DESCRIPTION:	**Effect of Ethylene Concentration in Storage on the Storage Life of Bartlett Pear Fruit**
PROJECT LEADER:	**Beth Mitcham- UC Davis**
2002 FUNDING:	**$18,606**
FUNDING SOURCE:	**California Pear Advisory Board**

Effect of Temperature and Ethylene during Cold Storage of California Bartlett Pears

A Report for the California Pear Advisory Board

December 2002

R.H. Veltman, W.V. Biasi and E.J. Mitcham

Department of Pomology, UC Davis.

Summary

The presence of ethylene in the storage environment has been shown to greatly reduce the quality and storage life of many fruit and vegetables. Pears can produce large amounts of ethylene during cold storage, especially if they are exposed to warmer than optimum temperatures and begin to ripen. It would seem reasonable to expect that removing ethylene from storage rooms containing pears would be beneficial. However, the effect of ethylene on stored Bartlett pears has not been fully evaluated.

In this trial, Bartlett pears were harvested in two commercial orchards, one in Sacramento and the other in Mendocino. The fruit were stored at 30, 32, 34 or 36°F in the presence of 0, 1 or 10 parts per million (ppm) ethylene. Color, firmness, and physiological disorders were evaluated at harvest and after 6 and 12 weeks of cold storage, both immediately and following 5 days of ripening at 68°F.

Pears stored at 30°F were still green and firm following 12 weeks of storage, regardless of the ethylene concentration used. The fruit ripened normally over 5 days at 68°F, reaching good dessert eating quality. In contrast, fruit stored at 36°F, and to a lesser extent fruit stored at 32 or 34°F, were already yellowish and partially soft when removed from storage. Many of the fruit stored at 36°F also had symptoms of superficial scald and internal breakdown. These symptoms worsened during 5 days at 68°F, by which time almost none of the fruit remained in an edible condition. Some fruit stored at 34°F developed scald, but pears stored at 32°F were free of external disorders. Fruit stored both at 32 and 34°F developed internal breakdown, but only after they were ripened for 5 days after removal from the cold store.

The ethylene concentrations tested significantly increased the incidence and severity of superficial scald and internal browning in the 2002 season. However, the effect of temperature was far greater than the effect of ethylene. While it remains desirable to minimize ethylene in the storage environment, good temperature control reduces the need to remove ethylene. Maintaining optimum storage temperature would therefore seem to be the most important factor in maximizing the storage life of Bartlett pears.

Introduction

Pear fruit can produce large amounts of ethylene, even during cold storage. This can become particularly significant if some of the fruit begin to ripen. The presence of ethylene in the storage environment has been shown to decrease the storage life of other fruit, and increase decay and the incidence of a number of physiological disorders. Although the effects of ethylene on cold stored Bartlett pears has not been directly tested, the fruit are certainly very sensitive to exogenous ethylene after they are transferred to room temperature. It would, therefore, seem likely that reducing ethylene in the storage environment could extend storage life and improve the quality of Bartlett pear fruit.

Table 1. Initial fruit maturity.

	Firmness (Lbs)	**Color (Hue°)[z]**	**TSS (%)**	**TA (%)**
Early season July, 16, 2002	19.5 a[y]	115 a	11.3 a	0.377 a
Late season August 14, 2002	16.3 b	112 b	11.9 b	0.284 b

[y] Numbers accompanied by different letters (a, b) are significantly different.
[z] Green fruit ≈ H°>105, yellowish fruit ≈ H°=95-105, dark yellow fruit ≈ H°<95

Both the amount of ethylene that fruit produce, and the effects of ethylene are influenced by temperature. This is important as, while removing ethylene may be beneficial, the costs entailed can also be significant. It is, therefore, critical to know how much ethylene pears of a particular maturity will produce at the storage temperature used, and what the effects of that ethylene will be.

We have tested how various ethylene concentrations in the storage environment affect the quality of Bartlett pears. Early and late season fruit were stored at four different temperatures for 6 and 12 weeks before ripening at room temperature. The results are discussed in terms of the economic value of removing ethylene from rooms containing stored pears.

