

# Postharvest Quality and Storage of Scab-resistant Apple Cultivars

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**Additional index words.** *Malus domestica*, controlled atmosphere, low O<sub>2</sub>, physiological disorders, storage rots

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**Summary.** This paper reports preliminary results on the postharvest quality and storage characteristics of several scab-resistant apple cultivars. 'Novaspy', 'Moira', 'Priscilla', 'Novamac', 'Nova Easygro', 'Prima', and 'Macfree' were stored for 3 months at 3C in air or standard controlled atmosphere (CA; 4.5% CO<sub>2</sub> and 2.5% O<sub>2</sub>) in 1990 and for 4 months at 0C in air, standard CA, or low-O<sub>2</sub> CA (LO; 1.5% CO<sub>2</sub> and 1.5% O<sub>2</sub>) in 1991. 'Moira', 'Prima', and 'Priscilla' had very limited storage life. 'Moira' was susceptible to bitterpit, scald, core browning, vascular breakdown, and storage rots. 'Prima' was susceptible to core browning and vascular breakdown and had a high incidence of storage rots in air storage. 'Priscilla' had several defects as a result of insect damage and was susceptible to bitterpit and scald. 'Novaspy' stored very well and had virtually no physiological disorders or storage rots. 'Novamac', 'Nova Easygro', and 'Macfree' developed few storage rots and were essentially at the end of their storage life after 4 months, regardless of storage conditions. Firmness in 'Novamac' decreased substantially in all storage atmospheres, while 'Nova Easygro' and 'Macfree' were susceptible to core browning and scald.

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**A**pple scab caused by *Venturia inaequalis* (Cke.) Wint. is one of the most serious diseases affecting apples grown in northeastern North America (Warner, 1990). The

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disease is managed mainly by repeated applications of fungicide sprays throughout the growing season (Dayton et al., 1977). However, due to concern about possible human health risks and undesirable environmental effects associated with the use of synthetic chemicals, spray programs and fungicide residues are becoming increasingly unacceptable to the public. Cultivars resistant to apple scab can eliminate the repeated application of fungicides required for scab control and thus reduce the use of synthetic chemicals in apple production.

Several scab-resistant cultivars have been released in recent years for possible commercial production. This study was designed to evaluate post-harvest quality and storage characteristics of scab-resistant cultivars grown in the Annapolis Valley, Nova Scotia. This paper reports preliminary results after 2 years of study involving apple cultivars Novaspy, Moira, Priscilla, Novamac, Nova Easygro, Prima, and Macfree.

## Materials and Methods

'Priscilla', 'Moira', 'Nova Easygro', 'Prima', and 'Macfree' were harvested in 1990 and 1991 from an orchard of 5-year-old trees on M.7 rootstock (Orchard 1). 'Novaspy' was harvested in 1990 and 1991 from 6-year-old trees on BA rootstock (Orchard 2). 'Novamac' was harvested from Orchard 1 in 1990 and from Orchard 2 in 1991. 'Nova Easygro', 'Prima', and 'Macfree' also were harvested in 1991 from 7- to 10-year-old trees on BA rootstock (Orchard 2).

Apples were precooled in vented plastic hampers to 3C in 1990 and 0C in 1991 within 12 h of harvest. One 10-kg sample per cultivar and orchard was placed randomly in standard controlled-atmosphere (CA) chambers, in which O<sub>2</sub> was reduced to 2.5% by N<sub>2</sub> flushing within 24 h of harvest and CO<sub>2</sub> was maintained at 4.5% with lime scrubbers. Another 10-kg sample per cultivar and orchard was placed in a 38- $\mu$ m perforated polyethylene liner in air storage to maintain relative humidities of 94% to 96% without modification of the surrounding O<sub>2</sub> or CO<sub>2</sub> levels. In 1991 a polyethylene liner was placed only on top of the hamper containing the sample, and another 10-kg sample per cultivar and orchard was placed in a low-O<sub>2</sub> (LO) CA of 1.5% O<sub>2</sub> and 1.5% CO<sub>2</sub>. Samples from

each treatment were removed after 3 months of storage in 1990-91 and after 4 months of storage in 1991-92.

