FINAL PROJECT REPORT

Project Title: Pear storage decay and fruit quality research

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Budget History:

Item	**Year 1:** 2004	**Year 2:** 2005	**Year 3:** 2006
Salaries	15,894	15,789	15,736
Benefits	8,106	8,211	9,599
Wages			
Benefits			
Equipment			
Supplies	5,600	5,600	4,265
Travel	400	400	400
Miscellaneous			
Total	30,000	30,000	30,000

Objectives: This research blends activities in the areas of postharvest pathology and physiology. One objective is to further develop a storage decay control program for winter pears in which diverse, independent decay control practices contribute to dependable reduction of postharvest diseases. A second objective is to develop and evaluate methods and materials for the promotion of pear quality during storage. Fruit quality research (including size enhancement) was included in this project beginning in 2006.

Significant Findings:

1. Postharvest decay control programs.

- Studies on the development of integrated decay control programs established a "backbone" of calcium and ziram treatments during summer, as core treatments for decay reduction.
- Calcium chloride sprays during August and early September were equally as effective as sprays during July and early August for Bosc pears, but a high dose of calcium chloride 1 week before harvest was damaging to fruit and led to greater decay.
- A series of studies to evaluate pre-harvest fungicide treatments identified Flint, Topsin, and Pristine as effective choices.
- The range of pear postharvest pathogens susceptible to each of the available fungicides for pear postharvest decay was unique; that is, each fungicide affects a unique set of pathogens.
- Sequential treatment programs, consisting of calcium and ziram in summer, a pre-harvest fungicide, a postharvest fungicide or biocontrol, and storage in modified atmosphere packaging, were the most effective approaches to decay control.
- Programs suitable for organic production significantly reduced decay, but not as effectively as programs including synthetic fungicides. Calcium in the orchard, BioSave 110 postharvest, and storage in LifeSpan MAP bags was the most effective potentially organic program tested.
- Strains of the blue mold fungus resistant to TBZ (Mertect) were found to be common in decayed pears. All strains collected from packinghouses that were resistant to TBZ were sensitive to Penbotec and Scholar.
- Both Scholar and Penbotec began to lose effectiveness when applied three weeks after spores were introduced into pear wounds prior to cold storage.

2. New technologies affecting pear decay.

- The biofumigant fungus *Muscodor albus* was found to be effective in reducing gray mold and blue mold in pears, but only if inoculated pears were exposed to the biofumigant at room temperature for 24-48 hours prior to cold storage.
- Laser coding of pears to replace the use of stickers, using the technology available through 2006, can lead to a slightly higher risk of decay.

3. Advances in postharvest management of pears.

- Ethylene treatment (100 ppm) of Comice pears for 48 hours at room temperature plus two weeks of cold storage can replace the traditional requirement for 30 days cold storage. Ethylene treatment for 72 hours can eliminate the postharvest chill requirement for Comice, but pears become too soft for long-distance shipping.
- Ethylene treatment (100 ppm) of Bosc pears for 24 hours at room temperature can eliminate the postharvest chill requirement.

- In a variety of tests to find an appropriate protocol for using 1-MCP in Bosc and Comice pears, no treatment was found that extended storage life while allowing consistent, predictable ripening.
- In a study of the chill requirement of Comice pears relative to fruit maturity at harvest, a linear relationship was found between the number of days after the orchard entered the maturity range when fruit were harvested and the number of days of chill required to induce ripening capacity. In other words, with each day later that the fruit are picked, the chill requirement becomes shorter.

4. Pear fruit quality enhancement.

- In 2 of 3 years, 5% and 7.5% urea sprays at full bloom resulted in increased tonnage of Bartlett pears size 90 or larger, while reducing yield of smaller fruit.
- Studies are underway to explore integrating urea treatments with hormone sprays for fruit size enhancement in Bartlett, Bosc, Anjou, and Comice pears.
- Calcium chloride summer sprays were more injurious to Bartlett pear leaves than to Bosc, and calcium treatments did not consistently enhance Bartlett firmness or storage potential.

Methods:

A variety of orchard, postharvest, and storage treatments were applied in a wide range of experiments.

