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Grower Summary

Summary of results & main conclusions for 'Meridian'

A series of trials was carried out from 1999 to 2002 with the objective of identifying the optimum harvest date for the storage of Meridian and to develop preliminary recommendations on storage conditions and likely storage life.

Two sites were chosen to supply fruits for these trials, one in East Kent and the other in Suffolk. The trees in the two orchards were on M.9 rootstock planted in 1996 in single rows. In 2001 additional samples were stored from 3 orchards at HRI-East Malling. Although it was not ideal to perform storage trials on such young trees it was necessary to obtain early indications of storage potential to aid the commercial development of the variety.

In each year fruit was harvested from each orchard on more than one occasion and stored in air and/or controlled atmosphere (CA) storage. There was insufficient funding to allow for a full evaluation of the effects of temperature, elevated carbon dioxide and low oxygen concentrations. Consequently the performance of Meridian in CA conditions used for Cox (<1.0% CO_2 + 1.2% O_2 or <1/1.2) and for Bramley / Gala (5% CO_2 + 1% O_2 or 5/1) were evaluated. The temperature of CA-stored fruit was maintained at 3.5-4.0^{0}C i.e. similar to Cox and in the initial trials air storage was provided at 0^{0}C or 3^{0}C. In 2002 the effects of storing Meridian apples in CA (<1/1.2 and 5/1) at lower storage temperatures (1.5-2.0^{0}C) was investigated.

It is clear from discussions held with marketing groups that the marketing 'slot' anticipated for Meridian is post-Christmas, possibly January or February. One of the difficulties in storing Meridian for this length of time is the lack of firmness. It appears that multiple retailers are unlikely to accept consignments of fruit that register penetrometer readings below 6.5 kg.

The following conclusions from the work carried out over the 4-year period have been drawn up on the basis of these commercial requirements.

Fruit firmness

- Starch pattern and internal ethylene concentration are poor indicators of maturity for harvesting for storage (both change too late to be of practical use). Fruit firmness is likely to be the prime indicator of harvest date. Current advice is to harvest when firmness has declined to 70-75 N (7.1-7.6 kg). Meridian has limited potential (less than 6 weeks) for storage in air at 3ºC. Fruits held at 0ºC remained firmer and developed less bitter pit than fruit stored at 3ºC and have the potential to store for 6 weeks or longer. The quality of fruit stored in air at 1.5ºC was intermediate between that of fruit at 0ºC and 3ºC.
- Firmness of fruit stored in CA (5/1 or <1/1.2) until January was maintained at or above the suggested (supermarket) threshold of 6.5 kg (63.8 N) by harvesting fruit with a firmness value of 7.1 kg (70 N) or above.

- Although storage in a 5/1 or <1/1.2 CA regime at 3.5-4ºC provided adequate firmness in fruit stored until January, only 5/1 provided fruit of the required firmness specification in March.
- Maintaining a lower storage temperature of 1.5-2ºC resulted in a greater retention of firmness in fruits kept in 5/1 and <1/1.2 but the development of low temperature breakdown in the 5/1 regime would preclude the use of the lower storage temperature.
- Fruit kept in the 'Cox-type' CA conditions of <1/1.2 at the lower temperature were as firm as those kept in the more stringent 5/1 regime at the higher temperature.
- It appears that a lower storage temperature may obviate the need for 5/1 storage. This would be beneficial to the UK industry since 'Cox type' (<1/1.2) conditions are more available within the industry.
- More experience is required using the 'Cox type' (<1/1.2) conditions at 1.5-2ºC to ensure that low temperature breakdown will not develop regardless of growing conditions.

Storage disorders

- More experience is required using the 'Cox type' (<1/1.2) conditions at 1.5-2ºC to ensure that low temperature breakdown will not develop regardless of growing conditions.
- Although bitter pit was a serious problem in fruit from the commercial orchards in the first year of the study in the final two years there were no significant amounts of the disorder. This may in part be due to the emphasis given to the use of calcium sprays as a means of preventing the problem and to the expected reduction in susceptibility with increasing age of the trees.
- Although bitter pit was more prevalent in fruit of lower calcium status it appears that the threshold level of calcium for avoidance of calcium-related disorders is higher in Meridian than in Cox. Further work may be required to establish threshold calcium concentration for the optimum storage of Meridian.

Soluble solids

- Soluble solids (sugar) levels in fruit ex-store were generally about 2% higher than at harvest and sufficiently high to provide good eating quality regardless of orchard site and harvest date.

Further testing and evaluation

The threshold level of firmness that provides satisfactory eating quality in Meridian apples has not been established. The impression is that Meridian eats well at a lower penetrometer value than Cox. It is important to establish the required firmness using mechanical tests, as this will affect the time of harvesting and the selection of suitable storage conditions. Any delay in harvesting that can be accommodated and the use of less stringent CA conditions are likely to generally improve eating quality (taste/flavour). Similarly, decisions regarding the marketing 'slot' for Meridian will have major effects on the time of harvest and the type of storage that is required.

Current indications are that the marketing 'slot' for Meridian is in February/March and that the firmness requirement is similar to that for Cox i.e. 6.5 kg (63.8N). The work within TF 117 was geared towards realising this objective. There is a prospect of using storage temperatures lower than for Cox (3.5-4^{o}C). Although low temperature breakdown did not occur in fruit stored in 'Cox type' (<1/1.2) conditions at 1.5-2^{o}C until March there needs to be further years of testing before a change can be made in the storage recommendations. Susceptibility to low temperature breakdown varies from orchard to orchard and from season to season and only after storing fruit from a range of orchards in a number of seasons can the robustness of storage recommendations be truly tested.

Summary of results & main conclusions for E11/20 'Park Farm Pippin'

The fate of E11/20 as a commercial variety was uncertain at the time that the trial work for harvest 2001 was planned.

Subsequently APRC decided not to pursue the release of E11/20 as a commercial variety for a number of reasons, not least its tough skin and indifferent eating quality. Due to its poor eating quality, E11/20 has not been viewed favourably for organic production despite its high degree of disease resistance.

Visual observations conducted on a small number of trees showed stem-end cracking to be a problem on fruit from one site. One commercial grower in East Kent reported that cracking had affected 30% of his fruit. There appears to be some potential for the variety in the amateur sector where it is now marketed as Park Farm Pippin (Marshalls). For whatever purpose envisaged for E11/20, it was considered important to have an idea of its time of ripening on the tree and parameters that may indicate an appropriate time to harvest.