Apple maturity was evaluated on a 10-fruit subsample at harvest using a starch index (Priest and Lougheed, 1981) and the internal ethylene concentration as determined by removing a 1-ml gas sample from the apple core and injecting it into a Carle 211 gas chromatograph (Saltveit, 1982). The quality of the apples was evaluated at harvest and after storage. Fruit firmness was determined on a 10-fruit subsample using a Ballauf penetrometer (Ballauf, Maryland) (11.1-mm-diameter tip) to test opposite sides of the fruit after the peel had been removed. The resulting juice was measured for soluble solids concentration (SSC) using a hand-held, temperature-compensated refractometer (Atago, Japan). Titratable acids content (TA) was measured by titrating a 2-ml juice sample with 0.1 N NaOH using a semiautomatic Multi-Dosimat E-415 titrator (Metrohm AG, Herisau, Switzerland) to an endpoint of pH 8.1, as indicated by phenolphthalein. After storage, the incidence of physiological disorders and diseases were evaluated and the percentage of marketable apples per sample was determined after 4 months of storage in 1991.

Selected poststorage data were tested using analysis of variance procedures from Genstat 5 (Payne, 1987). Cultivar and storage atmosphere were the factors, as the effects of orchard were not estimated. Although this study was conducted for 2 years, only data from apples harvested at optimum maturity for storage (1991) are presented in this report, with mention of some important points from the 1990 season. For statistically analyzed data, only sources of variation that were significant at  $P < 0.05$  are discussed.

## Results and Discussion

Maturity data at harvest were not analyzed statistically and are presented in Table 1, while poststorage data are shown in Tables 2-4. Poststorage data on scald (Table 3) and marketable apples (Table 4) were analyzed statistically, but data on the other physiological disorders (Table 3) and storage rots (Table 4) were not analyzed statistically because of their low incidence. Defects and bitterpit (Table 4) are not storage-related problems and

thus have not been analyzed statistically. High variability due to low replication can make some statistical analyses difficult to interpret. For example, due to the high SEM for percent marketable apples, there was no significant difference between no marketable 'Moira' apples after air storage and 76.6% marketable apples after LO storage (Table 4).

### 'Novaspy'

Prelimacteric fruit (internal C<sub>2</sub>H<sub>4</sub> < 1 ppm and starch index < 4) with 70% to 85% red blush over greenish-yellow ground color were harvested in early Oct. 1991 (Table 1). After 4 months of air storage at 0C, 'Novaspy' had a 3.7% weight loss and reduction in firmness of 39.9 N (Tables 1 and 2). SSC increased 1.1% and TA decreased 174 mg/100 ml of juice after air storage (Tables 1 and 2). CA storage reduced losses in firmness and weight but had no significant effects on SSC or TA (Table 2).

Although there was a slight incidence of scald in LO, 'Novaspy' did not develop internal physiological disorders, regardless of the storage atmosphere (Table 3). Bitterpit was not a problem in 'Novaspy', nor were storage rots (Table 4). The low incidence of defects in the apples (Table 4) may have reduced their susceptibility to pathogens.

'Novaspy' was harvested postclimacteric in 1990 and stored for 3 months at 3C (data not shown). Although the initial firmness, SSC, and TA were lower than those in 1991 as a result of advanced maturity, similar patterns were observed. CA reduced losses in firmness and weight, and no physiological disorders or storage rots developed, regardless of the storage atmosphere.

The percentage of marketable apples after 4 months of storage at 0C in 1991 was not influenced by the storage atmosphere (Table 4). 'Novaspy' stored very well in all atmospheres, with an average of 92.4% of the apples being marketable. A similar storage life has been reported in Ontario for 'Novaspy', 4 to 5 months at 1 C (Wilson et al., 1991).

