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# UK APPLE AND PEAR MATURITY PROGRAMME 1997/98

## INTRODUCTION

English Apples and Pears Ltd formed the Quality Fruit Group in Spring 1994 to provide the UK Fruit Industry with detailed technical information on growing, harvesting and storage methods designed to ensure optimum texture and flavour in Cox apples and Conference pears at point of sale. The main work of the group was to set up a UK fruit maturity programme to give growers clear guidelines on optimum harvest dates for long term storage each season and to provide data to improve our knowledge on the effects fruit maturity at harvest has on fruit quality after 4 and 7 months storage in ultra low oxygen.

The rate of deterioration of apples and pears in storage is influenced by their maturity at harvest. Research work at East Malling has shown a close relationship between the respiratory activity of Cox apples at harvest and the loss of eating quality in store and the susceptibility of fruit to low temperature injury, senescent breakdown and core flush. The harvest data which was associated with the longest storage life and lowest incidence of storage disorders occurred just prior to the onset of the respiration climacteric (Figure 1).

The onset of ripening is associated with the conversion of starch into sugar. Work carried out using taste panellists has consistently shown that, if fruit is picked before the starch has started to clear, the fruit coming out of store lacks flavour. As starch clears then the flavour potential increases, although the storage potential will tend to decrease. Thus a compromise has to be made between flavour and storage potential. In general, growers who have an average standard of CA storage facilities should start to pick their Cox apples when the starch pattern has fallen to 80% of the maximum coverage, and aim to complete picking for long-term storage by the time the starch coverage has fallen to 70%.

In a study funded by the APRC the harvest and storage data from the first two years of the QFG maturity programme were used to produce a mathematical model for growers to predict fruit quality after 4 and 7 months storage in 1.2% oxygen at harvest.

Initially all the pre-harvest measurements of background colour, soluble solids, acidity, starch patterns and fruit firmness were included. The most significant of these attributes was fruit firmness including the other factors only marginally improved the accuracy of the model. Thus if fruit was picked at the correct firmness, it would have the right background colour, acidity and soluble solids after 4 or 7 months storage.

A simple model was produced that relates harvest firmness to ex-store firmness. (Table 1).

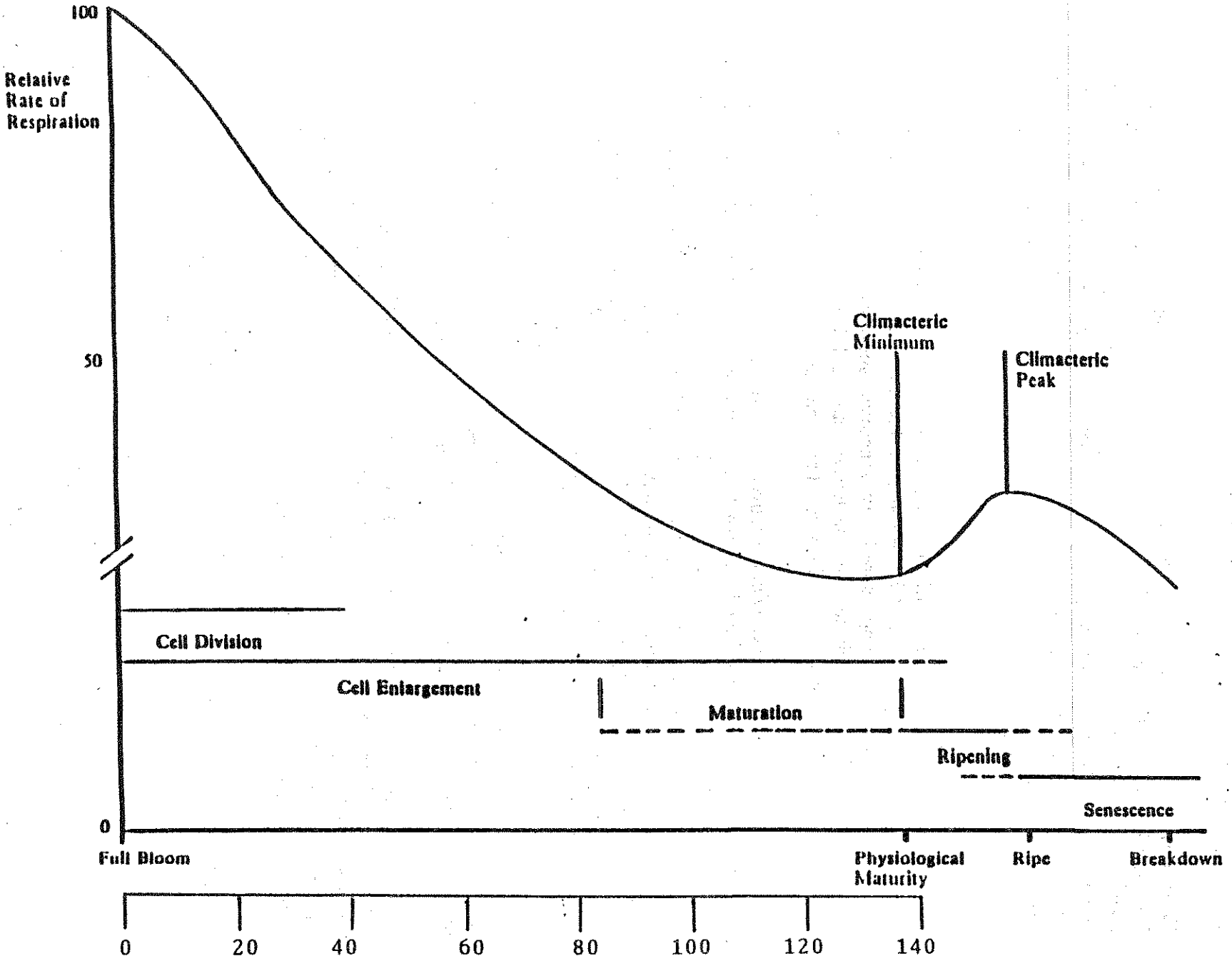

100
Relative Rate of Respiration
50
0
Climacteric Minimum
Climacteric Peak
Cell Division
Cell Enlargement
Maturation
Ripening
Senescence
Full Bloom
Physiological Maturity
Ripe
Breakdown
0
20
40
60
80
100
120
140
DAYS

Figure 1

**Table 1. Relationship between harvest and ex-store fruit firmness**

| Ex-store Firmness | Harvest Firmness (Kg) | |
|---|---|---|
| | January | April |
| 6.5 | 9.4 | 10.2 |
| 6.0 | 8.2 | 8.7 |

By using the model and carrying out maturity assessments in individual orchards, growers could calculate the optimum harvest date for each orchard depending on the proposed storage period.

A number of other fruit qualities have to be considered when deciding when to pick commercially for long term storage. Cox fruits should have a light green background colour, at least 15% red colour, a fruit firmness of at least 8.6kg (11mm probe) and be 65-70mm in diameter. If harvest has to be delayed to improve fruit size or red colour then the storage period will have to be adjusted.

It has long been recognised that the best eating quality on Conference pears is associated with low starch content and high soluble solids when harvested.

The recommended storage temperature for the variety is between -0.5°C and -1.0°C, thus it is important that fruit has an average soluble solids above 12% at harvest to avoid freezing in store.

The starch iodine test has been used for many years to indicate the finish date for harvesting pears for long term storage ie when the average starch pattern has decreased to one-third of the maximum average. Work carried out by ADAS and HRI East Malling indicated a more reliable guide to the cut off date for harvest could be obtained by including fruit firmness, soluble solids and starch pattern in a Streif index. Results from the first three years of the QFG maturity programme confirmed that the optimum harvest date for the long term storage of Conference pears coincided with a Streif index of 0.7.

Initially the project involved taking samples of Cox apples from 32 orchards and Conference pears from 12 orchards twice a week and measuring fruit size, colour, firmness, sugar content, acidity and starch pattern. On four separate occasions samples were taken and stored for 16 and 28 weeks after which time fruit was assessed for background colour, firmness and internal condition. The severe frost in April and May 1997 meant the UK crop for both Cox and Conference was very much reduced and the number of sites was reduced to 12 Cox and 5 Conference, for both that and the 1998 season.

The UK Apple and Pear Maturity Programme was set up with the following objectives.

1. To give clear guidance to the industry on the optimum picking periods for the major varieties.

2. To alert the industry to any quality problems in good time so that remedial action could be taken.

3. To assess the difference in maturity between the major growing areas of the country.

4. To provide a data base of pre and post harvest maturity attributes from a range of orchards over a number of seasons to improve the prediction in orchard to orchard and season to season variation on fruit maturity and storage potential.

The following report summarises the 1998/99 programme.

## MATERIALS

The ten Cox orchards located in Kent, Essex, Suffolk and Norfolk used last season were sampled in 1998. Unfortunately one orchard had suffered severe hail damage in mid August and although sampled pre-harvest no storage samples were taken. A similar aged orchard on the same rootstock a short distance away was therefore included to make the number of orchards stored up to 10. In a separate study staff from FAST carried out measurements in 2 orchards in the West Midlands and made the data available to the group.

The five Conference orchards used last season were sampled again in 1998 and storage samples were taken on four occasions.

At each site, 20 trees were labelled along a single row adjacent to the rows used in the previous three years. This was done to eliminate any influence on cropping and fruit quality of the previous three years sampling and the effect of fruit being left on the tree after the optimum date. Trees were selected to have at least 100 fruit. Where this was not possible the number of trees labelled was doubled to 40 to provide sufficient fruit for the study and 4 x 30lbs of fruit for storage samples.

The trees were sampled on the 20/8, 24/8, 27/8, 1/9, 3/9, 7/9, 14/9, 21/9 and 28/9. The start date was anticipated as being three weeks before the optimum harvest window and the final sample a week after.

On each sampling occasion, two fruits were taken at random from within the cropping canopy making a total of 40 fruits per sample. In the case of trees carrying less than 100 fruits one apple was taken from each of 40 trees making a similar sample size. Fruits were taken in such a way as to represent all positional aspects of the tree.

On four occasions at 7 days intervals starting on 7 September, a further 30lbs of fruit was harvested from 5 (10) pre-labelled trees in the row by picking 6lb (3lb) of fruit from a complete segment of the tree. Once harvested, these trees were discounted from the study.

## METHODS

### i. Maturity Assessments

#### Size

On arrival at Brogdale (within 4 hours of harvest) the 40 fruits in each sample were examined visually and the five largest and five smallest fruits were discarded. The remaining 30 apples and pears were weighed and the average fruit diameter calculated by measuring the total length of the 30 fruits arranged in a line, and dividing the resulting measurement in mm by 30. After being weighed and measured 10 pear fruits were taken at random and discarded to leave a total sample size of 20 fruits.

#### Acidity

Ten apples were taken at random from the 30 fruits and used to measure acidity. Opposite eights were cut and the stalk and pips removed. The fruit was homogenised in a blender and 10mls of the juice removed and titrated against N $Na(OH)_2$ to an end point of pH 7. The results were expressed as mg of malic acid per 100 gram of fruit.

The remaining 20 apples and pears were arranged on a fibre cell liner and the first 10 fruits numbered 1-10 using a fibre pen. These fruits were assessed individually for colour, firmness, soluble solids and starch patterns, and the record kept separately to allow an index to be calculated for each apple.

#### Background Colour

Overall background colour was assessed visually for each of the ten Cox fruits using the Fruition colour card which divides background colour into green (1), light green (2), light yellow (3) and yellow (4).

#### Fruit Firmness

A thin slice of peel was removed from opposite sides of the 10 numbered fruits and the firmness measured using an Effigi penetrometer mounted in a drill stand and fitted with an 11mm plunger for apples and an 8mm probe for pears. The results were expressed as kg force.

#### Soluble Solids

A sample of juice was taken from each numbered apple or pear using a plastic probe, and placed in a hand held refractometer with a scale of 0-20%. The % soluble solids present in each fruit was recorded. At the start and end of each days reading the instrument was calibrated using a set of standard sugar solution (8, 10, 12 and 14%w/v). The individual fruit readings were adjusted using this calibration curve.

**Starch**

Each of the 20 fruits were then cut transversely through the equator and the cut surface dipped in a solution of 1% iodine and 4% potassium iodide. After 10 minutes the percentage area stained black was measured using a transparent sheet printed with a series of gauges ranging in diameter from 45-70mm, each gauge had printed on it a series of concentric rings representing 90%-50% starch pattern.

ii. **C.A. Storage (Cox)**

On 7, 14, 21 and 28 September a 30lb box of fruit was harvested from 5 pre-labelled Cox trees as already described. Using this fruit four x 20 fruit netted storage samples were made up. The samples were transported and placed in a commercial controlled atmosphere store at <1%$CO_2$, 1.2%$O_2$ 3.5°C. On each occasion the fruit was initially placed in a coldstore for 7 days to ensure it was thoroughly cooled. The four nets from each site were then placed in two empty bulk bins which had previously been left under the hatch of a 100 ton commercial store. Two nets from each site and each pick were placed in each bin to facilitate removal of samples in January and March.

On 14 January, two nets from each orchard and each harvest date were removed to assess fruit quality. One twenty fruit sample was used to carry out initial measurement of background colour, soluble solids and fruit firmness as previously described. The fruit was then assessed externally for any sign of fungal infection before being cut and the internal condition of the fruit recorded.

The second netted samples were placed at 18°C for 10 days before being assessed for internal and external condition. On 19 March the remaining two nets from each orchard and harvest date were removed from store and assessed as before.

iii. **Air Storage -1°C (Conference)**

Thirty pounds of Conference pears were picked on the 7th, 14th, 21st and 28th of September and transported to HRI East Malling the same day where they were stored in air at -0.5 to -1.0°C.

A sample of 25 fruits was removed from each sample on the 14th January and placed in a ripening room at 18°C for 10 days. Penetrometer measurements (8mm probe) were made on opposite sides of 5 fruits after 0, 2 and 4 days at 18°C. The samples were then cut longitudinally and examined for the presence of physiological disorders and rot. The remaining 10 fruits were examined for physiological disorders and rots after 10 days at 18°C.

## RESULTS

### 1. Harvest

The average fruit weight, diameter, background colour, soluble solids, acidity, firmness and starch pattern was calculated for each orchard on each sample date.

For each of the 10 individual fruits in the sample a maturity index was calculated as follows. The % starch was converted into a 1-10 scale using a conversion table (Table 2).

**TABLE 2. Relationship between % starch pattern and 1-10 scale.**

| % STARCH (Black) | 1-10 SCALE | % RANGE |
|---|---|---|
| 100 | 1 | 100 |
| 80 | 2 | 77.6 - 99.9 |
| 75 | 3 | 70.1 - 77.5 |
| 65 | 4 | 57.6 - 70.0 |
| 50 | 5 | 40.1 - 57.5 |
| 30 | 6 | 27.6 - 40.0 |
| 25 | 7 | 17.6 - 27.5 |
| 10 | 8 | 7.6 - 17.5 |
| 5 | 9 | 2.6 - 7.5 |
| 0 | 10 | 0 - 2.5 |

Using the following formula the index for each of the 10 individual numbered apples and pears in the sample was calculated.

$$\frac{\text{Firmness (kg)} \times 9.81}{\text{Soluble solids (\%)} \times \text{starch pattern (1-10)}}$$

The mean maturity index for each orchard at each sampling date was found by taking the average of the 10 individual fruits.

Graphs were plotted of fruit firmness, starch pattern and maturity index with time using the data collected from mid-August until late September at each site (Appendix 1). A linear regression was fitted to both the fruit firmness and starch pattern data. The date at which the average fruit firmness fell to 8.6kg and the starch pattern declined to 70% was calculated from these regressions. A curve was fitted to the maturity index data and the date the index reached 2.1 extrapolated (Table 3).

For each of the 5 pear orchards graphs of change in fruit firmness, starch pattern and maturity index with time were plotted (Appendix 2). From these graphs the date the starch pattern reached 2/3 maximum and 1/3 maximum was extrapolated together with the date the maturity index reached 0.7 and fruit firmness fell to 6kg (Table 4).

**TABLE 3. Date at which average fruit at each Cox site reached 65mm diameter, a starch pattern of 70%, a firmness value of 8.6 kg (11mm probe) and an index of 2.1 in 1998.**

| Site Code | 65mm diameter | 70% Starch | 8.6kg Firmness | 2.1 Streif Index |
|---|---|---|---|---|
| K1 | 27/8 | 1/9 | 6/9 | 4/9 |
| K3 | 7/9 | 2/9 | 7/9 | 5/9 |
| K7 | 28/9 | 31/8 | 9/9 | 1/9 |
| K10 | 7/9 | 7/9 | 16/9 | 9/9 |
| K11 | 27/8 | 7/9 | 14/9 | 8/9 |
| K12 | 20/8 | 4/9 | 6/9 | 5/9 |
| K13 | 27/8 | 1/9 | 3/9 | 30/8 |
| E4 | 24/8 | 9/9 | 17/9 | 10/9 |
| SF2 | 7/9 | 5/9 | 14/9 | 6/9 |
| SF5 | 21/9 | 2/9 | 4/9 | 6/9 |
| N3 | 3/9 | 7/9 | 16/9 | 9/9 |
| WM4 | 1/9 | 13/9 | 7/9 | 11/9 |
| WM5 | 14/9 | 21/9 | 12/9 | 18/9 |

**TABLE 4. Date at which average fruit at each Conference site reached a diameter of 55mm, two thirds and one third of maximum starch pattern, a maturity index of 0.7 and a firmness of 6.0kg in 1998.**

| Area | Orchard Ref No: | Diameter 55mm | Starch 2/3 | Starch 1/3 | Index 0.7 | Firmness 6.0kg |
|---|---|---|---|---|---|---|
| Kent (KP) | KP1 | 24/8 | 3/9 | 20/9 | 12/9 | 18/9 |
| | KP3 | 27/8 | 9/9 | 23/9 | 10/9 | 5/9 |
| | KP4 | 3/9 | 7/9 | 21/9 | 14/9 | 14/9 |
| | KP6 | 27/8 | 7/9 | 17/9 | 10/9 | 8/9 |
| East-Anglia | EAP2 | 24/8 | 7/9 | 21/9 | 10/9 | 9/9 |

**Gala**

Gala samples were taken from two orchards in Kent and one in East Anglia on the 24, and 27 August, 1, 3, 7, 14, and 21st of September. Fruit size, soluble solids, background colour, firmness and starch pattern were measured on each occasion as described for Cox.
The average fruit size, firmness, background colour, starch pattern and index for the three sites are shown in figure 16. Each point is the mean of three observations.

As with Cox fruit size increased by about 2mm a week during September. Fruit firmness fell by 0.1 kg a day and starch pattern dropped by 2.5% a day.

Table 4a shows the date at which site reached a starch pattern of 90, 70, and 50%, a fruit firmness of 8.6kg, index 2.1 and a fruit size of 65mm.

Table 4a Date each site reached fruit size 65mm, starch pattern 50, 70, 90%, fruit firmness 8.6kg and index 2.1.

| Site | Size | Starch | | | Firmness | Streif |
|---|---|---|---|---|---|---|
| | 65mm | 50 | 70 | 90 | 8.6kg | 2.1 |
| Hononton | 24/8 | 19/9 | 11/9 | 3/9 | 17/9 | 14/9 |
| Broadwater | n/a | 24/9 | 17/9 | 7/9 | 1/10 | 19/9 |
| Feltons | 7/9 | 28/9 | 17/9 | 7/9 | 28/9 | 20/9 |
| Average | 7/9 | 22/9 | 14/9 | 7/9 | 22/9 | 18/9 |

2. **Cox Storage**

The average fruit firmness, and background colour of ten fruits was calculated for each orchard at each pick after 18 weeks in Controlled Atmosphere storage. The number of fruit in each sample with fungal infection or internal storage disorders was noted. After 10 days at 18°C the number of apples in each sample showing fungal infection and internal storage disorders were noted (Appendix 3).

The average fruit firmness, background colour of ten fruits was again calculated for each orchard at each pick after 28 weeks in Control Atmosphere storage. After 10 days shelf life at 18°C the number of apples in each sample showing fungal infection and internal storage disorders were noted (Appendix 4).

3. **Conference Storage**

The average fruit firmness of five fruits was calculated for each orchard at each pick after 18 weeks in air storage at -1.0°C after 0, 2 and 4 days at 18°C. The % fruit with internal breakdown or showing fungal infection after 10 days at 18°C was calculated, table 1 (Appendix 5).

The average fruit firmness of five fruits was calculated again for each orchard at each pick after 28 weeks in air storage at -1.0°C after 0, 2 and 4 days at 18°C. The % fruit with internal breakdown or showing fungal infection after 10 days at 19°C was calculated, table 2 (Appendix 5).

## DISCUSSION

1. **Cox**

As in the previous four seasons average fruit size increased by about 2.5mm a week during August. The rate then fell by about half to 1.1mm a week during early September and appeared to stop after the 21st, this was a similar pattern to that found in 1994, 95 and 96 (figure 2).

In general fruit size was 2-3mm larger than recorded in 1994, 95 and 96 but not as large as that recorded in 1997 when most trees carried a 50-70% crop due to the spring frosts.

Overall fruit size reached 65mm on the 4th of September. This was similar to 1995 and a week earlier than in 1994 or 1995 (table 5). The Kent sites reached an average of 65mm on the 3rd of September. This was similar to the East Anglia sites and 5 days earlier than the West Midlands.

**TABLE 5. Date on which mean fruit size reached 65mm at the average site in 1994, 95, 96, 97 and 98 and for the average site in Kent, East Anglia and the West Midlands areas.**

| CALENDAR DATE FRUIT SIZE REACHED 65MM | | | | |
|---|---|---|---|---|
| **Year** | **All Sites** | **Kent Sites** | **East Anglian Sites** | **West Midland Sites** |
| 1994 | 13/9 | 10/9 | 16/9 | 29/9 |
| 1995 | 6/9 | 31/8 | 12/9 | N/A |
| 1996 | 15/9 | 11/9 | 20/9 | 3/9 |
| 1997 | 31/8 | 29/8 | 5/9 | 31/8 |
| 1998 | 4/9 | 3/9 | 4/9 | 8/9 |

In 1998 average fruit background colour recorded during the entire study was slightly paler than that recorded in the previous four seasons. Background colour started mellowing rapidly (0.5 units a week) on 7th of September and reached an average of 2 by the 11th of the month, compared to about the 20th of September in 1994 and 95 (Figure 3).

Initially soluble solids were similar to that recorded in 1995 and about 1-1.5% higher than the previous three seasons. However there was a slight fall recorded on the 1st September after which the levels increased reaching the high values found in 1995 by the 14th. Overall the rate increased by about 0.1% a day (0.7% a week) this was a similar rate to that found in the four previous seasons (Figure 4).

Initially fruit acidity did not change during August and was steady at about 11.3mg per 100 grammes. This was slightly higher than the initial concentration of about 11.0mg recorded in 1994, 95 and 1997. From the 1st September acidity declined at about 0.5mg a week, this was a similar rate to that recorded in the previous four seasons (Figure 5).

Fruit firmness was very similar to that recorded last season (1997) and about 1.5-2.0kg lower than that recorded in 1994, 95 and 96. The rate of decline at 0.08kg a day was slightly faster than last season's rate of 0.05kg but significantly slower than the three seasons before of 0.10kg a day (Figure 6).