Materials and Methods

Pears were provided by two packinghouses, early season fruit from Sacramento (7/16/2002) and late season fruit from Mendocino (8/14/2002). Fruit (size 110) were not pre-cooled, and were obtained in standard, tight-fill commercial pear boxes. Fruits were transported to UC Davis the day of harvest, numbered and sorted into groups of 60 fruit (20 x 3 replicates). Each group was placed into a 42 gallon PVC tank at 30, 32, 34 or 36°F, and flushed continuously with humidified air containing 0, 1 or 10 ppm ethylene. During the experimental period air was sampled from the storage tanks twice or thrice a week to check that the concentration was near the set-point.

Table 2. Nominal set points for ethylene concentrations (in ppm) inside the storage tanks at 30, 32, 34 or 36°F and the actual (average) ethylene concentrations achieved over the entire experimental period (12 weeks).

Set points		Temperature (°F)			
		30	32	34	36
Early season	0 ppm	0.08 ± 0.08	0.06 ± 0.05	0.12 ± 0.07	0.18 ± 0.16
	1 ppm	0.99 ± 0.28	1.05 ± 0.21	1.31 ± 0.83	1.33 ± 0.33
	10 ppm	9.1 ± 1.9	9.8 ± 1.3	10.2 ± 1.6	11.3 ± 3.5
Late season	0 ppm	0.10 ± 0.10	0.08 ± 0.07	0.12 ± 0.06	0.29 ± 0.41
	1 ppm	0.94 ± 0.37	1.13 ± 0.28	1.37 ± 0.59	1.37 ± 0.66
	10 ppm	10.2 ± 0.5	10.1 ± 0.9	10.1 ± 2.0	10.8 ± 3.1

As storage progressed, some of the fruit began to produce significant amounts of ethylene, which increased the concentrations inside the tanks. To maintain the ethylene concentration at the set point level, the concentration in the air-stream entering the tanks was reduced or eliminated, and the flow rate of air entering the tank was adjusted. At 32, 34 and 36°F this was not effective enough; it became necessary to add potassium permanganate (an ethylene absorbent) to some of the tanks to maintain the set-point concentration of ethylene in the storage environment. A wooden crate covered with cheesecloth contained the permanganate grains.

The fruit were assessed on the day of harvest and following 6 or 12 weeks of cold storage. After harvest, measurements were taken immediately, as well as after 5 days of ripening at 68°F. Fruit were assessed in terms of color, firmness, severity of scald, the percentage of the fruit's surface that was affected with scald and internal breakdown. Internal breakdown and the severity of scald were both

scored into 4 classes, which are defined in Table 3. The scores for the severity of scald and internal breakdown were converted to a percentage according to Equation 1 to make results easier to read. In Equation 1 ‘a’ is the number of fruit in class I, ‘b’ is the number of fruit in class II, ‘c’ is the number of fruit in class III, and ‘n’ is the total number of fruits, a value of 100% means all pears have class III scald.

$$\frac{(a \cdot I + b \cdot II + c \cdot III)}{3 \cdot n} \cdot 100\% \quad Eq.1$$

Table 3. Definition of storage disorders for Bartlett pear

	Class			
	0	**I**	**II**	**III**
Scald severity	Free of disorders	Light brown spots	Brown spots or areas	Dark brown or black tissue
Internal breakdown	Free of disorders	Only core affected	Core and part of the cortex affected	All internal tissues affected

Initial measurements also included total soluble solids (TSS), and titratable acidity (TA) to establish the maturity stage at harvest. TA is a measure for juice sourness. It is determined by titrating the juice with NaOH. The reading is reported as % equivalent malic acid; the main acid in pear is malic acid. Color was measured with a Minolta Chroma meter and firmness was measured with an electronic penetrometer (Güss, South Africa). The results were analyzed using SAS statistical software.

Table 4. Overall significance levels of the effect of harvest maturity, applied ethylene concentration, storage time and storage temperature on the color, firmness, scald and internal break down.