### 'Moira'

Prelimacteric fruit with 40% to 80% red blush over a greenish-yellow ground color were harvested in mid-Sept. 1991 (Table 1). After 4 months

of air storage at 0C, 'Maira' had a 4.7% weight loss and reduction in firmness of 41.5 N (Tables 1 and 2). SSC remained at 11.0%, while TA decreased 730 mg/100 ml of juice after air storage (Tables 1 and 2). CA storage reduced losses in firmness and weight; LO reduced loss of TA (Table 2).

After 4 months of air storage at 0C, all 'Maira' apples had developed scald, and core browning and vascular breakdown were major problems (Table 3). CA storage reduced the incidence of scald, and LO may also reduce the incidence of vascular breakdown; however, storage in standard CA may increase the incidence of vascular breakdown. Core browning was observed in all storage atmospheres but may be reduced in air storage. Some bitterpit also was observed (Table 4).

Storage rots were observed in all storage atmospheres and may be suppressed by CA storage (Table 4). Defects generally occurred in 19.8% of the apples as a result of insect damage, which provides openings for pathogens.

'Maira' was harvested postclimacteric in 1990 and stored for 3 months at 3C (data not shown). As a result of advanced maturity, the initial firmness, SSC, and TA were lower than those in 1991, and senescent breakdown developed in air storage (23.7%). A lower incidence of scald in 1990 (14.7% in air storage) than in 1991 also may have been a result of more-mature apples. As with 1991 results, CA reduced firmness loss and increased the incidence of core browning. Storage rots did not develop in 1990 despite increased susceptibility associated with mature apples. How-

ever, there may have been a lower incidence of defects in 1990 than in 1991, as the presence of defects was not noted in 1990.

Sensory evaluations on the postclimacteric 'Maira' apples were conducted at harvest in 1990 (Sanford et al., 1990). Although 'McIntosh' control apples were rated more acceptable overall than 'Maira' apples, there were no significant differences in the appearance, color, and texture of 'McIntosh' and 'Maira' apples.

No 'Maira' apples were marketable after 4 months of air storage at 0C (Table 4) mainly due to scald and storage rots. CA storage may increase the incidence of core browning and vascular breakdown.

Although the storage life of 'Maira' apples grown in Ontario is 2 to 3 months at 1 to 2C (Warner and Potter, 1988; Wilson et al., 1991), the results of this study suggest that 'Maira' apples are unacceptable for market after 4 months at 0C or after 3 months at 3C. CA did not extend the storage life of 'Maira', as it does for many other apple cultivars.

**'Priscilla'**

Fruit with 60% to 80% dark-red blush over light-yellow ground color were harvested at the onset of the climacteric period in early Oct. 1991 (Table 1). After 4 months of air storage at 0C, 'Priscilla' had a 6.7% weight loss and reduction in firmness of 16.4 N (Tables 1 and 2). SSC increased 1.6% and TA decreased 167 mg/100

Table 1. Harvest date and firmness, soluble solids concentration (SSC), titratable acidity (TA), starch index, and internal ethylene for each apple cultivar at harvest in 1991.

Cultivar	Date	Firmness (N) <sup>1</sup>	SSC (%)	TA (mg malic acid/100 ml juice)	Starch index <sup>2</sup>	Internal C <sub>2</sub> H <sub>4</sub> (ppm)
Novaspy	4 Oct.	90.5	12.7	1200	2.6	0
Maira	19 Sept.	100.0	11.0	1173	2.6	0.2
Priscilla	4 Oct.	84.4	11.1	1059	6.7	9.3
Novamac	27 Sept.	83.5	12.2	1237	5.3	20.4
Nova Easygro	4 Oct.	92.9	13.0	781	3.0	0.5
Prima	21 Sept.	94.7	11.4	845	7.9	7.7
Macfree	4 Oct.	99.3	12.3	838	4.4	1.3

<sup>1</sup>lbs = N/4.5.

<sup>2</sup>Evaluated on a scale of 1 to 9; 1 = immature, 9 = mature.

Table 2. Effect of storage at 0C for 4 months in 1991 on firmness, soluble solids concentration (SSC), and titratable acidity (TA) for various apple cultivars.

