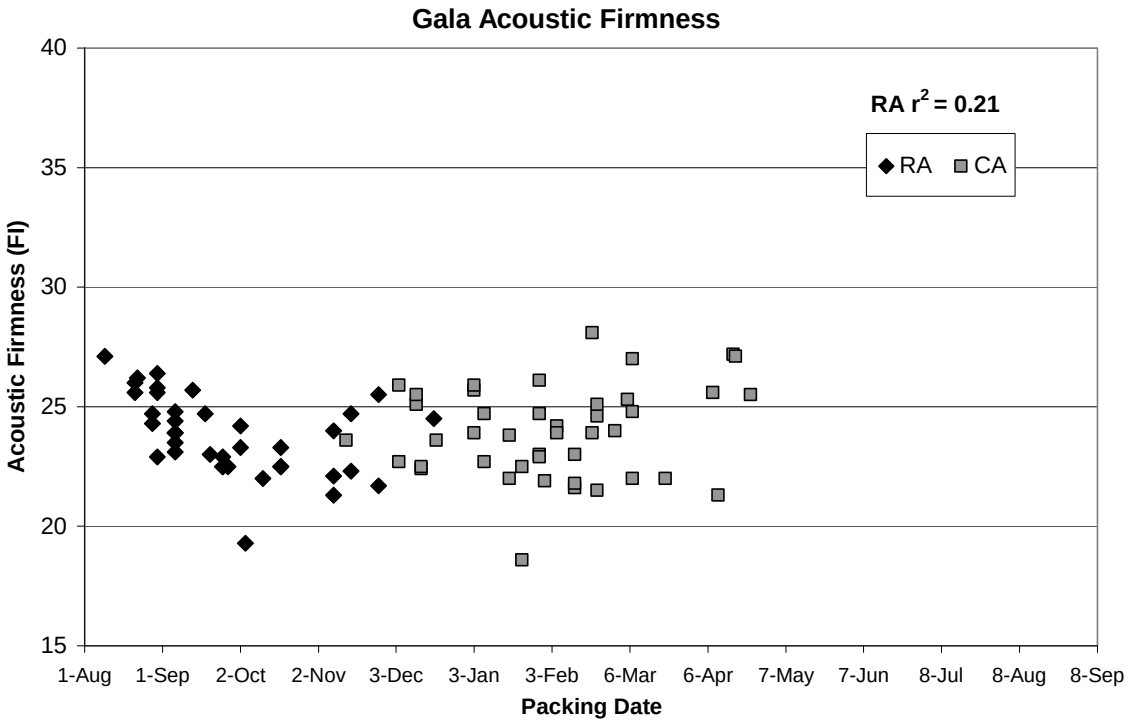


Figure 11. Gala acoustic and destructive firmness based on individual apples, 2001 crop.



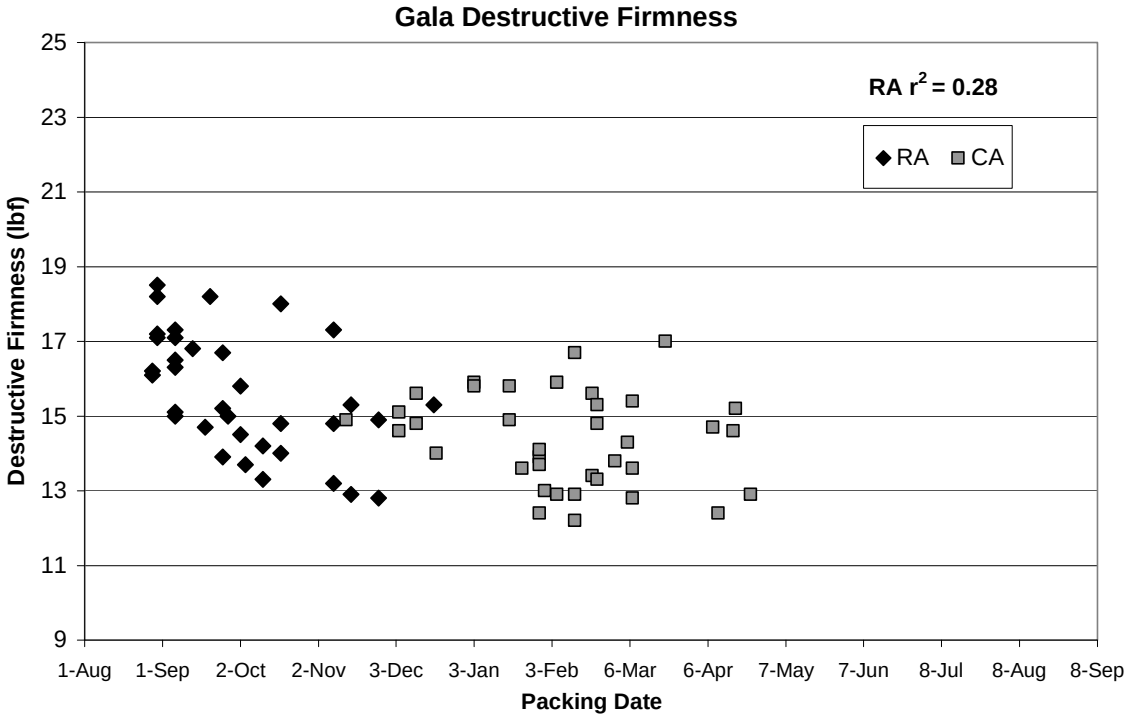


Figure 12. Gala sample average acoustic and destructive firmness by week, 2001 crop.

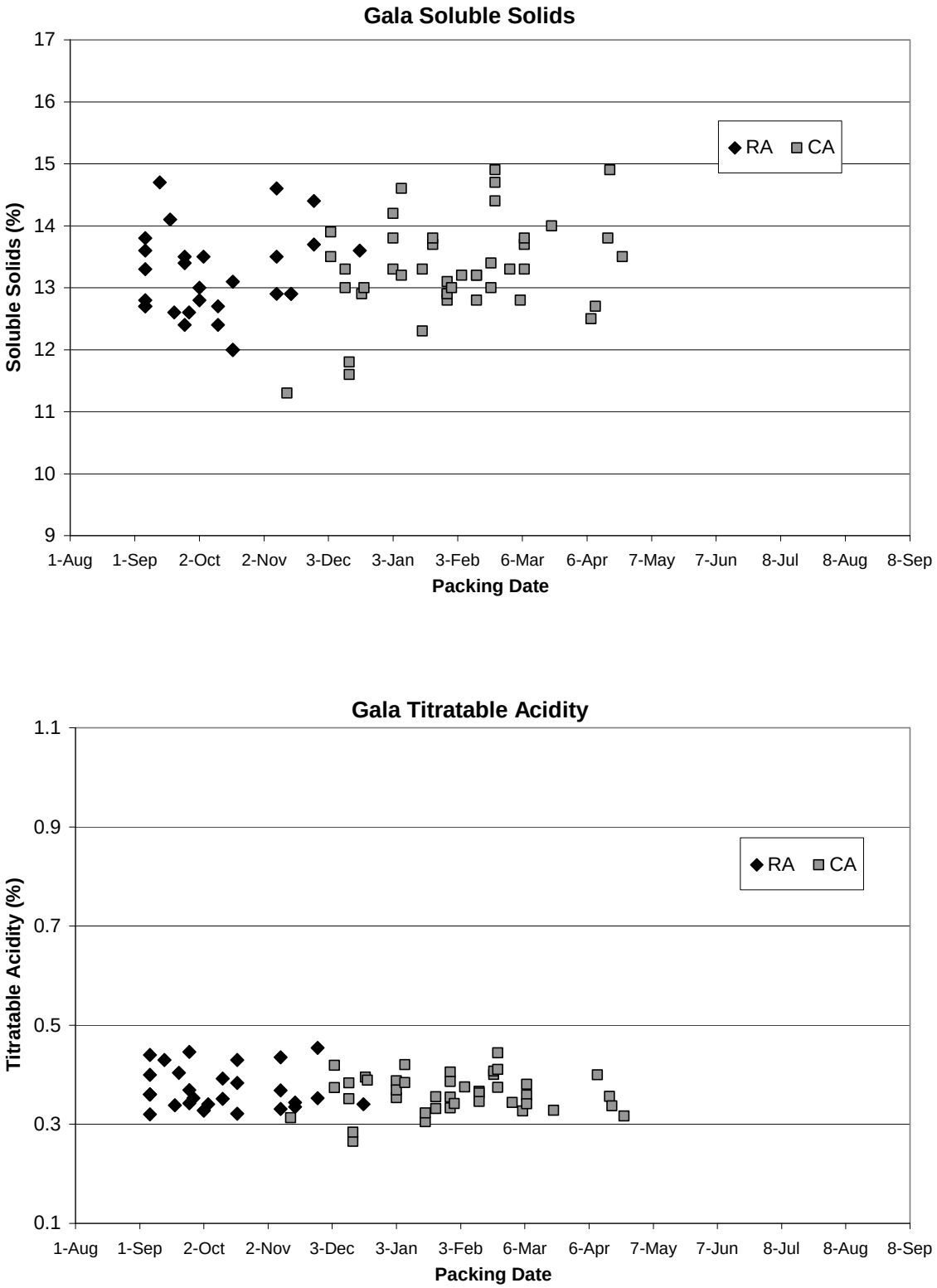


Figure 13. Gala sample average SS and TA by week, 2001 crop.

2.5 GOLDEN DELICIOUS QUALITY—2001 CROP

A total of 2020 apples (83 samples) of Golden Delicious were obtained from the 2001 crop.

2.5.1 Individual apples

In general, Golden Delicious apples sampled from RA were firmer than those from CA as measured by either the destructive or acoustical method (Figure 14). The acoustical firmness generally ranged between 25 FI and 29 FI for RA and showed a strong peak at 22 FI for CA. Although the destructive firmness of both RA and CA fruit peaked at about the same point, there were more firm fruit from RA than from CA.

2.5.2 Apple samples

Firmness in Golden Delicious apples was highest in fruit packed at harvest. The fruit lost firmness rapidly as the RA season progressed as measured destructively, with sample averages as low as 9.7 lbf (Figure 15). A similar pattern emerged with the acoustical firmness (Figure 15). After the release of CA-stored fruit low firmness values were not associated with later packing dates and the destructive firmness of only one sample averaged below 11 lbf. The average and range of acoustic and destructive firmness are presented in Table 11.

Soluble solids concentration in samples of Golden Delicious apples was not associated with the date of packing, although 20% of samples packed at the end of the RA storage season were below 12.0 % (Figure 16). The average and range of Golden Delicious soluble solids are presented in Table 11.

The acidity in Golden Delicious was highest in the first weeks of sampling RA-stored fruit, with values as high as 0.600% acidity but at the end of the RA-stored packing season values were as low as 0.294 %. Acidity concentration of fruit held in CA storage was not associated with the date of packing (Figure 16). The average and range of Golden Delicious acidity are presented in Table 11.

2.5.3 Packinghouse information

Table 11. Summary of Golden Delicious quality attributes by packinghouse.

Packinghouse	No. of samples	Temperature (ºF)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
a	4	66	72	12.4	0.497	16.4	25.2
b	**6**	**41**	**67**	**13.1**	**0.473**	**14.1**	**25.6**
c	**19**	**51**	**60**	**13.5**	**0.418**	**15.2**	**23.1**
d	1	56	73	12.0	0.520	18.2	25.7
e	2	56	69	14.0	0.386	11.8	20.3
f	2	60	72	12.2	0.405	15.4	—
k	1	61	75	13.7	—	15.4	19.8
l	**7**	**48**	**62**	**12.4**	**0.436**	**15.4**	**25.8**
n	**7**	**44**	**64**	**13.4**	**0.435**	**13.6**	**23.5**
o	**9**	**66**	**69**	**13.8**	**0.451**	**15.8**	**23.4**
q	**5**	**43**	**64**	**12.8**	**0.416**	**15.9**	**23.7**
r	**6**	**55**	**72**	**12.8**	**0.383**	**14.2**	**24.0**
s	3	59	68	12.5	0.410	15.1	21.4
u	**11**	**56**	**69**	**13.5**	**0.399**	**14.8**	**22.7**
Average and range of all Golden Delicious samples.							
Average of samples	**53**	**66**		**13.2**	**0.428**	**15.1**	**23.6**
Range of samples	34 to 75	49 to 83		11.4 to 14.9	0.294 to 0.600	9.7 to 23.6	17.0 to 32.4

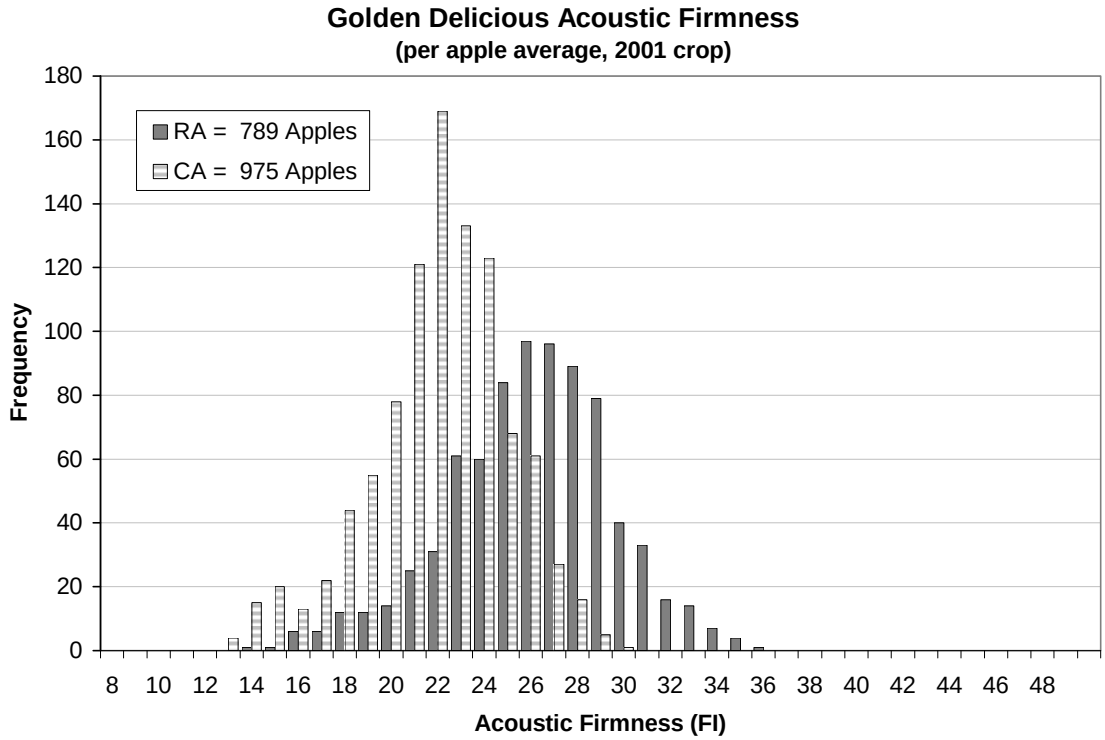
Numbers in **bold** type indicate packinghouse averages are comprised of five or more lots of fruit.

