Northwest Pear Research Review

Time	Page	PI	Organization	Project title
9:10	3	Mielke	OSU, Hood River	Rootstocks evaluations at Hood River
9:15	8	Mielke	OSU, Hood River	Northwest multi-site rootstock trials
9:20	12	Auvil	WTFRC	Rootstock and deficit irrigation trial
9:25	15	Elfving	WSU, Wenatchee	Branch induction with bioregulators
9:30	18	Drake	ARS, Wenatchee	Quality and condition of winter pears
9:35	22	Unruh	ARS, Wapato	Effects of new pesticides on natural enemies of pears
9:40	28	Sholberg	PARC	Hexanal vapor for aroma production & decay control
9:50	34	Sanderson	WTFRC	Postharvest decay control
10:15	40	Seavert	OSU, Hood River	Water management to optimize fruit production
10:30	47	Seavert	OSU, Hood River	Maturity and quality of pear cultivars
10:45	56	Proebsting	OSU, Corvallis	Propagation of pear rootstocks
11:00	60	Righetti	OSU, Corvallis	Nitrogen nutrition in different soils and environments
11:15	70	Mielke	OSU, Hood River	Improving Concorde fruit quality
11:30	73	Dunley	WSU, Wenatchee	Pesticide management for psylla
11:45	79	Hansen	ARS, Wapato	Radio frequency to control spider mites
8:00	86	Ing	Private	Interaction, coordination, information, varieties
8:15	88	Horton	ARS, Wapato	Chemical ecology of pear psylla
8:30	91	Horton	ARS, Wapato	Biology and management of pear pests
9:15	96	Unruh	ARS, Wapato	Biochemical approach to estimating psylla predation
9:30	100	Johnson	OSU, Corvallis	Integrated fire blight management
9:45	107	Xiao	WSU - Wenatchee	Phacidiopycnis rot of pears
10:15	115	Spotts	OSU, Hood River	New approaches to decay control of pear
10:30	123	Sugar	OSU, Medford	Storage decay research
10:45	129	Sugar	OSU, Medford	Epidemiology of Bull's Eye Rot in pear
11:00	135	Mattheis	ARS, Wenatchee	Pear fruit ripening with SmartFresh
11:15	140	Chen	OSU, Hood River	Postharvest physiology of winter pears

CONTINUING PROJECT REPORT **YEAR 3/3**
WTFRC Project #: PR-01-92

Project title: Evaluation of Pear Rootstocks

PI: Eugene A. Mielke

Organization: OSU – Mid-Columbia Agricultural Research and Extension Center

Cooperator: Bill Proebsting, Horticulture Department

Research Assistant: Laurie Smith

Objectives: To develop a rootstock that is precocious, produces large crops of high quality fruit, and has dwarfing character. This would produce orchards that can be efficiently managed from the ground or with short ladders and use newer equipment that is more environmentally friendly. Ideally the rootstock should be resistant (or at least tolerant) to the pests and diseases that plague Northwest growers.

1. Determine the optimum rootstocks for inducing dwarfing character, precocity, production, and fruit quality under varying soil and climatic conditions in the Northwest utilizing conventional rootstocks, interstems, and newly available rootstock material.
2. Determine the effect of three budding heights on productivity and size control.
3. Determine the fire blight sensitivity of the new rootstocks

Significant findings:

- Hard to propagate rootstocks, when used as interstems, produced significant differences in d'Anjou and Bartlett pears. The only consistent and significant differences from the non-interstemmed control throughout the ten years of the trial were increased d'Anjou fruit weight when BP-2 interstems were utilized, and a reduced fruit weight when PYR-2146 interstems were used.
- When cultivars were used as interstems, both cultivar and interstem induced significant differences in all parameters. Trees with Bartlett or Conference interstems had the smallest TCSA and the smallest canopy volume (CV). Interstemmed trees produced fewer fruit in 2002 than did the controls. Trees with Bosc and Bartlett interstems had the largest cumulative yields after adjustment for the number of trees per acre.
- Bartlett trees were taller and wider, had a greater CV, and produced significantly greater yields with 30% larger fruit when Betulaefolia rootstocks were used as compared to trees with seedling Bartlett rootstocks. Trees with Winter Nellis rootstocks were not significantly different in any parameter to trees with seedling Bartlett rootstocks.
- Horner rootstocks significantly affected tree height, canopy spread, CV, fruit number, yield, and fruit weight, both in 2002 and cumulatively over the 8-year trial. When the number of trees per acre was adjusted for tree size, trees with H-10 rootstocks continued to have a cumulative yield greater than the control.
- On d'Anjou, Bartlett, Golden Russet Bosc, and Comice trees with 708-2, 708-12, 708-36, OH11, and Bartlett seedling rootstocks, the rootstock significantly affected a number of the parameters. Most significant was smaller tree size in d'Anjou and Bartlett with OH11 rootstocks and more flowers, fruit, and yield in d'Anjou, Bartlett, and Golden Russet Bosc with 708-36.