The following conclusions are based on work done in one year (2001) only

- Fruit commenced ripening on the tree on 28th August 2001 as evidenced by a rise in the internal ethylene concentration (IEC).
- In general fruit was very firm directly from tree during the period 17th August to 3rd September 2001.
- There was little change in soluble solids concentration in the fruit over the same period.
- There was virtually no softening in fruit picked in an unripe condition (prior to 28th August) and stored for 7 days at 20°C.
- Fruits picked from 28th August onwards lost significant firmness during 7 days at 20°C. Later picking was generally associated with greater softening.
- Fruit generally remained firm during 2 months of air storage at 0°C.
- There was a marked reduction in the firmness of stored fruit subjected to a further 7 days at 20°C.
- Fruit picked on 31st August and 3rd September were particularly soft but fruit from all picks were insufficiently firm to meet the requirements of the consumer.
- E11/20 has limited storage potential due to its rapid softening ex-store.

No further work on the development of E11/20 was carried out in view of the APRC decision not to pursue its release as a commercial variety.

Experimental Section

I Picking dates and storage conditions trials for Meridian (1999 – 2002)

Background

Meridian has the right attributes to be a successful dessert apple in the market place. Information supplied by the HRI Apple and Pear Breeding Club upon release of Meridian in 1999 focussed on the following important attributes:

- Meridian is well liked by consumers and meets their top three requirements: taste, flavour and quality.
- Meridian fruit is attractive, very juicy with good fruit size.
- In trials, Meridian cropped 30% more than Queen Cox and with more Class 1 fruit.

In order to maximise the commercial potential of Meridian a series of trials was carried out from 1999 to 2002 with the objectives of identifying the optimum harvest date for storage and providing preliminary recommendations on storage conditions and likely storage life.

1999 trial

Experimental

The objective was to harvest fruits at three dates on each site at timings spanning the likely optimum maturity dates. Harvesting began in early September and the last pick was made on the East Kent site on 22 September. Insufficient fruits were available at the Suffolk site to facilitate a third pick. A fourth harvest was undertaken at the East Kent site. A sample of the fruits from each harvest was examined and measurements made of their size (diameter), firmness, starch, soluble solids and internal ethylene concentration. Samples of fruit were stored in air at 0^0C and 3^0C until 16 December 1999 and in CA (<1/1.2 and 5/1) until 8 March 2000. Fruit was examined immediately ex-store and after a simulated marketing period (SMP) of 7 days at 20^0C.

Results

Since full accounts of the results were presented in previous reports to the APRC (see Reports to 30 September 1999 and to 31 March 2000) only a summary of main findings are presented here.

By 1-3 September 1999 fruit size at both sites was large with average diameters of 73-74 mm (Table 1). This was anticipated in view of the young age of the trees. Levels of starch remained very high in fruits from the young trees and not until the fourth pick at the East Kent site did levels fall to below 90%. However, by this time

the harvested fruits were already showing signs of greasiness and firmness had declined to a level appropriate for apples for immediate sale. The levels of internal ethylene remained very low in all the samples harvested. Apples with an internal ethylene concentration (IEC) above 100 ppb that also show a sustained increase are normally considered to be ripening. Soluble solids concentration in the juice increased progressively with harvest delay. Neither starch coverage nor IEC were suitable indicators of optimum picking date for this variety.

Table 1. Size and harvest maturity assessments made on Meridian apples harvested from two sites during September 1999.

Site	Pick date	Mean fruit weight (g)	Mean fruit diameter (mm)	Firmness (N)	Sol. solids (%)	Starch (%)	Internal ethylene conc. (ppb)
Suffolk	3/9	169	74	70.7	11.5	95	46
	10/9	171	75	74.8	12.2	88	93
E. Kent	1/9	169	73	70.9	12.7	97	86
	8/9	182	76	68.8	13.2	91	89
	15/9	195	77	69.4	14.0	90	25
	22/9	209	79	65.7	13.8	76	91

Current indications are that Meridian apples need to be as firm as Cox apples at the point of sale i.e. 6.5 kg or 63.8 N (11 mm probe) and that the marketing 'slot' is likely to be February or March. Clearly the ability of Meridian apples to retain firmness in store will be crucial to its commercial development. Fruit stored in air at 3^0C until 16 December was too soft with an average firmness of only 48 N (4.9 kg) (see Reports to 31 March 2000). Storing in air at 0^0C improved firmness to 59 N (6 kg) but fruit was affected by low temperature breakdown. Fruit from the East Kent orchard stored in CA was insufficiently firm in March 2000. Firmness declined with delay in picking. The first pick of fruit from the Suffolk orchard was sufficiently firm after CA storage. Fruit from both orchards softened slowly during a further 7 days at 20^0C.

Although the soluble solids contents were lower in fruit harvested early (Table 1) the further conversion of starch to sugar during storage resulted in high concentrations (approximately 15%) of soluble solids in fruits after storage regardless of pick date and storage regime.

Stored fruit were highly susceptible to bitter pit which was not surprising in view of the young age of the trees and the large size of the fruit. The ranges in mean diameter of fruit from East Kent and Suffolk were 73-79 and 74-75 mm respectively.

The average incidences of bitter pit in the fruits from the different orchards and storage condition treatments are shown in Table 2. Fruits from the East Kent orchard were more affected than those from the Suffolk orchard. As expected fruits worst affected were those stored in air at 3^0C. Although bitter pit development in air-stored fruit was retarded by lowering the store temperature to 0^0C this induced low

temperature breakdown in the fruit. CA storage retarded the development of bitter pit particularly the 5/1 regime. Surprisingly there was no increase in bitter pit incidence during the simulated marketing period.

Table 2. Average incidence (%) of bitter pit in Meridian fruits harvested in 1999.

	East Kent		Suffolk	
	Ex-store	+7 days at 20^0C	Ex-store	+7 days at 20^0C
Air 3^0C	46	46	11	13
Air 0^0C	15	15	2	3
CA 5/1 3.5-4^0C	21	18	3	0
CA <1/1.2 3.5-4^0C	29	28	8	3

Other than bitter pit there were few other physiological disorders in the stored fruit. Some of the late-picked fruit from the East Kent orchard developed core flush and also CO_2 injury when stored in the 5/1 regime.

Conclusions from 1999 trial

On this preliminary evidence fruit firmness seemed to be the best indicator of optimum harvest date for Meridian in 1999. Harvesting at a firmness of 70-75 N (7.1-7.6 kg) gave the most acceptable firmness ex-store albeit not always sufficient to meet market requirements. Neither of the air storage regimes was successful with Meridian in 1999. At 3^0C short-term storage is only likely to be possible. Reduction in temperature was particularly beneficial for air-stored fruit but low temperature breakdown was problematic in December. Further work is required to identify the maximum storage periods for air-stored fruit at different storage temperatures. The two types of CA regime gave similar results for firmness ex-store but only fruit from the Suffolk orchard achieved the commercial firmness threshold. Orchard site may be an important factor in determining the acceptability of quality from store. The 5/1 regime was preferred on the basis of a greater effect in retarding bitter pit development. Bitter pit was a major problem in the fruit from both orchards despite the use of stringent CA conditions. Clearly there is a need to consider pre-harvest factors in order to minimise bitter pit potential in the fruit. A comprehensive programme of calcium sprays is advised in combination with a pre-harvest fruit mineral analysis to ascertain the risk of bitter pit. It is expected that bitter pit potential will reduce as the trees come into more regular cropping and the trees become more balanced as regards growth and cropping.