2.5.4 Historical perspective for Golden Delicious

We sampled Golden Delicious apples in 1991, 2000, and 2001 (Table 12). The 2000 fruit had the lowest average firmness, but the highest soluble solids levels. Fruit were sampled over the same part of the season (December to June) in 1991 and 2000. In 2001, fruit were sampled from early August (Gingergold) to mid-April 2002.

Table 12. Comparison of Golden Delicious quality attributes in 1991, 2000, and 2001.

		1991 Crop	2000 Crop	2001 Crop
Firmness (lbf)	average range	**14.5** (11 to 18)	**13.4** (12 to 19)	**15.1** (10 to 24)
Soluble solids (%)	average range	**12.8** (11 to 15)	**13.5** (11 to 16)	**13.2** (11 to 15)
Acidity (%)	average range	**0.39** (0.24 to 0.57)	**0.40** (0.20 to 0.55)	**0.43** (0.29 to 0.60)
Number of samples		148	94	83



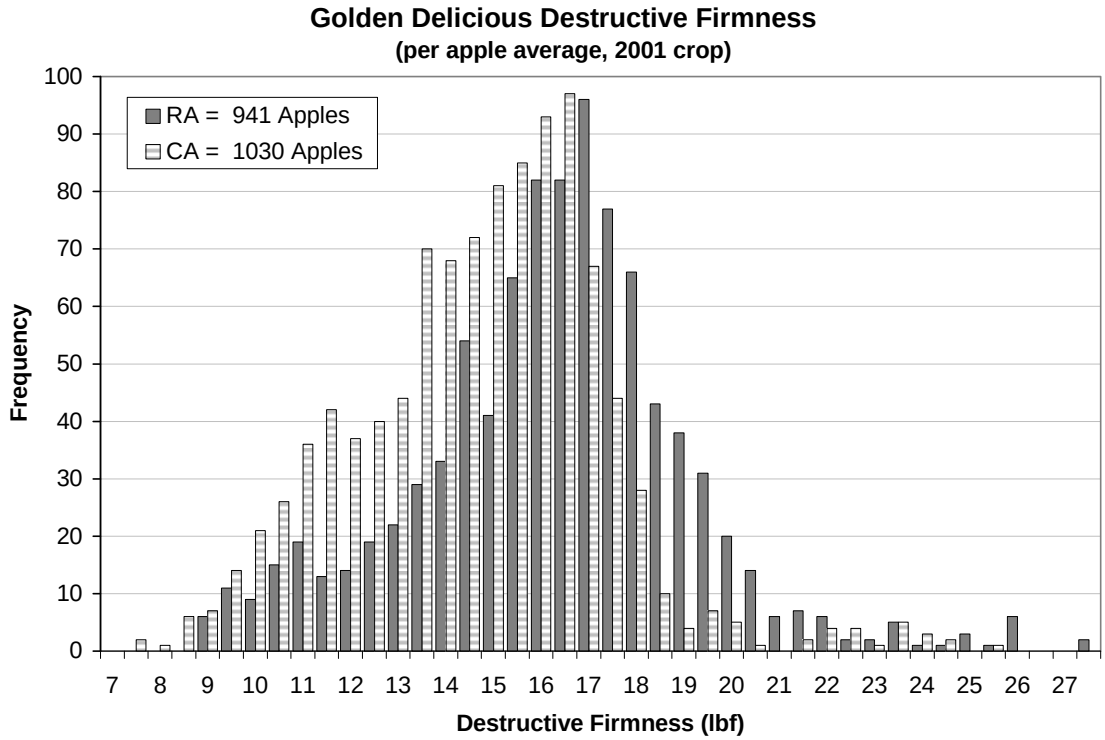


Figure 14. Golden Delicious acoustic and destructive firmness based on individual apples, 2001 crop.

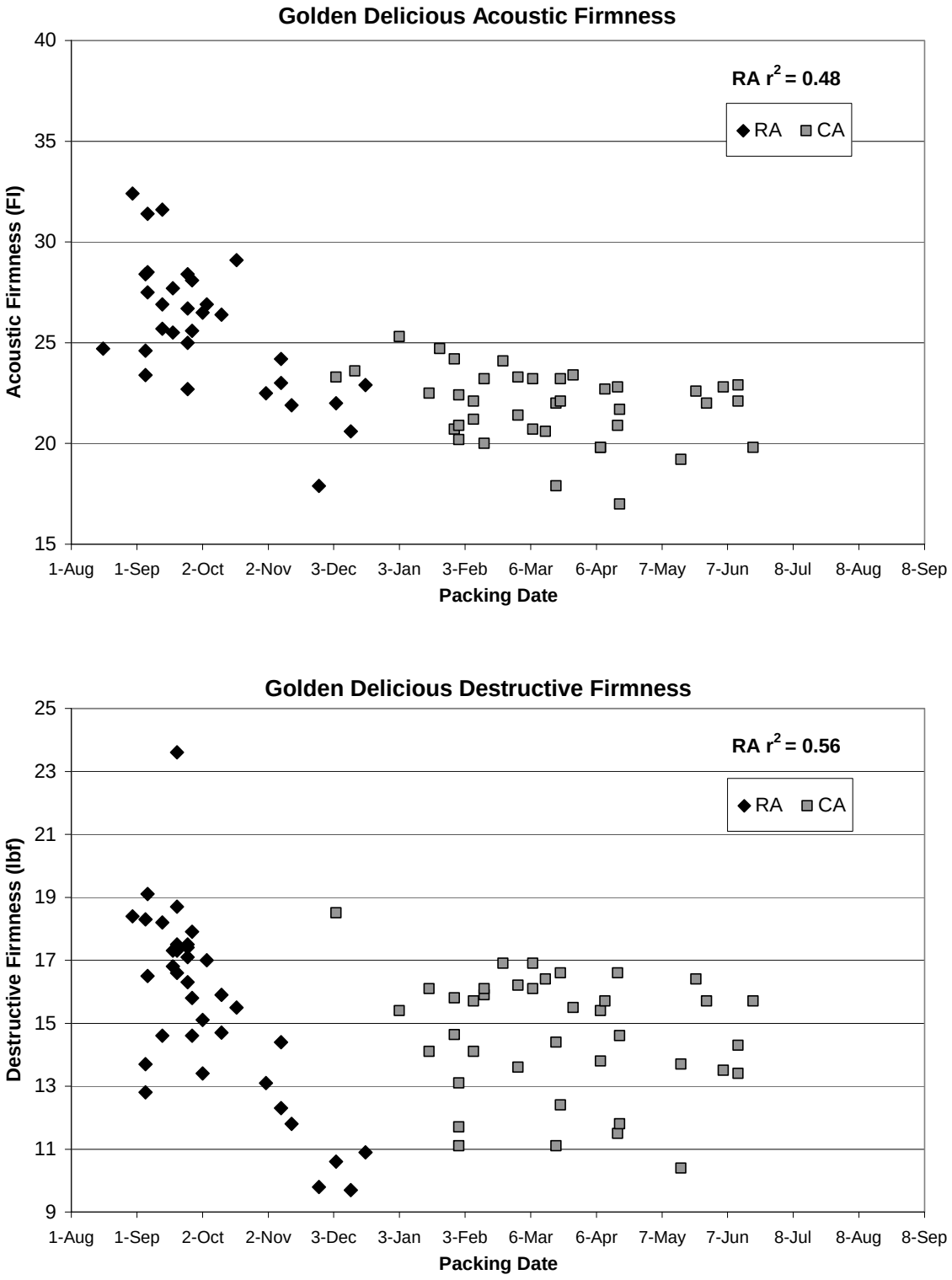
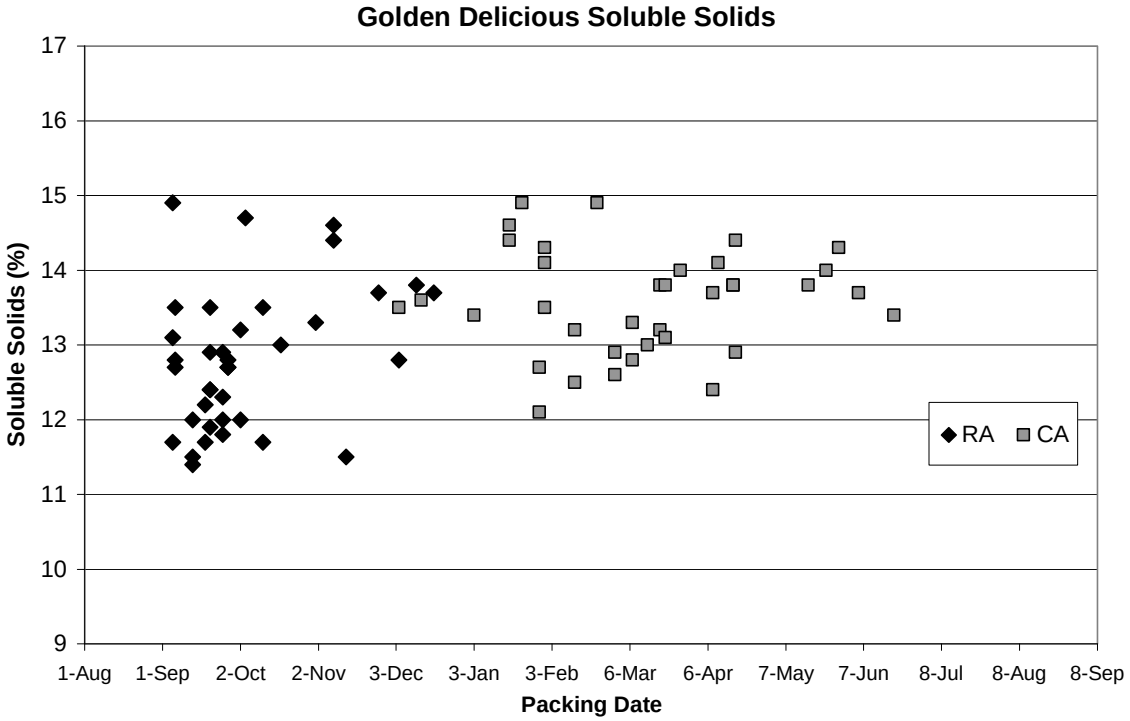


Figure 15. Golden Delicious sample average acoustic and destructive firmness by week, 2001 crop.



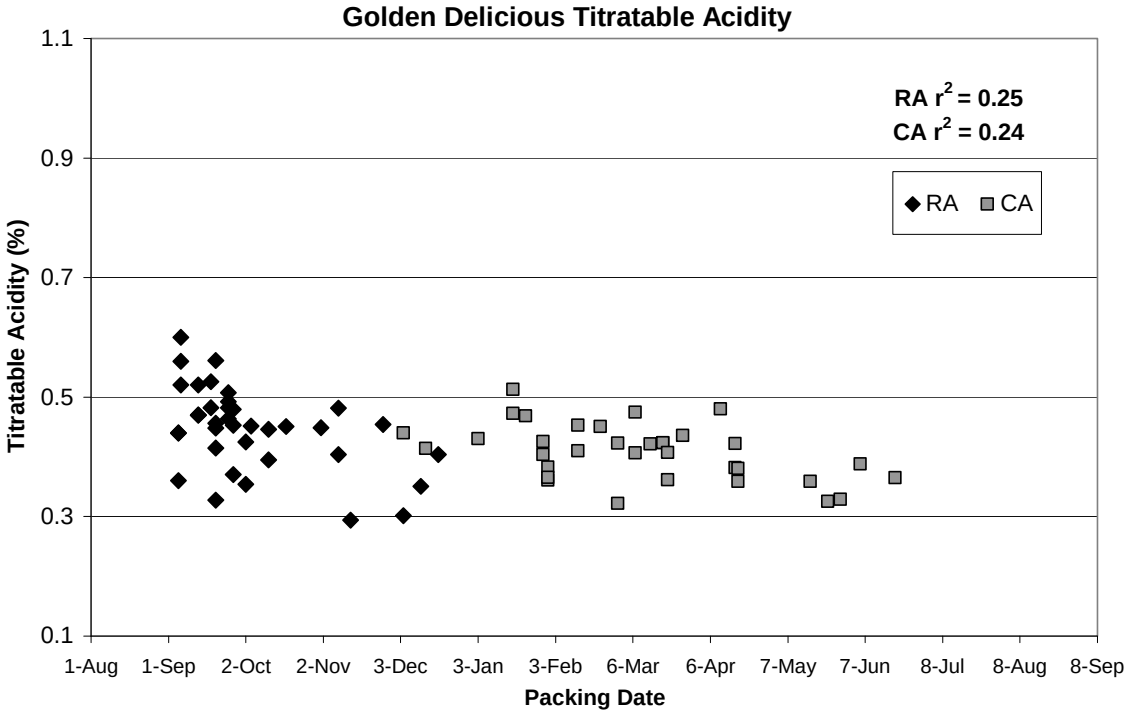


Figure 16. Golden Delicious sample average SS and TA by week, 2001 crop.