- Pyrodwarf, Pyro II, and OHxF 97 rootstocks significantly affected the number of flower clusters, fruit set, and fruit number in 3-year-old Bartlett, Comice, and Concorde pears. Trees with OHxF 97 rootstocks (control) produced significantly more flower clusters and fruit than did trees with Pyrodwarf rootstocks; however, trees with Pyrodwarf rootstocks set a significantly greater percentage of fruit on the flower clusters.
- Fox 16 rootstocks significantly increased TCSA in 2-year-old d'Anjou but not in Bartlett trees.
- While some significant differences in tree size and yield occur on an annual basis as a result of differences in budding height, cumulative fruit numbers, yield, fruit size, and yield efficiency were not affected by budding height.
- The 708-36 and Fox 11 rootstocks, and to a lesser extent, the other 708 clones, appear to be the most susceptible to fireblight, especially to infections in root suckers and shoots arising from below the graft union of budded trees. OHxF clones were the most resistant to fireblight.

Methods:

Objective 1: Determine the optimum rootstocks for inducing dwarfing character, precocity, production, and fruit quality under varying soil and climatic conditions in the Northwest utilizing conventional rootstocks, interstems, and newly available rootstock material.

Maintain the following plantings. Evaluate each plot annually for growth, flowering, productivity, and winter survival. Evaluate fruit for production, size, and quality.

a. 1993 Brossier interstems – **terminated 2002.**
b. 1994 *Pyrus communis* interstems – terminate 2003.
c. 1994 Bartlett trial – terminate 2003.
d. 1996 Horner – **terminated 2002.**
e. 1998 English 708 and French OH11 trial – terminate 2007.
f. 2000 Pyrodwarf and Pyro 2-33 trial – terminate 2009.
g. Pyrodwarf/Pyro II trial – terminate 2009
h. 2001 Fox/708 trial – terminate 2010
i. 2001 Pyronia trial – terminate 2010
j. Begin propagation of three Russian rootstocks for a 2005 trial – terminate 2014
k. Grossly evaluate the remainder of the Horner rootstock series. Three hundred of the Horner selections are currently at Fowler Nursery and will be planted in 2004. The remainder, propagated summer 2002 will be shipped to Fowler spring 2003 for field planting in 2005. Repropagated selections will be planted in 2006. Each set of selections would be evaluated for 5 years, and the superior selections identified for further development – Initial evaluation to terminate 2008-2010.

Objective 2. Determine the effect of budding height on productivity and size control.
Maintain existing d'Anjou planting budded at 3, 9, and 15 inches. Evaluate as above – **terminated 2002.**

Objective 3: Determine the fireblight sensitivity of the new rootstocks.

708-36, Fox 11, Fox 16, Pyrodwarf, Pyro 2-33, OHxF 97, OHxF 40, Betulaefolia seedling, and Winter Nellis seedling rootstocks liners were shipped to Kerneysville, WV spring 2001, and placed in pots in the greenhouse. D'Anjou, Bartlett, Golden Russet Bosc, and Comice scions on 708-36, Fox 11, Fox 16, Pyrodwarf, Pyro 2-33, OHxF 97, OHxF 40, Betulaefolia seedling, and Winter Nellis seedling rootstocks were shipped to Kerneysville, WV spring 2002, and placed in pots in the greenhouse. The phase II trees of the Northwest pear rootstock trial will be shipped spring 2005.

When the shoots on the 2001rootstock liners were actively growing and the main leaders reached at least 20 cm in length in 2002, the plants were inoculated and arranged in a randomized complete design with 10 blocks. The inoculum was an equal mixture of two virulent isolates, Ea273 and AFRS 554, at 2 x 10^{-8} cfu • ml^{-1} in phosphate buffer. Each tree was inoculated by cutting the unexpanded leaves, plus the top two youngest expanding leaves of a single upright leader shoot with scissors dipped in the inoculum. Following inoculation, the bench was covered with plastic sheeting for 24 hours, and humidity maintained at ~70-85% RH.

Shoot length was measured one week after inoculation, and the length of infection determined at 1, 2, 4, and 6 weeks after inoculation. Infection into 1-year old wood was included in the total lesion length. Length of lesion divided by the total current seasons shoot length equaled the proportional lesion length, which was used as the index of resistance.

The 2002 trees will be evaluated in 2003 and the 2005 trees in 2006.