Parameter		Grand mean values				
		Firmness	Color	Scald		Break-down
				Severity	Area	
		(Lbs)	(Hue°)	(%)	(%)	(%)
Harvest maturity	Early	10.1a	101.2 a	0.25 a	3.14 a	0.41 a
	Late	7.8 b	98.3 b	0.08 b	1.30 b	0.20 b
Ethylene	0 ppm	9.0 a	99.8 a	0.10 a	1.66 a	0.25 a
	1 ppm	8.8 b	99.4 b	0.21 c	3.22 b	0.35 c
	10 ppm	8.9 b	100.0 a	0.18 b	1.77 a	0.32 b
Storage time	6 weeks	9.2 a	101.1a	0.08 a	0.59 a	0.02 a
	12 weeks	8.6 b	98.3 b	0.25 b	3.85 b	0.59 b
Storage temp	30°F	9.3 a	102.8 a	0 a	0 a	0 a
	32°F	9.2 b	101.4 b	0 a	0 a	0.06 b
	34°F	8.6 c	98.5 c	0.11 b	0.81 b	0.38 c
	36°F	8.5 c	96.1 d	0.55 c	8.10 c	0.79 d

Results

Initial Measurements

Pears from the two harvests differed significantly in terms of their initial firmness and color, as well as TSS and TA (Table 1), confirming the different stages of maturity. Early season fruit were harder and greener than later fruit, had a lower soluble TSS value, and higher TA value. Late season fruit contained higher TSS and less TA.

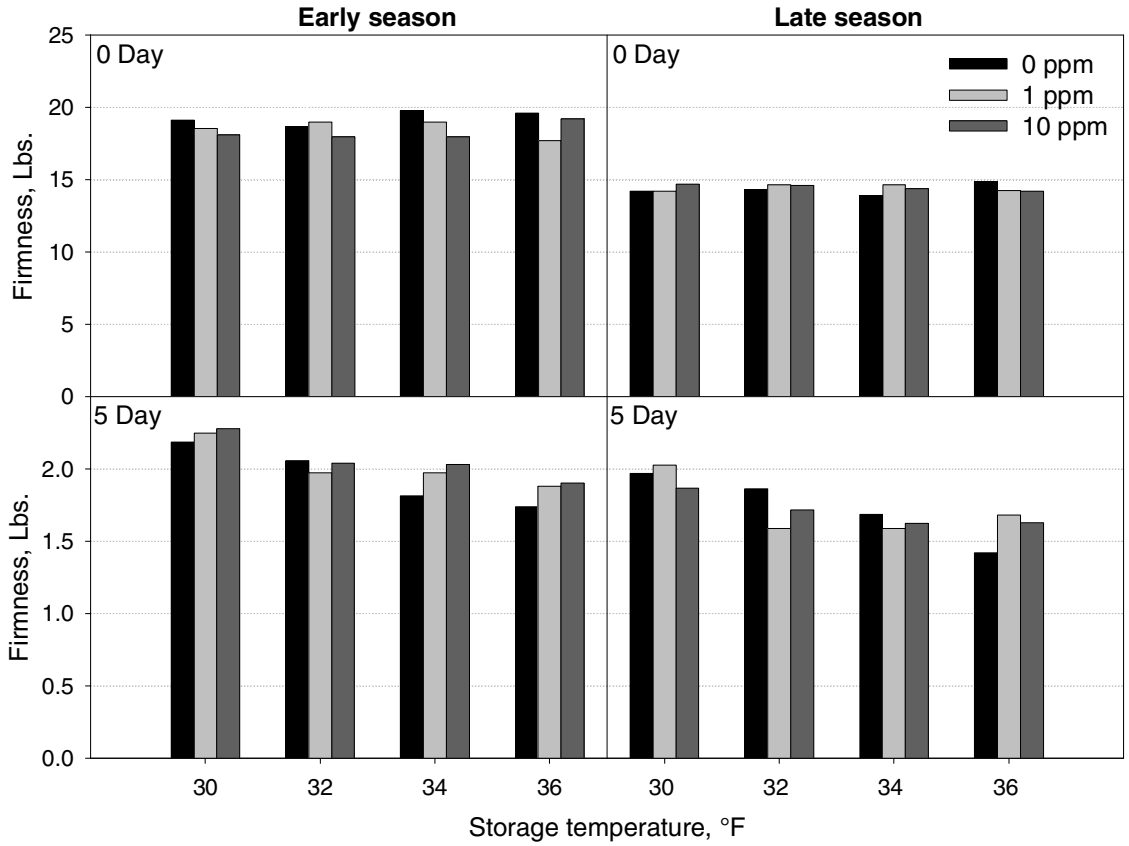

Figure 1. Firmness from early and late season fruit directly after 6 weeks of storage at 30, 32, 34 or 36°F and exposure to three ethylene concentrations (0 Day), and after 6 weeks of storage under these conditions followed by 5 days of ripening at 68°F (5 Day).