Overall the average fruit firmness reached 8.6kg on the 10th September. This was a week later than last season, a week earlier than 1994, 95 and two weeks earlier than 1996. The Kent sites reached 8.6kg on the 9/9 while the East Anglian sites were 4

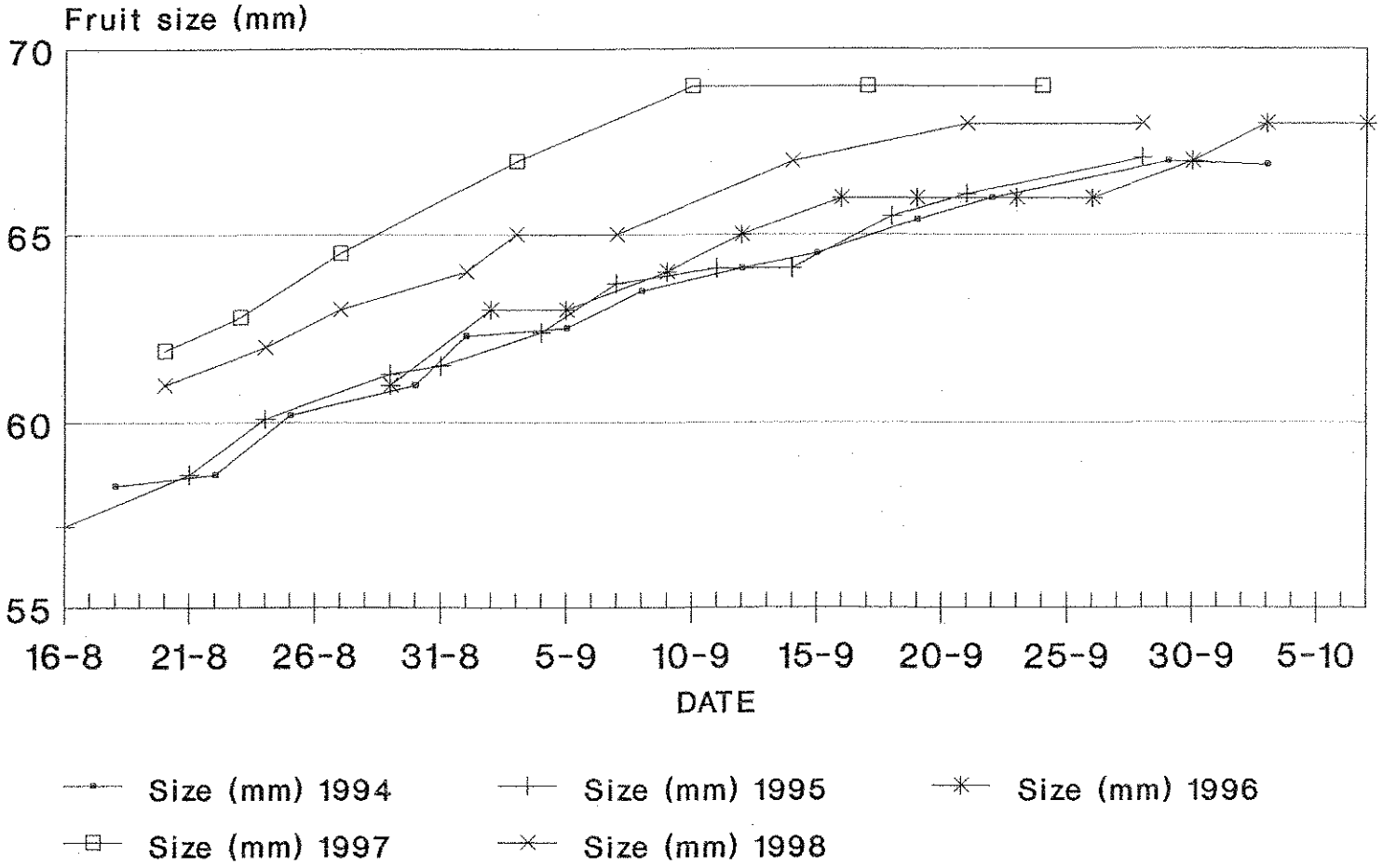

COUNTRY WIDE COX 1998
FRUIT SIZE(mm)
Fruit size (mm)
70
65
60
55
16-8
21-8
26-8
31-8
5-9
10-9
15-9
20-9
25-9
30-9
5-10
DATE
Size (mm) 1994
Size (mm) 1995
Size (mm) 1996
Size (mm) 1997
Size (mm) 1998

Figure 2

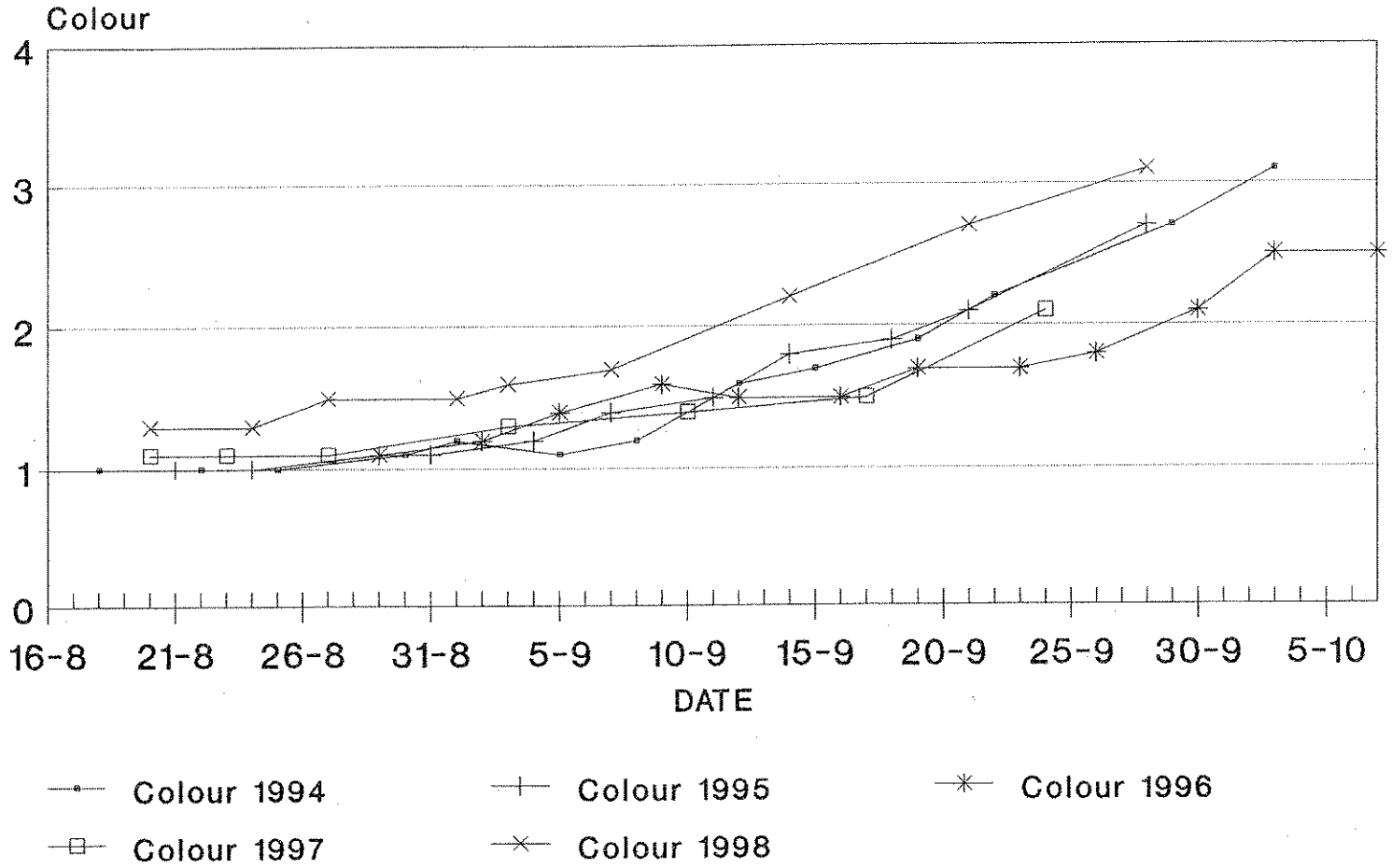

COUNTRY WIDE COX 1998
Background Colour
Colour
4
3
2
1
0
16-8
21-8
26-8
31-8
5-9
10-9
15-9
20-9
25-9
30-9
5-10
DATE
Colour 1994
Colour 1995
Colour 1996
Colour 1997
Colour 1998

Figure 3

days later on the 13/9. For the first time in the five years of the study the West Midland sites were very close to the Kent sites (Table 6).

**TABLE 6. Date on which the mean fruit firmness reached 8.6kg at the average site in 1994, 95, 96, 97 and 98 and for the average site in Kent, East Anglia and the West Midlands area.**

| CALENDAR DATE FRUIT FIRMNESS REACHED 8.6Kg | | | | |
|---|---|---|---|---|
| **Year** | **All Sites** | **Kent Sites** | **East Anglia Sites** | **West Midland Sites** |
| 1994 | 17/9 | 16/9 | 17/9 | >3/10 |
| 1995 | 17/9 | 16/9 | 17/9 | >28/9 |
| 1996 | 25/9 | 22/9 | 25/9 | >7/10 |
| 1997 | 3/9 | 30/8 | 8/9 | >24/9 |
| 1998 | 10/9 | 9/9 | 13/9 | 10/9 |

The decline in starch pattern at about 1.7% a day was very similar to the decline recorded the previous season of 1.6% a day and slightly slower than the 2% recorded in the first three seasons of the study. However as in 1997 the decline started much earlier, 20th August, compared to 1995 and 96 where starch patterns did not start changing until the first week of September (Figure 7). Although the same person assessed starch on each occasion the results recorded on the 3rd of September increased. No physiological explanation for this can be found, (the same happened for the Conference pear samples) however the samples may not have been left long enough to develop or a stronger iodine solution may have been used. The results do highlight the need to adopt a standard procedure when assessing starch patterns.

On average fruit starch patterns reached 70% on 6th September, this was similar to the previous season and 1994 and 8 to 12 days earlier than 1995 and 1996 respectively (Table 7). The Kent sites were three days earlier than the East Anglian sites and two weeks earlier than the West Midlands sites.

**TABLE 7. Date on which mean fruit starch pattern fell to 70% at the average site in 1994, 95, 96, 97 and 98 and for the average site in Kent, East Anglia and the West Midlands area.**

| CALENDAR DATE AVERAGE STARCH PATTERN 70% | | | | |
|---|---|---|---|---|
| **Year** | **All Sites** | **Kent Sites** | **East Anglia Sites** | **West Midland Sites** |
| 1994 | 9/9 | 4/9 | 8/9 | 29/9 |
| 1995 | 14/9 | 13/9 | 12/9 | N/A |
| 1996 | 18/9 | 6/9 | 17/9 | 29/9 |
| 1997 | 7/9 | 31/8 | 4/9 | 16/9 |
| 1998 | 6/9 | 3/9 | 6/9 | 17/9 |

# COUNTRY WIDE COX 1998
# SOLUBLE SOLIDS(%)

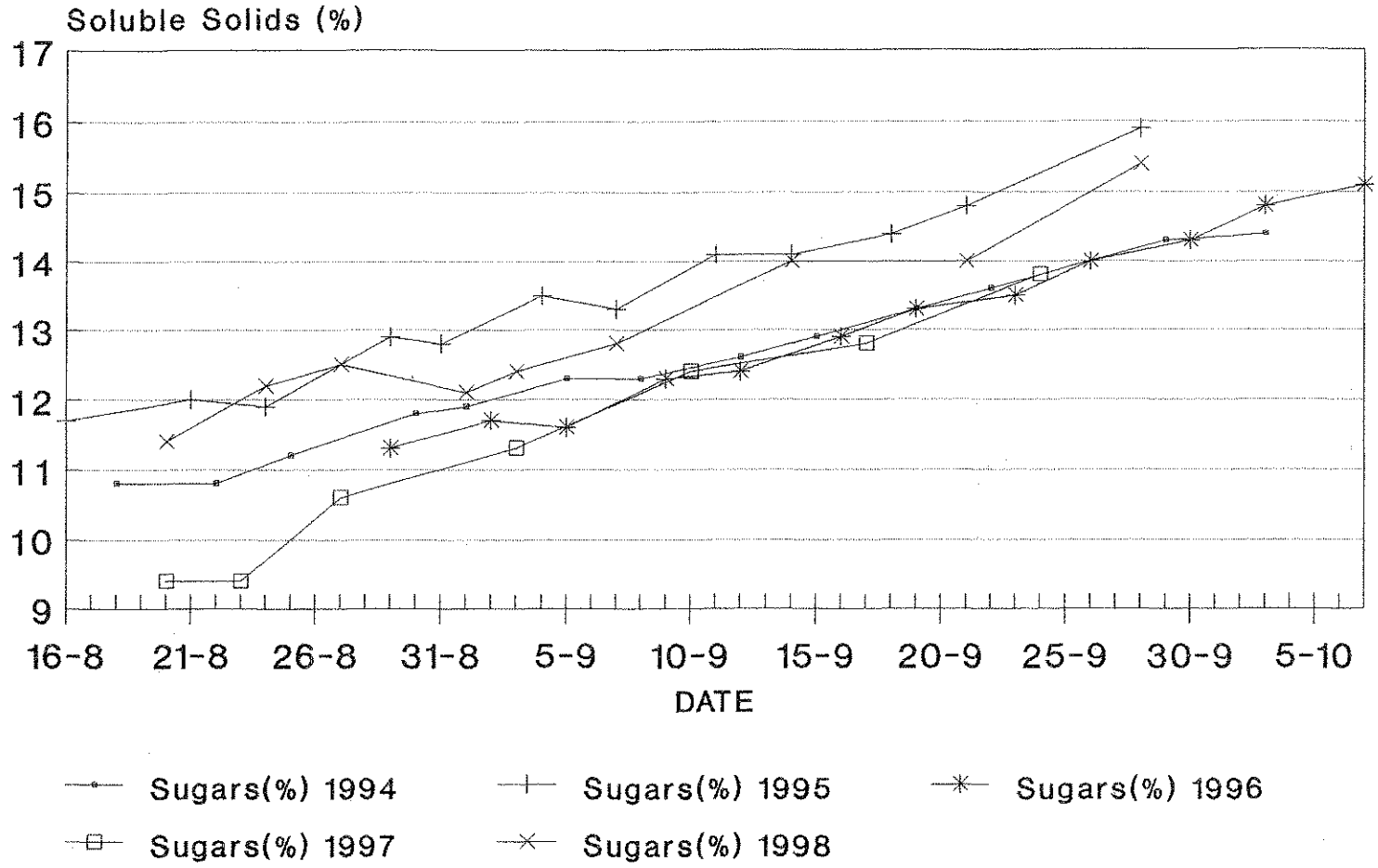



Figure 4

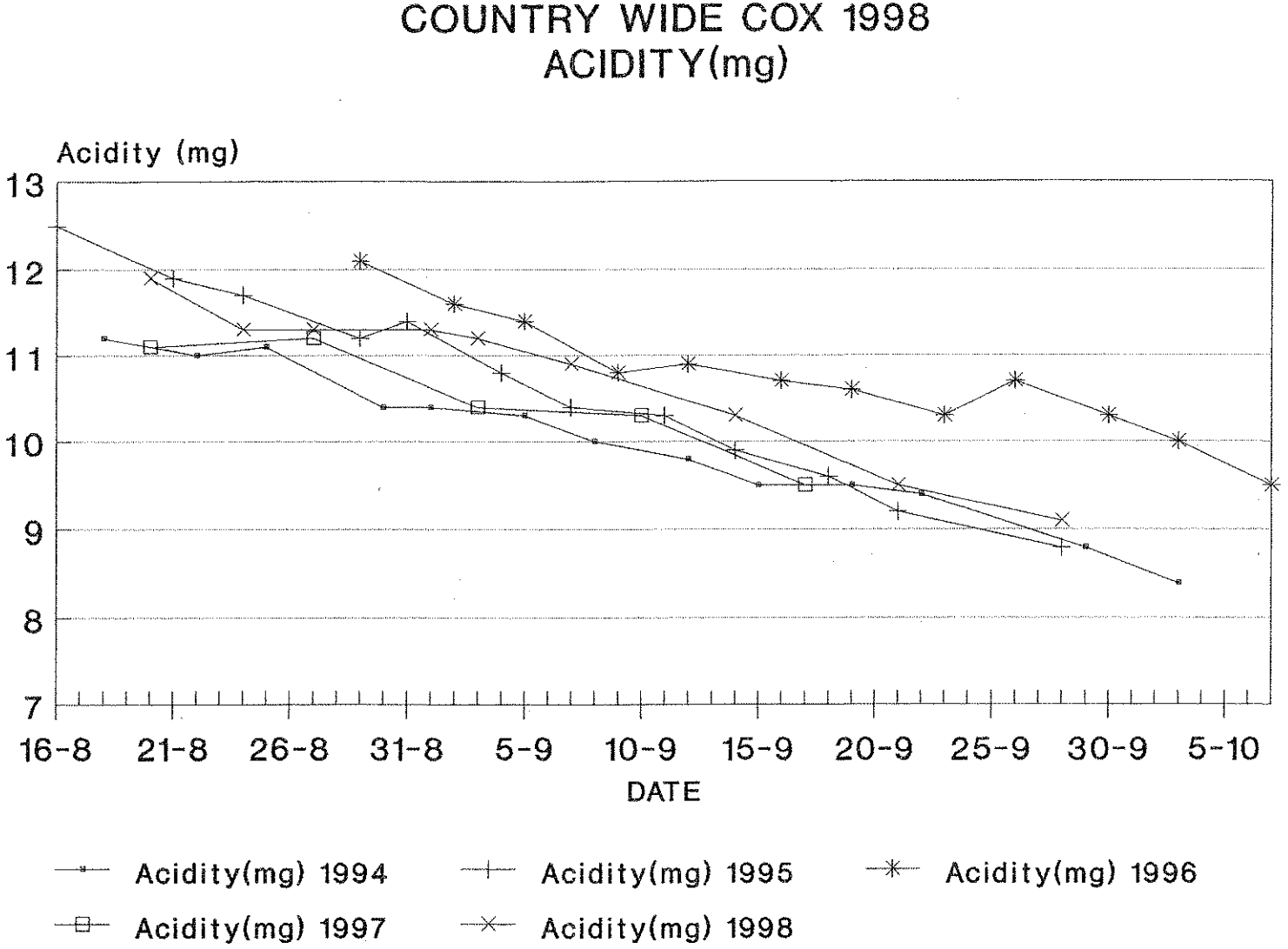

COUNTRY WIDE COX 1998
ACIDITY(mg)
Acidity (mg)
13
12
11
10
9
8
7
16-8
21-8
26-8
31-8
5-9
10-9
15-9
20-9
25-9
30-9
5-10
DATE
Acidity(mg) 1994
Acidity(mg) 1995
Acidity(mg) 1996
Acidity(mg) 1997
Acidity(mg) 1998

Figure 5

# COUNTRY WIDE COX 1998
## Firmness (kg)

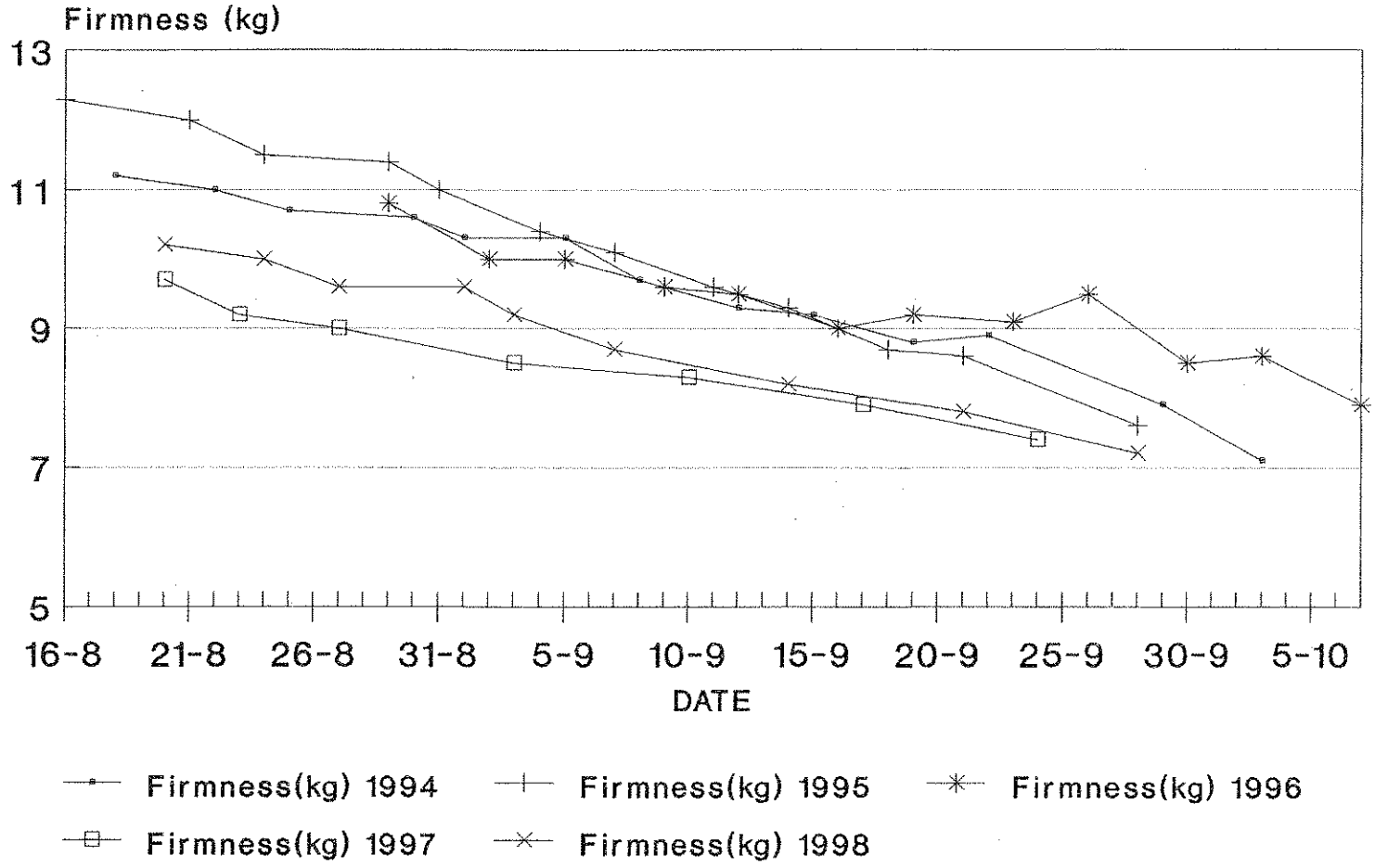



Figure 6

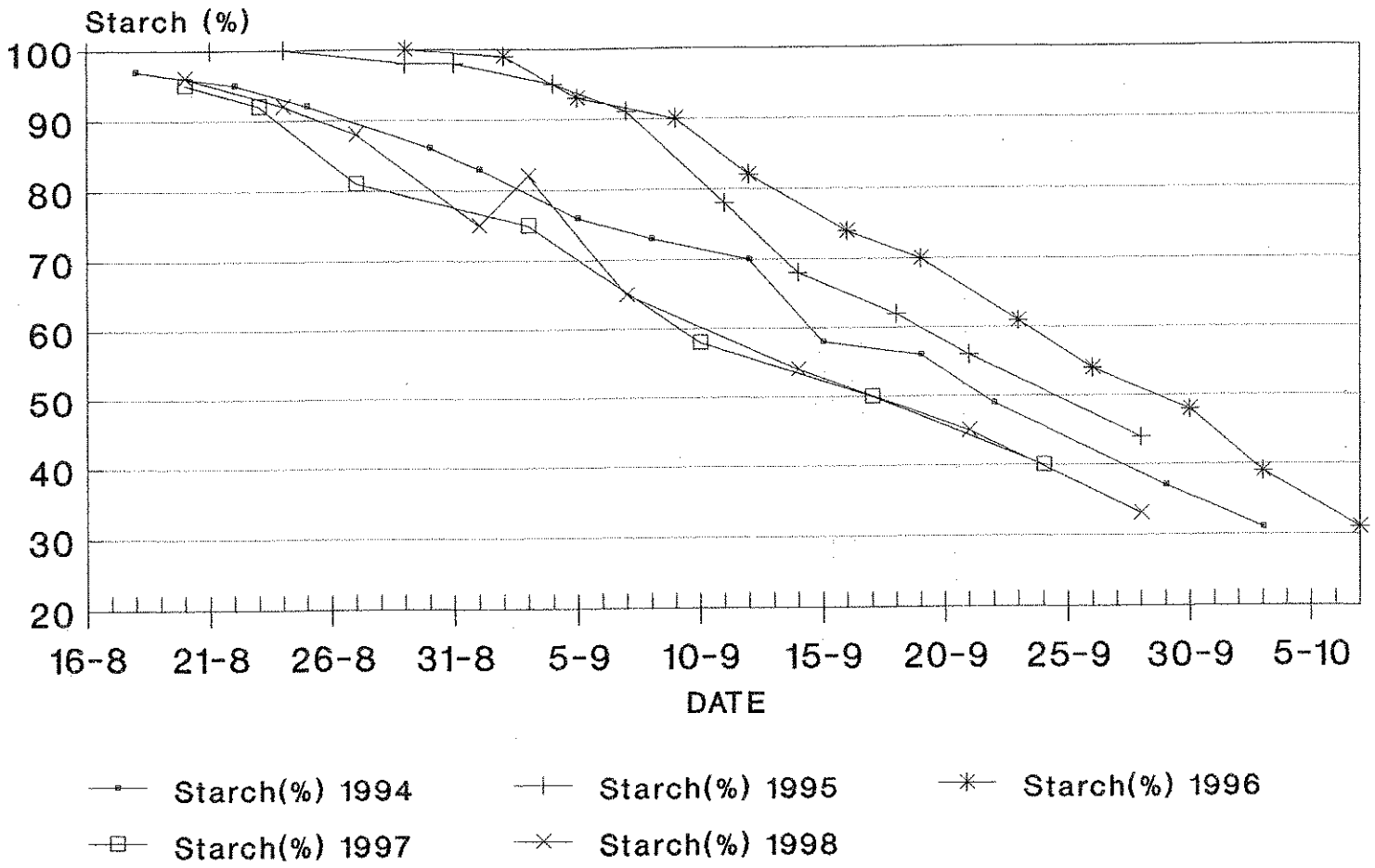

COUNTRY WIDE COX 1998
Starch (%)
Starch (%)
100
90
80
70
60
50
40
30
20
16-8
21-8
26-8
31-8
5-9
10-9
15-9
20-9
25-9
30-9
5-10
DATE
Starch(%) 1994
Starch(%) 1995
Starch(%) 1996
Starch(%) 1997
Starch(%) 1998

Figure 7

As in previous seasons the maturity index did not show as large a variation between the sites as either the fruit firmness or starch pattern above. This is due to the combination of three variables having a 'smoothing out' effect on the data.