Results and Discussion:

I. Postharvest decay control programs.

1. A treatment program consisting of summer calcium chloride sprays, preharvest Pristine fungicide, and postharvest either Scholar or Penbotec fungicide, based on experience in this research project, offers a powerful approach to decay management. In orchards where bull's-eye rot or side rot has been a problem, adding ziram enhances the program. Other preharvest sprays have also been effective: Flint and Topsin M, as will be shown below.

Calcium chloride sprays in summer followed by Pristine one week before harvest increased the resistance of Bosc pears to blue mold (Fig. 1). Resistance to blue mold was determined by wounding the pears and inoculating with the fungus after harvest, then measuring the extent of decay lesion development after 6-8 weeks in cold storage. This study also compared alternative calcium programs; a late summer calcium program (3 lb. actual calcium applied 3 times in August and early September) was equivalent to a mid-summer program (3 lb. actual calcium applied 3 times in July and early August). A single-shot high dose (5 lb. actual calcium) of calcium chloride applied one week before harvest appeared to injure the fruit, and increased the amount of decay, presumably by diminishing natural fruit resistance, facilitating pathogen entry into tissue.

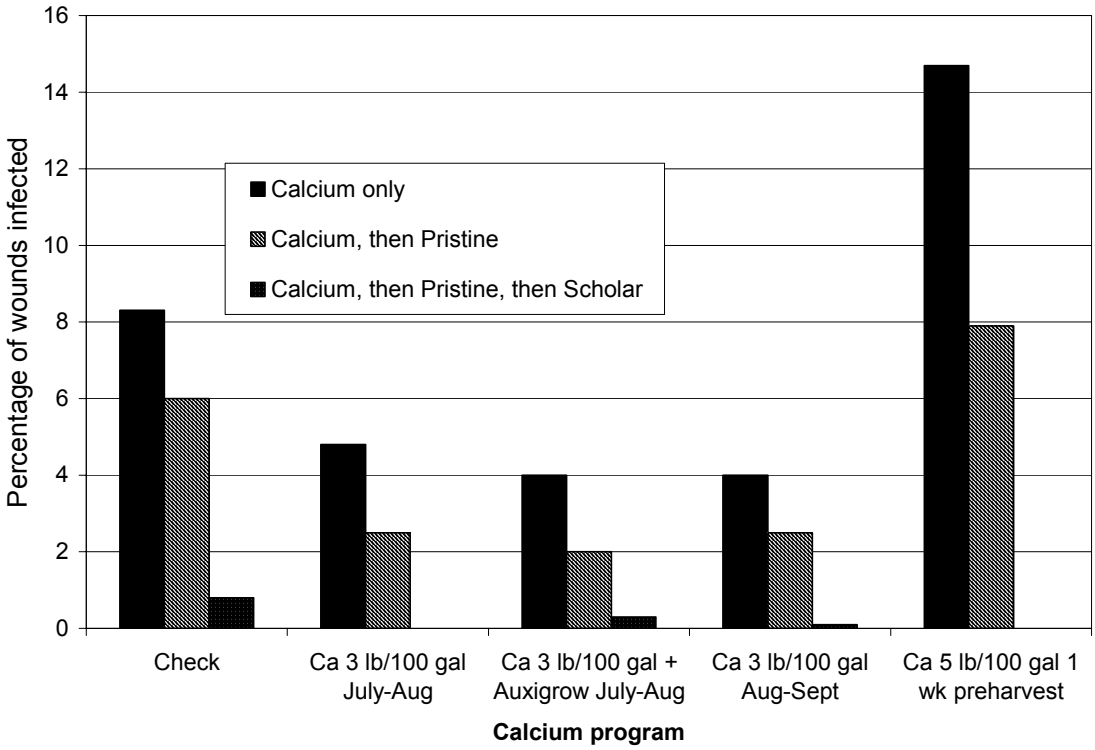

Fig. 1. Decay severity in Bosc pears inoculated after various calcium programs, with and without Pristine treatment one week preharvest, and with and without Scholar treatment postharvest.