Ethylene Concentrations

The ethylene production by fruit stored at 34 and 36°F was such that it became difficult to keep the concentration around the fruit to the specified level. This was particularly true for the fruit stored at '0' and 1 ppm ethylene. The actual mean ethylene concentrations inside the containers over the entire storage period are shown in Table 2.

Firmness

The early season pears remained significantly firmer than the later harvested pears, regardless of storage temperature and storage time (6 weeks or 12 weeks). This difference was still visible after 6 weeks of cold storage and 5 days of ripening, but was lost after 12 weeks of cold storage and 5 days ripening. Some of the firmness results after 12 weeks of cold storage and 5 days of ripening are misleading. Bartlett pears do not ripen normally at low temperatures, and with prolonged storage (more than 12 weeks) they loose their ability to ripen normally at any temperature. As the condition evolves fruit become yellow and ultimately develop senescent scald. The pears remain (locally) firm, but the skin turns brown and sloughs off rather easily. Senescent scald was seen for the first time after 12 weeks of storage, and masks the drop in firmness due to the natural process of ripening of the fruit that one would expect. This phenomenon was found for pears from both harvests, especially after storage at 36°F (Fig. 2).

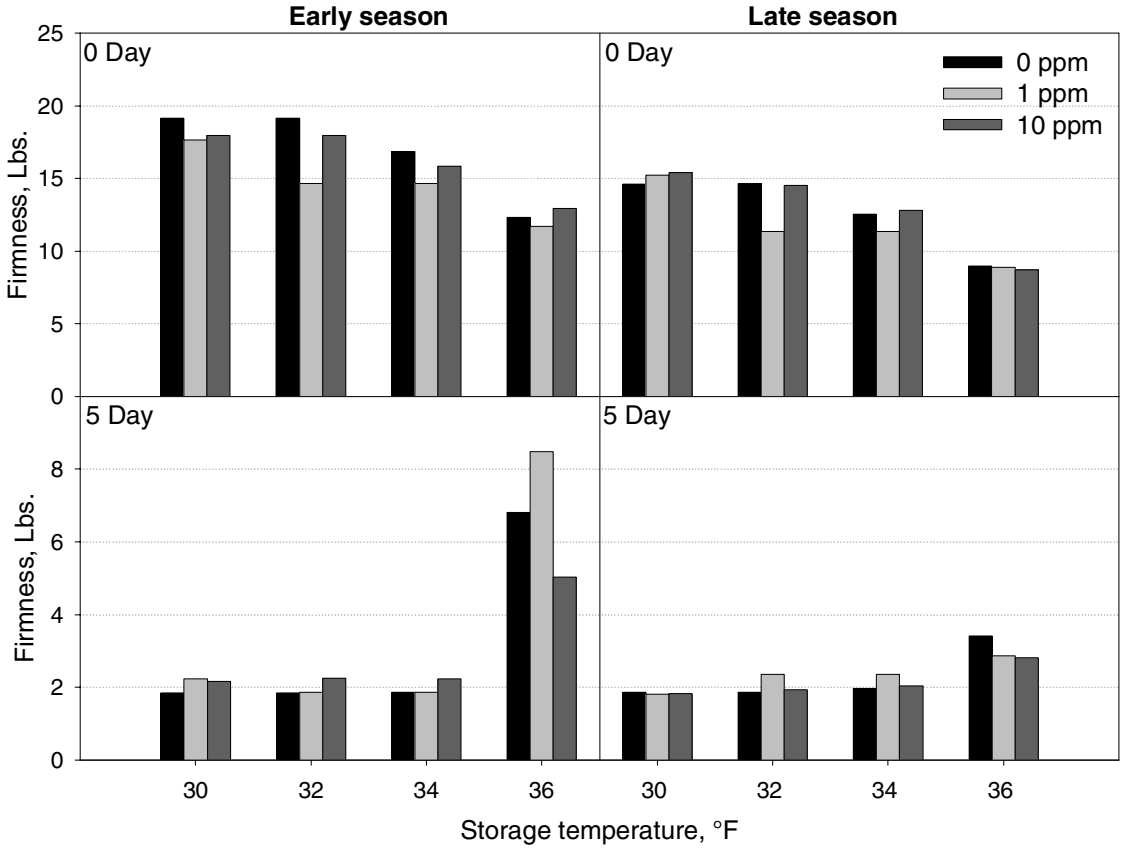

Figure 2. Firmness from early and late season fruit directly after 12 weeks of storage at 30, 32, 34 or 36°F and exposure to three ethylene concentrations (0 Day), and after 12 weeks of storage under these conditions followed by 5 days of ripening at 68°F (5 Day).

Ethylene concentration had a significant overall effect on fruit firmness (Table 4). Firmness, however, was often not noticeably affected by the ethylene concentration in any of the storage time/temperature combinations tested. The main factor affecting fruit firmness was storage temperature.

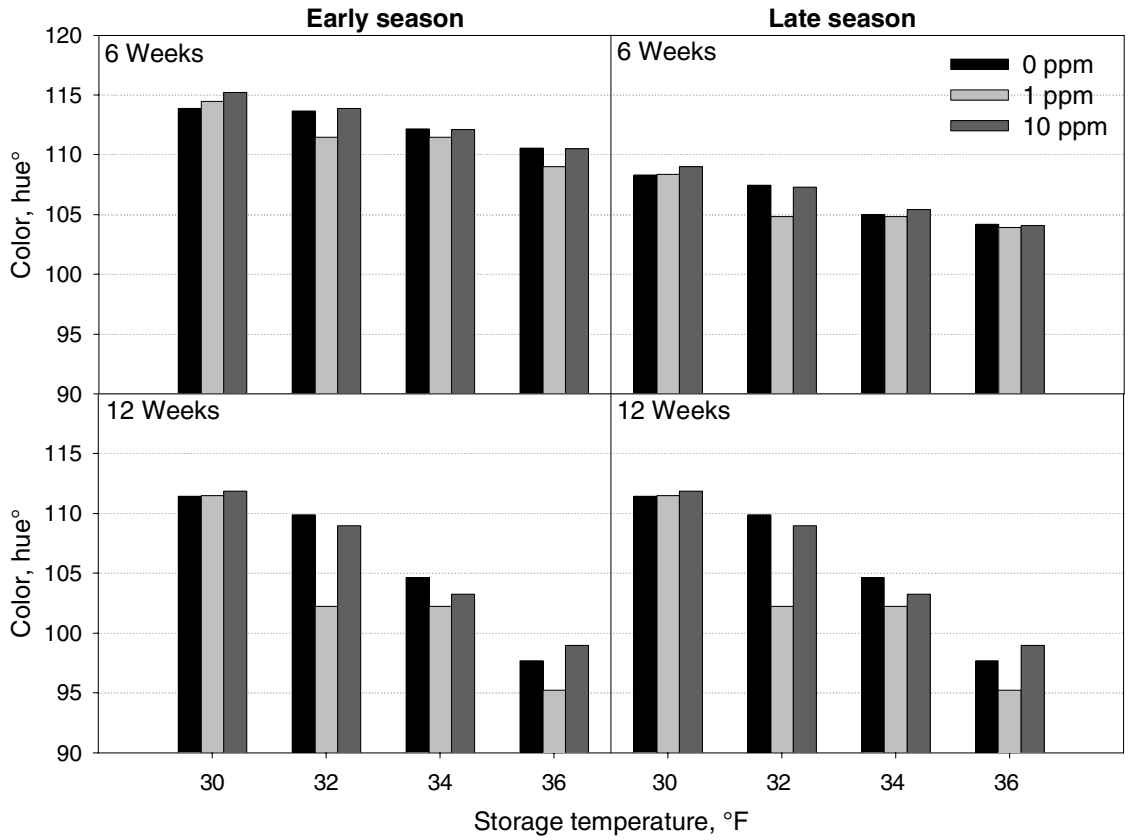

Figure 3. Color (Hue°) of early and late season pears after 6 (upper panel) or 12 weeks (lower panel) of storage at 30, 32, 34 or 36°F and exposure to three ethylene concentrations (0, 1 and 10 ppm). Green ≈ H°>105, light yellow ≈ H°=95-105, dark yellow ≈ H°<95.