Initially the index fell fairly rapidly at about 2.0 units a week, this was similar to the previous season and almost double the rate recorded in the first three seasons (Figure 8). As in all previous seasons the index flattened out at about a value of 2.

On average the index reached 2.1 on the 6th of September, this was similar to last season and 3 days earlier than 1994 and 8 and 12 days earlier than 1995 and 96 respectively. The Kent sites reached an average index of 2.1 on the 5th of September, this was three days earlier than the East Anglian sites and 10 days earlier than the sites in the West Midlands (Table 8).

**TABLE 8. Date on which mean fruit index reached 2.1 at the average site in 1994, 95, 96, 97, and 98 and for the average site in Kent, East Anglia and the West Midlands areas.**

| CALENDAR DATE AVERAGE INDEX REACHED 2.1 | | | | |
|---|---|---|---|---|
| **Year** | **All Sites** | **Kent Sites** | **East Anglia Sites** | **West Midland Sites** |
| 1994 | 12/9 | 9/9 | 12/9 | >3/10 |
| 1995 | 13/9 | 12/9 | 12/9 | >28/9 |
| 1996 | 20/9 | 15/9 | 20/9 | 2/10 |
| 1997 | 8/9 | 2/9 | 5/9 | 18/9 |
| 1998 | 6/9 | 5/9 | 8/9 | 15/9 |

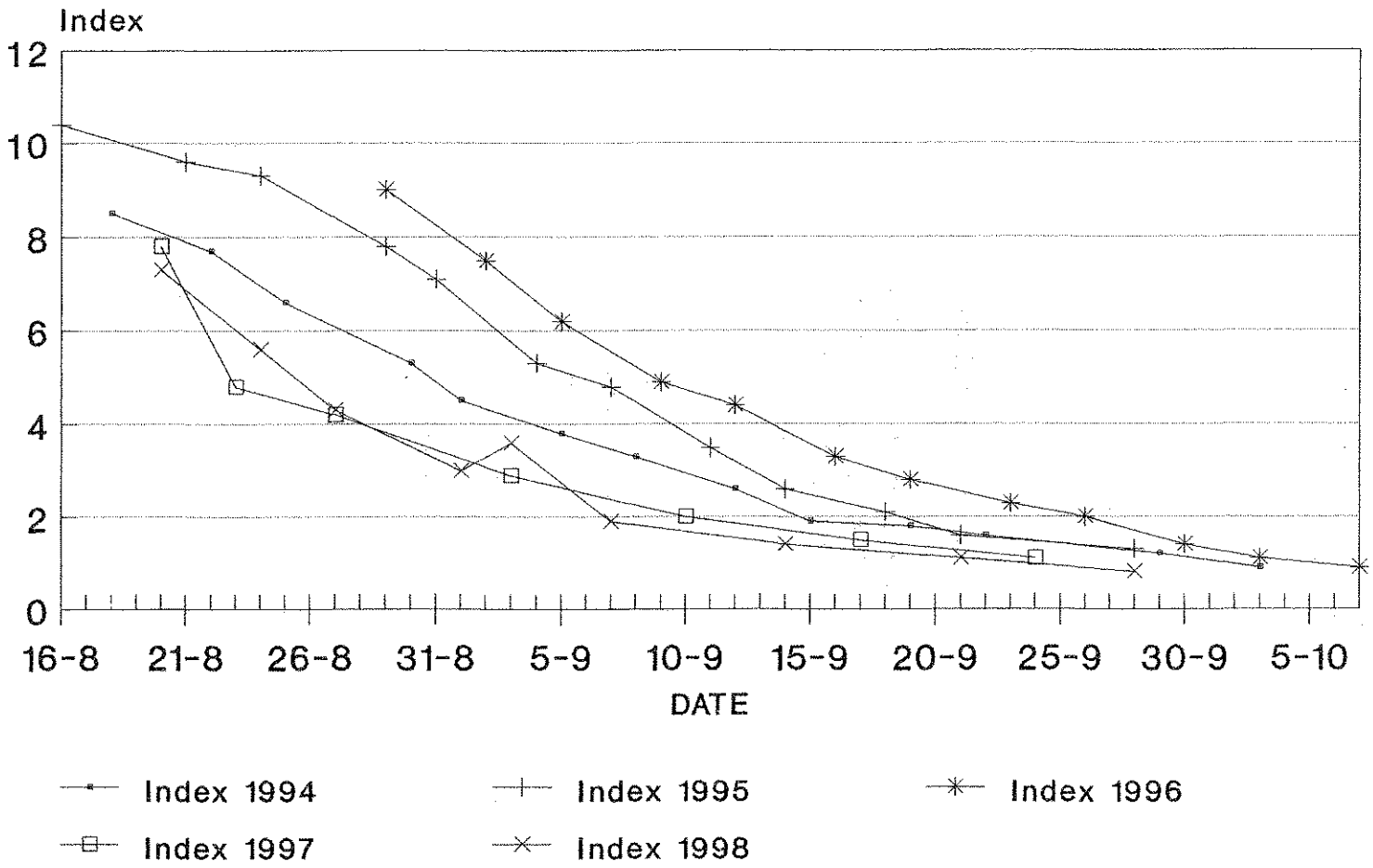

COUNTRY WIDE COX 1998
Index
Index
12
10
8
6
4
2
0
16-8
21-8
26-8
31-8
5-9
10-9
15-9
20-9
25-9
30-9
5-10
DATE
Index 1994
Index 1995
Index 1996
Index 1997
Index 1998

Figure 8

## 2. Conference

Conference fruit size increased by about 2mm a week during August and the first two weeks of September. This was similar to the previous four years of the study. Growth then slowed down to 1mm a week finally stopping on the 21st of September. Initially fruit size was similar to 1994 and 1995, however as growth continued during the first two weeks of September final fruit size was larger than the previous four years (Figure 9).

Soluble solids increased by about 0.1% a day from mid-August until the first week of September, after which time the sugar content of fruit did not increase significantly (Figure 10). Sugar content of fruit was about 1% above that recorded in 1994, 96 and 1997 but not as high as the very high levels found in 1995.

Like Cox average fruit firmness for Conference pears was similar to that recorded last season and about 0.5-1.0kg lower than the first three seasons of the study (Figure 11).

Initially fruit firmness fell as in the previous season, very slowly, 0.07kg a day, however between the 7th and 14th of September fruit firmness fell by over 1.0kg, to almost 5.0kg making it the softest recorded in the 5 years of the study. This may have been due to low night temperatures (6.5 – 7.0°C) recorded on the 12 and 13$^{th}$ September.

The maximum starch pattern recorded in 1998 was 70% on the 21st of August. Initially no change in starch pattern occurred, however a large drop occurred between the 27th August and 1st of September, as with the Cox samples this was followed by a large increase on the 3rd of September. Following this starch pattern declined fairly linearly during the rest of the study at a rate of 2% a day, this was similar to previous seasons (Figure 12).

Due to the erratic change on both fruit firmness and starch pattern the Streif index also showed more erratic changes during August and early September. The low fruit firmness caused the initial value of the index to be low and similar to 1994.

The average index reached 1.0 on the 6th September and fell to 0.7 by the 11th September, five days later (Figure 13).

Using data from the five Conference pear sites the dates on which the thresholds of a number of attributes were calculated and compared to previous seasons (Table 9).

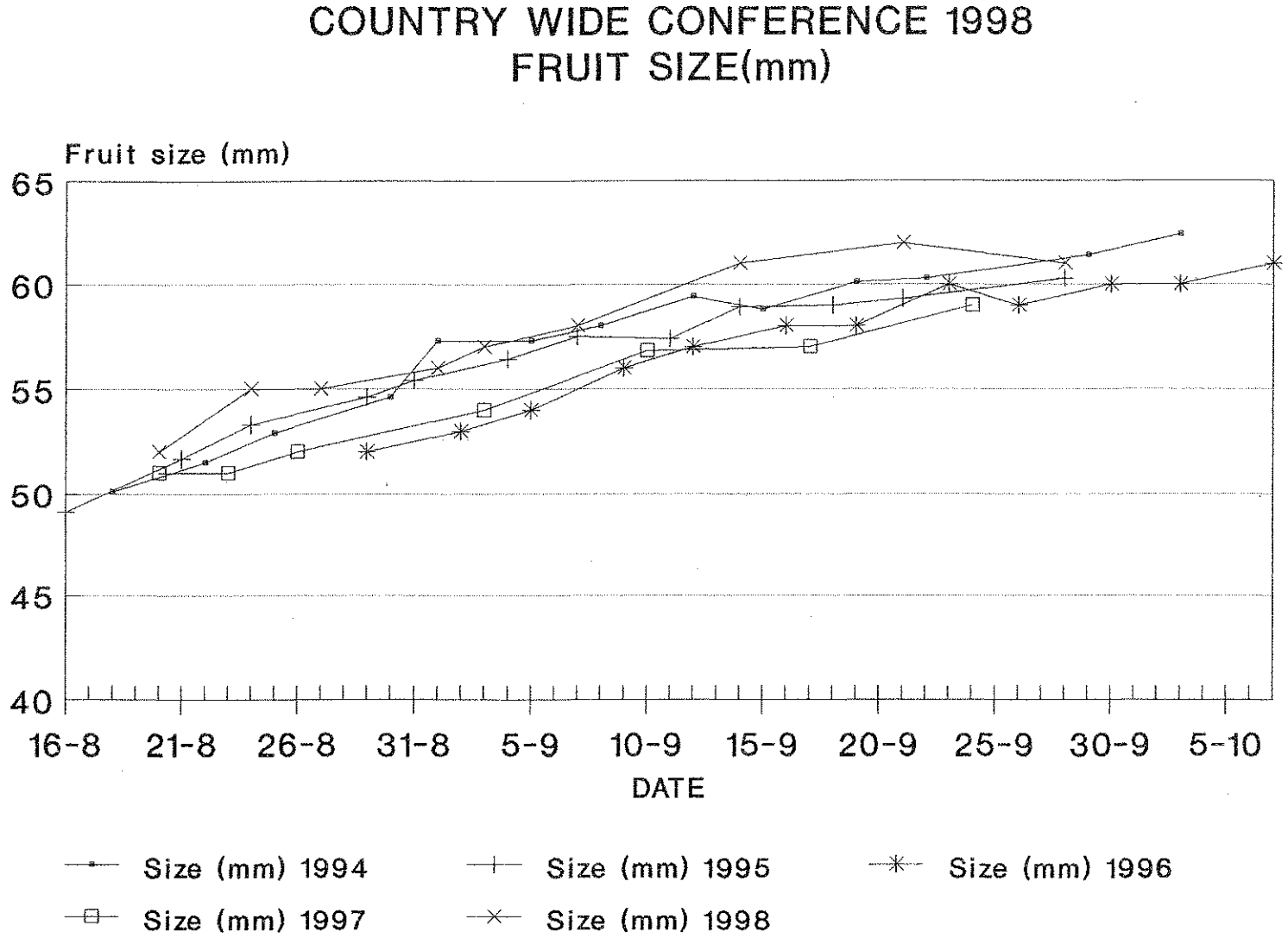

COUNTRY WIDE CONFERENCE 1998
FRUIT SIZE(mm)
Fruit size (mm)
65
60
55
50
45
40
16-8
21-8
26-8
31-8
5-9
10-9
15-9
20-9
25-9
30-9
5-10
DATE
Size (mm) 1994
Size (mm) 1995
Size (mm) 1996
Size (mm) 1997
Size (mm) 1998