2.6 GRANNY SMITH QUALITY—2001 CROP

A total of 850 apples (34 samples) of Granny Smith were taken from the 2001 crop.

2.6.1 Individual apples

Acoustic firmness was generally higher in RA-stored fruit than in CA-stored fruit (Figure 17). The distribution of destructive firmness for Granny Smith apples packed after CA and RA storage were similar with both peaking at 18 lbf (Figure 17). However there were more firm fruit from RA than from CA. Values of destructive firmness were as high as 24.0 lbf and no individual fruit was below 12.5 lbf.

2.6.2 Apple samples

Granny Smith apples were typically of lower destructive or acoustical firmness when packed later in the season (Figure 18). Acoustical firmness showed a strong correlation with packing date, especially out of RA storage (Figure 18). Destructive firmness tests showed a reasonable correlation with packing date, especially out of CA storage. The sample averages and ranges of acoustic and destructive firmness are presented in Table 13.

Soluble solids concentration increased with later dates of packing for Granny Smith apples stored in RA, but was less associated with packing date in CA-stored fruit (Figure 19). The sample average and range of soluble solids are presented in Table 13.

There was a steep decline in Granny Smith acidity of both RA and CA-stored fruit over the season (Figure 19). RA-stored apples declined from above 1.00% acidity to below 0.60%. CA-stored apples declined from 0.88% to 0.27%. The average and range of Granny Smith acidity are presented in Table 13.

2.6.3 Packinghouse information

More than five samples of Granny Smith apples were sampled from packinghouse 'v' (Table 13).

Table 13. Summary of Granny Smith quality attributes by packinghouse.

Packinghouse	No. of samples	Temperature (°F)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
a	4	64	66	11.8	0.766	17.9	30.2
b	2	60	83	11.7	0.874	16.8	30.0
c	1	58	57	13.0	0.685	—	28.5
g	1	46	60	11.6	0.760	17.2	30.9
j	1	69	63	11.5	0.594	17.3	27.4
k	1	60	72	13.6	0.626	15.7	32.0
m	1	46	64	11.9	0.673	15.8	31.0
n	1	78	66	12.1	1.023	19.8	31.1
o	3	61	67	11.7	0.704	18.8	31.0
q	3	54	64	12.3	0.675	18.4	29.9
r	1	50	68	12.0	0.744	17.0	28.8
u	2	54	70	11.1	0.941	18.3	31.9
v	**12**	**47**	**60**	**12.0**	**0.524**	**17.4**	**29.8**
Average and range of all Granny Smith samples.							
Average of samples	**54**		**65**	**11.9**	**0.680**	**17.6**	**30.1**
Range of samples	40 to 78		54 to 87	9.0 to 13.6	0.273 to 1.053	14.4 to 19.8	27.0 to 33.3

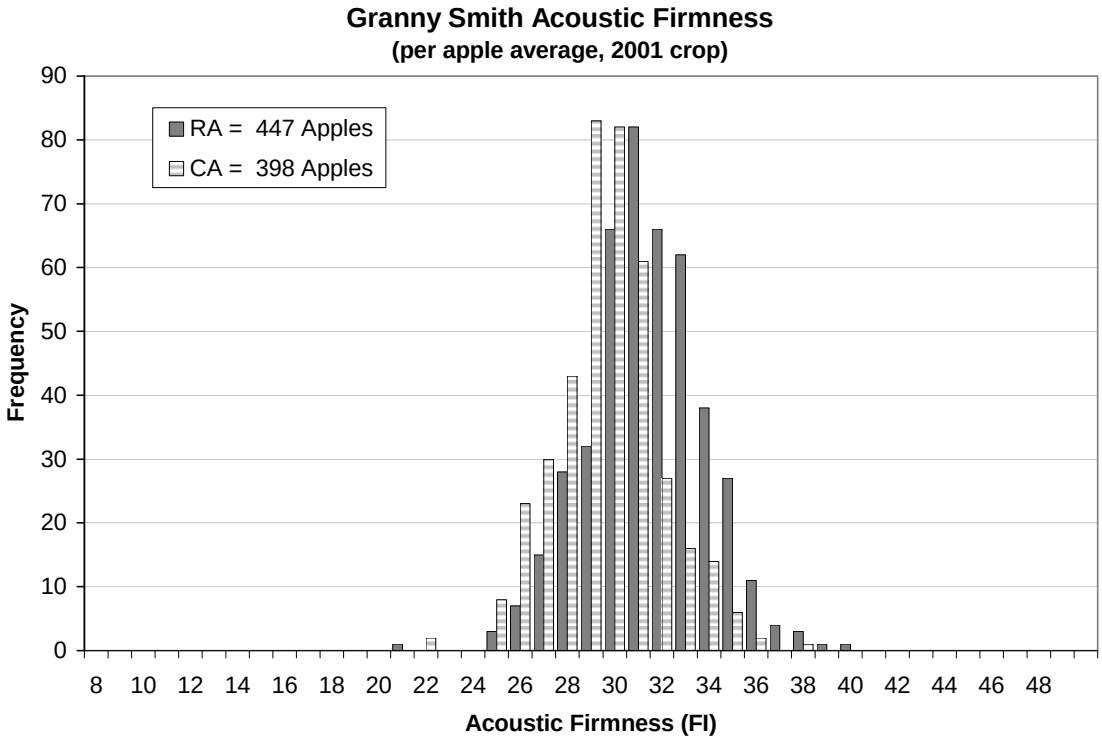
Numbers in **bold** type indicate packinghouse averages are comprised of five or more lots of fruit.

2.6.4 Historical perspective for Granny Smith

There is a very limited amount of data from 1995 to compare with the 2000 and 2001 crops (Table 14). Granny Smith apples sampled in 1995 were firmer than those sampled in 2000. Soluble solids levels were about the same, while acidity was much more variable in 2000.

Table 14. Comparison of Granny Smith quality attributes in 1995, 2000, and 2001.

		1995 Crop	2000 Crop	2001 Crop
Firmness (lbf)	average range	**18.7** (18 to 19)	**16.5** (11 to 21)	**17.6** (14 to 20)
Soluble solids (%)	average range	**12.9** (12 to 13)	**12.7** (11 to 15)	**11.9** (9 to 14)
Acidity (%)	average range	**0.54** (0.51 to 0.56)	**0.58** (0.32 to 0.76)	**0.68** (0.27 to 1.05)
Number of samples		14	56	34



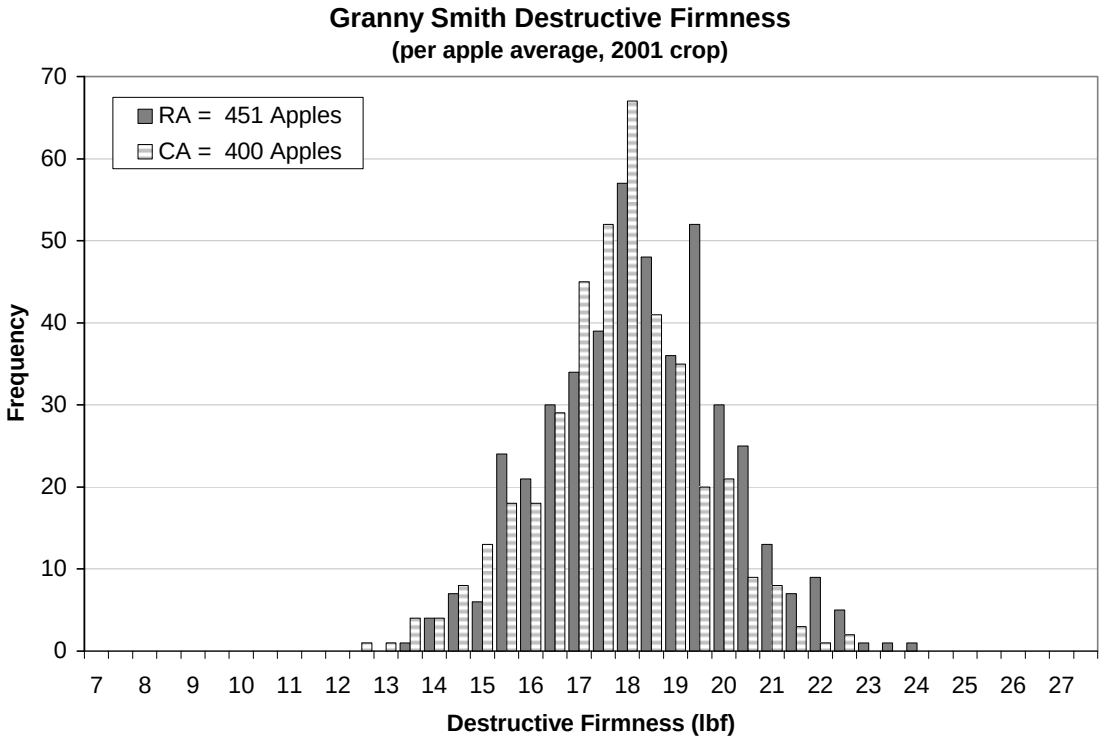


Figure 17. Granny Smith acoustic and destructive firmness based on individual apples, 2001 crop.

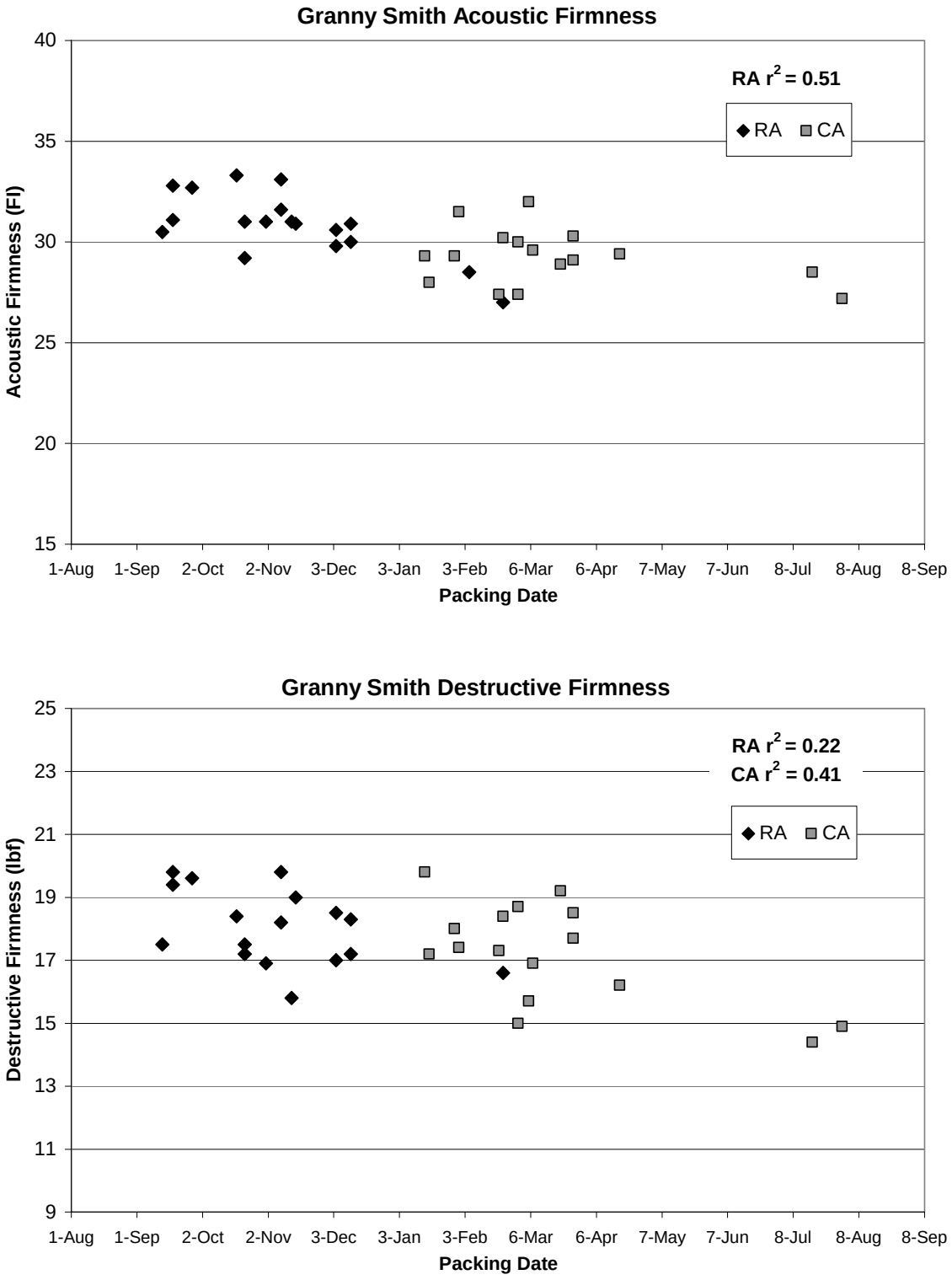
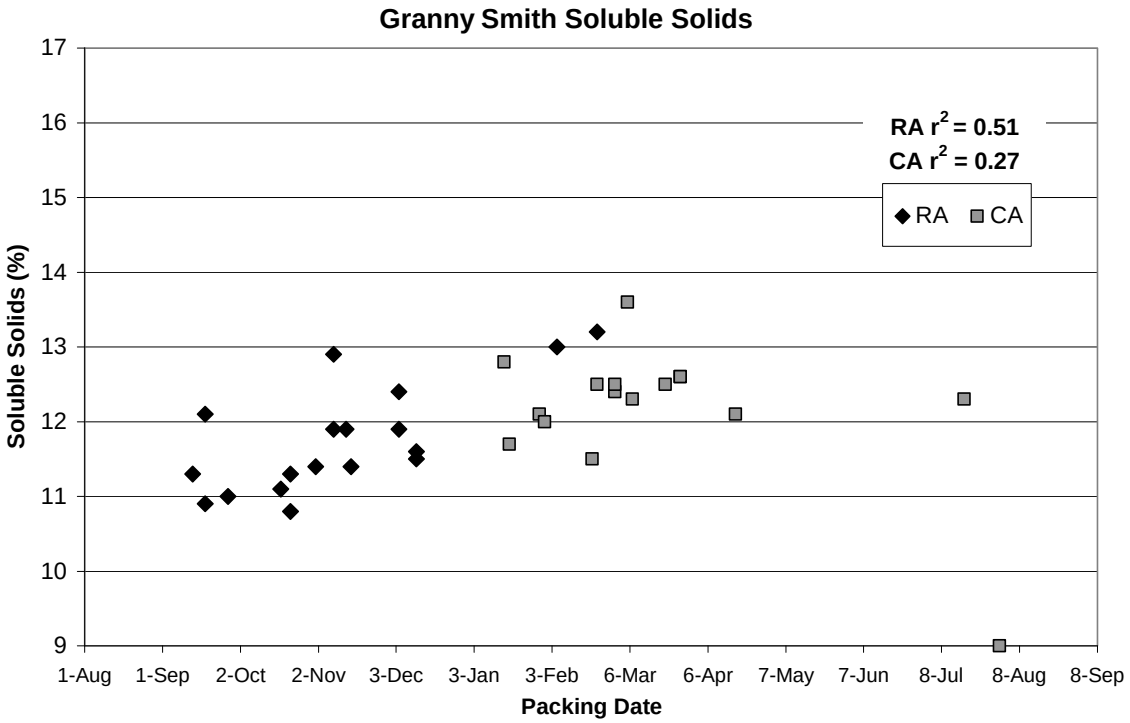