Cultivar	Firmness (N <sup>1</sup> )			SSC (%)			TA (mg malic acid/100 ml juice)			Wt loss (%)		
	Air	SCA <sup>2</sup>	LO <sup>2</sup>	Air	SCA	LO	Air	SCA	LO	Air	SCA	LO
Novaspy	50.6	83.7	84.3	13.8	14.3	13.5	1026	1153	1200	3.7	0.7	1.4
Maira	59.5	87.9	89.0	11.0	11.7	11.3	443	791	986	4.7	2.1	2.4
Priscilla	68.0	90.4	72.1	12.7	11.5	12.7	892	684	919	6.7	0.4	1.6
Novamac	56.3	57.7	62.3	13.6	14.0	14.0	825	858	1240	3.7	0.7	1.1
SEM <sup>3</sup> (n = 1, df = 35)		6.06			0.89			122.7			2.21	
Nova Easygro	67.5	81.2	86.6	13.6	13.8	13.7	322	888	616	3.8	1.3	1.4
Prima	57.9	71.6	72.9	11.5	12.1	11.8	664	768	821	5.1	5.3	1.9
Macfree	70.8	82.9	92.4	12.9	13.2	13.6	536	600	560	5.2	0.9	1.0
SEM <sup>3</sup> (n = 2, df = 35)		4.28			0.63			86.8			1.56	
Significance		C <sup>**</sup> , S <sup>***</sup>			C <sup>**</sup>			C <sup>***</sup> , S <sup>*</sup>			S <sup>***</sup>	

<sup>1</sup>lbs = N/4.5.

<sup>2</sup>Weight loss data were analyzed after angular transformation, angles (°) = sin<sup>-1</sup> 0%/100 but are presented in the table as percentages.

<sup>3</sup>SCA = standard controlled atmosphere; LO = low O<sub>2</sub>.

<sup>4</sup>To compare effects of cultivar × storage interaction, SEM is presented in angles for weight loss data.

\*, \*\*, \*\*\*Significant at P < 0.05, 0.01, or 0.001, respectively, where C = cultivar and S = storage.

ml of juice after air storage (Tables 1 and 2). CA storage reduced weight loss, while firmness loss was reduced by standard CA storage, but not by LO (Table 2).

No internal physiological disorders or storage rots developed in 'Priscilla' apples, regardless of the storage atmosphere or the high incidence of defects (Tables 3 and 4). Some bitterpit was observed (Table 4), and the development of scald, which occurred in air and standard CA storage, may be controlled by LO (Table 3).

'Priscilla' was harvested postclimacteric in 1990 and stored for 3 months at 3C (data not shown). These apples were more mature than those harvested in 1991, but the firmness

and SSC were similar. Less weight loss occurred in air storage than in 1991, and core browning developed (30.2%). Standard CA did not reduce the amount of weight loss but did control core browning. As in 1991, there were no storage rots.

Sensory evaluations on the postclimacteric 'Priscilla' apples were conducted at harvest in 1990 (Sanford et al., 1990). Although 'Cortland' control apples were rated more acceptable overall than 'Priscilla' apples, there were no significant differences in appearance. Color was rated higher for 'Priscilla' than for 'Cortland', while flavor and texture were rated higher for 'Cortland' than for 'Priscilla'. These results are similar to other studies in

which 'Priscilla' apples received low taste ratings and were considered unacceptable to consumers (Durner et al., 1992; Grauslund, 1986).

In this study nearly half the 'Priscilla' apples stored were unacceptable for market after 4 months at 0C (Table 4) or after 3 months at 3C (data not shown). Although some apples were termed unmarketable in 1991 due to their small size, this did not influence the overall assessment of storage characteristics. CA did not extend the storage life of 'Priscilla', as it does for many other apple cultivars. The storage life of 'Priscilla' apples grown in Ontario is 3 to 4 months at 1C (Wilson et al., 1991) and 2 to 3 months in the northeastern United

Table 3. Effect of storage at 0C for 4 months in 1991 on the incidence of physiological disorders for various apple cultivars.