Figure 9

# COUNTRY WIDE CONFERENCE 1998
# SOLUBLE SOLIDS(%)

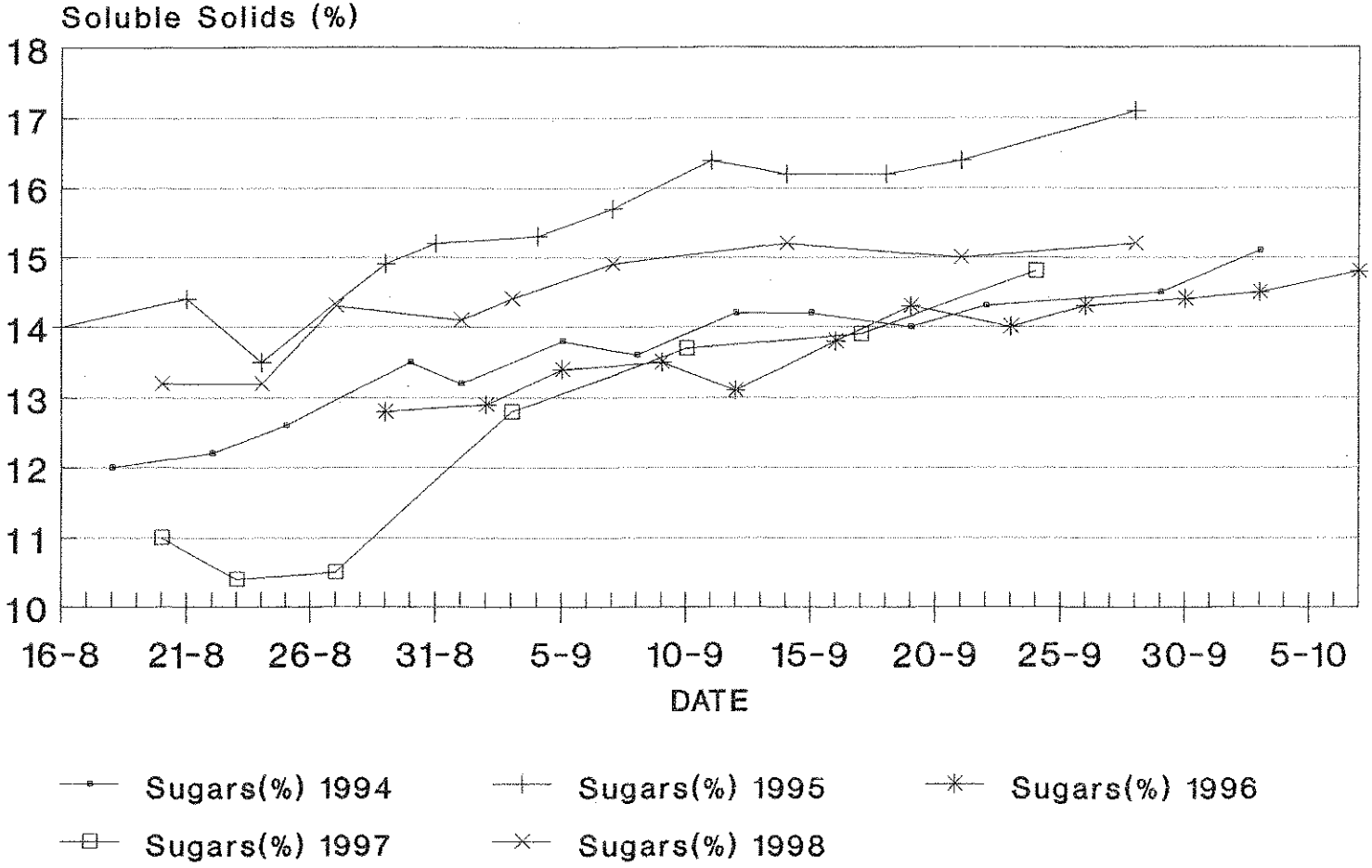



Figure 10

# COUNTRY WIDE CONFERENCE 1998
## Firmness (kg)

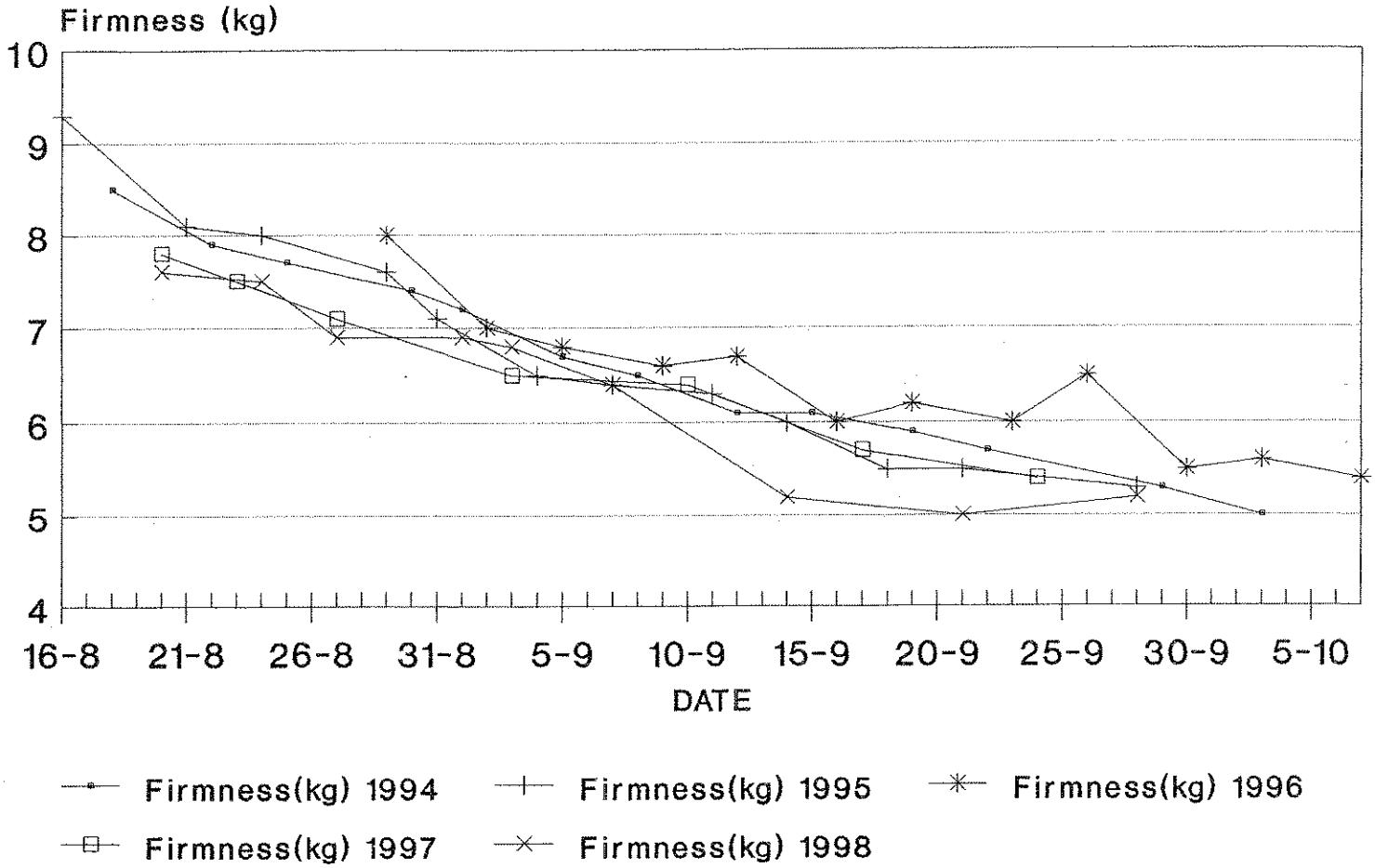



Figure 11

# COUNTRY WIDE CONFERENCE 1998
## Starch (%)

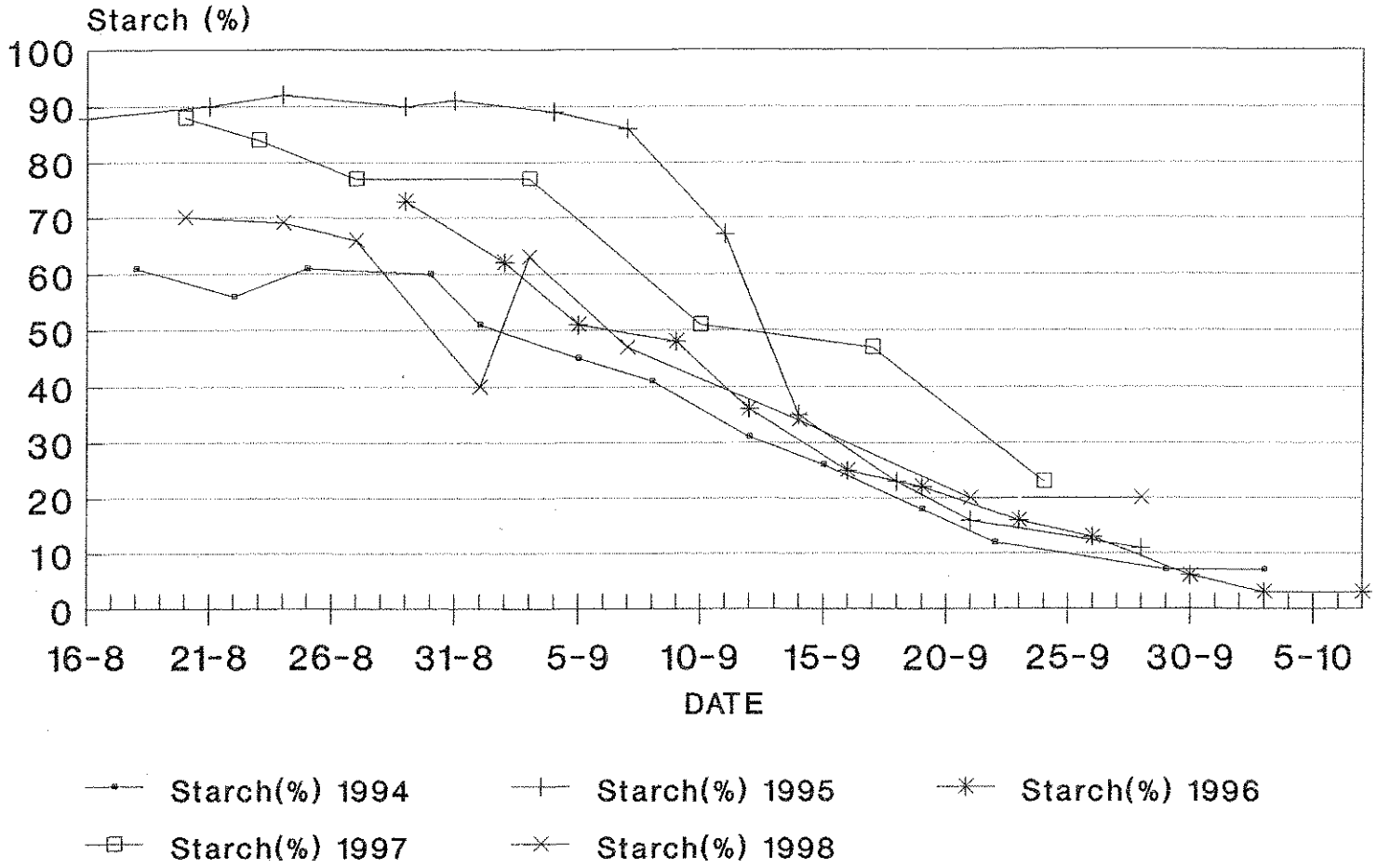



Figure 12

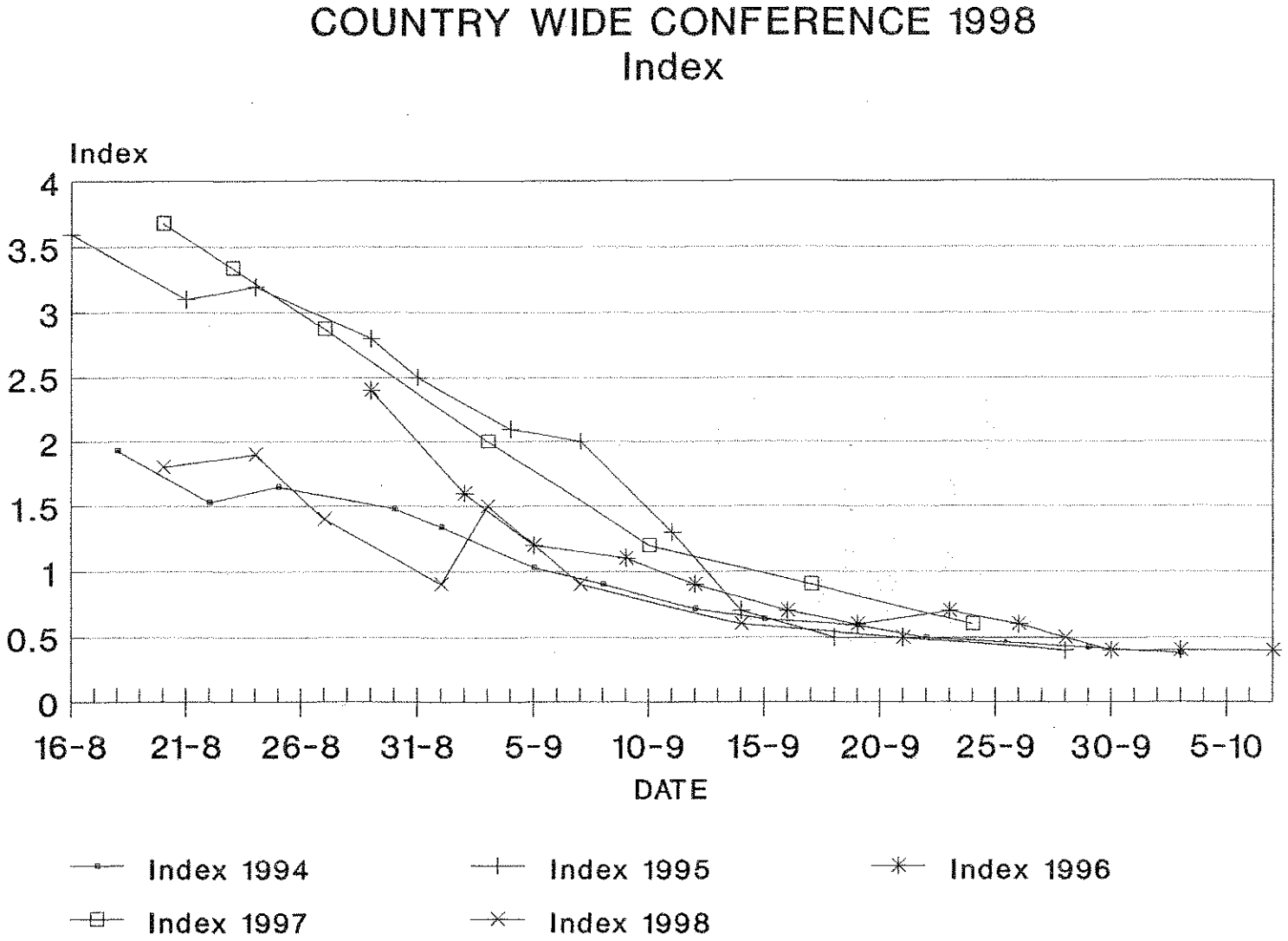

COUNTRY WIDE CONFERENCE 1998
Index
Index
4
3.5
3
2.5
2
1.5
1
0.5
0
16-8
21-8
26-8
31-8
5-9
10-9
15-9
20-9
25-9
30-9
5-10
DATE
Index 1994
Index 1995
Index 1996
Index 1997
Index 1998

Figure 13

**TABLE 9. Date on which mean fruit size reached 55mm, firmness 6.0kg, starch pattern 2/3 and 1/3 of maximum and maturity index 1.0 and 0.7 at the average site in 1994, 1995, 1996, 1997 and 1998.**

| Year | CALENDAR DATE AVERAGE SITE REACHED | | | | | |
|---|---|---|---|---|---|---|
| | 55mm Diam. | 6.0kg Firm. | 2/3 Starch | 1/3 Starch | Index 1 | Index 0.7 |
| 1994 | 30/8 | 17/9 | 8/9 | 18/9 | 5/9 | 17/9 |
| 1995 | 30/8 | 14/9 | 12/9 | 16/9 | 12/9 | 14/9 |
| 1996 | 4/9 | 24/9 | 7/9 | 19/9 | 9/9 | 16/9 |
| 1997 | 7/9 | 13/9 | 9/9 | 22/9 | 14/9 | 19/9 |
| 1998 | 27/8 | 11/9 | 7/9 | 20/9 | 6/9 | 11/9 |

The average fruit size reached 55mm on 27 August, this was the earliest date recorded during the five years of the study, three days earlier than 1994 and 1995 and 8 and 11 days earlier than 1996 and 1997 respectively.

Fruit firmness fell to 6.0kg on the 11th of September, this was the earliest date recorded during the five years of the study and two days earlier than the previous season and almost two weeks earlier than in 1996.

Starch pattern fell to 2/3 maximum on the 7th September and 1/3 maximum by the 20th September, this was similar to the previous two seasons.

The maturity index reached 1.0 on the 6th of September, this was similar to 1994, however it fell to 0.7 by 11th September, the earliest date recorded in the five years of the study.

## 3. Gala Storage

With the variety Gala a simple model to predict harvest date based on fruit firmness alone cannot be used. John Stow in a 3 year project funded by the APRC examined the optimum picking date for coloured clones of Gala. Gala for long term storage should be picked when the starch pattern is between 50-90% and the firmness is above 7kg.

The Quality Fruit Group monitored Gala from three sites in 1998. Figure 16 shows the average fruit firmness was above 9kg for the entire period. Based on starch pattern, the average site reached 90% on the 7th September and fell to 50% by the 22nd of September. Recommendations from the Quality Fruit Group were to pick Gala from early sites starting on the 16th September and the average site from the 21st, and finish by the 25th.

As with Cox the picking window is very narrow. The increase in acreage planted over the past few years coupled with the reduction in casual labour means it becomes increasingly difficult to harvest fruit within the optimum period. However commercial experience has shown this season that fruit picked after 25th of September did not have acceptable eating quality following even short term storage.

## 4. Cox Storage

A summary of the storage information obtained from the 1st inspection of fruit is shown in Table 10.

**Table 10: The effect of harvest date on the storage quality of Cox's Orange Pippin apples stored in 1.2%$O_2$ (<1%$CO_2$) at 3.5$^0$C until early January (18 weeks). Figures in brackets refer to fruit kept in air at 18$^0$C for a further 10 days to simulate marketing.**

| Harvest Date | Firmness | Colour | Rots | Bitter Pit | Breakdown |
|---|---|---|---|---|---|
| 07/9/98 | 7.4 | 1.8 | 1.5 (6.0) | 1.5 (11.0) | 0.5 (3) |
| 14/09/98 | 7.2 | 2.4 | 0 (6.0) | 1.0 (13.5) | 0.5 (3) |
| 21/09/98 | 6.5 | 2.5 | 1.5 (6.5) | 0 (13.0) | 0 (2.5) |
| 28/09/98 | 6.2 | 2.8 | 2.5 (12.5) | 2.0 (12.5) | 0 (3.0) |

**Footnotes:**

1. Fruition colour card 1 = green, 4= yellow colour grade 2 optimum for marketing.
2. Firmness measured using a Effigi penetrometer fitted in a drill stand.

Each figure is the mean of the 10 Cox sites used in the study. After 18 weeks storage at <1% $CO_2$ 1.2%$O_2$ 3.5°C the average fruit firmness for fruit picked on the first three harvest dates was above the threshold of 6.5kg required ex-store to ensure sufficient shelf life to reach the standards of most retail outlets.

Of the ten sites in the study all had an average fruit firmness after 18 weeks storage above 6.5kg when picked on the 7th or 14th of September. When picked on the 21st of September three sites failed to reach the minimum ex-store firmness of 6.5kg. Only one site out of the ten had an average fruit firmness ex-store of 6.5kg when harvest was delayed to the 28th September.

Figure 14 shows the relationship between fruit firmness at harvest and after 18 weeks storage is 1.2% $O_2$ at 3.5°C for fruit from each of the four picks at the 10 sites. To ensure that fruit comes out of store with a fruit firmness above 6.5kg then the harvest firmness needs to be above 8.3kg. If the ex-store firmness is reduced to 6.0kg then fruit has to be harvested with a firmness above 7.6kg. This compares with values of 9.4 and 8.2kg predicted from the model produced using the first two years data from 32 sites involved in the study. Thus in 1998 fruit from the 10 sites could be harvested at 1.1 and 0.6kg lower than expected and come out of store with a fruit firmness of 6.5 and 6.0kg respectively.

Background colour mellowed with delayed harvest and only fruit picked on the 7th September had an average background colour below 2.

Of the ten sites stored for 18 weeks in 1.2% $O_2$ seven had a background colour below 2 when picked on 7 September, this was reduced to 2 when picking was delayed to the 14th. One site produced fruit with a background colour below 2 from all four harvest dates after storage in 1.2% $O_2$ for 18 weeks.

Fungal wastage was between 0-2.5% initially rising to 6-12.5% after shelf life. Delayed picking after 21st September increased the level of rots. A trace of bitter pit was found immediately in store, this increased significantly after the 10 day shelf life. The level of bitter pit was not affected by delayed harvest and was found mainly in three of the ten sites. A small amount of breakdown was found after shelf life, again this was generally confined to the three sites where bitter pit was found. As with the bitter pit the level did not increase significantly with delayed harvest.

Table 11 summarises the results from the second inspection of fruit stored for 28 weeks in <1%$CO_2$, 1.2% $O_2$, 3.5°C. Each result is the mean of the 10 sites used in the study.

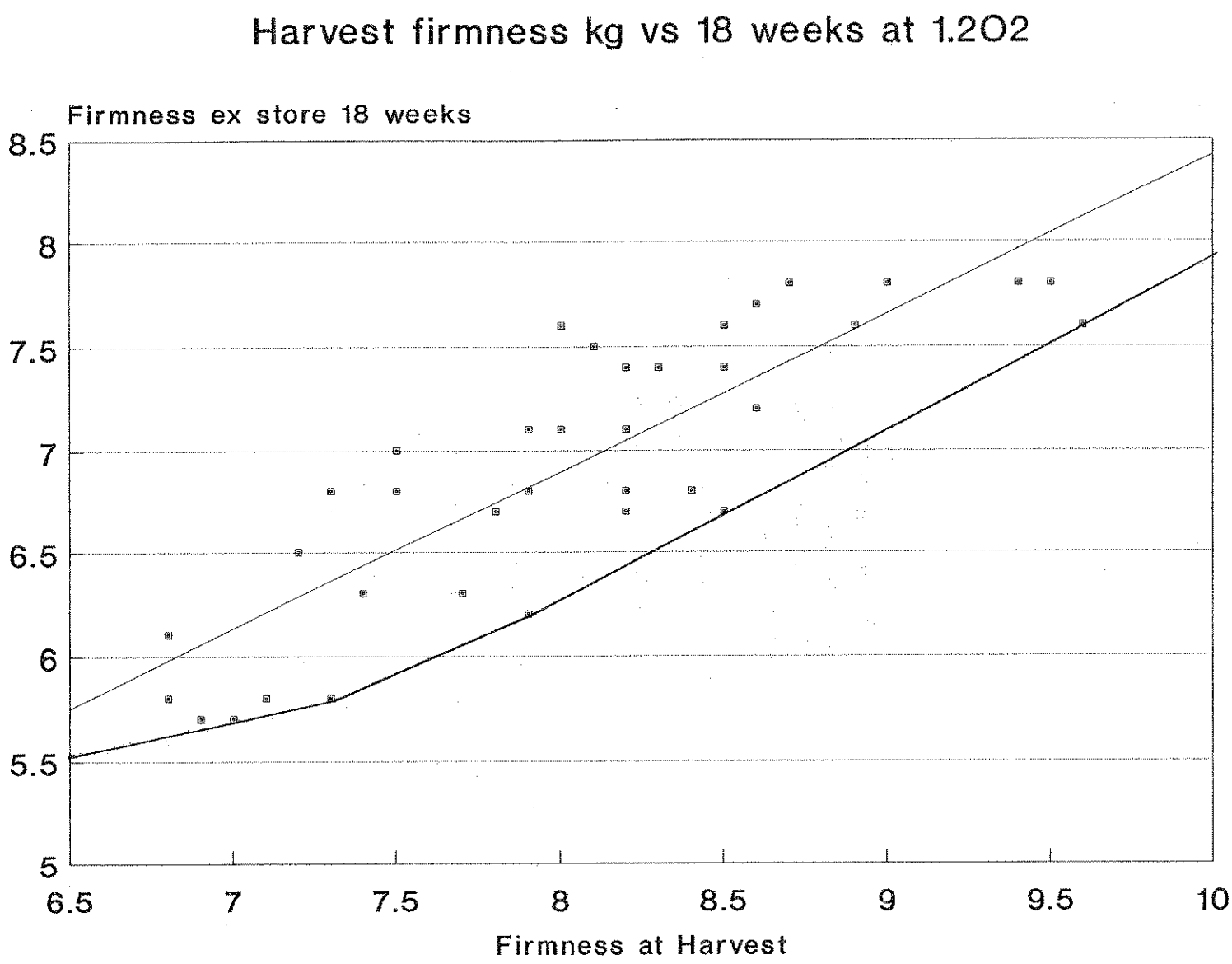

Harvest firmness kg vs 18 weeks at 1.202
Firmness ex store 18 weeks
8.5
8
7.5
7
6.5
6
5.5
5
6.5
7
7.5
8
8.5
9
9.5
10
Firmness at Harvest

Figure 14

**Table 11: The effect of harvest date on the storage quality of Cox's Orange Pippin apples stored in 1.2%$0_2$ <1% $CO_2$ at 3.5$^0$C March. Figures in brackets refer to fruit kept in air at 18$^0$C for a further 10 days to simulate marketing.**

| Harvest Date | Firmness | Colour | Rots | Bitter Pit | Breakdown |
|---|---|---|---|---|---|
| 07/9/98 | 7.3 | 1.7 | 4.5(14) | 13.0 (17) | 6.5 (4.5) |
| 14/09/98 | 7.1 | 2.0 | 3.0(14) | 11.0 (33) | 9.5 (5.0) |
| 21/09/98 | 6.3 | 2.7 | 6.0(9) | 12.0 (22) | 5.0 (2.5) |
| 28/09/98 | 6.2 | 3.2 | 12.0(18) | 10.0 (21) | 5.5 (2.5) |

**Footnotes:**

1. Fruition colour card 1 = green, 4= yellow colour, grade 2 optimum for marketing.
2. Firmness measured using a Effigi penetrometer fitted in a drill stand.

Average fruit firmness for each harvest date had fallen by 0-0.2kg compared to fruit inspected in early January. The average fruit firmness for fruit picked on the 7th September and 14th September and stored for 28 weeks in <1%$CO_2$, 1.2% $O_2$, 3.5°C was above the threshold of 6.5kg required ex-store to ensure sufficient shelf life to meet the requirement of most retail outlets.

Of the ten sites in the study all had an average ex-store fruit firmness after 28 weeks storage above 6.5kg when picked on the 7th of September. When picked on the 14th of September two sites failed to reach the minimum of 6.5kg after storage, this was increased to seven sites when harvest was delayed to the 21st September. Only one site had an ex-store fruit firmness above 6.5kg when harvested on the 28th September.

Figure 15 shows the relationship between fruit firmness at harvest and after 28 weeks storage in 1.2% $O_2$ at 3.5°C for fruit from each of the ten sites picked on the four occasions. To ensure that fruit comes out of store with a fruit firmness above 6.5kg then the harvest firmness needs to be above 8.4kg.

If the ex-store firmness is reduced to 6.0kg then fruit has to be harvested with a firmness above 7.8kg. This is 1.8 and 0.9kg below the predicted values of 10.2 and 8.7kg produced by the model for an ex-store firmness of 6.5 and 6.0kg respectively.

The average background colour did not change for fruit harvested on 7th or 14th of September after 28 weeks stored compared to the results obtained after 18 weeks storage. Once again background colour was found to mellow with delayed harvest however fruit from both pick one and two had a value below two immediately ex-store. The average background colour of fruit picked on the 21st September and 28th September had a definite yellow appearance and was significantly above the index of 2.

Of the ten sites stored for 28 weeks at 1.2% $O_2$ seven had a background colour below 2 when picked on 7th September, this was reduced by one to six when picking was delayed to the 14th. Only one site had a background colour below 2 when fruit was picked on the 21st September, all sites were above 2 when picked a week later.

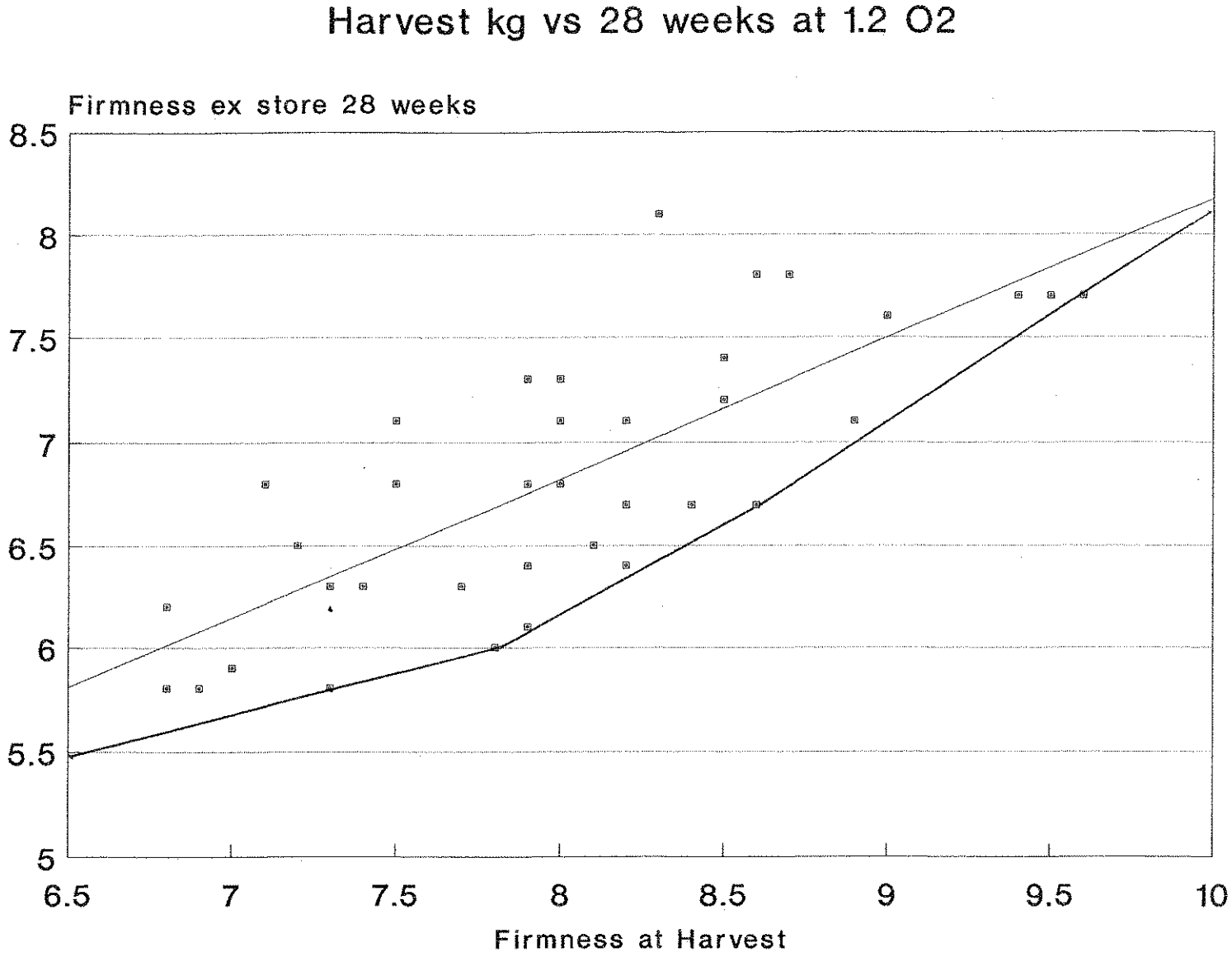

Harvest kg vs 28 weeks at 1.2 O2
Firmness ex store 28 weeks
8.5
8
7.5
7
6.5
6
5.5
5
6.5
7
7.5
8
8.5
9
9.5
10
Firmness at Harvest

Figure 15

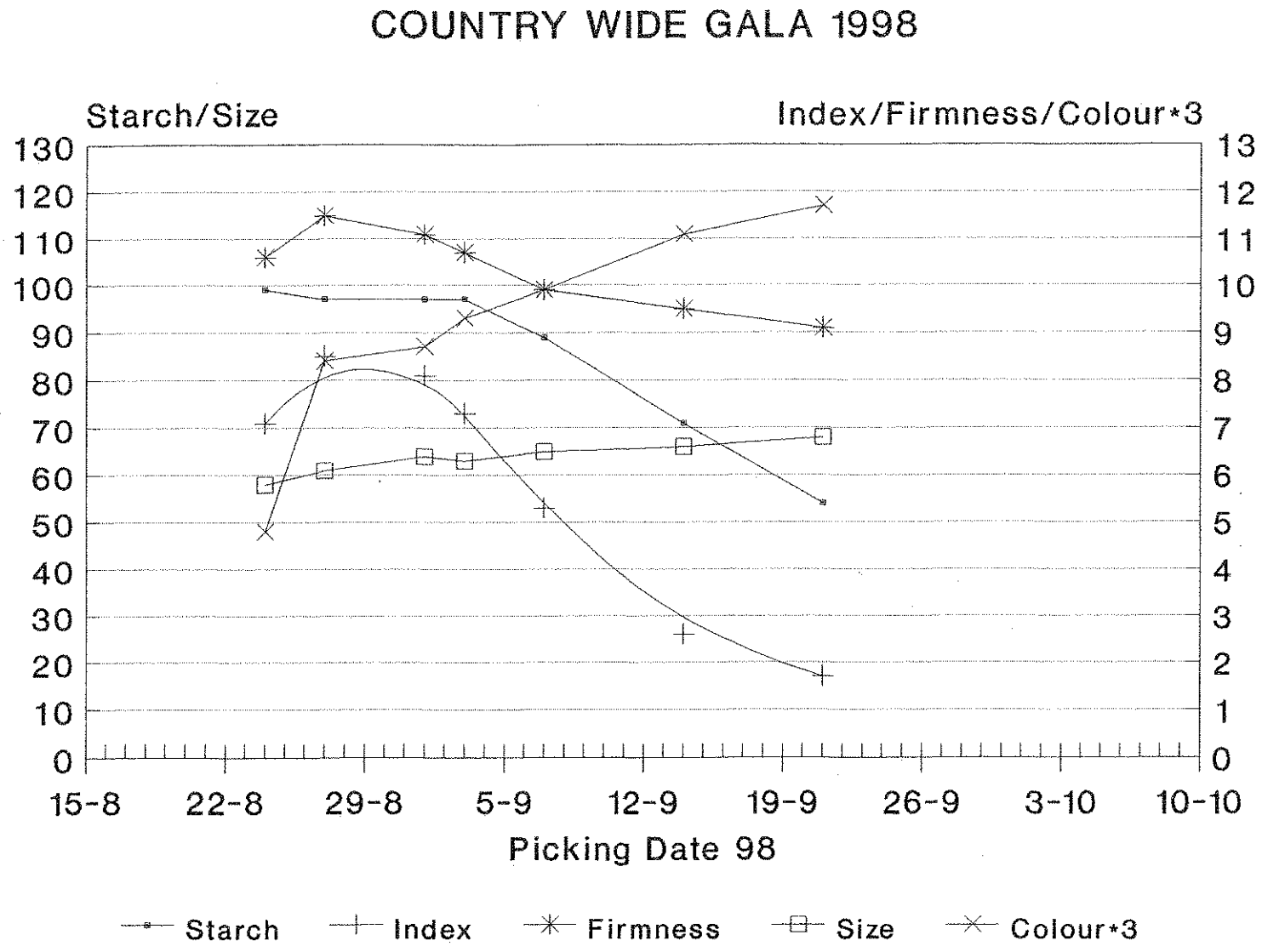

COUNTRY WIDE GALA 1998
Starch/Size
Index/Firmness/Colour*3
130
120
110
100
90
80
70
60
50
40
30
20
10
0
13
12
11
10
9
8
7
6
5
4
3
2
1
0
15-8
22-8
29-8
5-9
12-9
19-9
26-9
3-10
10-10
Picking Date 98
Starch
Index
Firmness
Size
Colour*3

Figure 16

The level of rots increased by four times in fruit stored for 28 weeks compared to that found after 18 weeks storage. The occurrence of rots increased significantly in the last two picks.