2. A two-year study of alternative decay control programs combining orchard, postharvest, and storage treatments was completed in 2005 (Table 1). Among orchard treatments, Messenger was not shown to be beneficial, while calcium chloride reduced decay. Among postharvest treatments, BioSave 110 and sodium bicarbonate (5%) reduced decay while chitosan and StorOx did not (as used in these experiments). Pears stored in LifeSpan MAP bags had less decay than those stored in standard perforated liners. Pears that had received calcium in the orchard had higher oxygen and lower carbon dioxide atmospheres in the LifeSpan bags, likely indicating a slower rate of respiration. The treatment program consisting of calcium chloride in the orchard, BioSave 110 postharvest, and storage in LifeSpan MAP was the most effective in minimizing decay incidence.

Table 1. Effects of alternative orchard, postharvest, and storage treatments on natural decay in wounded Bosc pears.

Orchard treatment	**Percent of wounds infected**	
	Year 1	Year 2
Check	6.9 a	22.0 a
Messenger	5.7 a	16.8 a
Calcium chloride	3.1 b	7.3 b
Postharvest treatment	Year 1	Year 2
Check	3.4 bc	22.2 a
Chitosan (Elexa 4)	12.6 a	29.6 a
Mertect	3.6 bc	8.3 b
StorOx	4.8 b	22.3 a
BioSave 110	4.0 bc	5.1 c
Sodium bicarbonate	2.8 c	4.7 c
Storage treatment	Year 1	Year 2
Check (Standard liner)	6.4 a	17.8 a
LifeSpan MAP	4.0 b	13.0 a

Combined Effects:

Orchard	**Postharvest**	**Storage**	**% infected wounds**
Year 1			
Check	Water	Standard liner	5.7 a
Calcium chloride	BioSave 110	LifeSpan MAP	3.3 a
Year 2			
Check	Water	Standard liner	44.2 a
Calcium chloride	BioSave 110	LifeSpan MAP	2.1 b

Orchard treatment	**Average gas content in LifeSpan MAP**	
	Oxygen	**Carbon dioxide**
Check	11.9 a	3.6 a
Messenger	11.9 a	3.7 a
Calcium chloride	13.7 b	2.8 b

3. In laboratory tests, Scholar and Pristine had the broadest range of effectiveness among postharvest pathogens, followed by Penbotec (Table 2). Scholar and Pristine were generally effective at lower concentrations than other fungicides. These results show the excellent potential of newer fungicides to give broad-spectrum decay control. They also stress the value of knowing the target fungi in a pear orchard-packinghouse system for designing the most effective treatment strategy.

Table 2. Minimum concentration (ppm) of fungicides effective against major pathogens in laboratory tests. 10, 100, and 1000 ppm were tested. Dash (-) indicates no effect.

	Mertect	**Penbotec**	**Scholar**	**Pristine**	**Flint**	**Ziram**	**Shield TBZ**
Penicillium-S	1000	1000	10	10	100	-	1000
Penicillium-R	-	1000	10	10	100	-	-
Botrytis	1000	100	10	10	-	100	1000
Cladosporium	1000	-	100	10	10	-	1000
Alternaria	-	100	100	100	-	1000	-
Phialophora	-	1000	10	10	100	100	-

4. A wide array of possible pre-harvest – postharvest fungicide combinations is available for decay control. All of the pre-harvest fungicides tested provided some decay control, even without use of a postharvest fungicide, and all postharvest fungicides provided some decay control, even without use of a pre-harvest fungicide (Table 3). However, combinations of pre- and postharvest fungicides can improve control, and broaden the range of possible pathogens to be controlled.

Table 3. Effect of pre-harvest – postharvest spray programs on natural decay incidence in Bosc pears.

	Total decay (% of wounds infected)							
	Orchard sprays Application timing relative to harvest							
2004 **Postharvest treatment**	**Check**	**Ziram** 1 wk	**Flint** 1 wk	**Topsin** 1 wk	**Pristine** 1 wk	**Ziram** 1 mo. **Flint** 1 wk	**Ziram** 1 mo. **Topsin** 1 wk	**Ziram** 1 mo. **Pristine** 1 wk
None	6.2 a	2.4 a	1.3 ab	1.6 ab	1.1 a	0.5 ab	1.1 a	0.8 a
Scholar	1.2 b	0.0 c	0.0 b	0.0 b	0.0 a	0.0 b	0.0 a	0.0 a
Penbotec	0.6 b	0.5 bc	0.8 ab	0.3 b	0.0 a	0.0 b	0.5 a	0.0 a
Mertect	3.2 ab	2.2 ab	2.7 a	3.5 a	0.3 a	1.1 a	3.2 a	2.1 a