Figure 18. Granny Smith sample average acoustic and destructive firmness by week, 2001 crop.



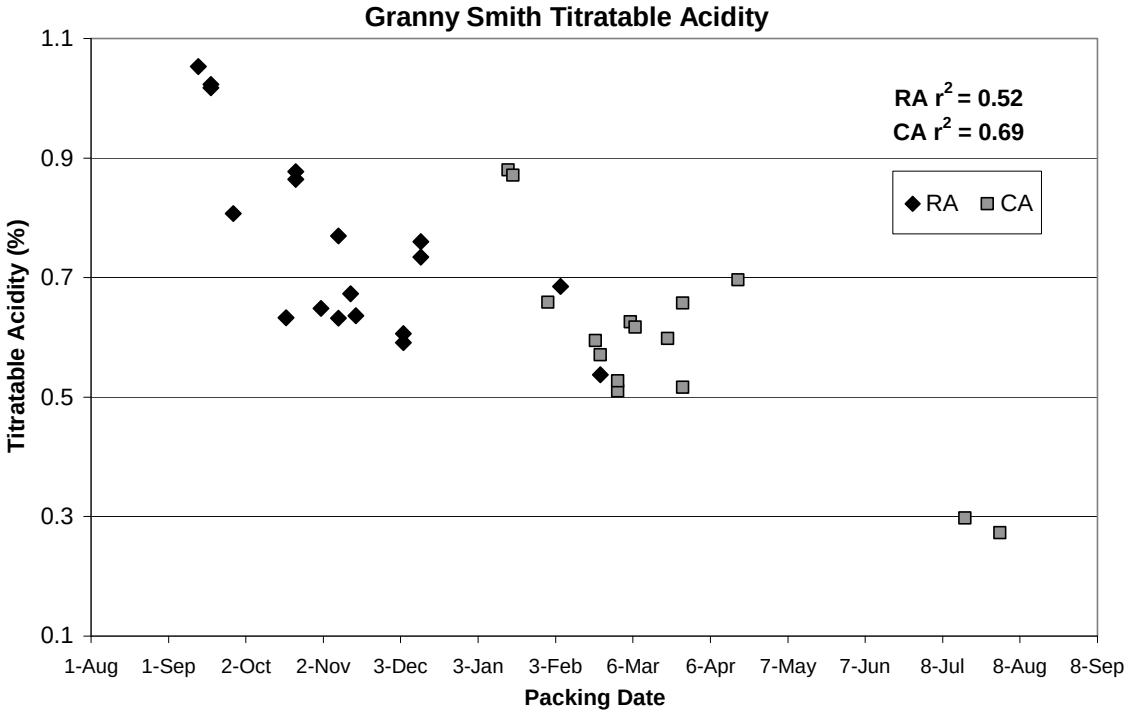


Figure 19. Granny Smith sample average SS and TA by week, 2001 crop.

2.7 JONAGOLD QUALITY—2001 CROP

A total of 369 apples (14 samples) of Jonagold were taken from the 2001 crop.

2.7.1 Individual apples

Acoustical firmness values of Jonagold apples were closely distributed, with 90% of the apples measuring between 22 and 30 FI. Destructive firmness in Jonagold was highly variable, with individual apples measuring between 7.5 and 26.0 lbf (Figure 20). RA apples were firmer than those packed from CA. Fruit from RA peaked at 15.5 lbf while those from CA peaked at 8.5 lbf, with a smaller peak around 15.5 lbf.

2.7.2 Apple samples

The date of packing was closely associated with a loss of acoustic firmness in RA, but less correlated with CA-stored fruit (Figure 21). Destructive firmness of RA-stored Jonagold showed a strong relationship with packing date. RA-stored fruit declined from above 20.0 lbf in September to 10.3 lbf at the end of December. Destructive firmness of CA-stored Jonagold was not associated with the date of packing (Figure 21). The sample averages and ranges of firmness values are presented in Table 15.

Soluble solids concentrations increased with the date of packing in samples of RA-stored Jonagold apples from a low of 11.7% in September to high values of 13.5% in October and December (Figure 22). All CA-stored Jonagold apples had at least 13.0% soluble solids. The sample average and range of SS are presented in Table 15.

Acidity was not closely associated with the date of packing in RA and CA-stored Jonagold apples (Figure 22). The sample average and range of acidity are presented in Table 15.

2.7.3 Packinghouse information

Jonagold was sampled only one or two times per packinghouse (Table 15).

Table 15. Summary of Jonagold quality attributes by packinghouse.

Packinghouse	No. of samples	Temperature (ºF)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
a	2	64	72	12.6	0.532	15.5	24.2
c	1	—	—	13.5	0.390	10.3	22.2
d	2	50	72	12.8	0.491	15.0	24.8
e	2	51	68	13.2	0.492	15.8	24.8
j	1	53	60	12.5	0.474	15.2	26.8
k	2	57	62	13.0	0.368	9.3	23.2
n	2	57	66	13.2	0.516	14.3	25.9
o	1	43	54	14.1	0.544	16.4	25.3
s	1	55	76	12.6	0.583	20.5	28.2
Average and range of all Jonagold samples.							
Average of samples		**54**	**67**	**13.0**	**0.494**	**14.5**	**24.9**
Range of samples		43 to 74	54 to 79	11.7 to 14.1	0.368 to 0.627	9.1 to 20.5	22.2 to 28.2

2.7.4 Historical perspective for Jonagold

The quality attributes of the 2000 and 2001 Jonagold crops are shown in Table 16.

Table 16. Comparison of Jonagold quality attributes in 2000 and 2001.

		2000 Crop	2001 Crop
Firmness (lbf)	average range	**10.8** (10 to 13)	**14.5** (9 to 21)
Soluble solids (%brix)	average range	**13.6** (12 to 15)	**13.0** (12 to 14)
Acidity (%)	average range	**0.39** (0.27 to 0.52)	**0.49** (0.37 to 0.63)
Number of lots		13	14

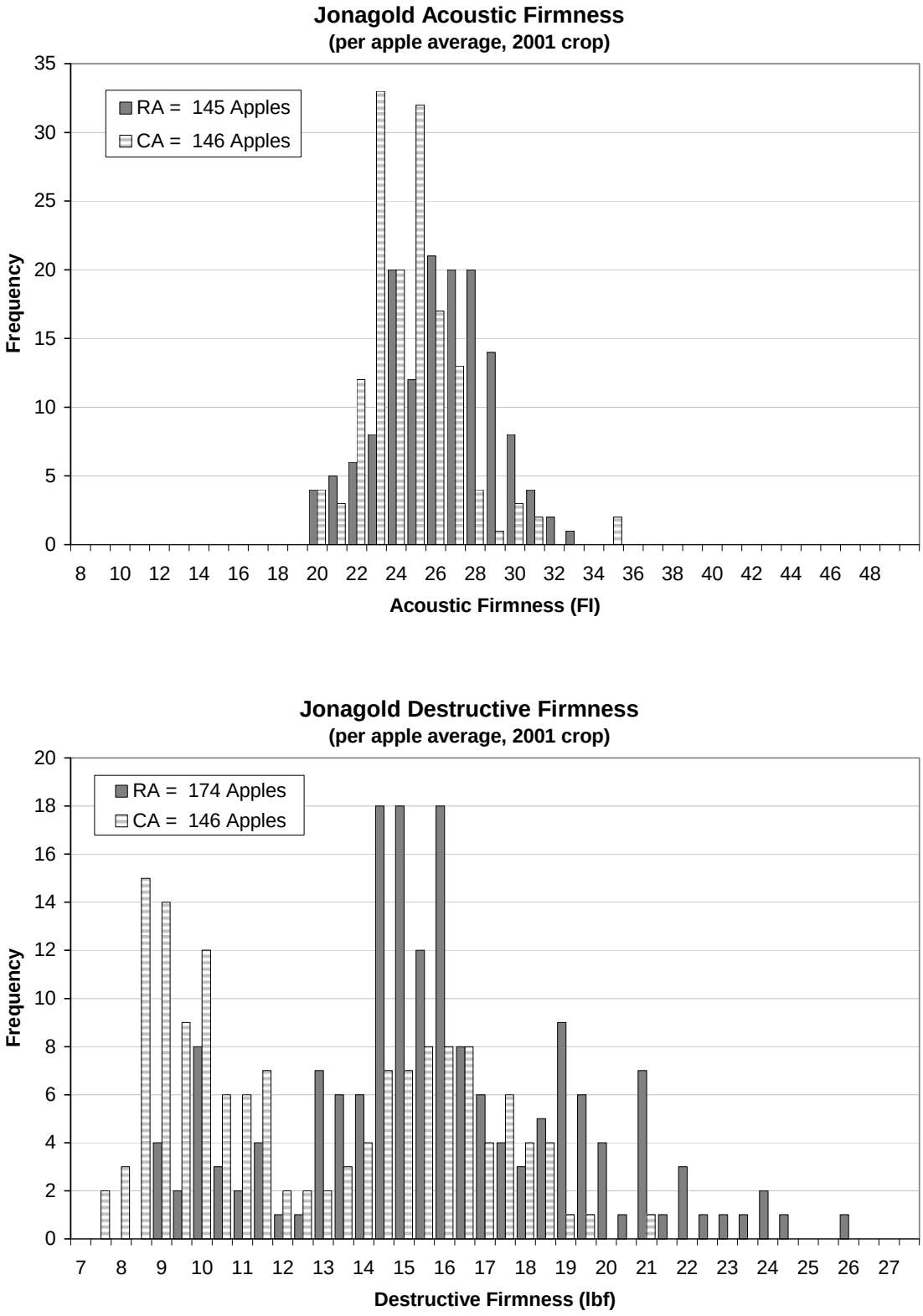


Figure 20. Jonagold acoustic and destructive firmness based on individual apples, 2001 crop.