Cultivar	Vascular breakdown (%)			Core browning (%)			Internal browning (%)			Scald (%) <sup>2</sup>		
	Air	SCA <sup>3</sup>	LO <sup>3</sup>	Air	SCA	LO	Air	SCA	LO	Air	SCA	LO
Novaspy	0	0	0	0	0	0	0	0	0	0	0	4.7
Moira	38.7	95.8	9.6	46.8	95.8	90.9	0	0	3.9	100	14.6	11.7
Priscilla	0	0	0	0	0	0	0	0	0	11.1	14.7	0
Novamac	0	0	14.3	0	0	0	0	0	0	6.2	6.7	15.6
SEM <sup>4</sup> (n = 1, df = 35)											9.25	
Nova Easygro	0	0	0	11.1	14.1	0	0	0	0	21.1	6.3	1.7
Prima	2.1	10.0	3.9	11.4	24.2	1.2	0	8.2	7.3	0.7	3.1	4.2
Macfree	0	0	0	0.6	15.0	2.2	0	0	0	9.6	3.4	1.7
SEM <sup>4</sup> (n = 2, df = 35)											6.54	

Significance

C\*\*, S\*

<sup>1</sup>Scald was analyzed after angular transformation, angles (°) =  $\sin^{-1} \sqrt{\theta}/100$  but are presented in the table as percentages.

<sup>2</sup>SCA = standard controlled atmosphere; LO = low O<sub>2</sub>.

<sup>3</sup>To compare effects of cultivar × storage interaction, SEM is in angles.

<sup>4</sup>\*\*\*Significant at P < 0.05 or 0.01, respectively, where C = cultivar and S = storage.

Table 4. Effect of storage at 0C for 4 months in 1991 on the incidence of storage rots, complete rots, marketable apples, defects, and bitterpit. All data are shown as percentages.

Cultivar	Storage rots <sup>2</sup>			Complete rots <sup>2</sup>			Marketable apples <sup>3</sup>			Defects	Bitterpit
	Air	SCA <sup>3</sup>	LO <sup>3</sup>	Air	SCA	LO	Air	SCA	LO		
Novaspy	0	0	1.6	0	0	0	91.5	88.7	96.9	3.5	0.5
Moira	64.5	4.7	3.9	0	4.7	3.9	0	66.7	76.6	19.8	8.8
Priscilla	0	0	0	0	0	0	51.9	58.8	46.7	37.8	8.7
Novamac	2.5	1.1	3.9	2.5	0	1.3	90.1	86.5	90.9	3.9	0
SEM <sup>4</sup> (n = 1, df = 35)								31.82			
Nova Easygro	6.3	2.9	0	0	0	1.7	64.4	76.2	61.2	16.7	2.9
Prima	38.5	9.2	13.8	28.3	6.0	9.8	35.3	71.2	64.3	16.6	3.1
Macfree	3.2	8.9	1.7	1.2	0.9	0.9	80.9	72.2	76.4	16.8	0.5
SEM <sup>4</sup> (n = 2, df = 35)								22.50			

Significance

NS

<sup>1</sup>The majority of storage rots were caused by *Botrytis cinerea*, *Penicillium expansum*, and *Gloeosporium perennans*.

<sup>2</sup>Marketable apples was based on external appearance.

<sup>3</sup>SCA = standard controlled atmosphere; LO = low O<sub>2</sub>.

<sup>4</sup>To compare the effects of cultivar × storage interaction, SEM is in angles.

<sup>5</sup>Nonsignificant, where C = cultivar and S = storage.

States (Costante et al., 1990). Conversely, Grauslund (1986) found 'Priscilla' apples in Denmark to have a very limited storage life. Crowe (1988) did not recommend 'Priscilla' for Nova Scotia and New Brunswick, as its color tends to be dull, fruit size small, and quality only fair.