2005 **Postharvest treatment**	**Check**	**Topsin** 1 wk	**Pristine** 1 wk	**Flint** 1 wk	**Ziram** 1 mo. **Topsin** 1 wk	**Ziram** 1 mo. **Pristine** 1 wk	**Ziram** 1 mo. **Flint** 1 wk
Water	47.4 a	18.0 a	8.8 a	33.0 a	13.4 a	13.2 a	16.6 a
Scholar	2.2 c	0.4 b	1.4 b	2.6 b	0.4 c	2.4 b	0.8 b
Penbotec	9.0 b	2.2 b	2.2 b	1.2 b	3.4 b	1.4 b	3.0 b
Mertect	3.2 c	1.6 b	1.8 b	1.4 b	3.0 b	0.4 b	0.8 b
Shield TBZ	1.6 c	1.6 b	1.6 b	0.4 b	0.6 c	1.0 b	0.8 b

5. Penbotec and Scholar fungicides were highly effective in controlling blue mold in pear wounds when applied up to three weeks after spores were introduced into wounds (Fig. 2). This is based on prompt fruit storage at 31 °F following inoculation. At three weeks post-inoculation, decay control was still significantly better than the control, but it was apparent that the ability to inhibit decay was diminishing.

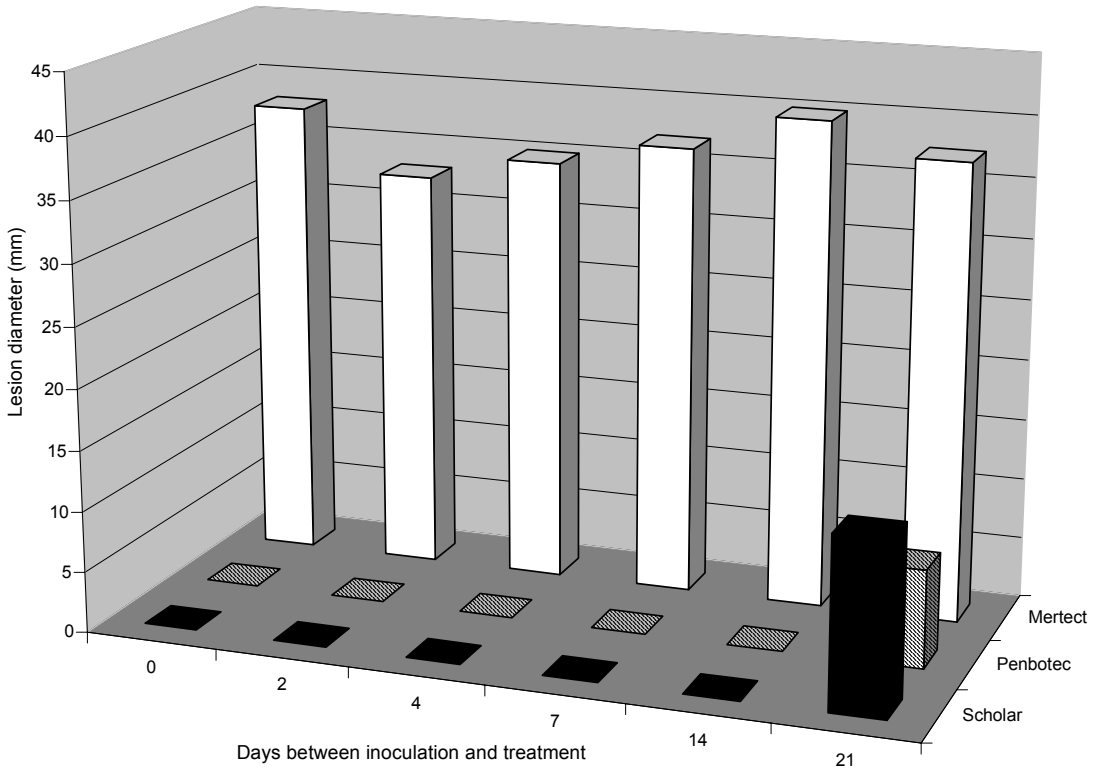

Fig. 2. Effect of length of delay between pathogen inoculation into wounds and fungicide treatment on the severity of blue mold decay in Bosc pears, using a TBZ-resistant strain.