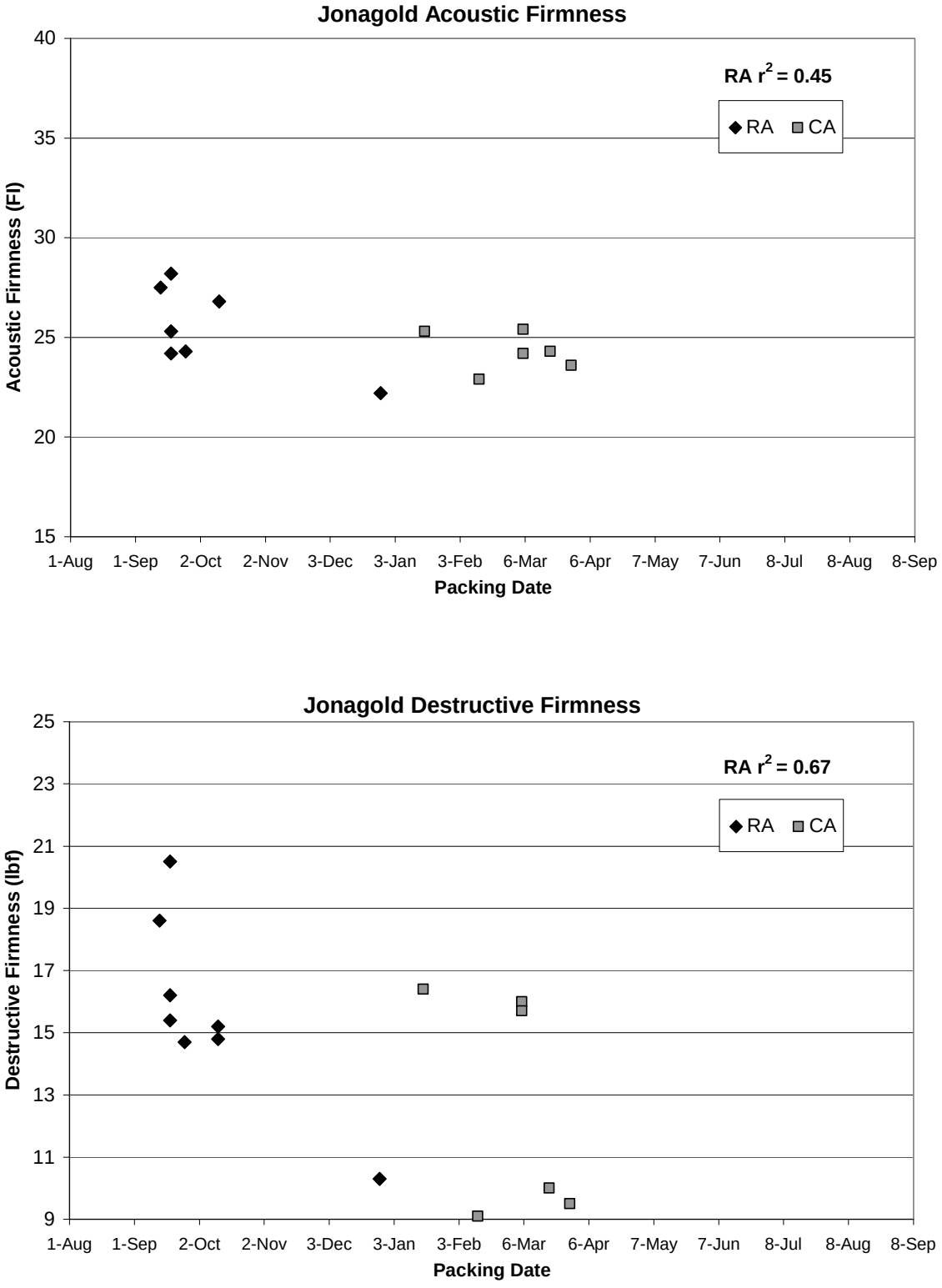
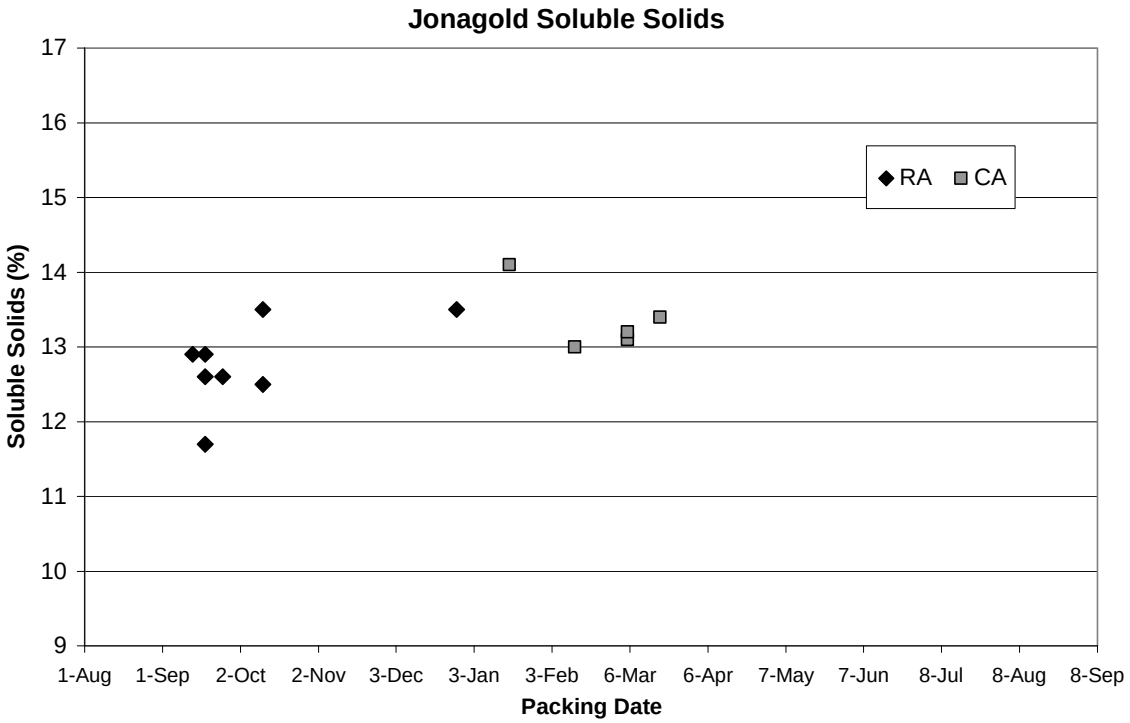


Figure 21. Jonagold sample average acoustic and destructive firmness by week, 2001 crop.



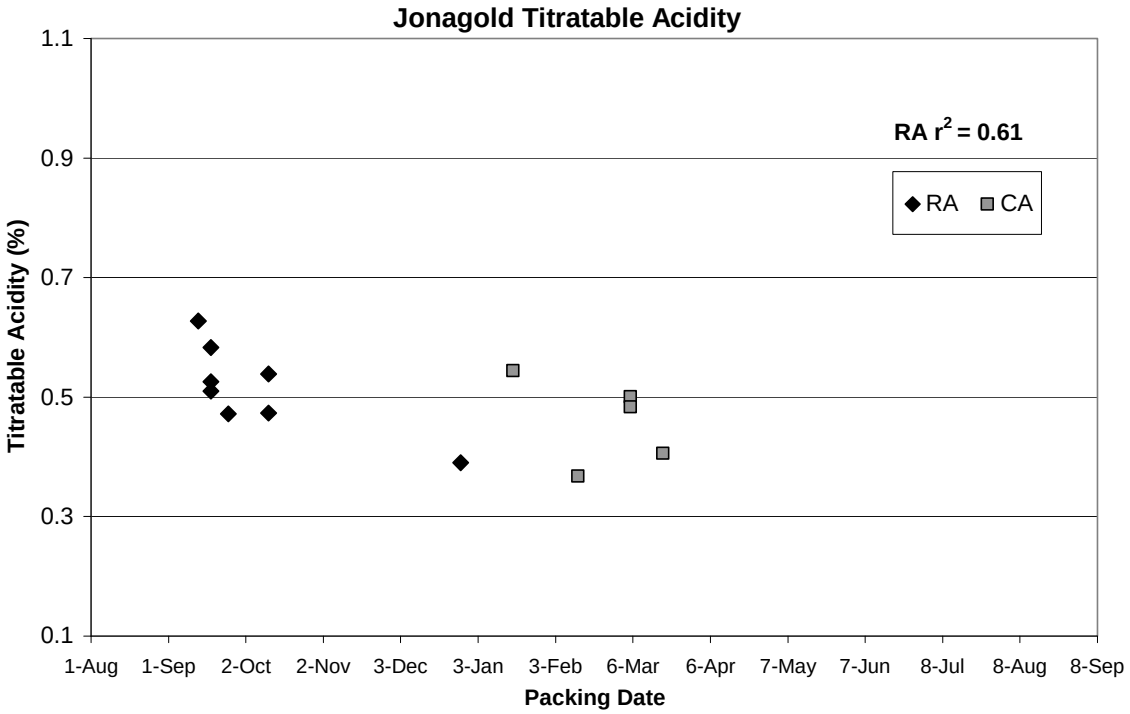


Figure 22. Jonagold sample average SS and TA by week, 2001 crop.

2.8 PINK LADY® BRAND APPLE QUALITY—2001 CROP

A total of 225 apples (9 samples) of Pink Lady® brand were taken from the 2001 crop.

2.8.1 Individual apples

Pink Lady® brand apples yielded the highest acoustic and destructive firmness values among all varieties sampled (Figure 23). Acoustical firmness measurement showed very clearly that fruit from RA was much firmer than that from CA. Fruit from CA was as firm as that from RA when measured destructively. The peak for destructive firmness was 19.5 lbf for fruit from CA storage.

2.8.2 Apple samples

There were only 9 samples of Pink Lady® brand apples so it is difficult to discern trends (Figure 24). It appeared that firmness dropped off at the end of the CA season. Soluble solids increased with later packing dates in Pink Lady® brand apples packed after RA or CA storage (Figure 25). Percent acidity increased with later packing dates in RA-stored fruit and decreased in CA-stored fruit (Figure 25). The average and range of soluble solids and acidity are presented in Table 17.

2.8.3 Packinghouse information

No single packinghouse provided more than five samples of Pink Lady® brand apples (Table 17).

Table 17. Summary of Pink Lady® brand apple quality attributes by packinghouse.

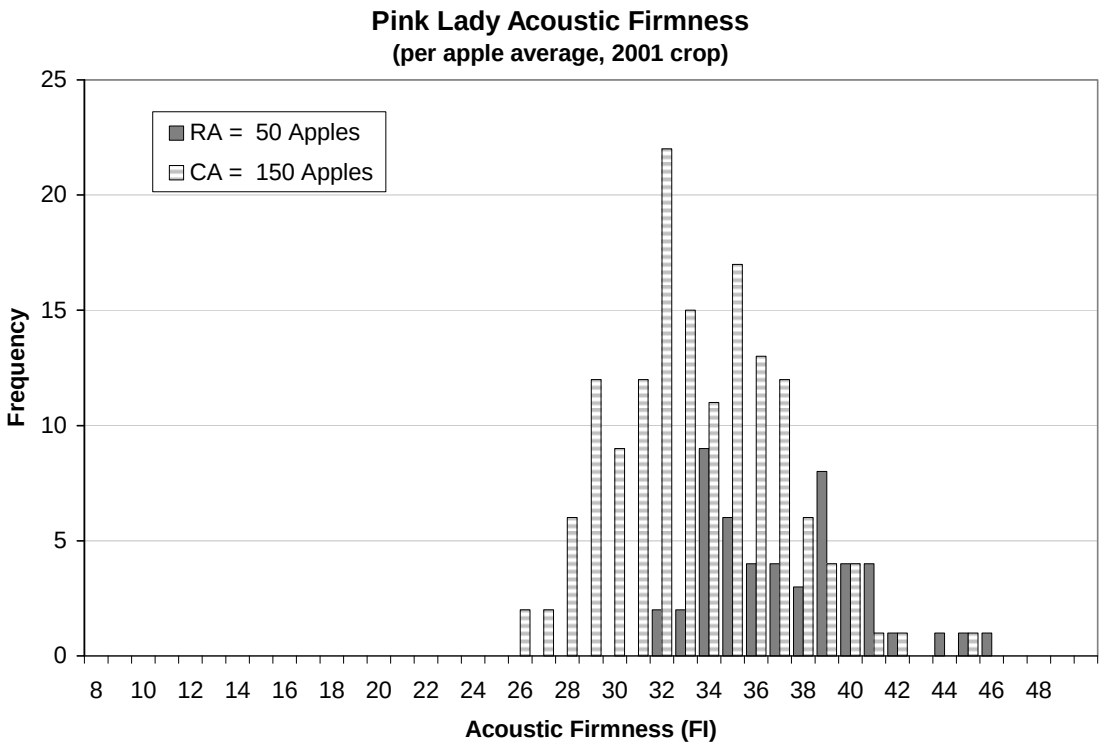
Packinghouse	No. of samples	Temperature (°F)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
k	4	60	65	14.1	0.718	19.8	31.8
o	1	72	66	13.3	0.799	19.2	34.9
r	1	47	59	14.0	0.781	19.9	38.6
u	3	51	66	14.8	0.722	17.8	30.3
Average and range of all Pink Lady® brand apple samples.							
Average of samples	**57**	**65**		**14.2**	**0.735**	**19.2**	**32.7**
Range of samples	43 to 72	59 to 77		13.3 to 15.2	0.579 to 0.892	17.5 to 20.3	27.3 to 38.6

2.8.4 Historical perspective for Pink Lady® brand apples

The quality attributes of the 2000 and 2001 Pink Lady® brand crops are shown in Table 18.

Table 18. Comparison of Pink Lady® brand apple quality attributes in 2000 and 2001.

		2000 Crop	2001 Crop
Firmness (lbf)	average	**18.3**	**19.2**
	range	(16 to 21)	(17 to 20)
Soluble solids (%)	average	**14.0**	**14.2**
	range	(14 to 15)	(13 to 15)
Acidity (%)	average	**0.69**	**0.74**
	range	(0.56 to 0.80)	(0.58 to 0.89)
Number of samples		6	9



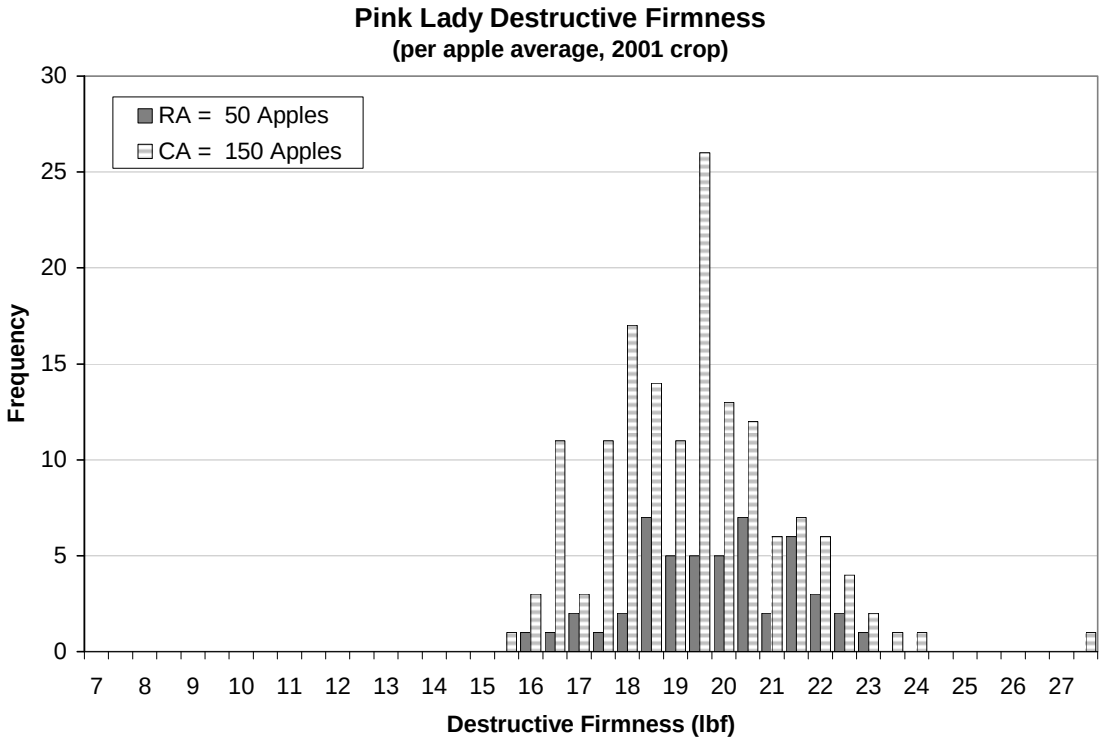


Figure 23. Pink Lady® brand acoustic and destructive firmness based on individual apples, 2001 crop.