The level of bitter pit increased about ten times after 28 weeks storage compared to that found after 18 weeks. Delaying the harvest did not appear to have any effect on bitter pit, and most of the bitter pit found was confined to three sites.

The occurrence of breakdown increased with time in store however the level did not appear to be affected by delayed picking. Breakdown was found mainly in five sites, none of which had significant level of bitter pit.

## 5. Conference Pears. Storage

The storage results for all five orchards in the study are presented in Annexe 5. This provides the opportunity for participating growers to examine the effects of harvest date on the storage behaviour of fruit from their own orchards.

Generally there is little influence of pre-harvest factors on the storage quality of Conference pears. Correct harvest date combined with storage practice should ensure satisfactory quality over the recommended duration of storage. Optimum harvest date (OHD) is considered to be that which provides the following.

- A minimum ex-store firmness of 4.5kg to avoid damage during mechanical grading and marketing.
- Minimal rotting.
- Freedom from physiological disorders and senescent breakdown.
- Maximum eating quality - normally achieved by delaying harvesting as long as possible.

The average data from the five orchards after 18 weeks storage are presented in Table 12 for each of the four harvest dates.

**TABLE 12. The effect of harvest date on the storage quality of Conference pears stored in air at -1°C until early January (18 weeks). Each figure is the mean of five sites.**

| Harvest date | 7/9 | 14/9 | 21/9 | 28/9 |
|---|---|---|---|---|
| Firmness Day 0 at 18°C | 5.3 | 5.0 | 4.9 | 4.6 |
| Day 4 at 18°C | 2.1 | 2.0 | 2.4 | 1.8 |
| % breakdown | 0 | 0 | 1 | 2 |
| % rots | 1 | 0 | 3 | 10 |
| % soluble solids at harvest | 14.9 | 15.2 | 15.0 | 16.8 |

After 18 weeks storage the average fruit firmness for each of the picks was above the 4.5kg threshold and it took at least 4 days for fruit to ripen and pressure to fall to

1.5kg. Fruit picked on the 28 September was starting to show signs of breakdown and had a high level of rots (10%). The concentration of soluble solids in fruit from all picking dates was sufficiently high to provide good eating quality. Thus the picking date that satisfied all the criteria listed above after 18 weeks storage at -1°C was between 7th and 21st of September.

The average data after 28 weeks storage for the five orchards are presented in Table 13 for each of the four harvest dates.

**TABLE 13. The effect of harvest date on the storage quality of Conference pears stored in air at -1°C until March (28 weeks). Each figure is the mean of five sites.**

| Harvest date | 7/9 | 14/9 | 21/9 | 28/9 |
|---|---|---|---|---|
| Firmness Day 0 at 18°C | 4.9 | 4.6 | 4.4 | 4.1 |
| Day 4 at 18°C | 2.1 | 2.0 | 2.1 | 1.9 |
| % breakdown | 0 | 0 | 1 | 2 |
| % rots | 0 | 3 | 4 | 19 |
| % soluble solids at harvest | 14.9 | 15.2 | 15.0 | 16.8 |

After 28 weeks storage the average fruit firmness for fruit picked on the 21 and 28th of September was below the 4.5kg recommended. Once again it took at least four days for fruit from each harvest date to reach – ready to eat ripeness and prssure of 1.5kg.

There was no significant increase in the amount of breakdown found after 28 weeks compared to 18 weeks, however the rot levels showed an increase. Thus the picking date that satisfied all the criteria after 28 weeks storage at -1°C was between 7 and 14th September.

## SUMMARY

The objective of the QFG maturity programme was to provide data on the seasonal variation in fruit maturity and storage quality. The data was thus used:-

1. To give clear recommendations to the industry on the correct harvest dates for different market requirements in view of the climatic and seasonal factors peculiar to the year.

2. To improve the current model that relates harvest attributes to optimum fruit quality for different storage periods.

3. To provide a long term prediction on the relationship between climatic factors and harvest dates for different storage periods.

(i) **Cox**

Fruit maturity in 1998 developed as a similar pattern to the previous season 1997.

Fruit size was generally good and increased by about 2.5mm a week.

Background colour was slightly paler than recorded in previous seasons.

Soluble solids were good and increased by 1-1.5% a week.

Fruit acidity was good and declined at a steady rate during September.

Fruit firmness was again low and very similar to the previous season, however the rate of decline at 0.08kg a day was lower than the average of 0.10kg.

As in 1997 the starch pattern started to deline earlier in 1998, however the rate at 1.7% a day was slightly slower than the average of 2%.

Previous work had shown a significant variation in fruit firmness between sites and proposed marketing periods. Comprehensive guidelines were produced by the group at the beginning of September based on early, average and late sites and for long, medium and short-term storage. Table 14 shows the predicted dates fruit firmness would reach 8.5, 8.0 and 7.5kg for early, average and late sites and the actual dates.

**TABLE 14. The predicted and actual dates (September) fruit firmness reached 8.5, 8.0 and 7.5kg for early, medium and late sites.**

| | Early | | Medium | | Late | |
|---|---|---|---|---|---|---|
| **Kg** | **Predicted** | **Actual** | **Predicted** | **Actual** | **Predicted** | **Actual** |
| 8.5 | 11 | 7 | 13 | 11 | 16 | 16 |
| 8.0 | 16 | 13 | 18 | 17 | 21 | 23 |
| 7.5 | 20 | 21 | 22 | 24 | 25 | 28 |

In general there was good correlation between the actual and predicted dates.

Using the results from the storage assessments the latest date fruit could be harvested and have a firmness of 6.5kg after storage in 1.2% $O_2$ until March, early January or in air until mid-October was found, Table 15.

**TABLE 15. Latest date fruit could be harvested and have a firmness of 6.5kg after storage in 1.2% $O_2$ until March, early January or air until mid-October.**

| **Site** | **March** | **Early January** | **Mid-October** |
|---|---|---|---|
| K1 | 14/9 | 21/9 | 21/9 |
| K3 | 14/9 | 14/9 | 28/9 |
| K7 | 14/9 | 21/9 | 21/9 |
| K10 | 21/9 | 21/9 | 21/9 |

| | | | |
|---|---|---|---|
| K11 | 7/9 | 21/9 | >28/9 |
| K13 | 7/9 | 14/9 | 14/9 |
| E4 | 14/9 | 21/9 | >28/9 |
| SF2 | 21/9 | >28/9 | >28/9 |
| SF5 | 14/9 | 14/9 | 14/9 |
| N3 | 21/9 | 21/9 | >28/9 |

The Quality Fruit Group recommended at the end of August that fruit should be picked for long term storage by 11-16th September, medium storage by 16-21st September and for mid-October from 20-25th September. The actual dates recorded above were in close correlation with the recommended picking date for 1998.

The model developed using the data from the first three seasons of the maturity programme over-estimated the required firmness at harvest by 1.1 or 0.6kg in early January and by 1.8 and 0.9 kg for March.

Internally a high level of bitter pit was found after 18 weeks storage, however this was confined to three sites.

After 28 weeks storage the majority of sites were showing some degree of internal disorder, this was not aggravated by delayed harvest.

The storage results presented here have confirmed the recommended picking dates produced by the Quality Food Group at the end of August. However the Group could only make clear recommendations because of the data collected in late August.

Once again the work has highlighted the tremendous range in maturity dates between sites and the results demonstrated clearly that this range was reflected in the performance of fruit in ultra low oxygen storage. Unfortunately the variability in fruit maturity between orchards cannot be explained by one or two orchard factors alone.

(ii) **Conference**

Fruit size was generally good and increased by 1.2mm a week.

Soluble solids were good and were 1-1.5% above average. The concentration of soluble solids in fruit from all harvest dates was sufficiently high to provide good eating quality.

Fruit firmness was similar to that recorded in 1997 and initially 0.5-1.0 kg below average. However between 7th-14th September fruit firmness fell by 1.0kg making it the lowest recorded in the 5 years of the study.

Starch pattern fell by about 2% a day.

In 1998 the correct harvesting dates determined by measurements made on samples picked on the 7th, 14th, 21st and 28th September and stored in air at -0.5 to -1°C was

between 7-14th September for 28 weeks storage and 7-21st September for 18 weeks storage. These dates coincide with a Streif index of 0.9-0.6 and 0.9-0.5.

The results from the first four years of the programme had suggested that the Optimum Harvest Date for the long term storage of Conference pears conformed to a Streif index of 0.7. This figure was confirmed by the 1998 results. However for short-term storage up to 18 weeks the index can fall as low as 0.5.

The picking for long term storage should start as soon as fruit has sufficient size and the average soluble solids are above 12% and be concluded before the index falls below 0.7.

## CONCLUSIONS AND FUTURE NEEDS

The data and recommendations continue to provide an invaluable resource to the industry to enable it to have clear guidelines for correct harvest procedures. It also gives early warning of potential quality problems.

The consistency of the data allows confidence in making year to year comparisons and using these in the predictive analysis of the current years data.

The season was characterised by an early harvest period for Conference pears which was correctly identified. In Cox colour developed more slowly than other aspects of maturity and the focus by the Quality Fruit Group on the internal maturity factors and the relationship between those and storage life proved essential to the industry in managing the marketing programme.

The Streif index has again proved a useful guide in monitoring the maturity of Conference and the determination of a lower index for short term storage will be invaluable to the Industry. Further work is requested in order to test and confirm the exact figure for different storage periods.

The Streif index is however not sensitive enough for Cox where the critical starch level is 70-80% (Conference Jonagold are 30-40%) and the development of a specific Cox index should be a high priority for the industry.

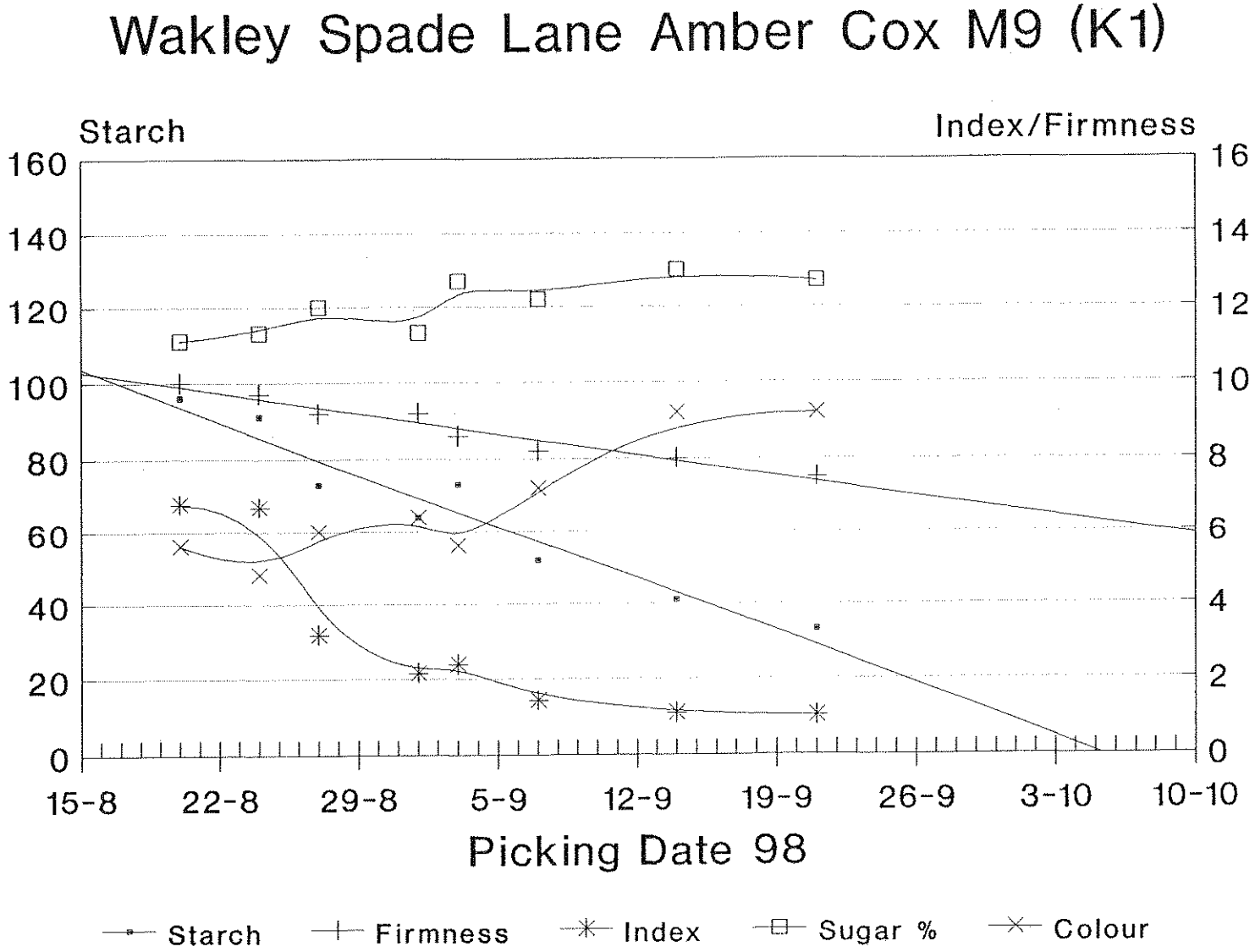
The formula for predicting required fruit firmness at harvest to ensure satisfactory firmness ex-store appears to be too strict. The fruit in 1998 was stored in good commercial stores rather than small experimental chambers and this may be a factor. It is essential that the QFG tests the formula over several more seasons so that accurate guidelines can be provided to the industry.

The Gala recommendations were found to be accurate and where they were followed avoided problems of greasiness developing. The extension of the work of the QFG into other varieties is another priority.

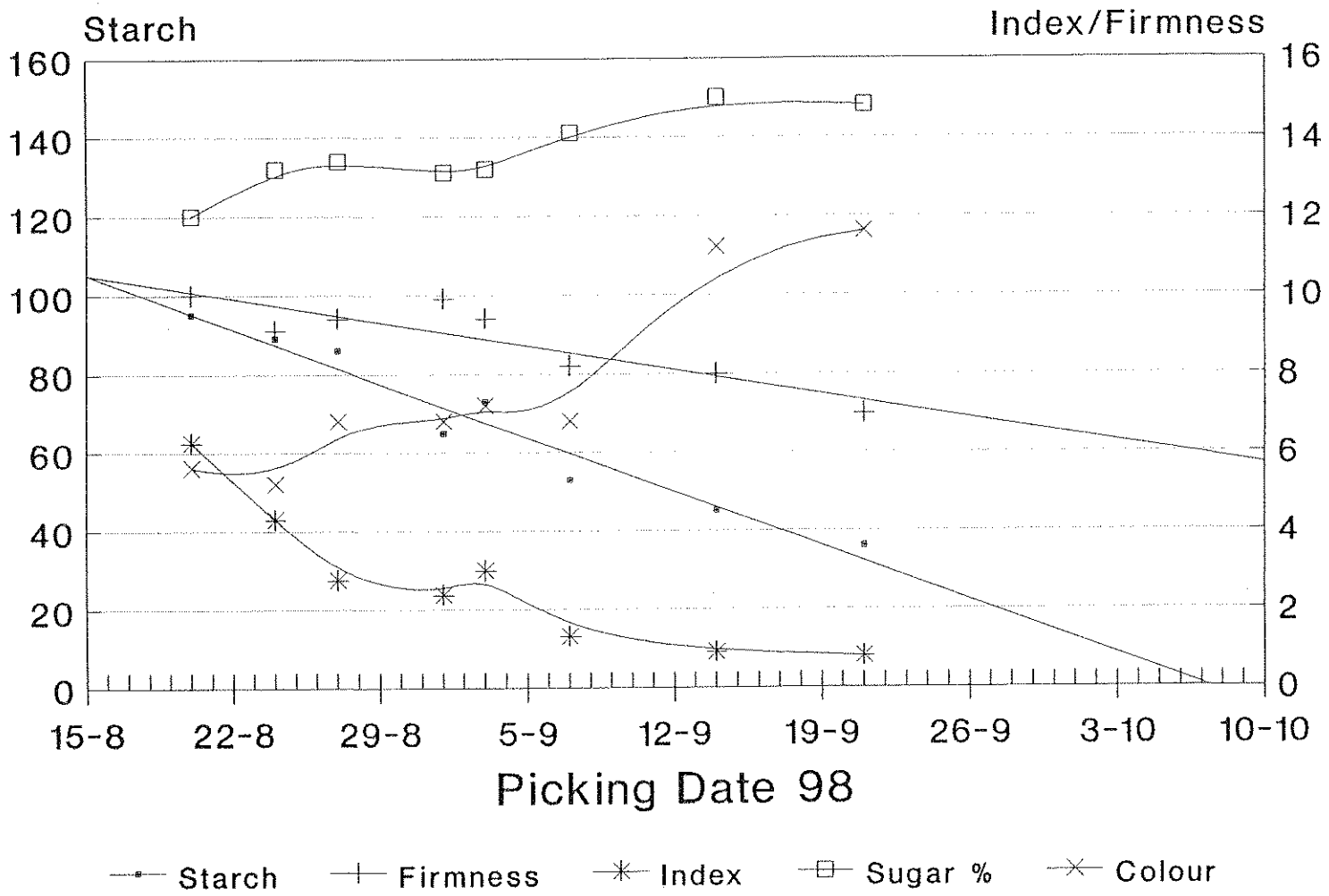
Other major apple producing nations and areas eg Washington State and South Africa have a maturity indexing programme which they have relied on for many years. It is recognised that the accuracy and benefit of the programmes increases with the number of seasons data that has been built up. The QFG recognise the need to maintain the programme and that the benefits will increase over the years as the database is improved and added to.

# APPENDIX 1

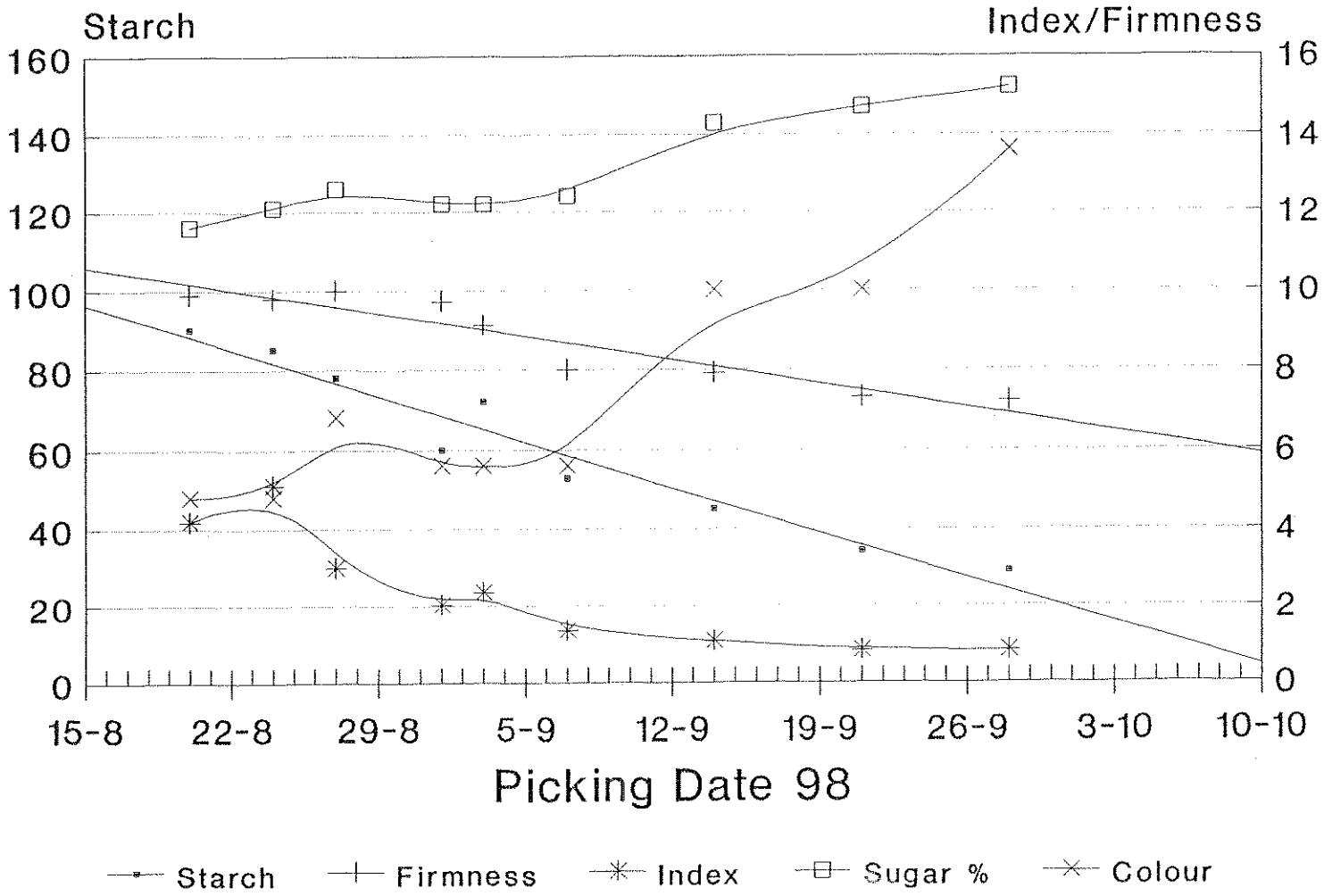
**Graphs of fruit firmness, starch pattern and maturity index with time for each of the 13 Cox orchards**

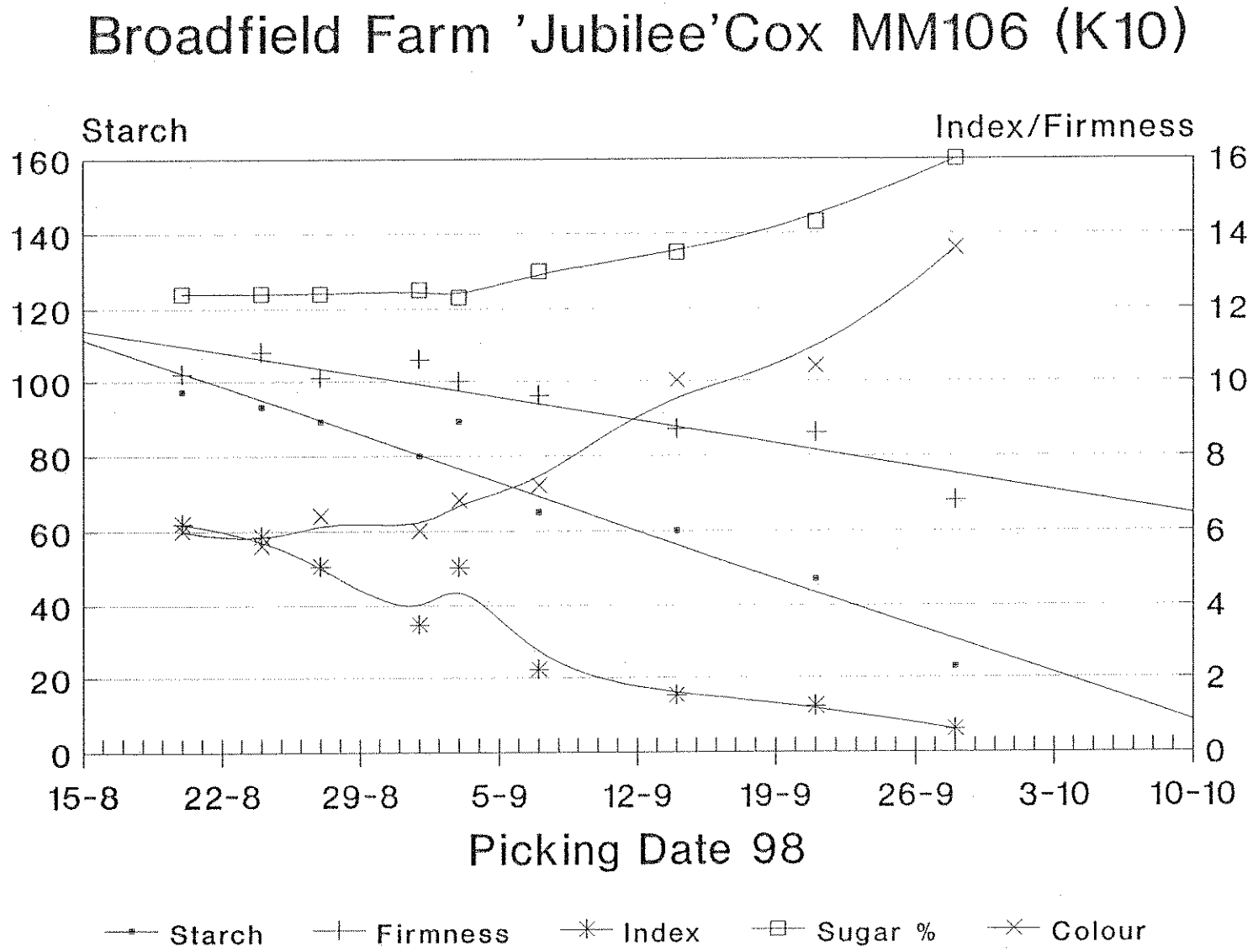

Wakley Spade Lane Amber Cox M9 (K1)
Starch
Index/Firmness
160
140
120
100
80
60
40
20
0
16
14
12
10
8
6
4
2
0
15-8
22-8
29-8
5-9
12-9
19-9
26-9
3-10
10-10
Picking Date 98
Starch
Firmness
Index
Sugar %
Colour