2000 trial

Experimental

Investigations of the effects of harvest date and storage conditions on the ex-store quality of Meridian apples continued using the same orchards as in 1999. The first picks of fruit from the East Kent and Suffolk orchards was on 6 and 8 September 2000 respectively and coincided with a fruit firmness value of 67-69 N (6.8-7 kg) (Table 3). A second pick was made 9 days later. Fruit was stored in air at 0, 1.5 and 3.0°C and assessed for quality on 31 October and 28 November 2000. It was clear from the trial done in 1999 that air storage into December was not possible since fruit was too soft at 3.0°C and developed low temperature breakdown at 0°C. Fruit was also stored in the same CA regimes used in the previous year i.e. <1%CO_2 + 1.2% O_2 (<1/1.2) and 5% CO_2 + 1% O_2 (5/1) at 3.5-4°C and examined on 9 January 2001 and 12 March 2001.

Table 3. Size and harvest maturity assessments made on Meridian apples harvested from two sites during September 2000.

Site	Picking date	Mean fruit weight (g)	Mean fruit diameter (mm)	Firmness (N)	Soluble solids (%)	Starch (%)
Suffolk	8/9	127.4	67.4	73.8	11.7	94.5
	17/9*	143.2	70.8	65.4	13.2	75.5
East Kent	6/9	135.8	69.2	69.2	13.3	92.5
	15/9	144.8	70.4	66.6	13.4	92.0

* Fruit harvested on 17/9/00 and assessed on 22/9/00

Results

Since full accounts of the results were presented in previous reports to the APRC (see Reports to 30 September 2000 and to 31 March 2001) only a summary of main findings are presented here.

Air storage

As found in the previous year fruit stored at 3°C softened rapidly so that firmness was unacceptable (54-57 N or 5.5-5.8 kg) by the end of October (Table 4). Major benefits in maintaining firmness were achieved by storing at lower temperatures. To achieve a firmness of 6.5 kg (63.8N) at the end of October early picking and storage at 0°C was necessary in samples harvested in 2000. If the firmness requirement by the retailers was relaxed slightly to say 6 kg (58.9 N) then storage at 1.5°C would have provided suitable fruit at the end of October and storage at 0°C could have been extended to the end of November. No symptoms of low temperature breakdown were observed unlike in the previous year when fruit stored at 0°C until mid December were affected slightly by this disorder.

Table 4. Influence of picking date and storage temperature on the firmness (N) of Meridian apples stored in air.

		31 October 2000			28 November 2000		
Site	Pick date	0°C	1.5°C	3°C	0°C	1.5°C	3°C
Suffolk	8/9	65	62	57	59	53	50
	17/9	62	59	56	57	53	49
East Kent	6/9	63	58	54	59	52	49
	15/9	62	58	56	57	51	48

Bitter pit was less of a problem in air-stored fruit than in the previous year and generally only affected fruit from the East Kent orchard. The lower susceptibility of fruit to bitter pit in 2000 was likely to be related to the smaller fruit size. Comparing fruit harvested on similar calendar dates in the 2 years showed a reduction in mean fruit weight of 44-46 g and in mean fruit diameter of 7-8 mm. In general the concentration of calcium in fruits increases with reduced mean fruit weight. There was little effect of harvest date on bitter pit incidence but as expected the development of the disorder was retarded by lower storage temperatures (Table 5). Clearly, for maintaining quality (firmness) and preventing bitter pit the preferred temperature is 0°C. Storing at 0°C as opposed to 3°C (data not presented) did not compromise the increase in soluble solids concentration during storage.

Table 5. Influence of picking date and storage temperature on the incidence (%) of bitter pit in Meridian apples stored in air.

		31 October 2000			28 November 2000		
Site	Pick date	0°C	1.5°C	3°C	0°C	1.5°C	3°C
Suffolk	8/9	0	0	3	0	0	0
	17/9	3	0	3	0	0	0
East Kent	6/9	5	10	15	3	20	15
	15/9	3	5	13	8	8	28

CA storage

Fruit stored in the 5/1 atmosphere was firmer than that stored in <1/1.2 (Table 6). This was not the case in the previous year. To achieve an ex-store firmness of 6.5 kg (63.8 N) required 5/1 storage and in the East Kent orchard early harvesting of the fruit was also necessary. Firmness acceptability of fruit from the <1/1.2 atmosphere was marginal in January and unacceptable (59 N (6 kg) or less) in March.

Table 6. Influence of picking date and storage temperature on the firmness (N) of Meridian apples stored in CA conditions of <1%CO_2 + 1.2% O_2 (<1/1.2) and 5% CO_2 + 1% O_2 (5/1) at 3.5-4^oC.

		9 January 2001		12 March 2001	
Site	Pick date	5/1	<1/1.2	5/1	<1/1.2
Suffolk	8/9	67	63	65	57
	17/9	64	62	67	56
East Kent	6/9	63	61	63	59
	15/9	60	59	60	57

There was no clear indication of an effect of CA regime on bitter pit incidence although as expected the level of pitting was generally worse in the fruit examined in March (Table 7).

Table 7. Influence of picking date and storage temperature on the incidence (%) of bitter pit in Meridian apples stored in CA conditions of <1%CO_2 + 1.2% O_2 (<1/1.2) and 5% CO_2 + 1% O_2 (5/1) at 3.5-4^oC.

		9 January 2001		12 March 2001	
Site	Pick date	5/1	<1/1.2	5/1	<1/1.2
Suffolk	8/9	0	0	0	0
	17/9	0	0	0	0
East Kent	6/9	10	3	17	3
	15/9	3	13	20	18

Conclusions from 2000 trial

- It was confirmed that fruit has limited potential (less than 6 weeks) for storage in air at 3°C. Fruits held at 0°C remained firmer and developed less bitter pit than fruit stored at 3°C and have the potential to store for 6 weeks or longer. The quality of fruit stored in air at 1.5°C was intermediate between that of fruit at 0°C and 3°C.
- To achieve the desired firmness level in CA-stored fruit required an atmosphere 5% CO_2 + 1% O_2 particularly where storage was extended to March. Early picking again proved essential to ensure adequate firmness in stored fruits particularly for those stored in CA conditions.
- Penetrometer readings may provide the best indicators of optimum harvest date. The firmest fruit ex-store were those picked with a firmness of 69-74 N (7.0-7.5 kg).
- The second pick of fruit from the Suffolk orchard was firmer ex-store than was expected from the harvest firmness. However the harvest measurements were delayed to 5 days after picking and as a consequence the fruit would have been judged more mature than it was at the time of harvest.