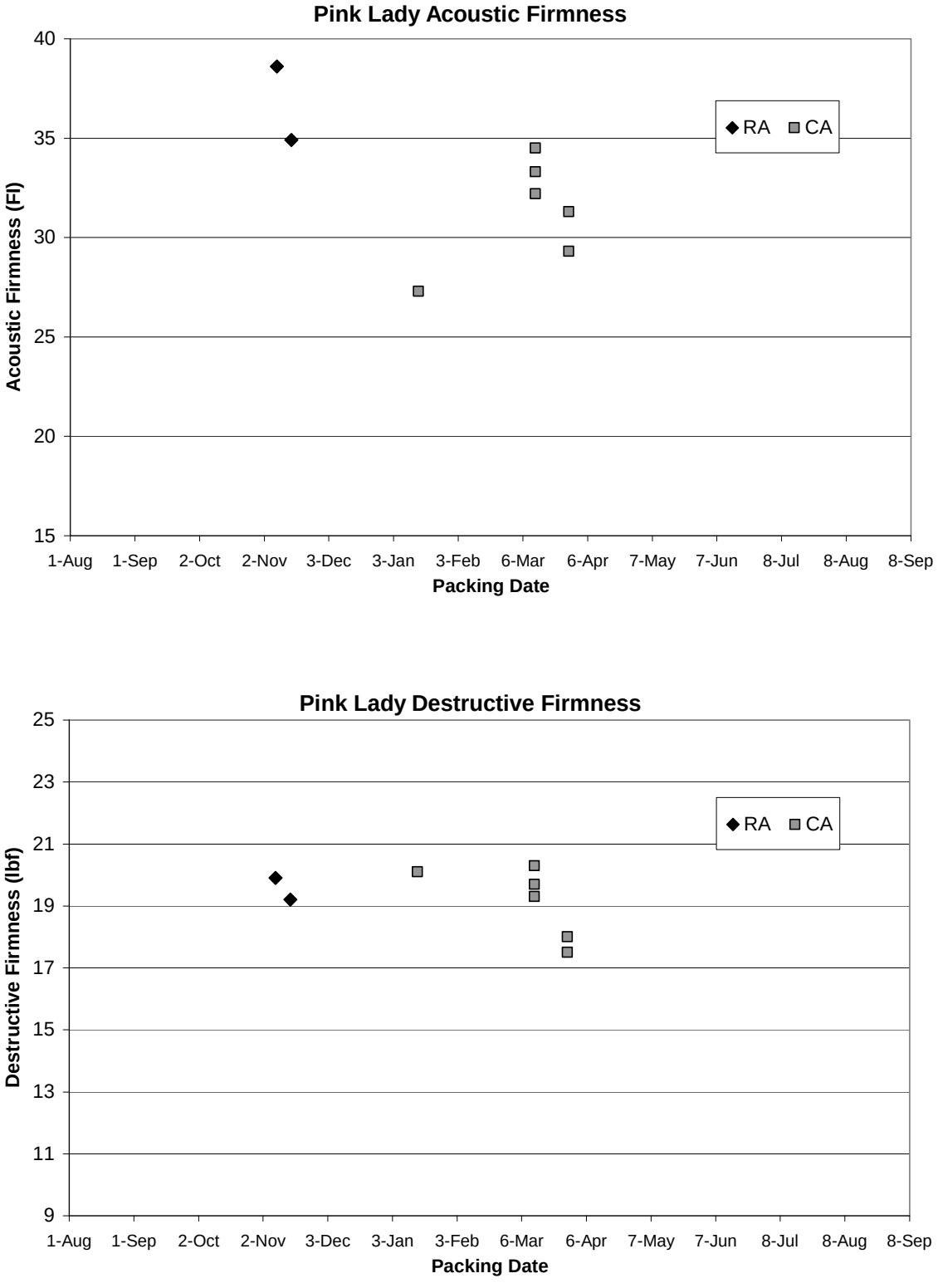


Figure 24. Pink Lady® brand sample average acoustic and destructive firmness by week, 2001 crop.

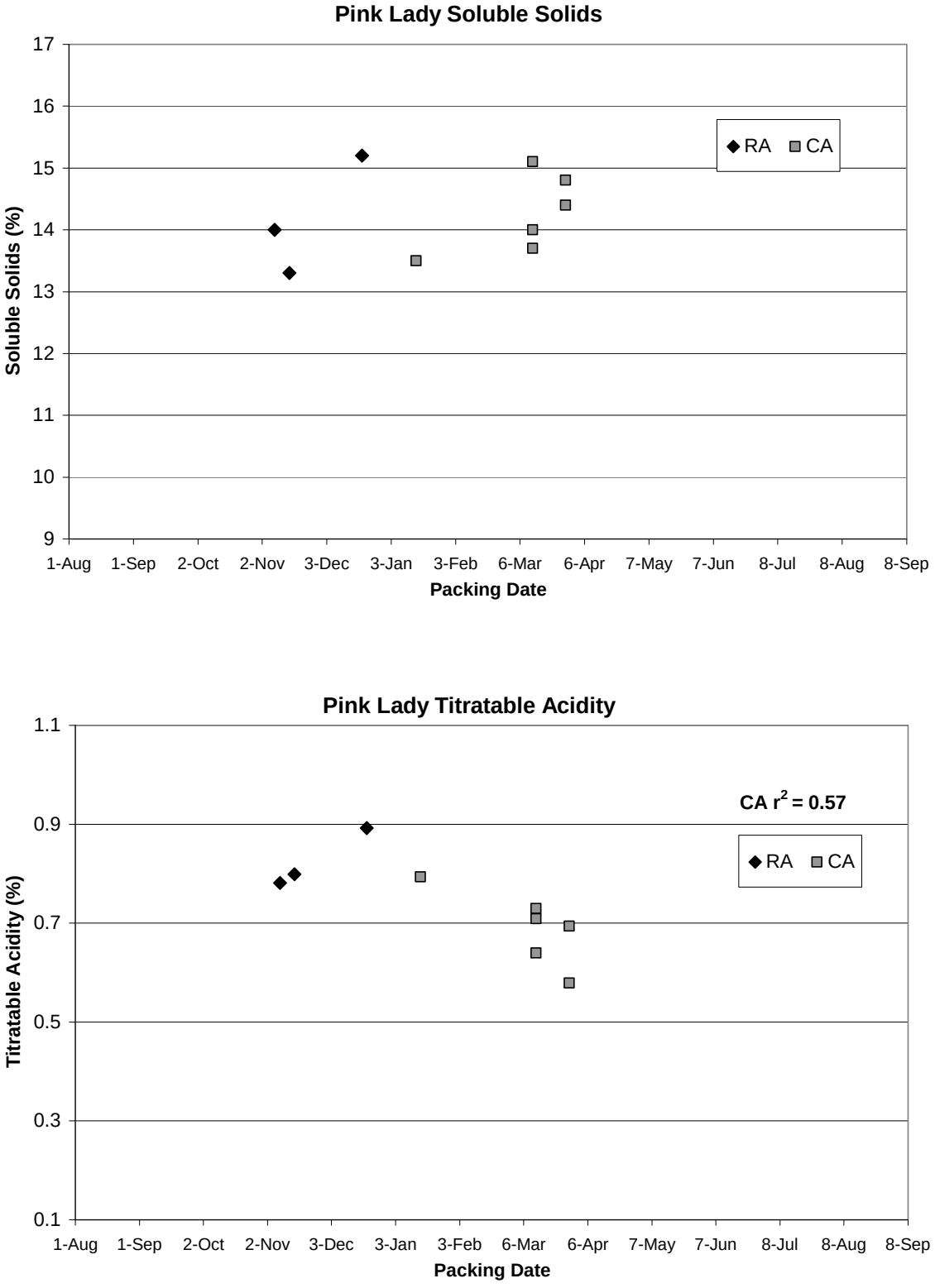


Figure 25. Pink Lady® brand sample average SS and TA by week, 2001 crop.

2.9 RED DELICIOUS QUALITY—2001 CROP

A total of 3,187 apples (138 samples) of Red Delicious were taken from the 2001 crop.

2.9.1 Individual apples

Acoustic firmness of CA-stored fruit was higher than RA, while destructive firmness for RA-stored fruit was slightly higher than CA (Figure 26). The range in destructive firmness was from 7 lbf to 24 lbf; the peak for CA fruit was 15.5 lbf and RA fruit peaked at 16 lbf.

2.9.2 Apple samples

There was a huge range in sample firmness throughout the season whether measured destructively or acoustically. Firmness of CA-stored fruit was not correlated with time of packing, although RA-stored fruit showed a decline in destructive firmness over time (Figure 27). Acoustic firmness average and range for Red Delicious are presented in Table 19.

Red Delicious soluble solids concentration was slightly correlated with time of packing in fruit stored in RA, with values in September as low as 10.0% and in November and December above 14.0 % (Figure 28). Soluble solids concentration of fruit stored in CA was not associated with an increase or decrease over time. The sample average and range of soluble solids in Red Delicious are presented in Table 19.

A decline in acidity was only slightly associated with the date of packing in Red Delicious stored in RA, with values in September as high as 0.376% and concentrations in December below 0.250% (Figure 28). Acidity out of CA storage was more closely associated with the date of packing. In CA-stored Red Delicious 39% of all samples measured below 0.200%.

2.9.3 Packinghouse information

The variability of Red Delicious quality among packinghouses was relatively small, with packinghouse averages of soluble solids ranging from 12.2% to 13.9% and acidity ranging from 0.213% to 0.284% (Table 19).

Table 19. Summary of Red Delicious quality attributes by packinghouse.

Packinghouse	No. of samples	Temperature (ºF)		Soluble Solids (%)	Titratable Acidity (%)	Destructive Firmness (lbf)	Acoustic Firmness (FI)
		Internal	External				
a	**13**	**59**	**65**	**13.1**	**0.257**	**14.7**	**26.1**
b	**6**	**59**	**71**	**13.3**	**0.255**	**15.9**	**26.0**
c	**33**	**54**	**67**	**13.5**	**0.222**	**14.9**	**26.7**
d	1	44	53	13.6	0.284	—	28.9
e	**6**	**59**	**63**	**13.4**	**0.238**	**14.8**	**27.3**
f	4	61	65	12.7	0.216	15.9	27.3
g	3	50	62	13.3	0.210	14.9	25.6
j	**5**	**57**	**69**	**13.6**	**0.258**	**14.9**	**26.3**
k	3	69	77	13.9	0.208	14.5	28.2
l	**5**	**58**	**78**	**13.9**	**0.213**	**13.6**	**27.6**
m	**13**	**53**	**72**	**12.9**	**0.240**	**14.3**	**25.7**
n	**6**	**50**	**64**	**13.0**	**0.273**	**14.4**	**25.2**
o	**6**	**62**	**74**	**12.9**	**0.230**	**15.4**	**25.5**
q	**10**	**50**	**69**	**12.2**	**0.257**	**15.9**	**25.9**
r	1	58	76	12.7	0.237	17.4	25.8
s	**5**	**57**	**68**	**12.3**	**0.284**	**16.1**	**28.8**
u	**5**	**48**	**70**	**13.3**	**0.251**	**14.6**	**26.0**
v	**13**	**45**	**59**	**12.8**	**0.213**	**13.8**	**22.5**
Average and range of all Red Delicious samples.							
Average of samples	**55**	**68**		**13.1**	**0.237**	**14.9**	**26.1**
Range of samples	39 to 90	44 to 83		10.0 to 15.3	0.119 to 0.376	10.3 to 18.4	21.3 to 32.7

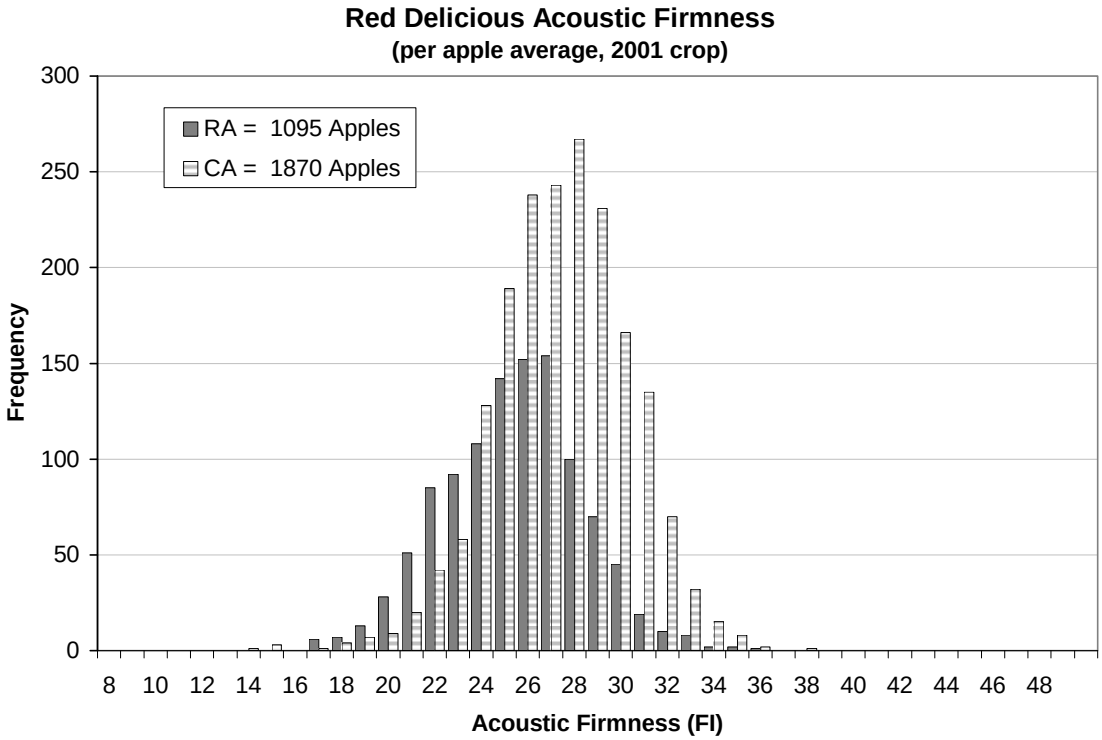
Numbers in **bold** type indicate packinghouse averages are comprised of five or more lots of fruit.