#### 'Novamac'

Fruit with 70% to 90% red blush or striped over a light greenish-yellow ground color were in the climacteric stage when harvested in late Sept. 1991 (Table 1). After 4 months of air storage at 0C, 'Novamac' had a 3.7% weight loss and reduction in firmness of 27.2 N (Tables 1 and 2). SSC increased 1.4% and TA decreased 412 mg/100 ml of juice after air storage (Tables 1 and 2). CA storage reduced weight loss but had no significant effect on firmness or SSC. Storage in LO maintained TA, whereas TA in air- and standard CA-stored apples decreased to similar levels.

Although some core browning developed in LO storage, no other physiological disorders were observed in 'Novamac' (Table 3). There were few problems with the development of storage rots, and only a few apples had defects (Table 4).

'Novamac' was harvested postclimacteric in 1990 and stored for 3 months at 3C (data not shown). Due to increased maturity, the initial firmness, SSC, and TA were lower than those in 1991. CA reduced firmness loss but had no significant effect on SSC or TA. No physiological disorders developed in 1990, including core browning, probably due to the higher storage temperature. The development of core browning in the 1991 sample suggests possible sensitivity to low temperature. Storage rots were not a major problem in 1990, despite increased susceptibility associated with mature apples.

Sensory evaluations on the postclimacteric 'Novamac' apples were conducted at harvest in 1990 (Sanford et al., 1990). Although 'McIntosh' control apples were rated higher in appearance than 'Novamac' apples, there were no significant differences in color, flavor, texture, or overall acceptability.

The percentage of marketable apples after 4 months of storage at 0C (1991) was not influenced significantly by the storage atmosphere (Table 4).

'Novamac' stored well in all atmospheres, with the exception of core browning development in LO. The firmness of 'Novamac' was very low in all storage atmospheres (Table 2). A similar storage life has been reported in Ontario for 'Novamac', 3 to 4 months at 1C (Wilson et al., 1991), whereas Costante et al. (1990) reported a storage life of 2 to 3 months in the northeastern United States. 'Novamac' has potential as a commercial cultivar in Nova Scotia and New Brunswick (Crowe, 1988), Ontario (Wilson et al., 1991), and Poland (A. Czynczyk, personal communication).

#### 'Nova Easygro'

Preclimacteric fruit with 80% to 99% striped or dull-red blush over a greenish-yellow ground color were harvested in early Oct. 1991 (Table 1). After 4 months of air storage at 0C, 'Nova Easygro' had a 3.8% weight loss and reduction in firmness of 25.4 N (Tables 1 and 2). SSC increased 0.6% and the low initial TA decreased 459 mg/100 ml of juice after air storage, resulting in very low-acid apples (Tables 1 and 2). CA storage reduced losses in weight, firmness, and TA but had no significant effect on SSC.

'Nova Easygro' had a slight incidence of bitterpit, and core browning developed in air and standard CA storage (Table 3). Scald was observed in air-stored apples, but CA storage may reduce its incidence. Storage rots were not a major problem, despite the presence of defects (Table 4).

'Nova Easygro' was harvested postclimacteric in 1990 and stored for 3 months at 3C (data not shown). As a result of increased maturity, the initial firmness and TA were lower than those in 1991. CA reduced firmness loss but had no significant effect on SSC or TA. Scald developed in air-stored apples but was reduced by standard CA storage. No other physiological disorder developed in 'Nova Easygro', and storage rots were not a major problem in 1990.

Sensory evaluations on the postclimacteric 'Nova Easygro' apples were conducted at harvest in 1990 (Sanford et al., 1990). Although there were no significant differences in color or appearance of 'Cortland' and 'Nova Easygro' apples, 'Cortland' was rated higher in flavor, texture, and overall acceptability.

The percentage of marketable apples after 4 months of storage at 0C in 1991 was not influenced significantly by the storage atmosphere (Table 4). 'Nova Easygro' stored moderately well in all atmospheres; 67.3% of the apples were marketable after storage. Similarly, 'Nova Easygro' in Ontario has a storage life of 2 to 3 months at 1C (Wilson et al., 1991) and 3 months in the northeastern United States (Costante et al., 1990). 'Nova Easygro' has been recommended for home garden use in Ontario (Wilson et al., 1991) and for commercial trial and home garden use in Nova Scotia and New Brunswick (Crowe, 1988).