2001 trial

Experimental

Fruit was harvested from 5 sites on 5-7 September 2001. This provided a range in harvest firmness values (Table 8) that could be correlated with ex-store firmness. Indications from the first 2 years of the project were that a harvest firmness of at least 7 kg (69 N) is required in order to achieve the minimum ex-store firmness of 6.5 kg (63.8 N) that is demanded by retailers.

Table 8. Effect of picking date in September 2001 on harvest maturity parameters of Meridian apples from orchards in East Kent, Suffolk and HRI-East Malling. Firmness measured with an automated penetrometer; starch pattern determined using the Ctifl chart (1-black, 10-white), soluble solids measured using a refractometer and internal ethylene concentration (IEC) measured by gas chromatography.

Pick date	5/9	6/9	7/9	7/9	7/9
Orchard	E Kent	Suffolk	HRI (CE)	HRI (DM)	HRI (EE)
Firmness (N)*	67.9	71.5	67.1	76.5	71.2
Starch (1-10)	1.6	1.9	3.7	1.7	1.6
Soluble solids (%)	12.3	11.5	11.4	12.1	12.5
IEC (ppb)	3	1	13	80	25
IEC (% >100 ppb)	0	0	0	20	10

* Firmness in kg can be derived approximately by dividing Newtons (N) by 10 (1kg = 9.81N).

Fruit was stored in the same CA regimes (5% CO_2 and 1% O_2, <1% CO_2 and 1.2% O_2 at 3.5^{o}C) as used in the previous years of the project and removed for examination on 14 January and 1 March 2002. Immediately after removal from store the samples were weighed prior to measurement of the firmness of the fruit and of the soluble solids concentration of the juice. The fruits were then cut and examined for the presence of bitter pit and other internal disorders. An additional set of samples was placed into a room at 20^{o}C for 7 days and then assessed as described for fruit immediately ex-store.

Results

Since full accounts of the results were presented in previous reports to the APRC (see Reports to 30 September 2001 and to 31 March 2002) only a summary of main findings are presented here.

Fruit firmness

The firmness of fruits stored in CA conditions until January was generally at or above the 6.5 kg (63.8 N) threshold normally imposed by multiple retailers on other dessert cultivars such as Cox (Tables 9 and 10). There was little difference between the <1/1.2 and 5/1 CA regimes as regards firmness of fruit immediately ex-store and after a further 7 days at 20°C. Samples that were firmer at harvest were firmer ex-store and the recommendation to harvest above a firmness of 7 kg (69 N) was generally confirmed. Fruit in CA storage continued to soften between January and March albeit at a slow rate. By March there was a clear benefit of storing in the 5/1 regime as opposed to <1/1.2 (Tables 11 and 12). Fruit stored in the former regime was on average 5.5 N (0.6 kg) firmer. As in January there was a good relationship between harvest and ex-store firmness and again the requirement for a minimum firmness at harvest of 69 N (7 kg) was endorsed. It appears that for March marketing 5/1 storage is required in addition to harvesting above 7 kg firmness. However if the eating texture of Meridian is considered acceptable at penetrometer values below 64 N then there is scope for using 'Cox' type storage which is generally more available.

Table 9. The effect of orchard site on mean weight (g), firmness (N), soluble solids concentration (%) and incidence of bitter pit in Meridian apples picked on 5-7 September 2001 and stored in an atmosphere of 5% CO_2 + 1% O_2 (balance nitrogen) at 3.5°C until 14 January 2002. Figures in brackets refer to fruit kept for a further 7 days at 20°C to simulate a marketing period.

Picking date	5/9	6/9	7/9	7/9	7/9
Orchard	E Kent	Suffolk	HRI (CE)	HRI (DM)	HRI (EE)
Mean fruit wt.(g)	130.4	143.6	125.3	159.1	132.8
Firmness (N)*	64.7 (57.5)	67.6 (59.5)	62.5 (58.8)	71.3 (60.9)	67.7 (58.6)
Soluble solids (%)	14.2 (13.5)	13.1 (13.4)	13.1 (12.6)	14.9 (14.6)	14.9 (14.7)
Bitter pit (%)	0 (0)	0 (5)	20 (16)	50 (55)	15 (37)

*Firmness in kg can be derived approximately by dividing Newtons (N) by 10 (1 kg = 9.81N).

Table 10. The effect of orchard site on mean weight (g), firmness (N), soluble solids concentration (%) and incidence of bitter pit in Meridian apples picked on 5-7 September 2001 and stored in an atmosphere of <1% CO_2 + 1.2% O_2 (balance nitrogen) at 3.5°C until 14 January 2002. Figures in brackets refer to fruit kept for a further 7 days at 20°C to simulate a marketing period.

Picking date	5/9	6/9	7/9	7/9	7/9
Orchard	E Kent	Suffolk	HRI (CE)	HRI (DM)	HRI (EE)
Mean fruit wt.(kg) post store	131.2	134.7	125.6	161.2	132.0
Firmness (N)*	64.0 (59.3)	64.8 (58.9)	64.3 (61.9)	71.1 (63.5)	65.6 (57.4)
Soluble solids (%)	14.1 (14.2)	13.2 (13.0)	13.7 (13.2)	15.3 (15.1)	14.8 (14.4)
Bitter pit (%)	0 (0)	5 (0)	45 (40)	65 (90)	70 (75)

*Firmness in kg can be derived approximately by dividing Newtons (N) by 10 (1 kg = 9.81N).

Table 11. The effect of orchard site on mean weight (g), firmness (N), soluble solids concentration (%) and incidence of bitter pit in Meridian apples picked on 5-7 September 2001 and stored in an atmosphere of 5% CO_2 + 1% O_2 (balance nitrogen) at 3.5°C until 1 March 2002. Figures in brackets refer to fruit kept for a further 7 days at 20°C to simulate a marketing period.

Picking date	5/9	6/9	7/9	7/9	7/9
Orchard	E Kent	Suffolk	HRI (CE)	HRI (DM)	HRI (EE)
Mean fruit wt.(g)	130.9	141.1	125.6	164.4	132.3
Firmness (N)*	63.0 (57.0)	65.7 (57.5)	63.1 (58.2)	69.5 (61.1)	65.4 (56.5)
Soluble solids (%)	14.0 (13.3)	13.3 (13.0)	13.1 (12.5)	15.4 (14.8)	14.5 (14.2)
Bitter pit (%)	0 (0)	0 (0)	11 (16)	68 (80)	40 (35)

*Firmness in kg can be derived approximately by dividing Newtons (N) by 10 (1 kg = 9.81N).