# Goldstone Potts Cox MM106 (K3)

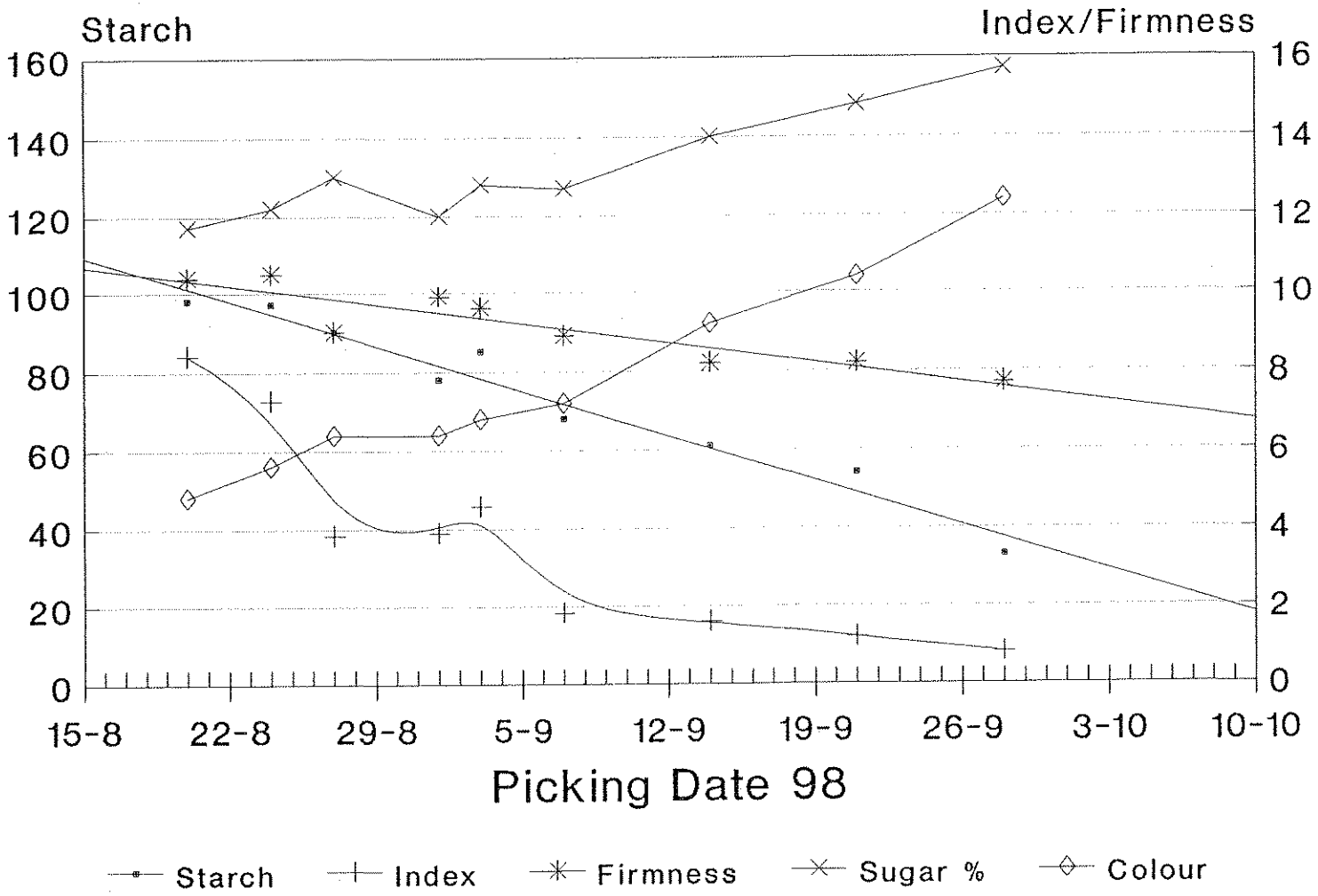


# Monks Farm A 19 Cox M9(K7)

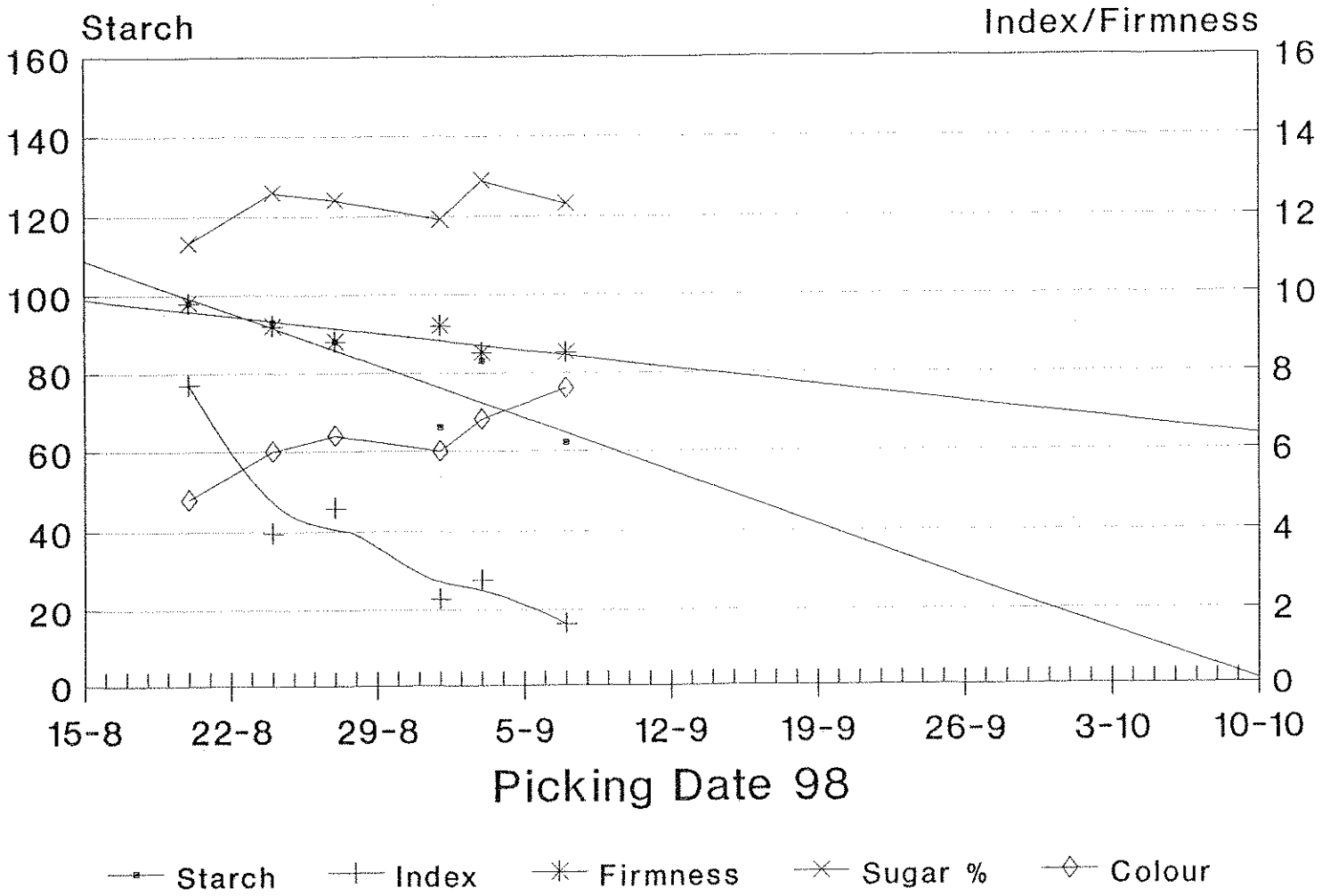



Broadfield Farm 'Jubilee'Cox MM106 (K10)
Starch
Index/Firmness
160
140
120
100
80
60
40
20
0
16
14
12
10
8
6
4
2
0
15-8
22-8
29-8
5-9
12-9
19-9
26-9
3-10
10-10
Picking Date 98
Starch
Firmness
Index
Sugar %
Colour

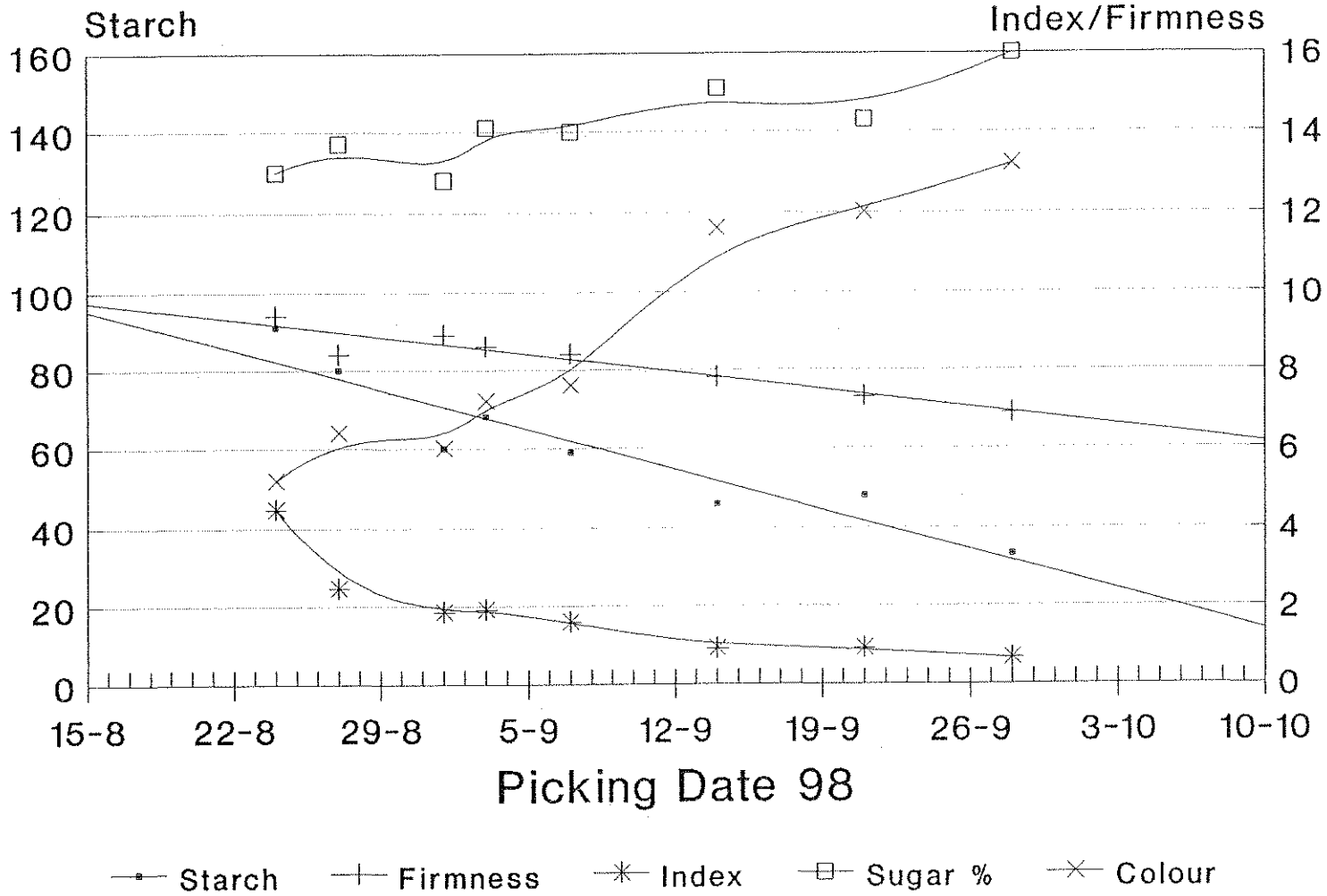
# Wares Farm Maytums Cox M9 (K11)



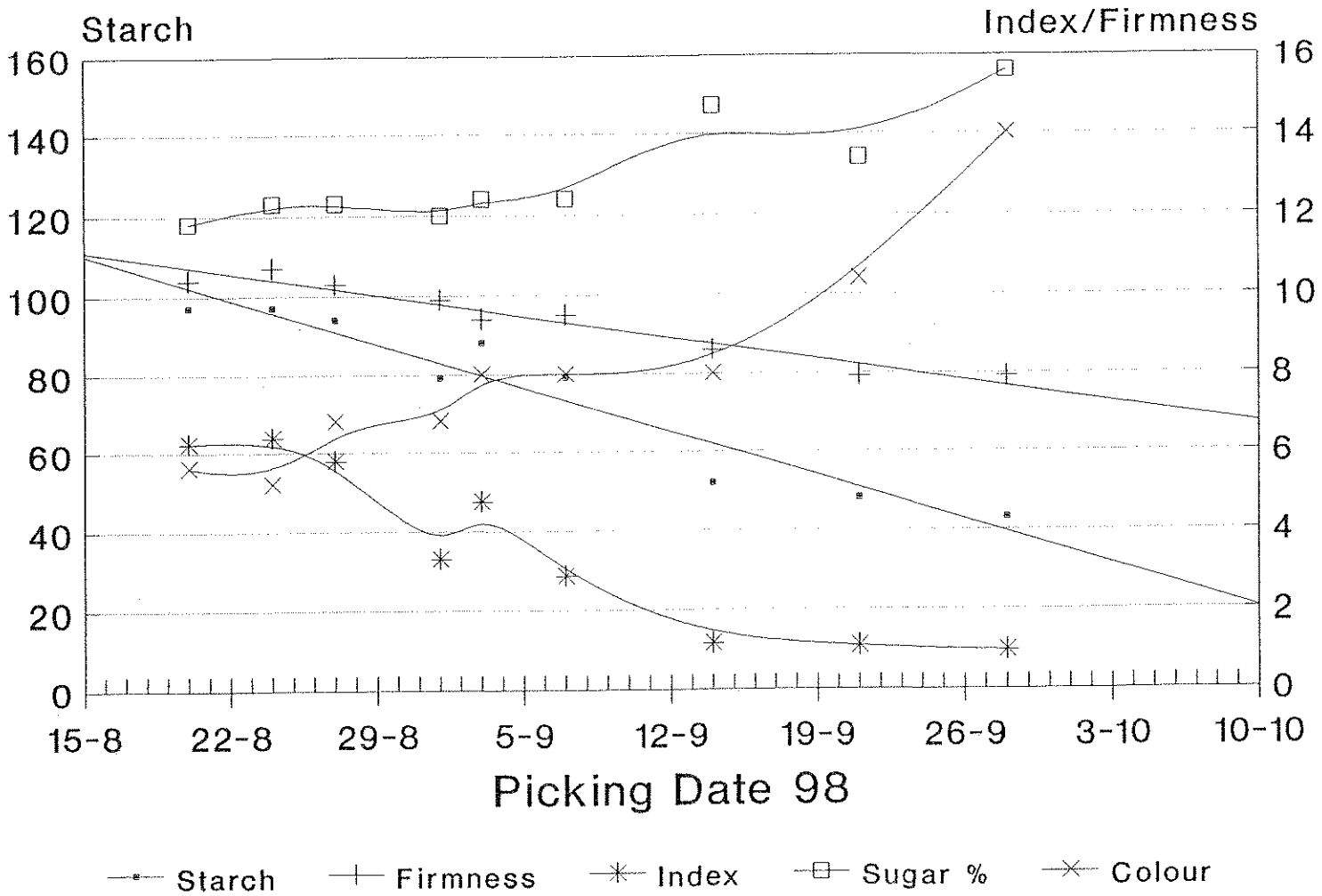
# Wares Farm Cobblers Cox M9 4RB (K12)



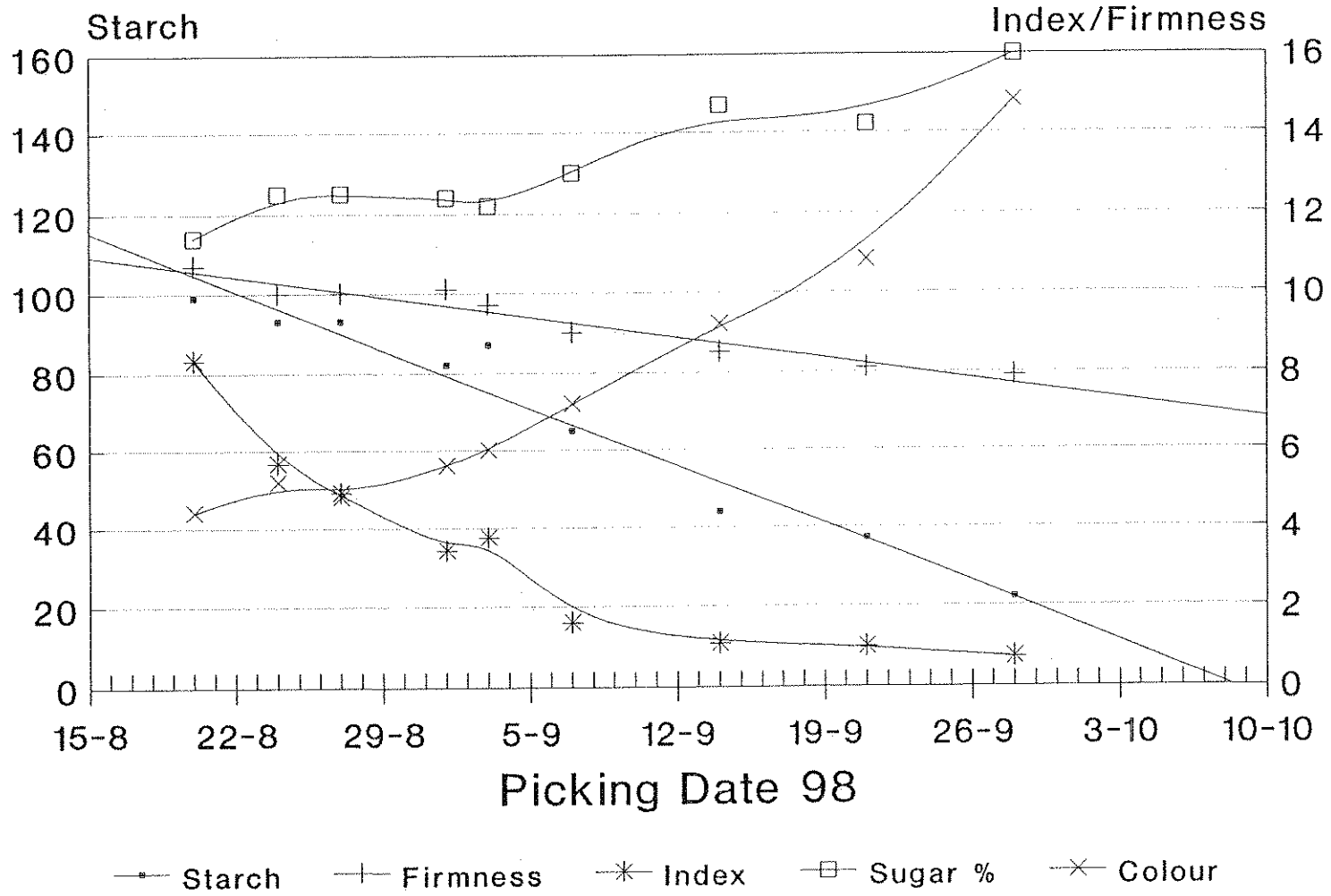
# River Farm Pond Cox M9(K13)



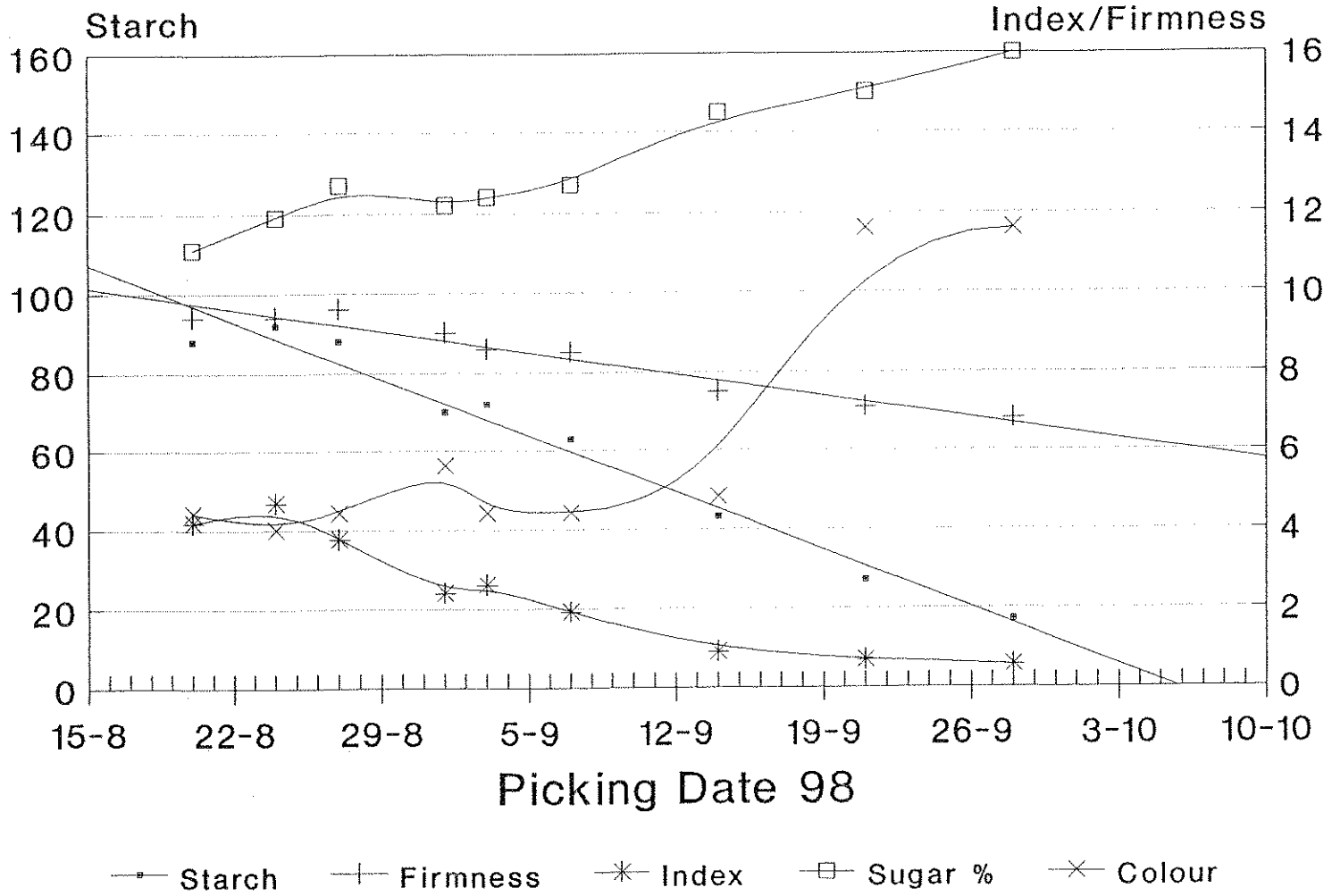
# Plains Farm Q Cox M9 (E4)