#### 'Prima'

Fruit with 40% to 70% bright-red blush on a yellow ground color were harvested at the onset of the climacteric period in late Sept. 1991 (Table 1). After 4 months of air storage at 0C, 'Prima' had a 5.1% weight loss and reduction in firmness of 36.8 N (Tables 1 and 2). TA decreased 181 mg/100 ml of juice after air storage, and SSC remained similar to initial SSC (Tables 1 and 2). CA storage reduced firmness loss in 'Prima' apples but had no significant effects on SSC or TA. Weight loss was reduced by storage in LO, but not by storage in standard CA.

'Prima' apples developed core browning, vascular breakdown, and scald, and standard CA storage resulted in the development of internal browning (Table 3). 'Prima' grown in Ireland has consistently developed internal corking symptoms associated with low B levels (Hennerty, 1983).

Although there was only a slight incidence of bitterpit in 1991 (Table 4), 25.9% of 'Prima' apples had bitterpit in 1990. This finding corresponds to previous reports of large 'Prima' fruit in Oregon often developing bitterpit (Stebbins, 1990).

'Prima' had a high incidence of both storage rots and complete rots, which may be suppressed in CA (Table 4). Reducing the number of apples with defects (Table 4) could reduce the amount of storage rot.

'Prima' was harvested postclimacteric in 1990 and stored for 3 months at 3C (data not shown). As a result of increased maturity, the initial firmness, SSC, and TA were lower than those in 1991. Other than a 9.3% incidence of scald in air-stored 'Prima',

no physiological disorders developed. The higher incidence of core browning at 0C (1991) than at 3C (1990) suggests possible sensitivity to low temperature. CA reduced firmness loss in 1990 but had no significant effects on weight loss, SSC, or TA. There was a lower incidence of storage rots in 1990 (1% to 4%) than in 1991 (Table 4), despite increased susceptibility associated with mature apples. However, there may have been a lower incidence of defects in 1990 than in 1991, as the presence of defects was not noted in 1990.

Sensory evaluations on the postclimacteric 'Prima' apples were conducted at harvest in 1990 (Sanford et al., 1990). 'McIntosh' control apples were rated higher than 'Prima' for color, appearance, flavor, texture, and overall acceptability. However, an untrained sensory panel in New Jersey rated 'Prima' as having good to very good overall quality at harvest, and in a separate, blind, random preference test, 'Prima' received higher preference ratings than 'Priscilla' (Durner et al., 1992).

This study confirms previous reports that describe 'Prima' as having a short storage life (1 to 2 months) at 0 to 2C (Costante et al., 1990; Craig and Whitman, 1989; Dayton et al., 1970, 1977; Hennerty, 1983; Korban and Morrisey, 1989; Stebbins, 1990; Warner and Potter, 1988; Wilson et al., 1991). After 4 months of air storage at 0C, only one-third of the 'Prima' apples were marketable (Table 4). This was mostly due to the development of storage rots (Table 4). CA storage may reduce the incidence of storage rots and thus increase the percentage of marketable apples. However, core browning became a greater problem in CA storage.

#### 'Macfree'

Fruit with 50% to 80% medium to dark-red blush on a greenish-yellow ground color were harvested at the onset of the climacteric period in early Oct. 1991 (Table 1). After 4 months of air storage at 0C, 'Macfree' had a 5.2% weight loss and reduction in firmness of 28.5 N (Tables 1 and 2). SSC increased 0.6% and TA decreased 302 mg/100 ml of juice after air storage (Tables 1 and 2). CA storage reduced losses in firmness and weight but had no significant effects on SSC or TA.

Core browning developed in all storage atmospheres, especially standard CA storage. A low incidence of scald and storage rots developed regardless of the storage atmosphere, and defects were present in 16.8% of the apples.