Table 12. The effect of orchard site on mean weight (g), firmness (N), soluble solids concentration (%) and incidence of bitter pit in Meridian apples picked on 5-7 September 2001 and stored in an atmosphere of <1% CO_2 + 1.2% O_2 (balance nitrogen) at 3.5°C until 1 March 2002. Figures in brackets refer to fruit kept for a further 7 days at 20°C to simulate a marketing period.

Picking date	5/9	6/9	7/9	7/9	7/9
Orchard	E Kent	Suffolk	HRI (CE)	HRI (DM)	HRI (EE)
Mean fruit wt.(g)	131.1	141.9	128.7	158.3	131.3
Firmness (N)*	58.7 (57.2)	61.0 (56.5)	63.3 (59.7)	65.4 (61.0)	59.9 (55.5)
Soluble solids (%)	13.6 (14.0)	13.0 (12.9)	13.5 (13.4)	15.0 (14.6)	14.1 (13.6)
Bitter Pit (%)	0 (0)	5 (10)	42 (61)	68 (75)	65 (80)

*Firmness in kg can be derived approximately by dividing Newtons (N) by 10 (1 kg = 9.81N).

Soluble solids concentration

The average soluble solids concentration at harvest was 12.0% (Table 8). Further conversion of starch to sugar during storage resulted in an increase in soluble solids concentration of about 2%. There was generally no effect of CA conditions, storage duration or a simulated marketing period on the concentration of soluble solids (data not presented).

Bitter pit

Bitter pit was a problem in fruit from the HRI orchards presumably due to the young age of the trees and the absence of calcium sprays (Tables 9-12). The commercial orchards (Suffolk and East Kent) were generally free of bitter pit and it was confirmed that these more mature orchards had received routine application of calcium sprays. Mineral analysis of fruit from these orchards provided by WWF indicated levels of calcium (4.8-5 mg $100g^{-1}$) that would be regarded as satisfactory for Cox (data not presented). Clearly Meridian apples from young trees are likely to be particularly susceptible to bitter pit and it is advised that growers arrange for a mineral analysis of their fruits prior to harvest to estimate storage potential. For the time being it may be appropriate to use the calcium and potassium standards recommended for Cox. The 5/1 CA regime was more effective than <1/1.2 in reducing bitter pit incidence. Bitter pit incidence increased only slightly between January and March and similarly during a 7-day period at 20°C subsequent to CA storage.

Conclusions from 2001 trial

- Firmness of CA-stored fruit was maintained at or above the suggested (supermarket) threshold of 64 N (6.5 kg) by harvesting fruit with a firmness value of 69 N (7 kg) or above.
- Storage in a 5/1 or <1/1.2 CA regime at 3.5^{o}C provided adequate firmness in fruit stored until January but 5/1 was necessary to provide fruit to the required firmness specification in March.
- Bitter pit is potentially an important disorder of Meridian but hopefully as trees mature and with appropriate orchard management the problem can be resolved.
- Soluble solids (sugar) levels in fruit ex-store were sufficiently high to provide good eating quality.

2002 Trial

Having established the criterion for harvesting Meridian to achieve the required firmness ex-store it was decided to evaluate the potential benefit of storing Meridian in CA conditions at lower temperatures. Clearly any benefit in terms of fruit firmness would be particularly significant and may allow a slight delay in harvest to achieve higher eating quality ex-store. Lower storage temperatures may obviate the need for 5/1 storage. It would be beneficial if 'Cox type' (<1/1.2) conditions proved sufficient for the storage of fruit until February as facilities for this type of storage are more available within the industry. In experiments carried out in 1999 and 2000 firmness of air-stored fruit was retained more effectively at lower storage temperatures but low temperature breakdown occurred at 0ºC after 3 months.

Experimental

Meridian apples were harvested on 2 occasions from the same two sites in East Kent and Suffolk that were used as sources of fruit for storage experiments carried out in 1999, 2000 and 2001. Although according to the starch and ethylene data the fruit from both sites and picks were unripe the firmness was just above the 7 kg (69 N) required for long-term storage (Table 13). Fruit was stored in 5/1 and <1/1.2 regimes at storage temperatures of 1.5-2ºC and 3.5-4ºC. Fruit samples were removed from store on 7 January and 4 March 2003. Immediately after removal the samples were weighed prior to measurement of the firmness of the fruit and of the soluble solids concentration of the juice. The fruits were then cut and examined for the presence of internal disorders such as bitter pit and low temperature breakdown. An additional set of samples was placed into a room at 20ºC for 7 days and then assessed as described for fruit immediately ex-store.

Table 13. Effects of picking date in September 2002 on harvest maturity parameters of Meridian apples from orchards in East Kent and Suffolk. Firmness measured with an automated penetrometer; starch coverage determined using the iodine test, soluble solids measured using a refractometer and internal ethylene concentration measured by gas chromatography.

Site	Soluble solids (%)	Starch (% black)	Firmness (N)	Firmness (Kg)	Internal ethylene concentration* (ppb)
East Kent					
1st pick 2/9/02	12.2	100	73.9	7.5	26.3
2nd pick 9/9/02	12.7	96	73.0	7.4	51.6
Suffolk					
1st pick 3/9/02	11.3	100	72.0	7.3	18.5
2nd pick 10/9/02	11.9	98	70.4	7.2	16.1

* Ripening threshold approximately 100 ppb

Results

Since full accounts of the results were presented in previous reports to the APRC (see Reports to 30 September 2002 and to 31 March 2003) only a summary of main findings are presented here.

Fruit firmness

Generally all fruit achieved the desired level of firmness (6.5 kg or 63.8N) when stored until January regardless of orchard site, picking date and storage conditions (Table 14). However, when storage at the higher (recommended) temperature was extended to March only fruit stored in the 5/1 regime achieved the required firmness. The firmness of fruit from both orchards and both picking dates stored in 5/1 at 3.5-4^{o}C until March was 6.5 kg (63.8N) or above. Reducing the storage temperature to 1.5-2^{o}C generally improved the firmness of fruit held in both the 5/1 and <1/1.2 regimes until January and March particularly in fruit held for a further 7 days at 20^{o}C. Most importantly the firmness of fruit held in the <1/1.2 regime at the lower temperature until March was 6.5 kg (63.8N) or above regardless of orchard site or picking date.