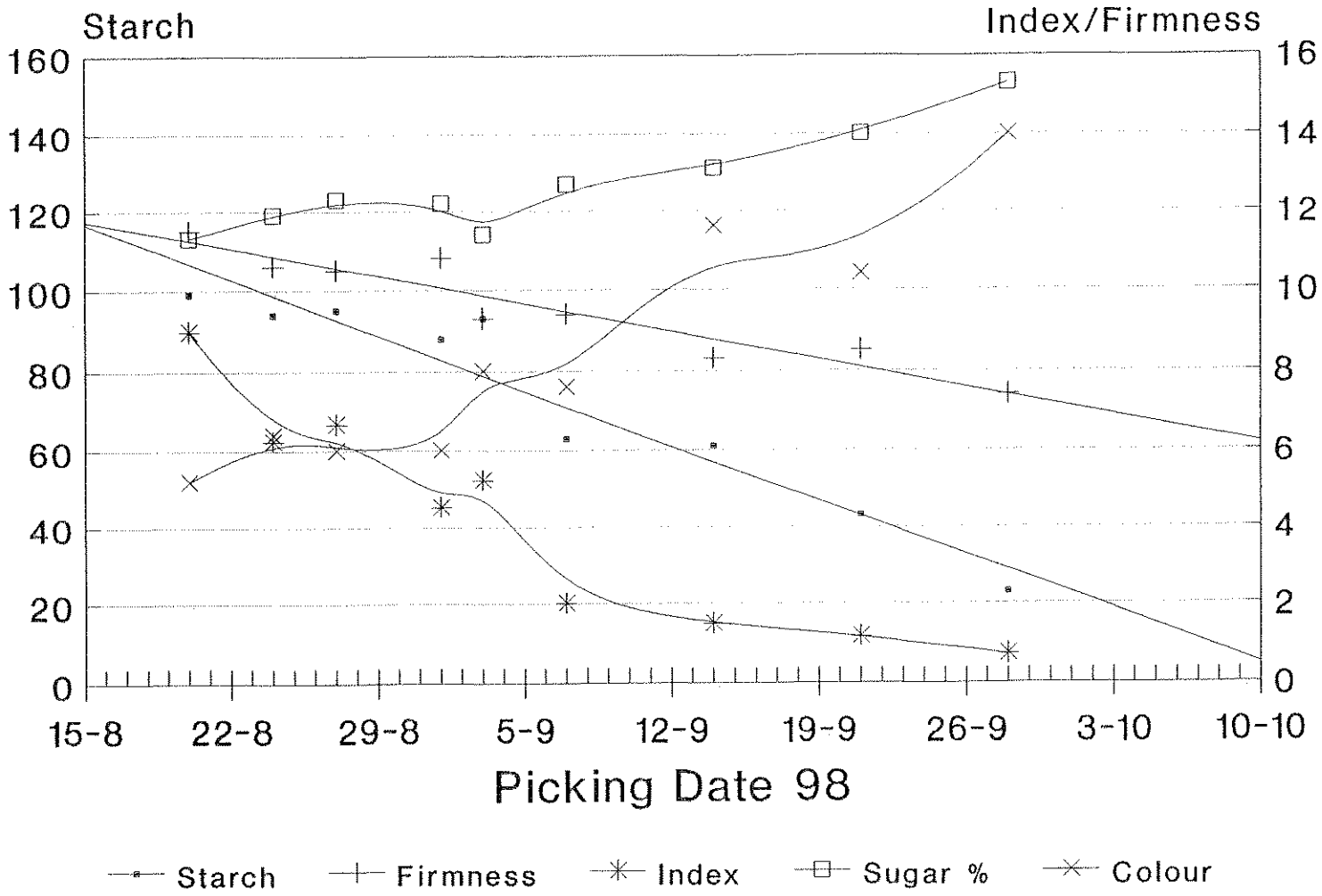
# Feltons Farm Horseshoes Cox M9 (SF2)

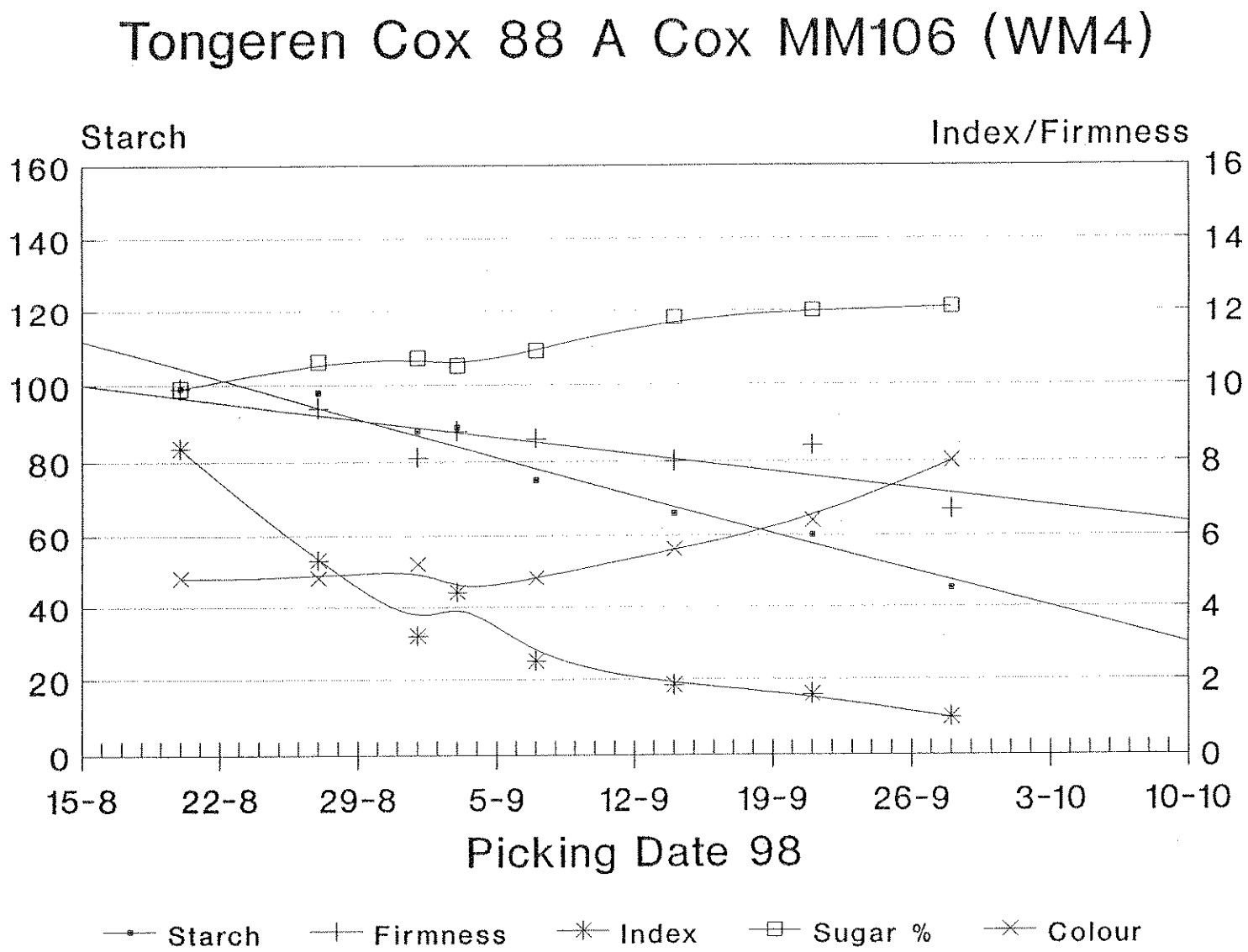


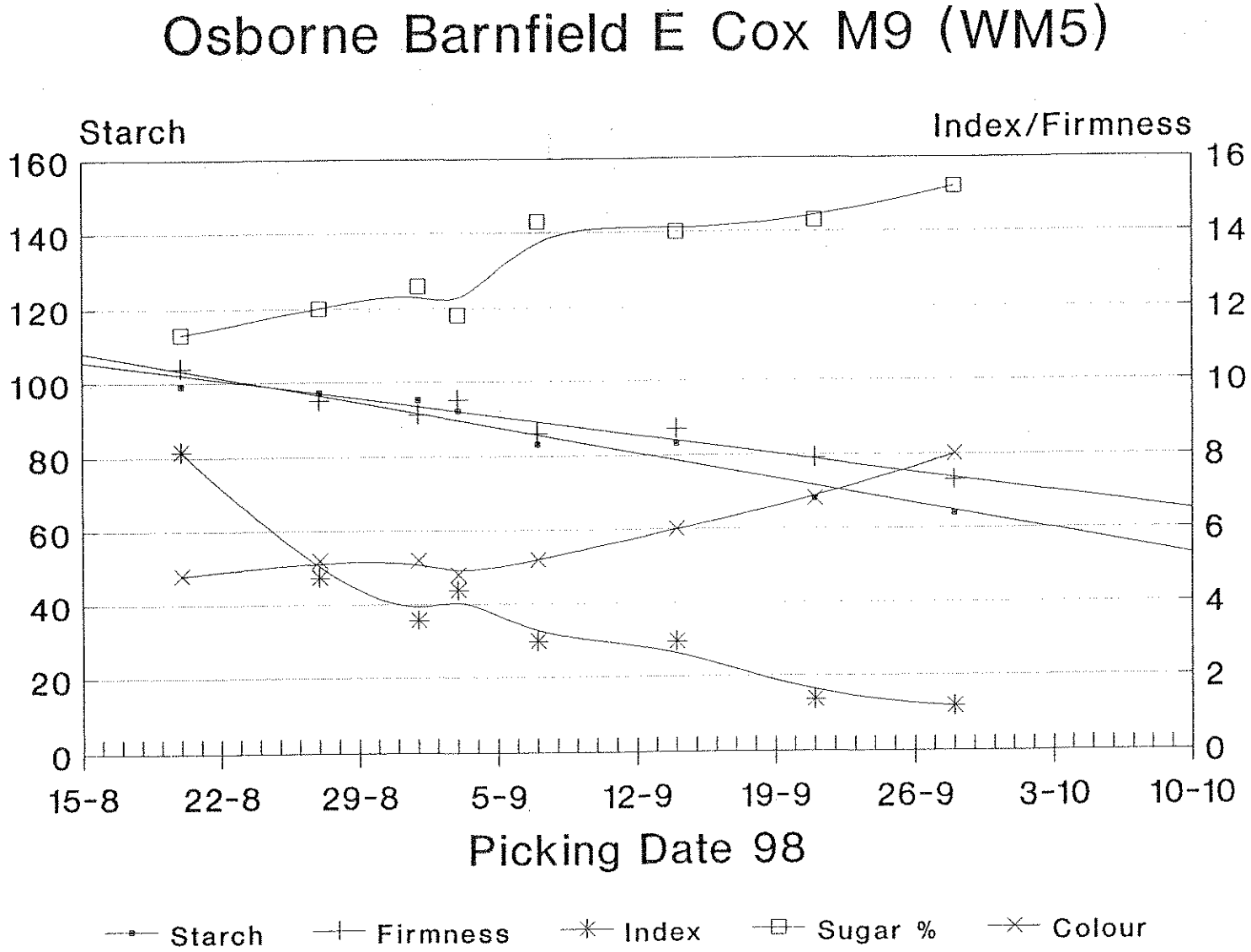
# Charity Farm Flint Cox M9 (SF5)



# Ranworth Farm N Lodge East Cox M9 (N3)

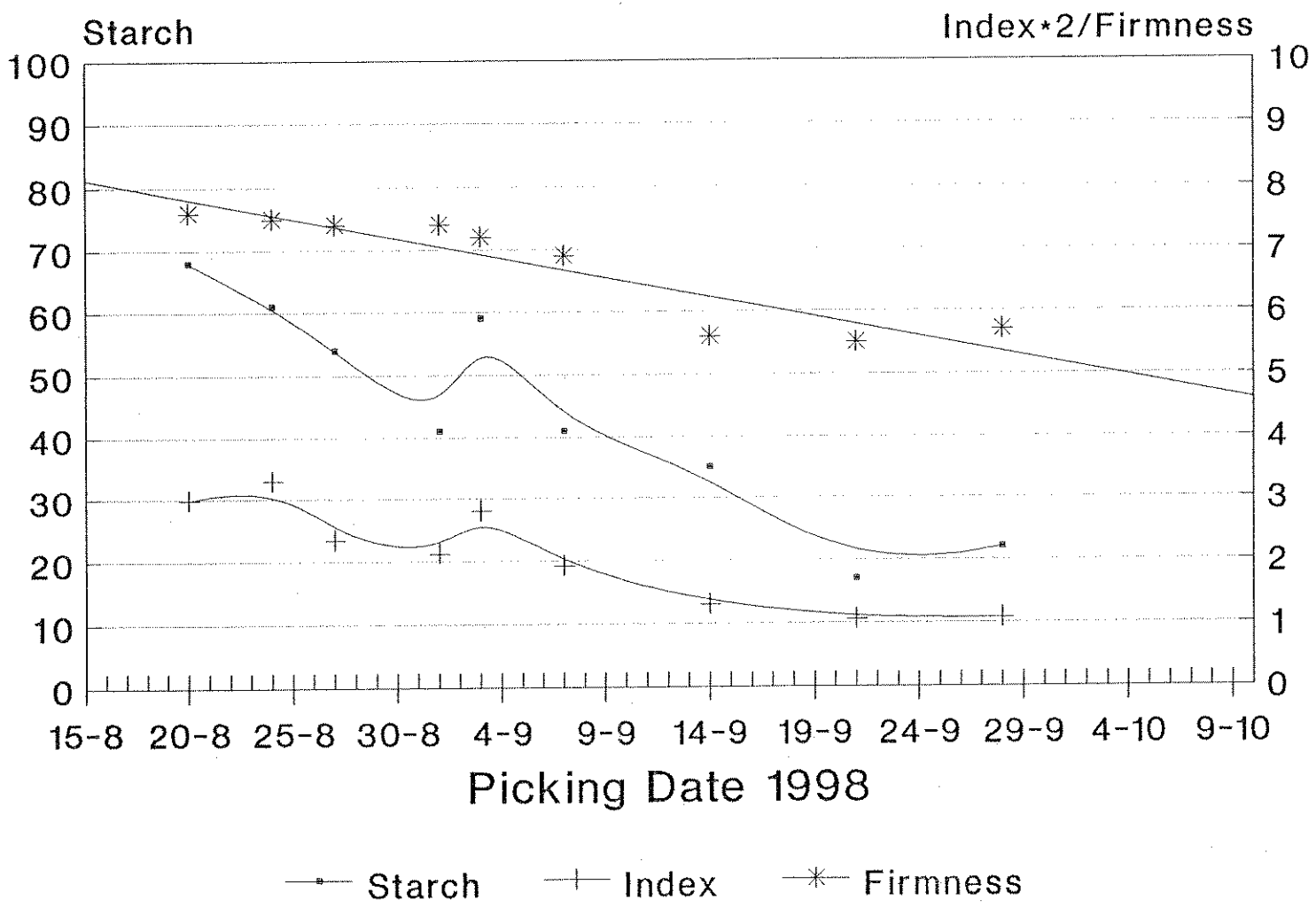


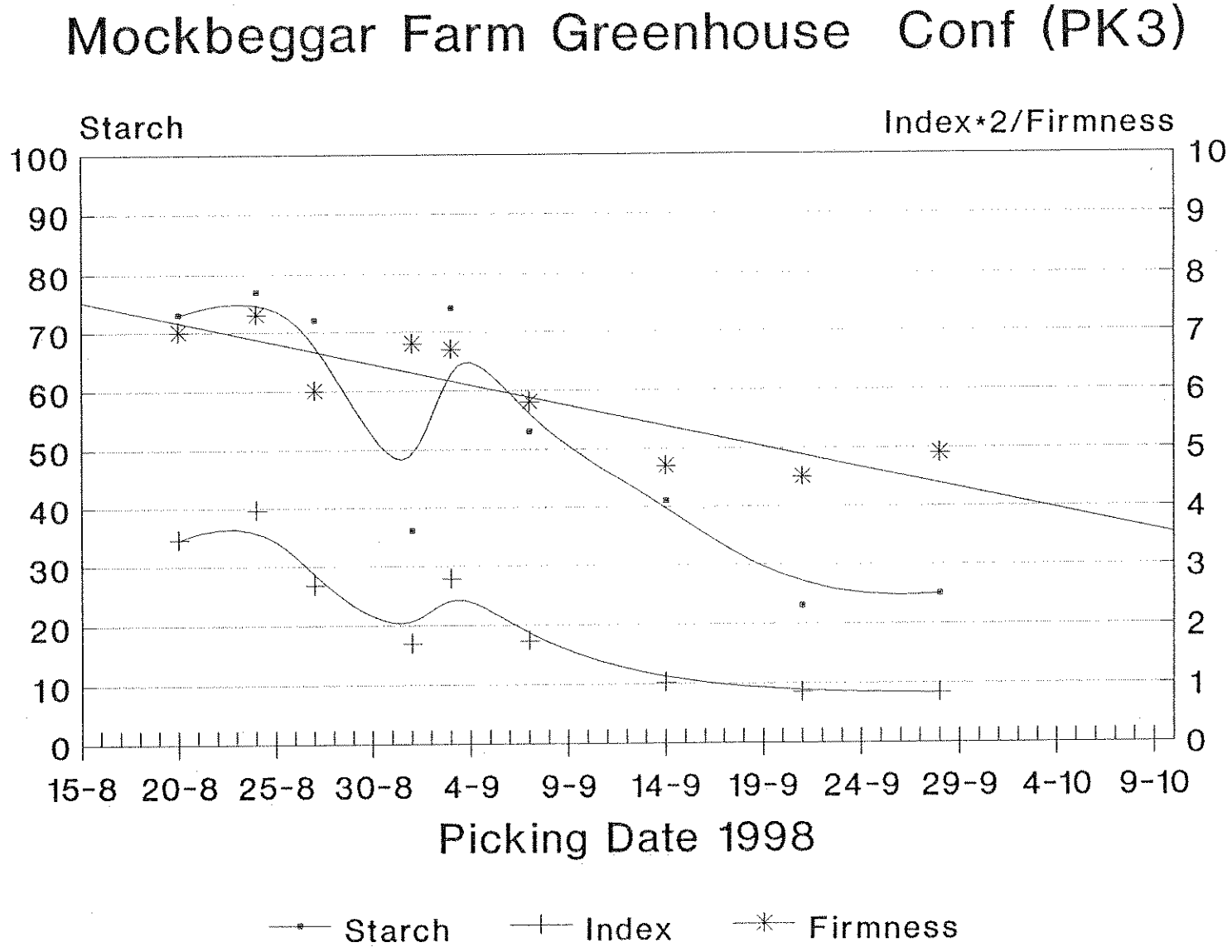

Tongeren Cox 88 A Cox MM106 (WM4)
Starch
Index/Firmness
160
140
120
100
80
60
40
20
0
16
14
12
10
8
6
4
2
0
15-8
22-8
29-8
5-9
12-9
19-9
26-9
3-10
10-10
Picking Date 98
Starch
Firmness
Index
Sugar %
Colour


Osborne Barnfield E Cox M9 (WM5)
Starch
Index/Firmness
160
140
120
100
80
60
40
20
0
16
14
12
10
8
6
4
2
0
15-8
22-8
29-8
5-9
12-9
19-9
26-9
3-10
10-10
Picking Date 98
Starch
Firmness
Index
Sugar %
Colour

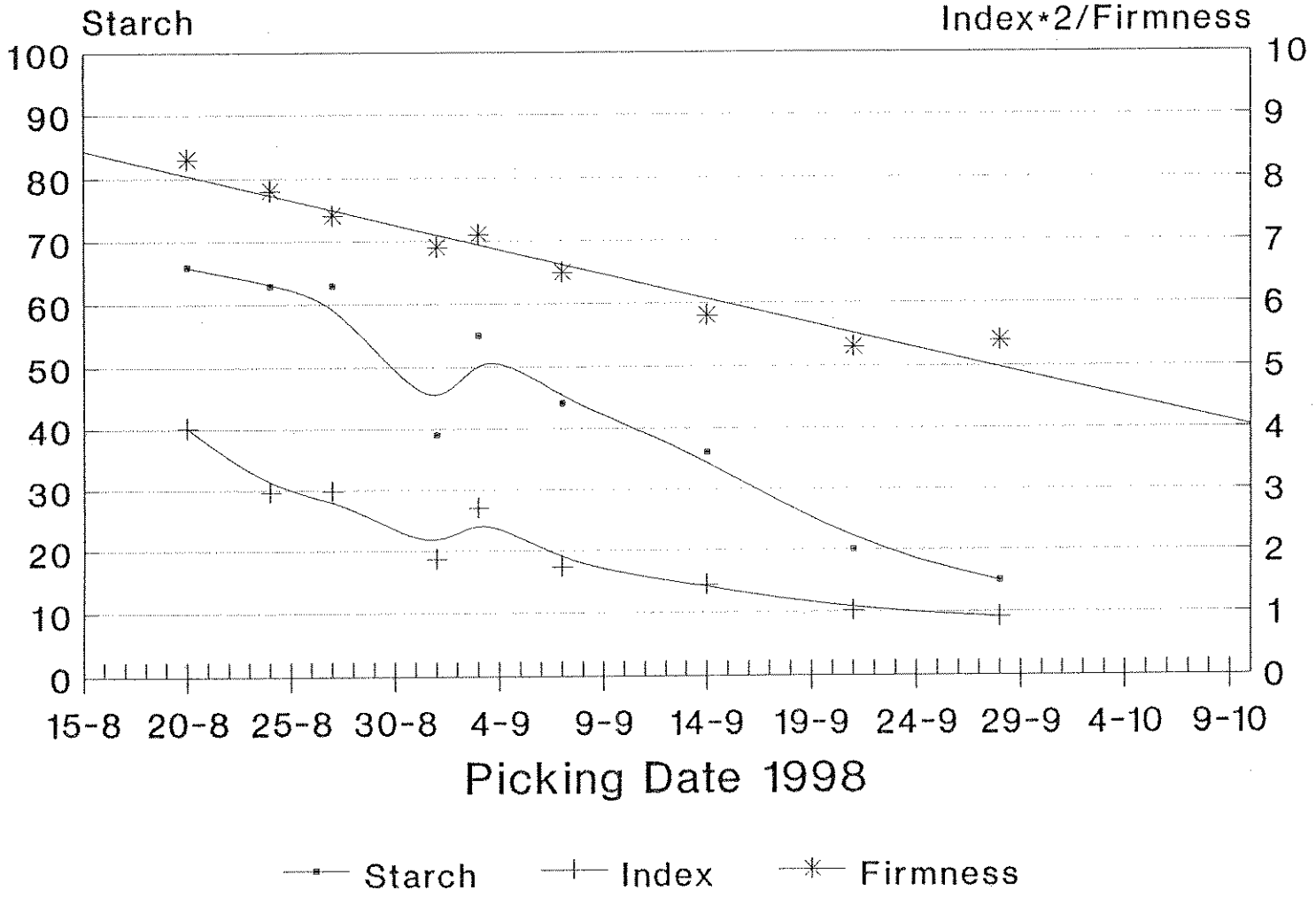
# APPENDIX 2

Graphs of fruit firmness, starch pattern
and maturity index with time for
each of the 5 Conference orchards