6. Large-scale (10 acre) plots in two commercial orchards were organized in 2005 and 2006 to compare Pristine pre-harvest treatments to standard programs. In a low-decay orchard, no difference was detected, but in a late-harvested high-decay orchard, Pristine applications reduced decay (Table 4).

Table 4. Effect of Pristine pre-harvest sprays on decay in large-scale commercial plots, 2005.

	Percent decay	
	Orchard 1	Orchard 2
Pristine 2 and 1 wk pre-harvest	0.4 a	17.8 b
Standard program (Ziram)	0.9 a	51.0 a

7. In the event that two postharvest fungicides are applied (e.g., drench - line-spray or pre-size line spray – packing line-spray), the various sequences available can provide different results (Table 5). In experimental trials with TBZ-sensitive blue mold, the most effective sequences involved Scholar applied early, followed by either Penbotec or Mertect, or Penbotec followed by Scholar.

Table 5. Effect of different postharvest fungicide sequences when the initial treatment occurs immediately after harvest and the second treatment to the same fruit occurs after three weeks in cold storage.

Treatment applied after harvest (initial)	**Treatment applied 3 weeks after initial**	**Percentage of wounds infected (Blue Mold)**
Water	Water	99.3 a
Water	Mertect	94.7 a
Water	Penbotec	84.7 b
Water	Scholar	82.7 b
Mertect	Water	40.7 b
Mertect	Penbotec	14.7 c
Mertect	Scholar	13.3 c
Penbotec	Water	39.3 b
Penbotec	Mertect	16.7 c
Penbotec	Scholar	8.7 d
Scholar	Water	4.7 d
Scholar	Penbotec	2.0 d
Scholar	Mertect	1.3 d

II. New technologies affecting pear decay.

1. The biofumigant *Muscodor albus* was highly effective in suppressing blue and gray mold in Bosc pears only when inoculated fruit were held in closed containers with *Muscodor* at room temperature for 24 or 48 hours prior to cold storage (Table 6).

Table 6. Lesion diameters (mm) at wounds inoculated with *Penicillium expansum* or *Botrytis cinerea*, held in closed containers at room temperature for 24 or 48 hours, then stored at 31°F for 2 months.

	Penicillium	***Botrytis***
24 hours exposure:		
Check	13.8 a	14.9 a
Muscodor albus	1.3 b	0.0 b
48 hours exposure:		
Check	18.4 a	20.9 a
Muscodor albus	2.1 b	0.2 b

2. Laser coding may find acceptance as an alternative to stickers in labeling individual pear fruit. Since the coding is accomplished by a certain amount of injury to fruit cells, tests were carried out to determine if laser codes can become entry points for postharvest pathogens. Dip and vacuum infiltration methods with blue mold and gray mold pathogens have thus far shown that laser codes may provide a slightly higher risk of fruit infection (Table 7). In some cases (without fungicide), fungi preferentially grew on laser-coded characters.

Table 7. Incidence of decay in Bosc pears with and without laser coding, following inoculation with decay pathogens by dipping or vacuum infiltration in solutions containing 10,000 spores per milliliter. Following inoculation, pears received either water or Scholar fungicide as a line-spray.

	Total decay incidence					
	Across all inoculation methods		No fungicide		Scholar fungicide	
Blue mold	No fungicide	Scholar fungicide	Dip	Vacuum infiltration	Dip	Vacuum infiltration
Laser coded	27.7 a	8.3 a	21.7 a	33.8 a	10.3 a	6.3 a
No code	16.4 b	2.6 b	16.5 a	16.3 b	4.0 b	1.3 b
Gray mold						
Laser coded	25.0 a	0.6 a	26.3 a	23.8 a	0.0 a	1.3 a
No code	23.9 a	0.6 a	31.6 a	16.3 a	1.3 a	0.0 a

III. Advances in postharvest management of pears.

1. Ethylene treatments were applied to Comice pears for 48, 54, 60, and 66 hours prior to cold storage. Consistent ripening to 5 lbf. or less within 7 days was found with 66 hours of ethylene plus 9 days of cold (Fig. 3). Fruit treated for 66 hours in ethylene plus 9 days cold storage were very close to 9 lbf. firmness prior to ripening, considered a minimum for long-distance shipping (Fig. 3). 54 hours ethylene exposure times did not appreciably reduce the length of time in cold storage needed as compared to the current Comice protocol: 48 hours ethylene plus 2 weeks cold storage.