'Macfree' was harvested postclimacteric in 1990 and stored for 3 months at 3C (data not shown). As a result of advanced maturity, initial firmness, SSC, and TA were lower than those in 1991. There was a low incidence of storage rots in all storage atmospheres, similar to 1991 (Table 4). Scald (11.3%) and core browning (19.1%) developed in air storage but were controlled in standard CA. Grauslund (1986) reported the development of core flush on 'Macfree' apples after long-term storage at 3 to 4C.

Sensory evaluations on the postclimacteric 'Macfree' apples were conducted at harvest in 1990 (Sanford et al., 1990). Although 'Cortland' control apples were rated higher in flavor and were more acceptable overall than 'Macfree' apples, there were no significant differences in appearance, color, and texture.

In our study, CA did not significantly increase the percentage of marketable apples after storage (Table 4) and did not extend the storage life of 'Macfree', as it does for many other apple cultivars. Similarly, 'Macfree' in Ontario has a storage life of 2 to 3 months at 0 to 2C (Spangelo et al., 1974; Warner and Potter, 1988; Wilson et al., 1991) and 3 months in the northeastern United States. Craig and Whitman (1989) stored 'Macfree' grown in the Annapolis Valley for 3 to 4 months at 0C.

### Summary

The preliminary results of this storage study suggest:

#### 'Novaspy'

- žRecommended for long-term storage (>4 months)
- žNo evidence of low-temperature sensitivity
- žNo major storage disorders
- žStandard CA and low-O<sub>2</sub>CA improve firmness retention and may reduce weight loss

#### 'Moirá'

- žRecommended for short-term storage (<2 months)

- žNo evidence of low-temperature sensitivity
- žSusceptible to vascular breakdown, core browning, scald, and bitterpit
- žStandard CA and low-O<sub>2</sub>CA reduce scald but may increase incidence of core browning and vascular breakdown
- žSusceptible to storage rots, which may be controlled by standard CA or low-O<sub>2</sub>CA
- žStandard CA and low-O<sub>2</sub>CA may improve firmness retention and reduce weight loss

#### 'Priscilla'

- žRecommended for short-term storage (<2 months)
- žNo evidence of low-temperature sensitivity
- žSusceptible to bitterpit and some scald, which may be controlled by low-O<sub>2</sub>CA
- žStandard CA may improve firmness retention and reduce weight loss

#### 'Novamac'

- žMay be acceptable for midterm storage (≤ 4 months)
- žEvidence of low-temperature sensitivity
- žMay be susceptible to core browning
- žStandard CA and low-O<sub>2</sub>CA may reduce weight loss

#### 'Nova Easygro'

- žMay be acceptable for midterm storage (14 months)
- žNo evidence of low-temperature sensitivity
- žSome scald susceptibility, which can be controlled in standard CA or low-O<sub>2</sub>CA
- žSusceptible to core browning and may be susceptible to bitterpit
- žStandard CA and low-O<sub>2</sub>CA may improve firmness retention and reduce weight loss and TA loss

#### 'Prima'

- Recommended for short-term storage (<2 months)
- žEvidence of low-temperature susceptibility
- žSusceptible to core browning and may be susceptible to vascular breakdown, internal browning, scald, and bitterpit

- žSusceptible to storage rots, which may be controlled by standard CA or low-O<sub>2</sub>CA
- žStandard CA and low-O<sub>2</sub>CA may improve firmness retention
- žWeight loss may be reduced by low-O<sub>2</sub>CA

#### 'Macfree'

- žMay be acceptable for midterm storage ( $\leq 4$  months)
- žNo evidence of low-temperature sensitivity
- žMay be susceptible to core browning and scald
- žStandard CA and low-O<sub>2</sub>CA may improve firmness retention and reduce weight loss

Our research suggests there are different responses to standard CA and LO. It is not clear if standard CA or LO is preferred or undesirable for each cultivar. Longer-term storage (>4 months) experiments may clarify the response of these cultivars to standard CA and LO.

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