Table 14. The effect of picking date and storage conditions on the firmness (N) of Meridian apples from orchards in Suffolk and East Kent. Fruit samples were stored in an atmosphere of 5% CO_2 + 1% O_2 or <1% CO_2 + 1.2% O_2 (balance nitrogen) until 7 January and 4 March 2003. Figures in brackets refer to fruit kept for a further 7 days at 20^{o}C to simulate a marketing period (SMP). Picks 1 and 2 refer to fruit picked on 2/3 and 9/10 September 2002 respectively. Shaded areas indicate where ex-store firmness was at or above the required threshold of 63.8N (6.5kg).

Orchard	Pick	CO_2 / O_2	January*		March	
			3.5-4^{o}C	1.5-2^{o}C	3.5-4^{o}C	1.5-2^{o}C
Suffolk	1	<1/1.2	65.5 (63.4)	66.8 (72.7)	56.2 (52.0)	64.3 (60.1)
		5/1	69.4 (65.3)	69.5 (71.6)	65.6 (56.8)	68.8 (63.7)
	2	<1/1.2	63.1 (63.6)	65.2 (70.7)	51.9 (50.3)	63.9 (59.8)
		5/1	66.3 (66.4)	67.4 (70.9)	64.9 (58.3)	65.4 (63.0)
East Kent	1	<1/1.2	67.5 (65.6)	67.8 (71.8)	61.3 (58.6)	66.9 (63.3)
		5/1	67.8 (63.8)	67.7 (72.9)	66.1 (58.9)	69.4 (63.3)
	2	<1/1.2	65.4 (63.1)	66.6 (67.3)	58.3 (55.0)	63.8 (58.6)
		5/1	65.3 (61.4)	67.0 (68.1)	63.9 (55.1)	65.7 (63.4)

*Motorised penetrometer used to test fruit immediately ex-store but problems with this instrument necessitated the use of a Lloyd LRX texture analyser for testing January fruit after a SMP.

Soluble solids concentration

The average soluble solids concentrations in the fruit harvested for the Suffolk and East Kent orchards were 11.6 and 12.5% (Table 13). Further conversion of starch to sugar during storage until January 2003 resulted in an increase in soluble solids concentration of about 2 and 2.8% in fruit from the Suffolk and East Kent orchards respectively (Table 15). Soluble solids concentrations declined slightly by about 0.3-0.4% where storage was extended to March. There was generally little effect of storage conditions on the concentration of soluble solids in the fruit after storage but Suffolk fruits were on average 1.7% lower in soluble solids ex-store than East Kent fruit.

Table 15. The effect of picking date and storage conditions on the concentration (%) of soluble solids in Meridian apples from orchards in Suffolk and East Kent. Fruit samples were stored in an atmosphere of 5% CO_2 + 1% O_2 or <1% CO_2 + 1.2% O_2 (balance nitrogen) until 7 January and 4 March 2003. Figures in brackets refer to fruit kept for a further 7 days at 20°C to simulate a marketing period (SMP). Picks 1 and 2 refer to fruit picked on 2/3 and 9/10 September 2002 respectively.

Orchard	Pick	CO_2 / O_2	January		March	
			3.5-4°C	1.5-2°C	3.5-4°C	1.5-2°C
Suffolk	1	<1/1.2	13.3 (12.9)	13.2 (13.3)	13.3 (12.9)	13.4 (12.6)
		5/1	13.5 (13.6)	13.3 (13.5)	13.4 (12.9)	13.5 (13.0)
	2	<1/1.2	13.8 (13.7)	14.0 (13.3)	13.1 (13.0)	13.8 (13.3)
		5/1	13.8 (13.9)	13.9 (13.7)	13.4 (13.5)	13.6 (13.1)
East Kent	1	<1/1.2	15.2 (15.5)	15.5 (16.1)	14.6 (15.2)	15.3 (15.1)
		5/1	15.2 (15.2)	15.3 (15.6)	14.6 (14.8)	15.4 (14.6)
	2	<1/1.2	15.3 (15.4)	15.5 (15.0)	14.7 (14.8)	14.9 (14.6)
		5/1	14.7 (15.1)	15.3 (15.4)	15.5 (14.8)	15.1 (15.1)

Rotting and physiological disorders

There was a very low susceptibility of fruit to rotting and bitter pit with an average incidence of 1% or less (data not presented). An unusual disorder affected the skin of apples from the East Kent orchard particularly those from the second harvest (data not presented). Brown sunken lesions were noted on the fruit on removal from store (Figure 7). Samples were taken in torrential rain and it is suspected that the cause may have been damage inflicted to the fruit during sampling and transport to East Malling possibly as a result of moisture present on the fruit at the time of picking. Abrasions of this type have been reported in the literature particularly where fruit had been transported after application of calcium solutions. Damage had not been noted on fruit from this orchard sampled in the three previous years. Low temperature breakdown was generally restricted to fruit stored until March at the lower storage temperature of 1.5-2°C and occurred only in fruit from the 5/1 CA regime (Table 4). Fruit from both orchards were affected and the incidence of the disorder increased markedly during a further 7 days at 20°C.

Table 16. The effect of picking date and storage conditions on the incidence of low temperature breakdown in Meridian apples from orchards in Suffolk and East Kent. Fruit samples were stored in an atmosphere of 5% CO_2 + 1% O_2 or <1% CO_2 + 1.2% O_2 (balance nitrogen) until 7 January and 4 March 2003. Figures in brackets refer to fruit kept for a further 7 days at 20°C to simulate a marketing period (SMP). Picks 1 and 2 refer to fruit picked on 2/3 and 9/10 September 2002 respectively.

Orchard	Pick	CO_2 / O_2	January		March	
			3.5-4°C	1.5-2°C	3.5-4°C	1.5-2°C
Suffolk	1	<1/1.2	0 (0)	0 (0)	0 (0)	0 (0)
		5/1	0 (0)	0 (0)	0 (0)	12.5 (35)
	2	<1/1.2	0 (0)	0 (0)	0 (0)	0 (0)
		5/1	0 (0)	0 (0)	0 (0)	12.5 (52.5)
East Kent	1	<1/1.2	0 (0)	0 (0)	0 (0)	0 (0)
		5/1	0 (0)	0 (2.5)	0 (0)	5.0 (45.0)
	2	<1/1.2	0 (0)	0 (0)	0 (0)	0 (0)
		5/1	0 (0)	0 (0)	0 (0)	2.5 (42.5)

Conclusions

- Firmness of fruit stored in CA (5/1 or <1/1.2) until January was maintained at or above the suggested (supermarket) threshold of 63.8 N (6.5 kg) by harvesting fruit with a firmness value of 70.4-73.9 N (7.2-7.5 kg).
- Although storage in a 5/1 or <1/1.2 CA regime at 3.5-4°C provided adequate firmness in fruit stored until January only 5/1 provided fruit of the required firmness specification in March.
- Maintaining a lower storage temperature of 1.5-2°C resulted in a greater retention of firmness in fruits kept in 5/1 and <1/1.2 but the development of low temperature breakdown in the 5/1 regime would preclude the use of the lower storage temperature.
- Fruit kept in the 'Cox-type' CA conditions of <1/1.2 at the lower temperature were as firm as those kept in the more stringent 5/1 regime at the higher temperature.
- It appears that lower storage temperatures may obviate the need for 5/1 storage. This would be beneficial to the UK industry since 'Cox type' (<1/1.2) conditions are more available within the industry.
- Unlike in the previous year (see Report to 31 March 2002) bitter pit was not a problem in the fruit stored in 2002-03. This may in part be due to the emphasis given to the use of calcium sprays as a means of preventing the problem.
- Soluble solids (sugar) levels in fruit ex-store were sufficiently high to provide good eating quality regardless of orchard site and harvest date.