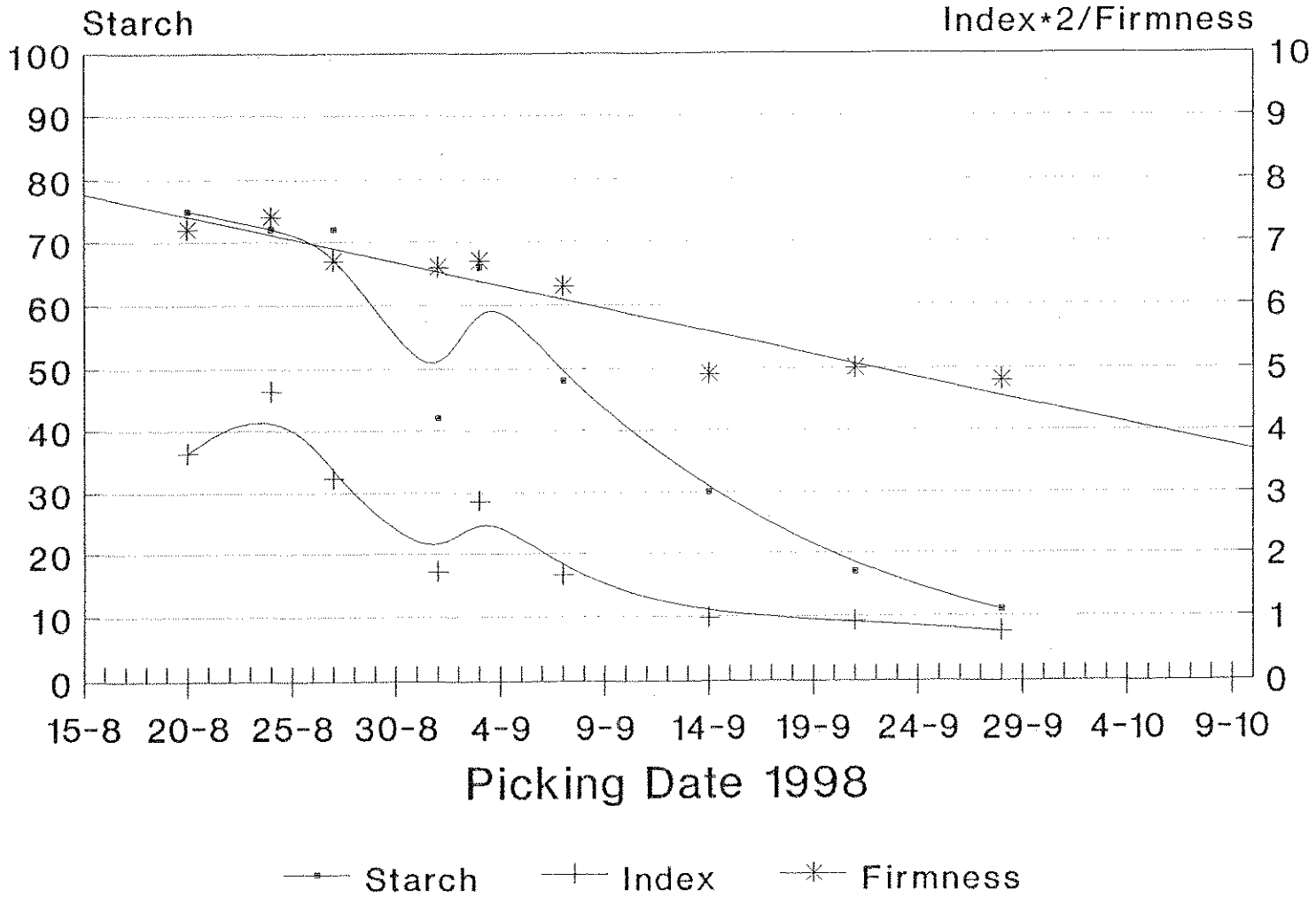

Sherenden Farm Stable Conf (PK1)
Starch
Index*2/Firmness
100
90
80
70
60
50
40
30
20
10
0
10
9
8
7
6
5
4
3
2
1
0
15-8
20-8
25-8
30-8
4-9
9-9
14-9
19-9
24-9
29-9
4-10
9-10
Picking Date 1998
Starch
Index
Firmness

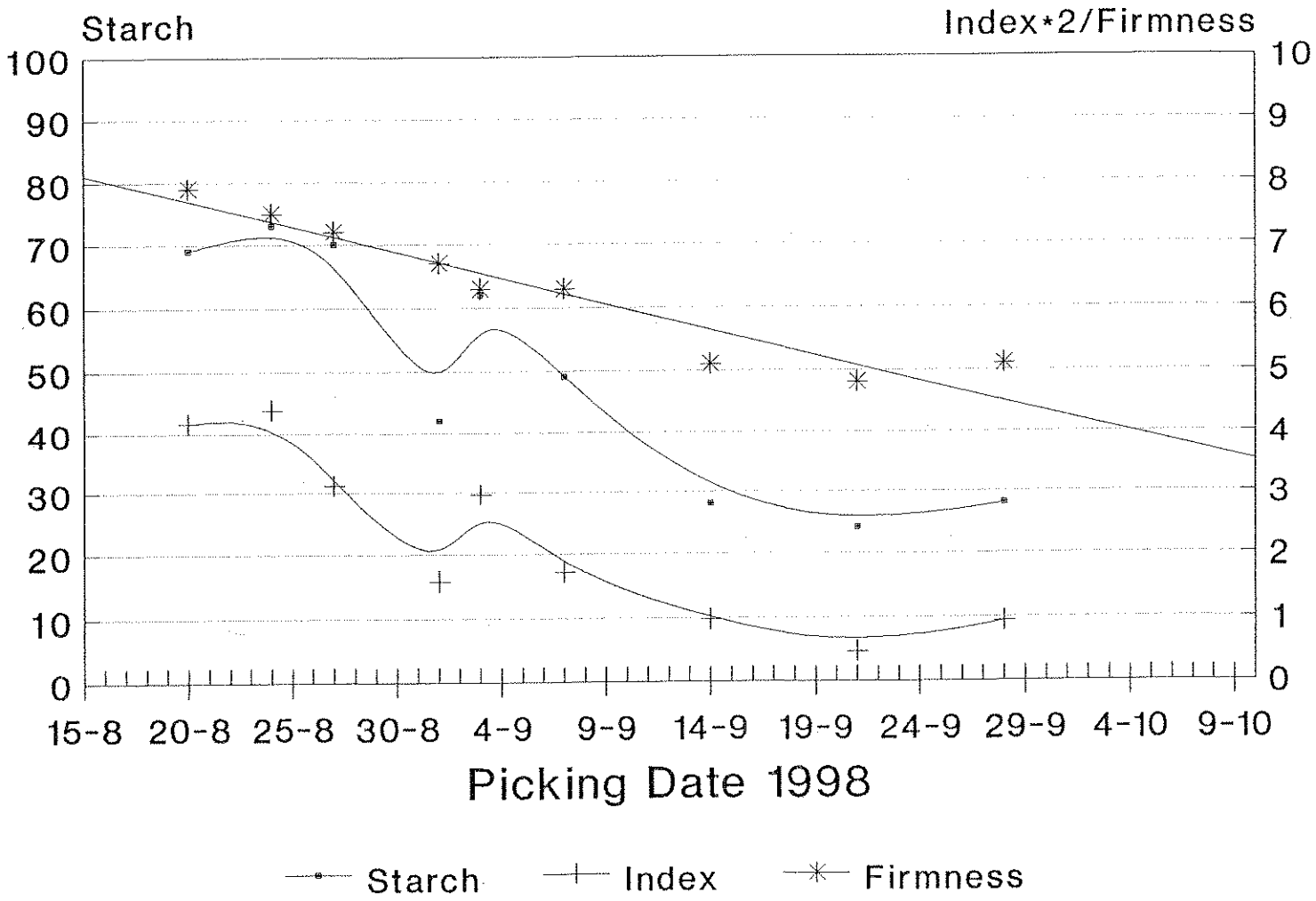

Mockbeggar Farm Greenhouse Conf (PK3)
Starch
Index*2/Firmness
100
90
80
70
60
50
40
30
20
10
0
10
9
8
7
6
5
4
3
2
1
0
15-8
20-8
25-8
30-8
4-9
9-9
14-9
19-9
24-9
29-9
4-10
9-10
Picking Date 1998
Starch
Index
Firmness

# Foxbury Farm Block C Conf (PK4)



# Highland Court Paramour Conf (PK6)




Feltons Farm Hs Conf (PEA2)
Starch
Index*2/Firmness
100
90
80
70
60
50
40
30
20
10
0
10
9
8
7
6
5
4
3
2
1
0
15-8
20-8
25-8
30-8
4-9
9-9
14-9
19-9
24-9
29-9
4-10
9-10
Picking Date 1998
Starch
Index
Firmness

## APPENDIX 3

**Average fruit firmness, background colour and internal condition of fruit after 18 weeks storage in 1.2%$O_2$ and after 10 days shelf life at 18°C, for 10 Cox sites at four different harvest dates**

Quality Fruit Group Maturity Study Storage Data
18 weeks in 1.2% O2

| Storage data 14th January 1999 | Colour 1-4 | Firmness kg | Storage disorders | | | | Shelf Life 10 days at 18C | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site | Pick | mean | mean | rots | pit | wc | sen | rot | pit | wc | sen |
| Bardsley Park West | 1 | 1.6 | 6.8 | 5 | | | | 10 | | | |
| | 2 | 2.2 | 6.7 | | | | | 25 | | | |
| | 3 | 2.7 | 5.8 | 5 | | | | 10 | 5 | | |
| | 4 | 2.7 | 5.7 | | | | | 20 | | | |
| | | | | | | | | | | | |
| Firmin Maytums | 1 | 2.5 | 7.6 | 5 | 5 | | 5 | 15 | 25 | | 5 |
| | 2 | 2.6 | 6.8 | | | | | 5 | 60 | | 5 |
| | 3 | 2.9 | 6.7 | | | | | 5 | 40 | | 10 |
| | 4 | 3.1 | 6.3 | | | | | 20 | 45 | | 5 |
| | | | | | | | | | | | |
| Clews Jubilee | 1 | 2.1 | 7.6 | | | | | | | | |
| | 2 | 2.5 | 7.8 | | | | | | | | 5 |
| | 3 | 2.8 | 7 | | | | | 10 | | | 5 |
| | 4 | 3.4 | 5.8 | | | | | | | | |
| | | | | | | | | | | | |
| Wakley Amber | 1 | 1.6 | 7.1 | | | | | 5 | | | 10 |
| | 2 | 2.4 | 7 | | | 5 | | | | | 5 |
| | 3 | 2.4 | 6.8 | | | | | | | | |
| | 4 | | | | | | | | | | |
| | | | | | | | | | | | |
| Bray A19 | 1 | 1.3 | 7.6 | | | | | | 10 | | |
| | 2 | 1.9 | 7.1 | | | | | 10 | | | 5 |
| | 3 | 2.2 | 6.8 | | | | | 5 | | | |
| | 4 | 2.6 | 6 | 10 | | | | 5 | 5 | | |
| | | | | | | | | | | | |
| Chandler Potts | 1 | 1.8 | 7.4 | 5 | | | | 15 | | | |
| | 2 | 3 | 7.1 | | | | | | | | 5 |
| | 3 | 3.3 | 5.7 | | | | | | | | |
| | 4 | | | | | | | | | | |
| | | | | | | | | | | | |
| Neuteboom Flint | 1 | 1.1 | 6.7 | | | | | 5 | 10 | | |
| | 2 | 1.9 | 7 | | | | | 15 | | | 5 |
| | 3 | 1.4 | 5.8 | 5 | | | | 10 | | | 5 |
| | 4 | 1.6 | 6.1 | | | | | 40 | | | |
| | | | | | | | | | | | |
| Boxford Plains | 1 | 2.5 | 7.8 | | 10 | | | | 55 | | 10 |
| | 2 | 3.1 | 7.2 | | 10 | | | | 55 | | |
| | 3 | 2.7 | 6.8 | 5 | | | | 20 | 60 | | |
| | 4 | 2.9 | 6.2 | 10 | 15 | | | 40 | 40 | | 5 |
| | | | | | | | | | | | |
| Feltons Horseshoe | 1 | 1.5 | 7.8 | | | | | 5 | | | |
| | 2 | 2 | 7.6 | | | | | 10 | | | |
| | 3 | 2.5 | 7 | | | | | 5 | | | 5 |
| | 4 | 3.1 | 7.1 | | 5 | | | | | | 10 |
| | | | | | | | | | | | |
| Ranworth New Lodge | 1 | 2 | 7.8 | | | | | 5 | 10 | | 5 |
| | 2 | 2.4 | 7.4 | | | | | | 20 | | |
| | 3 | 2.3 | 7 | | | | | | 25 | | |
| | 4 | 3.2 | 6.3 | | | | | | 35 | | 10 |

## APPENDIX 4

**Average fruit firmness, background colour and internal condition of fruit after 28 weeks in 1.2%$O_2$ and 10 days shelf life at 18°C for 10 Cox sites at four different harvest dates**

Quality Fruit Group Maturity Study Storage Data
28 weeks at 1.2% O2

| Storage data 19th March 1999 | | Colour 1-4 | | Firmness kg | Storage disorders | | | | Shelf Life 10 days at 18C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Pick | mean | | mean | rots | pit | LTB | sen | rot | pit | LSC | sen/LTB |
| Bardsley Park West | 1 | 1.5 | | 6.7 | 15 | | 10 | | 35 | | | 10 |
| | 2 | 1.5 | | 6 | 5 | | 20 | | 25 | | 15 | |
| | 3 | 2.8 | | 5.8 | 5 | | | | 25 | | | |
| | 4 | 3.3 | | 5.8 | 10 | | | | 10 | | 5 | 5 |
| | | | | | | | | | | | | |
| Firmin Maytums | 1 | 2.3 | | 7.1 | 5 | 35 | 5 | | 20 | | 35 | 20 |
| | 2 | 1.6 | | 6.4 | | 10 | 5 | | 20 | | 70 | 10 |
| | 3 | 2.8 | | 6 | | 25 | | | 5 | | 55 | |
| | 4 | 2.9 | | 6 | 10 | 15 | | | 20 | | 30 | |
| | | | | | | | | | | | | |
| Clews Jubilee | 1 | 1.5 | | 7.7 | 10 | | 10 | | | 5 | 40 | 10 |
| | 2 | 2.3 | | 7 | | | 20 | | | 5 | 45 | |
| | 3 | 3 | | 6.7 | | 5 | | | 15 | 5 | 15 | |
| | 4 | 3.7 | | 5.8 | | 5 | 25 | | 25 | 5 | 15 | |
| | | | | | | | | | | | | |
| Wakley Amber | 1 | 1.5 | | 7 | | 5 | 20 | | | | | |
| | 2 | 2 | | 7.1 | 5 | | 20 | | 15 | | 30 | 20 |
| | 3 | 3.3 | | 6 | | | 20 | | | | 15 | 10 |
| | 4 | | | | | | | | | | | |
| | | | | | | | | | | | | |
| Bray A19 | 1 | 1.3 | | 7.3 | | | | | 10 | | | |
| | 2 | 1.6 | | 7.3 | | 5 | | | 5 | | | |
| | 3 | 2.6 | | 6.3 | 10 | | | | | | 20 | |
| | 4 | 3.2 | | 6.5 | | 5 | | | | | 20 | |
| | | | | | | | | | | | | |
| Chandler Potts | 1 | 2.4 | | 7.1 | | 5 | 5 | | 10 | | 5 | 5 |
| | 2 | 2.4 | | 6.8 | | 10 | 10 | | 5 | | 15 | 5 |
| | 3 | 3.3 | | 5.9 | 10 | | 15 | | | 10 | 5 | |
| | 4 | | | | | | | | | | | |
| | | | | | | | | | | | | |
| Neuteboom Flint | 1 | 1.3 | | 7.2 | | | | | 30 | | | |
| | 2 | 1.4 | | 7.1 | 5 | 5 | | | 40 | | 15 | 15 |
| | 3 | 1.2 | | 6 | 20 | | | | 10 | | | 5 |
| | 4 | 2.2 | | 6.2 | 35 | | 5 | | 40 | | | 5 |
| | | | | | | | | | | | | |
| Boxford Plains | 1 | 2.3 | | 7.7 | | 65 | | | 20 | | 70 | |
| | 2 | 3 | | 7.8 | | 55 | | | | | 65 | |
| | 3 | 2.8 | | 6.4 | 15 | 55 | | | 35 | | 10 | |
| | 4 | 3.8 | | 6.1 | 25 | 45 | | | 20 | | 60 | 5 |
| | | | | | | | | | | | | |
| Feltons Horseshoe | 1 | 1.6 | | 7.6 | 15 | 5 | 15 | | 15 | | | |
| | 2 | 1.8 | | 7.4 | 15 | | 20 | | 25 | | 30 | |
| | 3 | 2.2 | | 6.5 | | | 15 | | | | 25 | |
| | 4 | 2.5 | | 6.8 | 5 | | 15 | | 10 | | 15 | 5 |
| | | | | | | | | | | | | |
| Ranworth New Lodge | 1 | 1.7 | | 7.7 | | 15 | | | | 5 | 5 | |
| | 2 | 2.4 | | 8.1 | | 25 | | | 5 | | 35 | |
| | 3 | 3.4 | | 7.4 | | 35 | | | | 10 | 45 | 10 |
| | 4 | 3.6 | | 6.3 | 10 | 10 | | 10 | 15 | | 15 | |

Quality Fruit Group Maturity Study Storage Data
28 weeks at 1.2% O2

| Storage data 19th March 1999 | | Colour 1-4 | Firmness kg | Storage disorders | | | | Shelf Life 10 days at 18C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Pick | mean | mean | rots | pit | LTB | sen | rot | pit | wc | sen |
| Bardsley Park West | 1 | 1.5 | 6.7 | 15 | | 10 | | | | | |
| | 2 | 1.5 | 6 | 5 | | 20 | | | | | |
| | 3 | 2.8 | 5.8 | 5 | | | | | | | |
| | 4 | 3.3 | 5.8 | 10 | | | | | | | |
| | | | | | | | | | | | |
| Firmin Maytums | 1 | 2.3 | 7.1 | 5 | 35 | 5 | | | | | |
| | 2 | 1.6 | 6.4 | | 10 | 5 | | | | | |
| | 3 | 2.8 | 6 | | 25 | | | | | | |
| | 4 | 2.9 | 6 | 10 | 15 | | | | | | |
| | | | | | | | | | | | |
| Clews Jubilee | 1 | 1.5 | 7.7 | 10 | | 10 | | | | | |
| | 2 | 2.3 | 7 | | | 20 | | | | | |
| | 3 | 3 | 6.7 | | 5 | | | | | | |
| | 4 | 3.7 | 5.8 | | 5 | 25 | | | | | |
| | | | | | | | | | | | |
| Wakley Amber | 1 | 1.5 | 7 | | 5 | 20 | | | | | |
| | 2 | 2 | 7.1 | 5 | | 20 | | | | | |
| | 3 | 3.3 | 6 | | | 20 | | | | | |
| | 4 | | | | | | | | | | |
| | | | | | | | | | | | |
| Bray A19 | 1 | 1.3 | 7.3 | | | | | | | | |
| | 2 | 1.6 | 7.3 | | 5 | | | | | | |
| | 3 | 2.6 | 6.3 | 10 | | | | | | | |
| | 4 | 3.2 | 6.5 | | 5 | | | | | | |
| | | | | | | | | | | | |
| Chandler Potts | 1 | 2.4 | 7.1 | | 5 | 5 | | | | | |
| | 2 | 2.4 | 6.8 | | 10 | 10 | | | | | |
| | 3 | 3.3 | 5.9 | 10 | | 15 | | | | | |
| | 4 | | | | | | | | | | |
| | | | | | | | | | | | |
| Neuteboom Flint | 1 | 1.3 | 7.2 | | | | | | | | |
| | 2 | 1.4 | 7.1 | 5 | 5 | | | | | | |
| | 3 | 1.2 | 6 | 20 | | | | | | | |
| | 4 | 2.2 | 6.2 | 35 | | 5 | | | | | |
| | | | | | | | | | | | |
| Boxford Plains | 1 | 2.3 | 7.7 | | 65 | | | | | | |
| | 2 | 3 | 7.8 | | 55 | | | | | | |
| | 3 | 2.8 | 6.4 | 15 | 55 | | | | | | |
| | 4 | 3.8 | 6.1 | 25 | 45 | | | | | | |
| | | | | | | | | | | | |
| Feltons Horseshoe | 1 | 1.6 | 7.6 | 15 | 5 | 15 | | | | | |
| | 2 | 1.8 | 7.4 | 15 | | 20 | | | | | |
| | 3 | 2.2 | 6.5 | | | 15 | | | | | |
| | 4 | 2.5 | 6.8 | 5 | | 15 | | | | | |
| | | | | | | | | | | | |
| Ranworth New Lodge | 1 | 1.7 | 7.7 | | 15 | | | | | | |
| | 2 | 2.4 | 8.1 | | 25 | | | | | | |
| | 3 | 3.4 | 7.4 | | 35 | | | | | | |
| | 4 | 3.6 | 6.3 | 10 | 10 | | 10 | | | | |

## APPENDIX 5

**Average fruit firmness immediately ex-store and after 2 and 4 days at 18°C together with % fruit showing internal breakdown and fungal spoilage after 10 days at 18°C for 5 individual Conference pear sites**

Table 1 Storage quality of Conference pears after 18 weeks at -1deg C

| Site | Harvest date | Firmness after days at 18 deg C | | | % | % |
|---|---|---|---|---|---|---|
| | | 0 | 2 | 4 | Breakdown | Rot |
| Mitchell | 07-Sep | 5.5 | 5.4 | 2.2 | | |
| | 14-Sep | 5.7 | 4.9 | 2 | | |
| | 21-Sep | 5.1 | 5.6 | 2.4 | | |
| | 28-Sep | 4.8 | 4 | 1.9 | | 12 |
| Feltons | 07-Sep | 4.8 | 4 | 1.7 | | |
| | 14-Sep | 5.1 | 4.2 | 2.1 | | 8 |
| | 21-Sep | 5 | 4 | 2.2 | | |
| | 28-Sep | 4.3 | 4.3 | 1.8 | | 8 |
| Highland Court | 07-Sep | 5.2 | 5.2 | 2 | | 4 |
| | 14-Sep | 4.8 | 5.2 | 1.8 | | |
| | 21-Sep | 4.8 | 3.9 | 1.6 | | |
| | 28-Sep | 4.7 | 3.7 | 1.6 | | 8 |
| Redsell | 07-Sep | 5.6 | 4.8 | 2.1 | | |
| | 14-Sep | 4.3 | 4.3 | 2.2 | | 8 |
| | 21-Sep | 4.8 | 4.7 | 3.2 | | |
| | 28-Sep | 4.3 | 3.7 | 1.8 | | 4 |
| Scripps | 07-Sep | 5.6 | 5.3 | 2.4 | | |
| | 14-Sep | 4.9 | 5 | 1.9 | | |
| | 21-Sep | 4.8 | 5.3 | 2.4 | 4 | 16 |
| | 28-Sep | 5 | 4.3 | 1.9 | 8 | 16 |

Table 2 Storage quality of Conference pears after 28 weeks at -1deg C

| Site | Harvest date | Firmness after days at 18 deg C | | | % | % |
|---|---|---|---|---|---|---|
| | | 0 | 2 | 4 | Breakdown | Rot |
| Mitchell | 07-Sep | 5 | 4.3 | 1.8 | | |
| | 14-Sep | 4.6 | 4.4 | 2.1 | | |
| | 21-Sep | 5 | 3.1 | 1.8 | | 2 |
| | 28-Sep | 4.2 | 3.9 | 2 | | 21 |
| Feltons | 07-Sep | 4.3 | 3.2 | 1.9 | | 2 |
| | 14-Sep | 4.5 | 3.8 | 2.1 | | |
| | 21-Sep | 4.1 | 3.7 | 2.3 | | 4 |
| | 28-Sep | 4 | 3 | 2.2 | | 19 |
| Highland Court | 07-Sep | 5.1 | 4.3 | 2.2 | | |
| | 14-Sep | 4.9 | 3 | 1.9 | | 4 |
| | 21-Sep | 4.2 | 3.3 | 1.8 | | 8 |
| | 28-Sep | 3.9 | 3.2 | 1.6 | | 14 |
| Redsell | 07-Sep | 5 | 4.6 | 2 | | |
| | 14-Sep | 4.7 | 3.7 | 1.8 | | 6 |
| | 21-Sep | 4.3 | 3.2 | 1.7 | | 8 |
| | 28-Sep | 3.7 | 3.1 | 1.5 | | 23 |
| Scripps | 07-Sep | 5.3 | 5 | 2.4 | | |
| | 14-Sep | 4.5 | 4.8 | 2.3 | | 3 |
| | 21-Sep | 4.5 | 5.2 | 2.7 | | |
| | 28-Sep | 4.6 | 3.8 | 2.1 | | 20 |