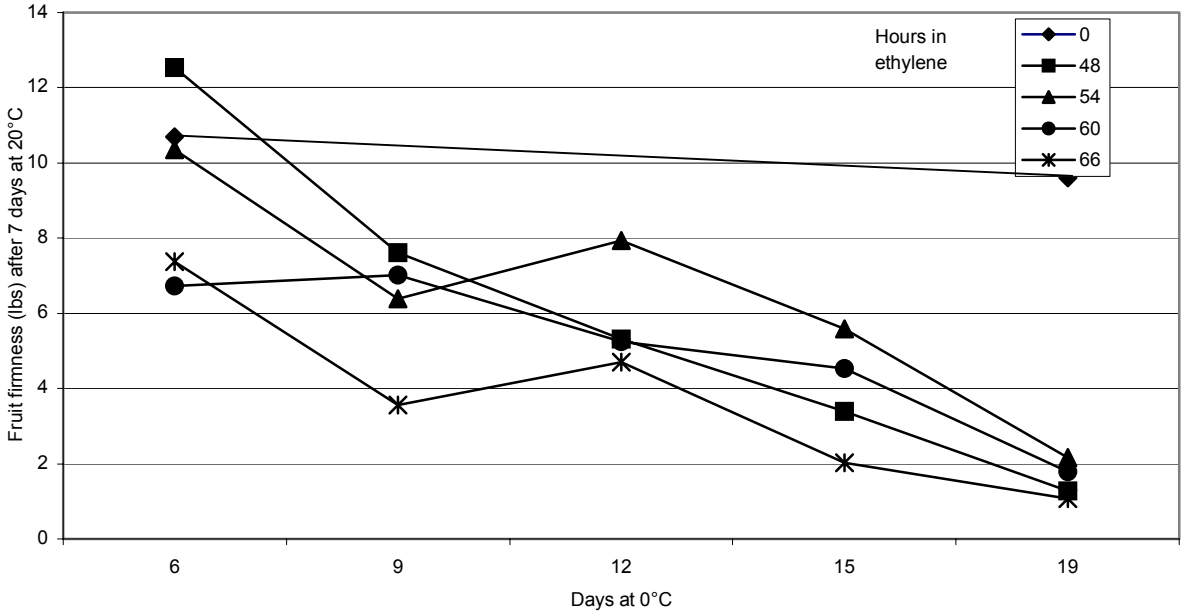

Fig. 3. Effect of ethylene exposure duration and length of cold storage on fruit firmness after 7 days at room temperature (ripe = ~5 lbf.).

2. Attempts to find an appropriate protocol for using 1-MCP in Bosc and Comice pears have been frustrating. No treatment was found that extended storage life while allowing consistent, predictable ripening. Variables tested have included dosage of 1-MCP (from 10 ppb to 1 ppm), fruit maturity at harvest, and exposure to ethylene before treatment with 1-MCP. Although studies with 1-MCP may resume if new information suggests a practical application, thus far I have not seen results that would dependably sustain fruit quality without interfering excessively in the essential ripening process for pears.

3. The relationship between harvest maturity and the length of postharvest chill necessary for inducing ripening capacity was studied in Comice pears. The date that the orchardist identified the orchard as entering the maturity range was the first harvest. Subsequent harvests were conducted weekly for 7 weeks. From each harvest, replicate groups of pears were stored at 31 °F for 5, 10, 15, 20, 25, or 30 days, then brought to room temperature for 7 days, then firmness was measured. A firmness of 5 lbf was considered "ripe". The number of days of chill required decreased in a linear fashion with each later harvest (Fig. 4). This indicates that while the standard 30 days chill requirement for Comice applies to fruit harvested at the top of the maturity range, fruit from later harvest times require shorter chilling duration. From the equation in Fig. 4, the chilling time corresponding to any number of days after entering the maturity range can be calculated.