In the 2001 season the fruit stored at 36°F with ethylene levels close to zero were greener than the ethylene treated fruit. There was no such a trend in 2002, neither after 12 weeks storage at 32 or 34°F (Fig. 3). Surprisingly however, fruit stored at 1 ppm ethylene were sometimes more yellow than fruit treated with 10 ppm ethylene during storage, both before and after ripening at 68°F. One might suggest that these differences have little real significance and that for practical purposes the ethylene treated pears were the same color as the untreated controls. However, the same trend can be seen for the firmness of fruit stored for 12 weeks at 32, 34 or 36°F. More important is that 1 ppm ethylene has a significantly more negative effect on scald formation and internal breakdown compared to ethylene levels close to zero and around 10 ppm (Table 4). There is no biological explanation for this observation at this moment. A detailed investigation would be necessary to further explore the relationship between ethylene concentration and ripening effects and storage disorders.

Scald and Internal Breakdown

The results of the 2001 season showed an obvious difference between the control and the ethylene treated fruit in the incidence of physiological disorders.

The trend was: the higher the level of ethylene (0, 0.01, 1, 5 or 10 ppm) the higher the incidence and severity of scald. In general the appearance of scald was more severe in 2001, and fruit was already greatly affected directly after cold storage. This was different for the 2002 season. Fruit did not show disorders directly after 6 weeks. After 12 weeks, some of the fruit stored at 36°F showed scald directly after they had been removed from storage; late season fruit were very slightly affected directly after removal (<1% of the fruit's peel covered with scald), and only when 1 ppm ethylene was applied during storage (Tables 5 and 6). Early season fruit were all affected directly after removal from storage at 36°F. For pears of both harvest dates scald worsened clearly following 5 days at 68°F (Tables 5 and 6). At 36°F, scald was always most severe when fruit were stored at 1 ppm ethylene, not at 10 ppm. In general, late season fruit were less susceptible to scald than early season fruit.

Table 5. The severity of scald on Bartlett pears after 6 or 12 weeks of storage at 30, 32, 34 or 36°F and 0, 1 or 10 ppm ethylene (0 Day), and after storage under these conditions followed by 5 days ripening at 68°F (5 Day). The severity of scald was originally scored into four classes, and was converted to a percentage according to Equation 1 in Materials and Methods, to make results easier to read.

		Scald severity (%)							
Temp	**Ethylene**	**Early season**				**Late season**			
(°F)	**(ppm)**	6 Weeks		12 Weeks		6 Weeks		12 Weeks	
		0 days	5 days	0 days	5 days	0 days	5 days	0 days	5 days
30	0	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-
32	0	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-
34	0	-	-	-	-	-	-	-	3
	1	-	-	-	14	-	-	-	6
	10	-	-	-	67	-	-	-	-
36	0	-	-	6	73	-	-	-	26
	1	-	-	80	80	-	-	6	40
	10	-	-	44	49	-	-	-	42

In 2001 ethylene significantly increased both the severity of scald and the surface area affected by scald when fruit were stored at 36°F. At 30°F, the effect of ethylene was less severe: only the 10 ppm ethylene treatment consistently increased scald. In the 2002 season no scald was visible after 6 or 12 weeks of storage at 30 or 32°F, or after storage plus 5 days ripening at 68°F.