2.9.4 Historical perspective for Red Delicious

The sampling work done with the previous crops shows that the firmness and acidity of Red Delicious at time of packing has changed only slightly over the years (Table 20).

Table 20. Comparison of Red Delicious quality attributes over the past 12 years.

		1990 Crop	1991 Crop	1992 Crop	2000 Crop	2001 Crop
Firmness (lbf)	average range	**15.4** (12 to 19)	**15.8** (12 to 20)	**14.6** (12 to 19)	**15.2** (11 to 18)	**14.9** (10 to 18)
Soluble solids (%brix)	average range	**13.2** (11 to 16)	**13.3** (11 to 15)	**13.7** (12 to 15)	**13.6** (10 to 16)	**13.1** (10 to 15)
Acidity (%)	average range	**0.21** (0.14 to 0.44)	**0.25** (0.18 to 0.41)	**0.32** (0.20 to 0.50)	**0.22** (0.11 to 0.33)	**0.24** (0.12 to 0.38)
Number of samples		338	265	240	170	138



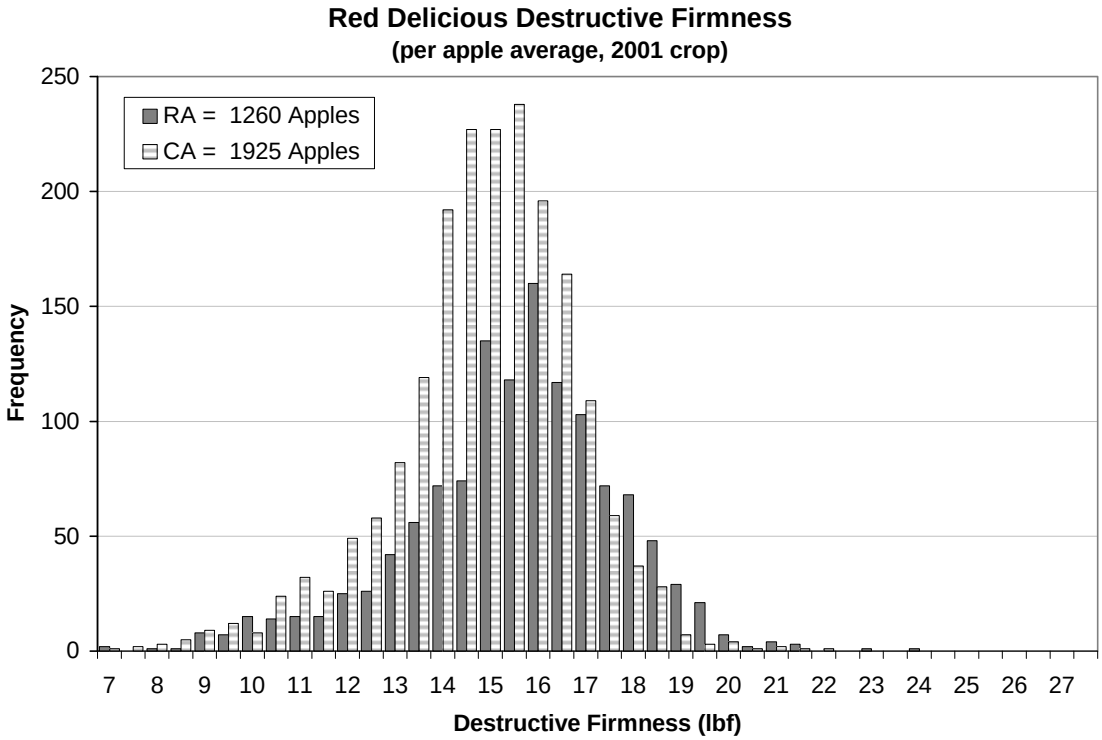


Figure 26. Red Delicious acoustic and destructive firmness based on individual apples, 2001 crop.

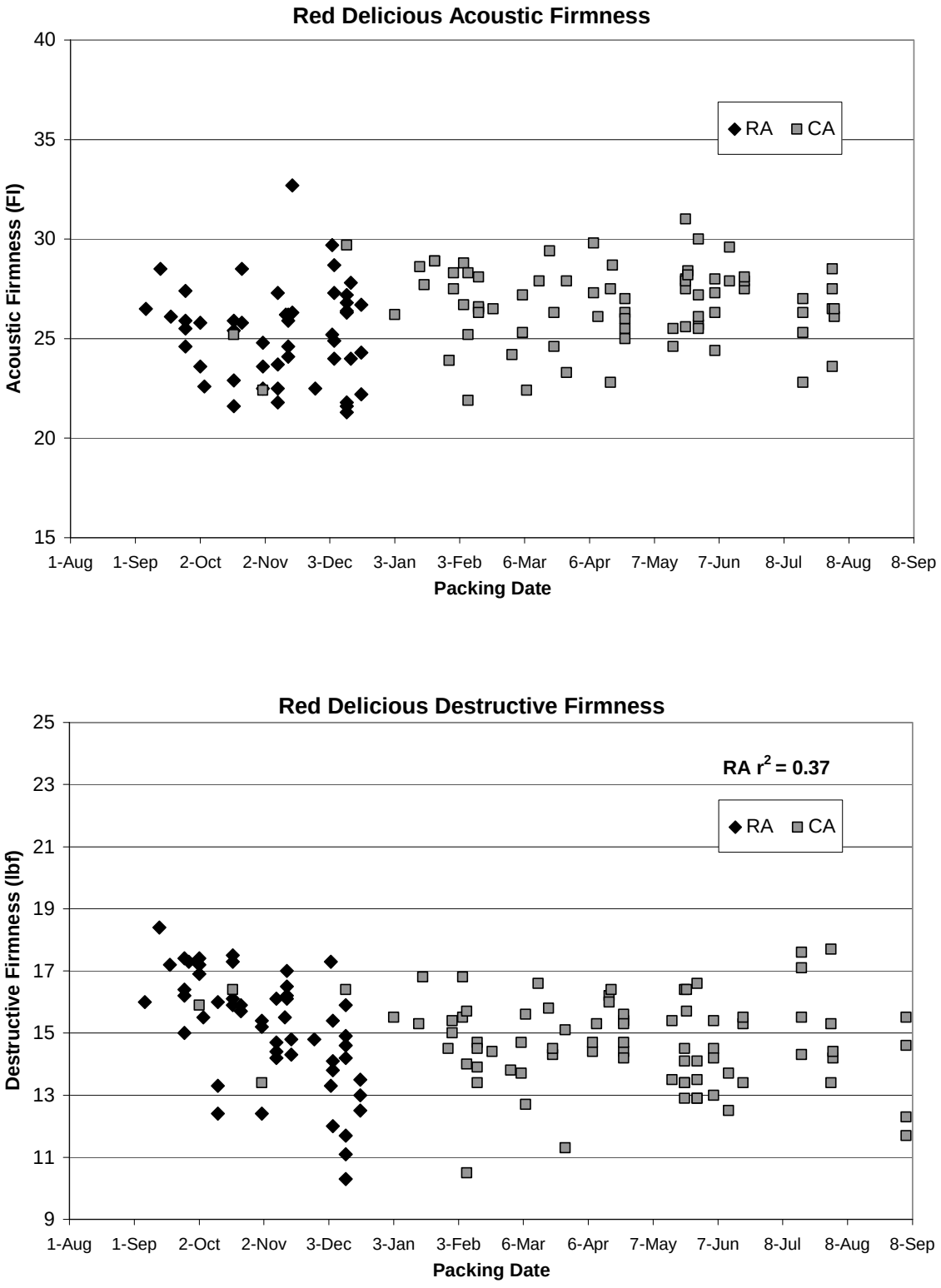


Figure 27. Red Delicious sample average acoustic and destructive firmness by week, 2001 crop.

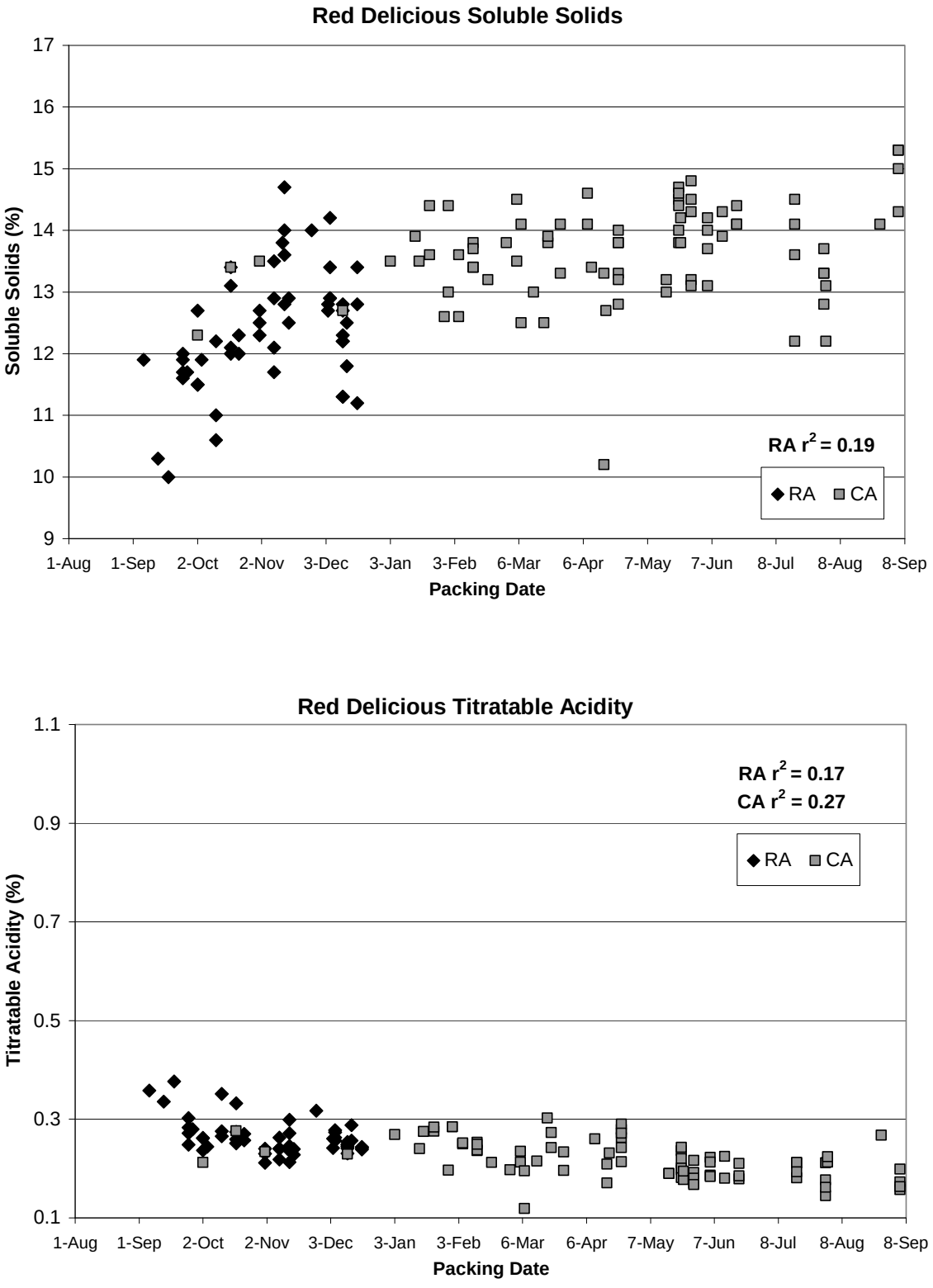


Figure 28. Red Delicious sample average SS and TA by week, 2001 crop.

3. CHANGES IN QUALITY

The scatter plots for fruit quality show that there were two distinct but overlapping periods in the packing season. The first began during harvest and RA storage, when fruit were firm, low in SS and high in acidity. The second period started when CA-stored apples were released, and was characterized by an increase in firmness and acidity, followed by a steady decline in both. Although this pattern holds true for most apple varieties sampled, quality characteristics in each variety fared differently in relation to time after harvest and type of storage. Three varieties, Gala, Golden Delicious and Red Delicious had distinctly contrasting quality patterns in relation to packing date.

3.1 GALA QUALITY

Gala quality characteristics were not strongly associated with the date of packing in RA and CA-stored fruit. Although there was a loss in firmness in RA-stored fruit it was less than in either Red or Golden Delicious (Figure 12). There was also less variability in firmness levels at each packing date. For example, in December, sample averages for Gala destructive firmness were within 2 lbf.