Mineral composition of leaves and fruits

Samples of extension leaves were collected from trees on four grower sites in late August or mid September 1999 and in mid September 2000. Samples of fruit for analysis were taken at harvest in 1999 and 2000. This was achieved with the collaboration of Dr. Martin Luton of Worldwide Fruit - Qualytech. The samples were analysed at HRI by Dr. Tim Samuelson. The results of these mineral analyses are presented in Annexe I and II.

Concentrations of nitrogen (N) in the leaves were similar or slightly higher than those recommended for Cox. Leaf potassium (K) concentrations were similar but phosphorus and magnesium concentrations were lower than those recommended for Cox. The concentrations of boron were within the 20-40ppm range usually recommended for Cox in the UK.

The concentrations of the major minerals in the fruit (N, P, K, Ca and Mg) conformed to those normally found in Cox apples. However it was interesting to note that calcium concentrations in Meridian exceeded the Cox requirement for Ca for the avoidance of bitter pit in CA storage (4.5 mg $100g^{-1}$). However, significant levels of bitter pit developed in CA-stored fruit in 1999-00 and 2000-01 despite calcium concentrations in the range 4.6-5.9 mg $100g^{-1}$. There was an inverse correlation between bitter pit incidence and Ca concentration but only at the highest concentration of 7.5 mg $100g^{-1}$ (Suffolk 2000) was bitter pit completely controlled. This suggests that the threshold Ca level for avoidance of bitter pit may be higher than for Cox. This is supported by data for a number of commercial orchards sampled by Worldwide Fruit - Qualytech in 2001-02 where significant bitter pit was recorded in CA-stored fruit despite Ca concentrations as high as 6.2 mg $100g^{-1}$. Further work may be required to establish threshold Ca concentration for the optimum storage of Meridian.

II Picking date trials for E11/20 'Park Farm Pippin' (2001)

Background

The fate of E11/20 as a commercial variety was uncertain at the time that the trial work for harvest 2001 was planned.

Subsequently APRC decided not to pursue the release of E11/20 as a commercial variety for a number of reasons, not least its tough skin and indifferent eating quality. Due to its poor eating quality, E11/20 has not been viewed favourably for organic production despite its high degree of disease resistance.

Visual observations conducted on a small number of trees showed stem-end cracking to be a problem on fruit from one site. One commercial grower in East Kent reported that cracking had affected 30% of his fruit. There appears to be some potential for the variety in the amateur sector where it is now marketed as Park Farm Pippin (Marshalls).

For whatever purpose envisaged for E11/20, it was considered important to have an idea of its time of ripening on the tree and parameters that may indicate an appropriate time to harvest.

Picking date trial 2001

Fruit was picked from 2 plots (CE and DM) at HRI-East Malling on five occasions in the period 17 August to 3 September 2001 (Table 17).

CE was an unthinned orchard carrying a heavy crop and DM was thinned by hand and carried a moderate crop. The higher firmness and soluble solids content in the fruit from orchard DM is likely to be an effect of the thinning treatment. The earlier ripening of DM fruit as evidenced by a higher percentage of fruit with ethylene above 100 parts per billion (ppb) and higher starch score (Ctifl chart where 1=100% black and 10=100% white) is also a characteristic of fruit from thinned trees.

In general fruit was very firm directly from the tree during the period 17 August to 3 September (Table 17). There was little change in soluble solids concentration in the fruit over the same period even though fruits were ripening on the tree from 28 August as evidenced by an increase in the internal ethylene concentration.

Table 17. Effect of picking date in 2001 on harvest maturity parameters of E11/20 from orchard plots at HRI-East Malling. Firmness measured with an automated penetrometer; starch pattern determined using the Ctifl chart (1-black, 10-white), soluble solids measured using a refractometer and internal ethylene concentration (IEC) measured by gas chromatography.

		Picking date				
	Plot	17/8	24/8	28/8	31/8	3/9
Firmness	DM	78.4	84.8	83.6	78.5	73
(N)*	CE	-	76.6	79.9	75.1	75.8
Starch	DM	3.7	4	6.5	7.7	8.8
(1-10)	CE	-	5.5	5.7	6.8	7.1
Soluble solids	DM	12.6	13.7	13.7	13.7	13.6
(%)	CE	-	11.1	11.7	11.6	11.8
IEC	DM	-	25	118	173	2554
(ppb)	CE	-	1	193	1232	1769
IEC	DM	-	0	70	70	78
(% >100 ppb)	CE	-	0	40	50	20

* Firmness in kg can be derived approximately by dividing Newtons (N) by 10 (1kg = 9.81N).

In fruits kept at 20°C for 7 days after picking there was a marked reduction in firmness of fruits picked on the 28 August onwards (Table 18). This coincided with the time of increased ethylene production by the fruit. Picking fruit from 28 August to 3 September provided fruit of good eating quality after 7 days at 20°C. These preliminary data suggest that starch should have cleared significantly (average of 6 on the Ctifl chart) to ensure that fruit softens sufficiently during the period for marketing and distribution.

Table 18. Effect of picking date in 2001 on the firmness and soluble solids concentration of E11/20 apples from orchard plots at HRI-East Malling after 7 days at 20°C. Firmness was measured with an automated penetrometer and soluble solids with a refractometer.