Directly after 6 weeks of cold storage there was no internal breakdown visible at any of the temperature and ethylene combinations. Directly after 12 weeks of storage it became only apparent at 36°F. Internal breakdown was severe in many

of the fruit stored at 36°F especially after 12 weeks of storage, but was completely absent from those stored at 30°F. The disorder at 36°F became particularly obvious after ripening at 68°F, by which time a large number of fruit were entirely brown and pulpy inside. In the 2002 season two temperatures, 32 and 34°F, were added to the trial. The results from this year's study showed that at the intermediate temperatures, pears still developed internal breakdown, but less than at 36°F. The disorder only became visible after ripening. The addition of ethylene may worsen internal breakdown to a small extent, although the relationship between ethylene and internal breakdown was difficult to understand in 2002, 10 ppm ethylene causing significantly less disorders compared to 1 ppm of ethylene (Table 7).

Table 6. Surface of Bartlett pears covered with scald after 6 or 12 weeks of storage at 30, 32, 34 and 36°F and 0, 1 or 10 ppm ethylene, and after storage under these conditions followed by 5 days ripening at 68°F.

		Scald surface (%)							
Temp (°F)	Ethylene (ppm)	Early season				Late season			
		6 Weeks		12 Weeks		6 Weeks		12 Weeks	
		0 days	5 days	0 days	5 days	0 days	5 days	0 days	5 days
30	0	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-
32	0	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-
34	0	-	-	-	-	-	-	-	1
	1	-	-	-	2	-	-	-	1
	10	-	-	-	15	-	-	-	-
36	0	-	-	1	38	-	-	-	13
	1	-	-	21	54	-	-	1	24
	10	-	-	5	16	-	-	-	23

Conclusions

Ethylene in the storage environment decreased the quality of stored pears in the 2001 season. However, in the 2002 season this was not evident and generally the negative effects on fruit quality caused by ethylene were minimal compared to the effects of increased temperature. When fruit were stored at 30°F they were still essentially green when removed from storage and ripened normally over 5 days at 68°F, regardless of ethylene concentration. However, increasing the storage temperature to 36°F resulted in fruit that were yellow, soft and with severe scald symptoms even when first removed from storage. The condition of the fruit worsened after ripening, by which time almost none of these fruit remained edible. While exposure to ethylene may sometimes further reduce the

quality of these fruit, this was not the difference between marketable or non-marketable pears. Rather, this was the difference between bad and worse.

Table 7. Internal breakdown in Bartlett pears after 6 or 12 weeks of storage at 30, 32, 34 and 36°F and 0, 1 or 10 ppm ethylene, and after storage under these conditions followed by 5 days ripening at 68°F. Internal breakdown was originally scored into four classes, and was converted to a percentage according to Equation 1 in Materials and Methods, to make results easier to read.

		Internal breakdown (%)							
Temp	**Ethylene**	**Early season**				**Late season**			
(°F)	**(ppm)**	6 Weeks		12 Weeks		6 Weeks		12 Weeks	
		0 days	5 days	0 days	5 days	0 days	5 days	0 days	5 days
30	0	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-
32	0	-	3	-	-	-	-	-	-
	1	-	13	-	1	-	-	-	2
	10	-	22	-	3	-	-	-	2
34	0	-	20	-	23	-	-	-	30
	1	-	18	-	56	-	-	-	46
	10	-	22	-	52	-	-	-	29
36	0	-	26	3	94	-	3	-	59
	1	-	51	17	97	-	3	-	73
	10	-	33	10	99	-	2	-	71

In conclusion, temperature is a more important factor in maintaining pear quality than is ethylene in the storage atmosphere. While it might be desirable to minimize ethylene concentrations around stored pears, it is important that this is not done at the expense of good temperature control. There was clearly a large difference in fruit quality between 30°F and 36°F in the 2001 season. Further work in the 2002 season confirmed this result, and showed the critical temperature for storing pears above which excessive ripening and physiological damage occurs. To guarantee fruits without disorders and with good quality attributes under any circumstance (storage time, growing location, ethylene concentration during storage) the storage temperature should not exceed 30°F. Scald was seen only at 34 and 36°F, but at 32°F internal breakdown developed already after 6 weeks. The overall conclusion is that an increase in storage temperature to 34 or even 32°F can be harmful, depending on factors like growing location and storage duration. It can be very damaging to take the risk of storing Bartlett pears at temperatures higher than 30°F without further considering these factors. It is more economically important to focus on maintaining storage temperature, and not on scrubbing ethylene.