There were only slight differences in SS and no seasonal pattern. Acidity averaged between 0.35% and 0.38% every month during the packing season (Figure 13).

3.2 GOLDEN DELICIOUS QUALITY

Golden Delicious apples showed the most dramatic loss in destructive firmness of any variety. During the RA period, sample average destructive firmness dropped from above 24 lbf to 10 lbf (Figure 15). Regular storage Golden Delicious packed in December averaged 10.4 lbf, which is below the range of acceptability for fruit shipped from Washington. Firmness of fruit held in CA and packed in December and January was higher than the firmness of RA fruit packed in November and December.

Acoustic firmness was highest in August, with samples as high as 32.4 FI, and dropped below 18 FI in November and December. In January, acoustical firmness of fruit from CA storage was only slightly higher than RA-stored fruit.

Golden Delicious soluble solids showed tremendous variability that was not related to time of packing or storage (Figure 16).

Acidity was highest in September but quickly leveled out for the remainder of the packing season. There was no rise in acidity in CA stored fruit.

3.3 RED DELICIOUS QUALITY

Red Delicious firmness declined from an average of 17.0 lbf in September to 13.6 lbf in December when measured destructively. This decline was less severe than in Golden Delicious (Figure 26). In contrast to Goldens, there was a great deal of variability in the sample destructive firmness at every packing date.

The acoustic firmness values of Red Delicious also showed a tremendous range at any packing date.

Soluble solids in RA Red Delicious were higher in each successive month until November, peaking at 13.1%, indicating a probability that fruit were harvested too early, packed and sent to

market with under-developed flavor. Average SS peaked in November and generally remained at that level throughout the CA packing season (Figure 28).

Acidity declined in Red Delicious packed from RA storage, from 0.32% in September to 0.25% in November where it remained for the rest of the season. This is also a testament to the immaturity of fruit packed early in the season.

3.4 COMPARING THE PATTERNS OF CHANGE OF GALA, GOLDEN DELICIOUS AND RED DELICIOUS

Quality of Gala, Golden Delicious and Red Delicious changed at different rates. Golden Delicious firmness declined rapidly during the RA packing season. Red Delicious quality also declined, but not as consistently or drastically as did Golden Delicious. There was a great deal of variability among samples of Red Delicious. Gala apples firmness declined slightly after the first month of packing, but not to the degree that Red and Golden Delicious did. Gala firmness was higher than that of Red Delicious.

In December, Red Delicious apples stored in RA were barely above the minimum quality standards, with 20% of samples averaging below 12 lbf. Golden Delicious stored in RA and packed in December were soft and lacked the acidity of CA stored fruit packed during the same period. Gala, previously thought to be a delicate apple that did not hold up well in storage, proved to be less susceptible to decline in quality associated with lengthy RA storage, than Red and Golden Delicious.

The destructive firmness of samples from RA storage declined as the number of days after harvest increased. No Gala samples from RA storage were below 12 lbf (Figure 29). In contrast, all samples of Golden Delicious held in RA storage for 60 or more days were less than 11 lbf (Figure 30) and all samples of Red Delicious held in RA storage for 60 or more days were below 12 lbf (Figure 31).

This rapid decline in quality in the last month of RA storage suggests the need for some changes in the handling of Red and Golden Delicious. Shortening the certification date for CA fruit to 45 days may help supply better quality Red and Golden Delicious apples to consumers.

Figure 29. Firmness of Gala samples 0 to 140 days after harvest, 2001 crop.

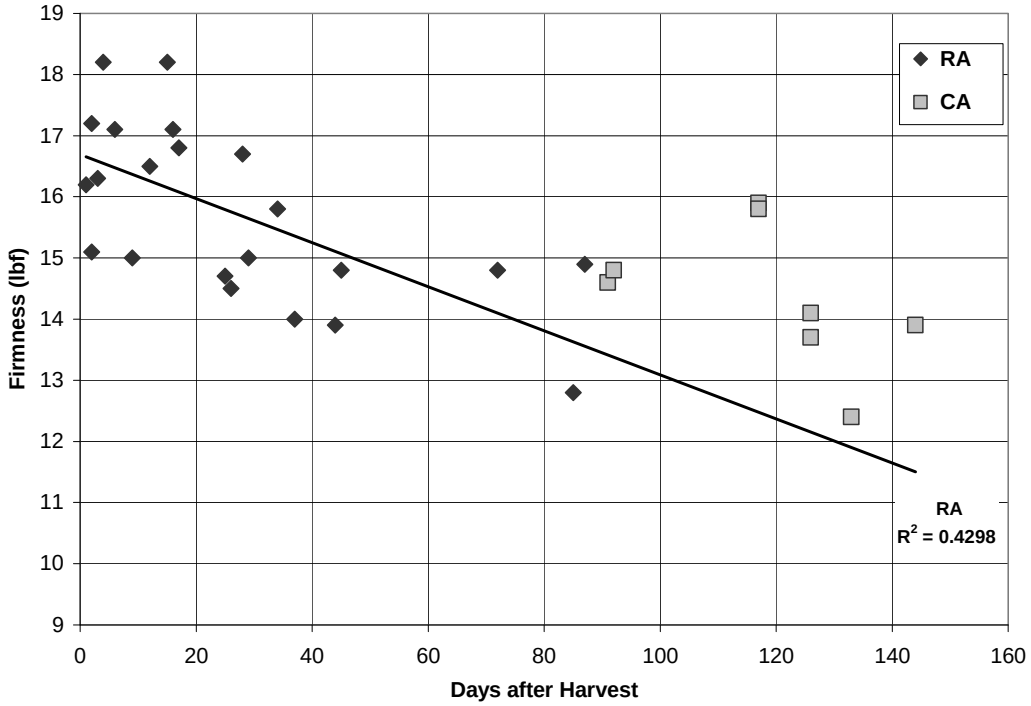


Figure 30. Firmness of Golden Delicious samples 0 to 140 days after harvest, 2001 crop.

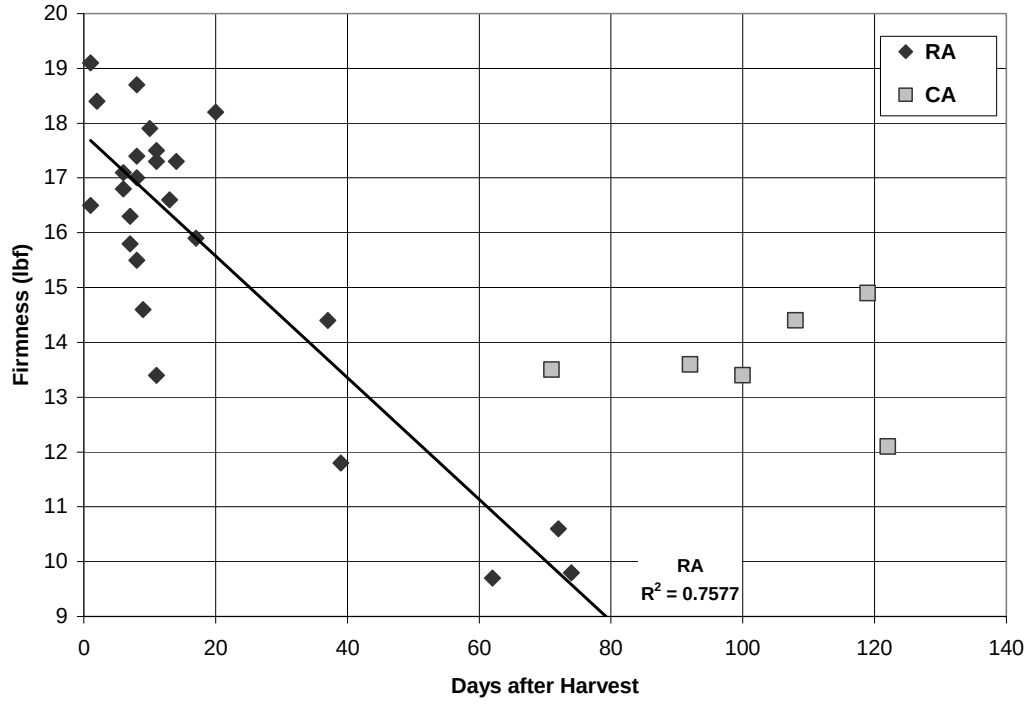
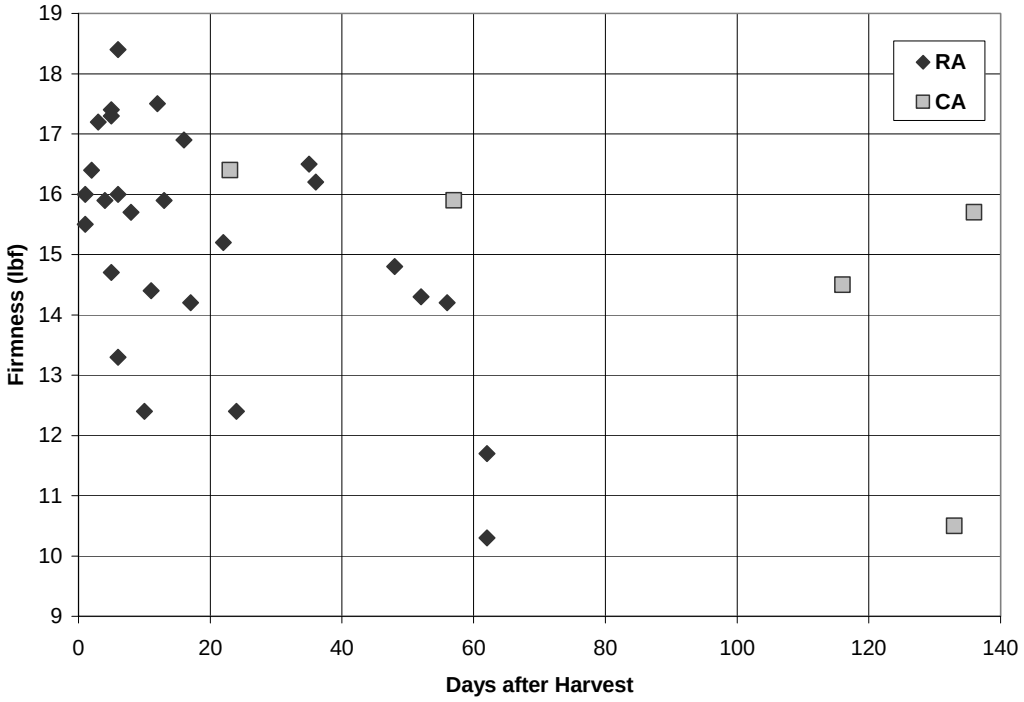


Figure 31. Firmness of Red Delicious samples 0 to 140 days after harvest, 2001 crop.



4. COMPARISON OF 2000 AND 2001 CROPS

Sampling of the 2000 crop began in December of 2000, whereas the first samples of the 2001 crop were taken in August of 2001. In the 2000 season RA-stored fruit was largely gone when sampling began. As a result, a year-long comparison of the two seasons is not valid. Comparisons in this section include only apples sampled from December through the end of the season in both years.

In general, apples packed from the 2001 crop were firmer, higher in SS and higher TA than those packed from the 2000 harvest. Not all varieties were significantly different in all quality parameters.

- Braeburn apples were higher in TA in 2001 than in 2000, while firmness and SS were the same both years. Note that there were many more Braeburn apples sampled from the 2001 crop than the previous season.
- Cameo apples were also about the same each year with only the acoustical firmness values higher in 2001.
- Golden Delicious apples sampled from the 2001 crop were firmer (destructively and acoustically) than those from the previous season. Neither SS nor acidity were different.
- Jonagold and Pink Lady® brand apple quality did not differ between years. Again there were many more of these apples sampled in 2001.
- Fuji apples packed from the 2001 crop were clearly superior to those packed in 2000 in all quality characteristics.
- Granny Smith apples from the 2001 crop were firmer and higher in SS but not in acidity than those packed from the 2000 harvest.
- Gala apple quality parameters were consistent each season and similar in 2000 and 2001. The acidity was the only quality parameter that differed between years, with fruit from the 2001 harvest having higher acidity values.
- Red Delicious apples were the same both years except for a slightly higher level of SS in fruit from the 2001 harvest.

5. CONCLUSIONS

1. Fruit quality varied from year to year. Quality of most varieties was higher in 2001 than in 2000.
2. Quality varied by storage regime. Fruit packed immediately after harvest was the firmest and highest in acidity. As the packing season progressed, fruit sampled from RA storage declined in firmness and acidity. When CA fruit was packed firmness increased then leveled off.
3. Golden Delicious apples lost firmness rapidly in RA storage. CA stored fruit were firmer. Thus it would be helpful to have more fruit placed in CA by reducing the time to certification to 45 days. There was a great deal of variability in SS levels throughout the season. This variety may benefit from a SS standard.
4. Red Delicious apples were highly variable in firmness throughout the year. It was possible to obtain firm apples or very soft apples throughout the year. The firmness standard should be raised or the minimum length of time in CA should be shortened from 60 to 45 days to reduce variability in sample to sample quality.
5. Gala apples were of consistent firmness, SS and acidity throughout the sampling season.
6. Braeburn, Granny Smith and Fuji apples lost firmness throughout the season but the levels remained high. Granny Smith apple lost a tremendous amount of acidity throughout the season, but levels remained high until the middle of the summer.
7. Fuji apples lost over half their acidity throughout the season, which may lead a reduction in consumer satisfaction.
8. Jonagold apples were of variable firmness throughout the season and by the end of the RA season and during the CA season they were very soft.
9. Measurement of firmness by the destructive method and acoustic method do not give comparable results, although they are correlated with one another.
10. Temperature management continues to need improvement as both internal and external temperatures are too high to conserve quality, especially when boxes do not have vent spaces and are palletized prior to cooling.