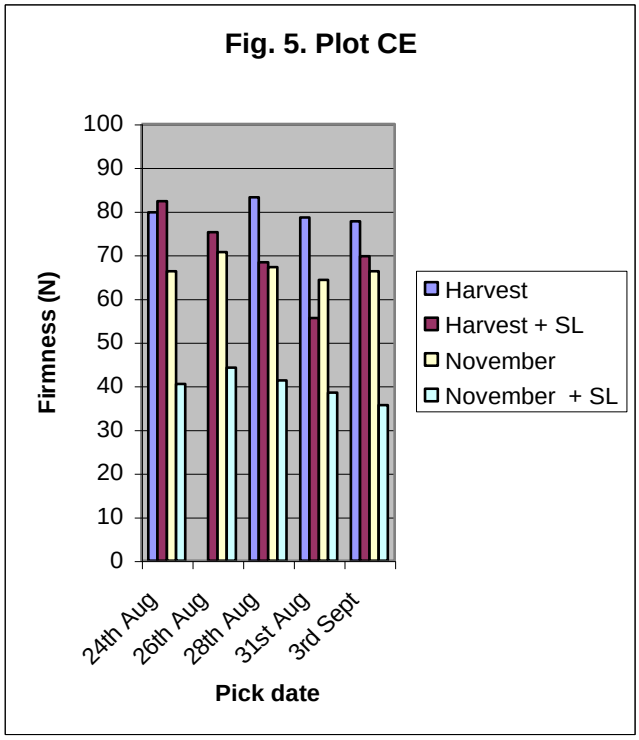
		Picking date			
	Plot	24/8	28/8	31/8	3/9
Firmness	DM	83.5	68.4	73.3	62.2
(N)*	CE	79.6	66.3	54.1	67
Soluble	DM	14.3	14.2	13.9	13.8
solids (%)	CE	12.2	11.9	12.3	12.2

* Firmness in kg can be derived approximately by dividing Newtons (N) by 10 (1kg = 9.81N).

Firmness data for fruit stored at 0ºC until 2 November 2001 before and after 'shelf-life' are presented in Figures 5 and 6. Firmness data for fruit at harvest are also presented for completeness. Firmness measurements were made using an LRX (Lloyd Instruments) materials testing machine fitted with an 11 mm probe. Firmness was the maximum force (N) recorded during penetration of the probe to a depth of 8 mm. The test is essentially similar to the 'industry standard' test using a hand-held penetrometer. The results for harvest firmness presented in the previous report were expressed as the load (N) at 8 mm depth. These firmness readings are slightly lower than those for maximum force presented here.

Fruit generally remained firm during 2 months of air storage at 0ºC. Fruit from the thinned plot (DM) was generally firmer (71-77N) than those from the unthinned plot (CE, 64-77 N). Firmness benefits attributed to thinning were also evident at harvest. Unlike at harvest time there was a marked reduction in the firmness of stored fruit subjected to a further 7 days at 20ºC. Firmness after 'shelf-life' ranged from 36-46 N with little difference in the firmness of fruit from the different plots. Fruit picked on 31 August and 3 September were particularly soft but fruit from all picks were insufficiently firm to meet the requirements of the consumer. Clearly E11/20 has limited storage potential due to its rapid softening ex-store.

Figures 5/6. Effect of harvest date on the firmness of E11/20 apples form orchards at HRI-East Malling (plots CE and DM) at harvest and after air storage at 0°C until 2 November 2001. SL refers to fruit stored for a further 7 days at 20°C to provide a 'shelf-life' test.



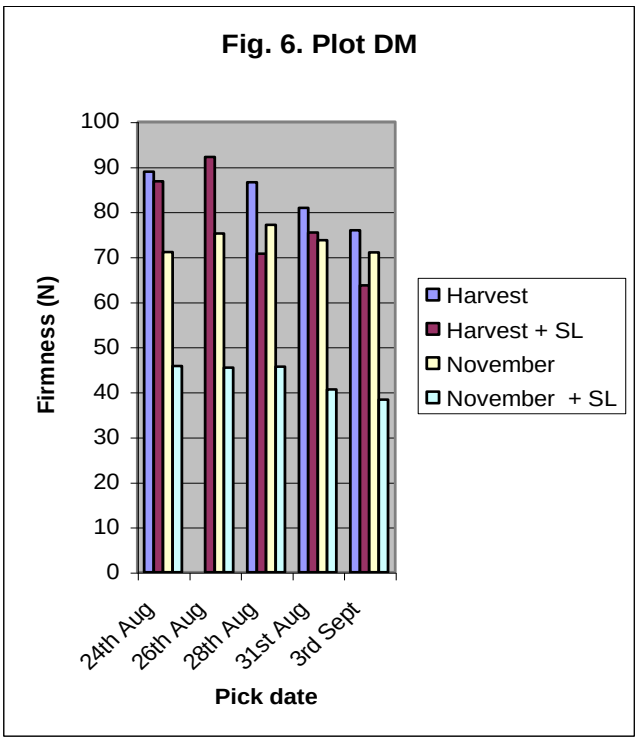


Figure 7. Damage symptoms on Meridian apples harvested from the East Kent orchard on 9 September 2002 and stored in controlled atmosphere conditions until January 2003.

Annexe I. Mineral analyses on extension leaves of Meridian collected in 1999 and 2000 from young orchards at four sites in the UK. Site 3a and 4b refer to the orchards in Suffolk and East Kent used to provide fruit for picking date and storage investigations.

Site	Sample date	N	P	K	Ca	Mg	Mn	Na	Zn	Cu	Fe	B
		(%)					μg $100g^{-1}$					
1	24/8/99	3.3	0.22	1.7	1.3	0.22	30	131	13.0	8.7	78	26.1
2	24/8/99	3.2	0.22	1.4	1.3	0.25	88	82	16.9	10.0	127	27.0
3a	24/8/99	3.1	0.19	1.6	1.8	0.22	52	177	13.2	9.2	89	26.4
3b	24/8/99	3.0	0.19	1.7	1.9	0.18	64	178	13.1	8.7	93	28.1
3a	10/9/99	2.7	0.15	1.6	1.6	0.17	47	120	10.6	7.3	96	22.8
4a	15/9/99	2.7	0.17	1.4	1.9	0.21	85	286	15.4	9.0	114	25.3
4b	15/9/99	2.7	0.18	1.4	2.0	0.24	80	225	14.8	9.0	121	23.6
3a	21/9/00	2.4	0.14	1.4	1.7	0.16	48	147	12.0	6.8	84	20.1
4a	15/9/00	2.5	0.16	1.4	1.7	0.22	82	137	15.8	8.2	78	17.3

Annexe II. Mineral and dry matter analyses of Meridian apples harvested in 1999 and 2000 from the orchards in Suffolk and East Kent.

Orchard	N	P	K	Ca	Mg	Mn	Na	Zn	Cu	B	Dry Wt
	mg $100g^{-1}$			μg $100g^{-1}$				(%)			
Suffolk 1999	65	11.7	153	5.9	6.3	51	0.5	28.9	49	283	14.6
Suffolk 2000	73	12.2	145	7.5	6.4	64	1.2	36.5	52	223	15.5
E. Kent 1999	60	12.5	158	4.6	6.9	62	1.6	31.9	53	234	16.4
E. Kent 2000	68	11.5	141	4.9	6.2	62	1.8	32.4	46	222	15.7