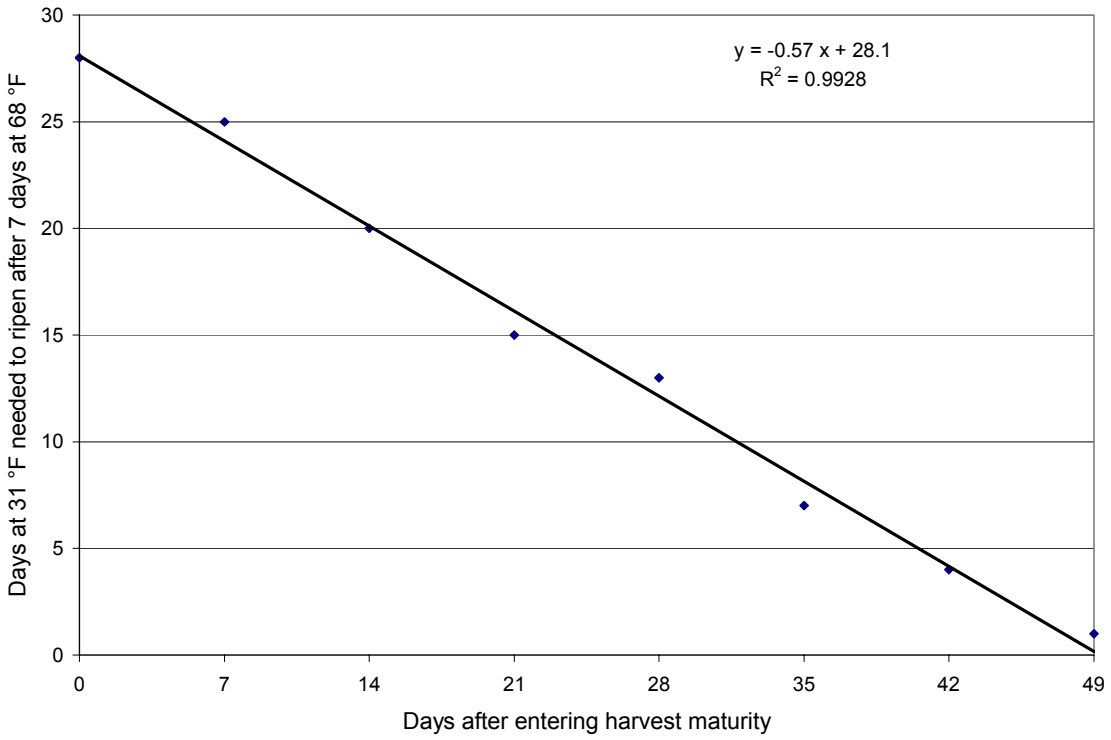

Fig. 4. Relationship of harvest date (relative to the onset of harvest maturity) to the length of postharvest chilling required to induce ripening capacity in Comice pears.

IV. Pear fruit quality enhancement.

1. In 2 of 3 years, 5% and 7.5% urea sprays at full bloom resulted in increased tonnage of Bartlett pears size 90 or larger, while reducing yield of smaller fruit (Table 8). The effectiveness of urea sprays may be dependent on crop load; further testing is needed to understand and predict the outcome of urea sprays. It appears that the effect may be a combination of blossom (fruit) thinning and providing nitrogen to developing fruitlets at a critical time to support fruit expansion. Urea sprays at earlier bloom (20%) have not been effective.

Table 8. Effect of urea sprays at full (80%) bloom on fruit size and yields of Bartlett pear.

2004	**Average fruit weight (grams)**	**Equivalent # fruit per box**	**Tons per acre**	**% size 90 or larger**	**Tons per acre size 90 or larger**
Check	189	106	23.7	26.8	6.35
Urea 5%	229	88	17.1	57.7	9.87
Urea 7.5%	243	82	18.7	71.3	13.30
2005					
Check	190	105	18.3	29.2	5.47
Urea 5%	200	100	14.5	39.6	5.81
Urea 7.5%	212	95	11.4	48.5	5.17
2006					
Check	164	122	19.2	8.9	1.76
Urea 5%	186	108	19.4	26.4	5.17
Urea 7.5%	203	99	17.3	38.4	6.02