Results and discussion:

1993 Interstems: D'Anjou tree size, as measured by trunk cross sectional area (TCSA), was significantly larger in trees with PYR-2146 interstems as compared to the controls. No interstemmed trees had significantly smaller TCSA than did the controls. While interstems did induce significant differences in tree height, diameter, and canopy volume, none of the interstems produced differences that were significantly different when compared to the non-interstemmed control in either the 10th leaf or cumulatively. Fruit weight was significantly affected by interstem. Fruit weight, in 2002 and over the ten years of the study was significantly larger on trees with BP-2 interstems than fruit on the non-interstemmed controls, and fruit on trees with PYR-2146 interstems was significantly smaller than fruit on the controls. In Bartlett, none of the interstems produced any significant differences. This trial was terminated following harvest in 2002

1994 Interstems: In the 9-year trial of d'Anjou, Bartlett, Bosc, and Comice pears with D'Anjou, Bartlett, Bosc, or Conference interstems, cultivar and interstem induced significant differences in all parameters evaluated. There were significant cultivar by interstem interactions, as measured by differences in tree height, tree diameter, adjusted trees per acre, and fruit weight. Generally d'Anjou and Bosc trees were largest, and Comice trees the smallest when evaluating growth parameters. D'Anjou trees were the most productive and Comice the least productive; however, when production was adjusted based on tree size, Bartlett was the most productive. Trees with Bartlett or Conference interstems had the smallest TCSA, and were the shortest, narrowest, and had the smallest canopy volume (CV).

Interstemmed trees produced fewer fruit in 2002 than did the controls. Cumulative and 2002 yields on trees with Bartlett or Conference interstems were significantly the lowest. Due to their smaller size, trees with Bartlett interstems had the greatest number of trees per acre after adjusting for tree size. Trees with Bosc and Bartlett interstems had the largest cumulative yields after adjusting for number of trees per acre.

1994 Bartlett: Trees with Betulaefolia rootstocks had a significantly larger TCSA when compared to trees with seedling Bartlett rootstocks. Trees with Betulaefolia rootstocks were taller, wider, and had a greater CV than trees with seedling Bartlett rootstocks. Rootstock did not significantly affect fruit number in 2002; however, yield was greater on trees with Betulaefolia rootstocks due to a 30% increase in fruit size. Fruit size was larger on trees with Betulaefolia rootstocks each year during the nine years of this study. The cumulative fruit number and yield were significantly larger with Betulaefolia rootstocks, as well. Yields were not significantly different when adjustments were made for tree size (2001 data). Trees with Winter Nellis rootstocks were not significantly different in any parameter to trees with seedling Bartlett rootstocks.

1996 Horner: Significant rootstock differences continue to exist in tree height, canopy spread, and CV among the Horner rootstocks following seven years of growth (2001 data). The smallest trees were 18% shorter and 40% narrower than the controls on OHxF 97 rootstocks. Rootstock significantly affected fruit number, yield, and fruit weight, in 2002 and cumulatively over the 8-year trial. Even with a dramatic yield increase on the control trees in 2002, trees with H-4 rootstocks had an accumulated yield higher than the controls, and when the number of trees per acre was adjusted for tree size, trees with H-10 rootstocks also had a cumulative yield greater than the control. Due to loss of the mother trees of several of the selections, the trial was terminated following harvest in 2002. Trees with rootstocks of interest will be transplanted and the d'Anjou tops removed to encourage regeneration of the rootstock material.

1999 English 708 and OH11 Rootstock Trials: In the 4-year-old green d'Anjou, Bartlett, Golden Russet Bosc, and Comice trial with 708-2, 708-12, 708-36, OH11, and Bartlett seedling rootstocks, rootstock significantly affected a number of the parameters. The following parameters had values that were significantly different from the Bartlett seedling control. In d'Anjou: Smaller TCSA, shorter, narrower branch spread, and smaller CV (OH11); and greater number of flower clusters, more fruit, greater yield, and greater yield efficiency (YE) (708-36). In Bartlett: Smaller TCSA, shorter, narrower branch spread, and smaller CV (OH11 and 708-2). In Golden Russet Bosc: Larger TCSA (708-12); and more flower clusters, more fruit, and greater yield (708-36). In Comice: More flower clusters (708-36). There was no significant rootstock effect on bloom date, fruit set per 100 clusters, or fruit weight for any of the cultivars.

2000 Pyrodwarf and Pyro II Rootstock Trial: In a 3-year-old Bartlett, Comice, and Concorde trial with Pyrodwarf, Pyro II, and OHxF 97 rootstocks, rootstock significantly affected the number of flower clusters, fruit set, and fruit number. Neither fruit weight nor yield was significantly affected by rootstock. Trees with OHxF 97 rootstocks (control) produced significantly more flower clusters and fruit than did trees with Pyrodwarf rootstocks; however, trees with Pyrodwarf rootstocks set a significantly greater percentage on the flower clusters.

2001 Hanner Rootstock Trial: In a 2-year-old d'Anjou and Bartlett trial with 708-2, 708-12, 708-36, Fox 11, Fox 16, OHxF 40, and OHxF 87 rootstocks, rootstock significantly affected TCSA in d'Anjou but not in Bartlett. Few of the rootstocks had TCSA values that were significantly different from trees on OHxF 87 rootstocks (the control) in 2001; however, trees with Fox 16 rootstocks had a significantly greater TCSA in 2002 than did the control trees.*2001 Pyronia and 708-36 Rootstock Trial:* In a 2-year-old d'Anjou and Columbia Red d'Anjou trial with Pyronia (*P. pyronia sp.*), 708-36, OHxF 87, and OHxF 97 rootstocks, rootstock had no significant effect on any parameter measured in d'Anjou. Columbia Red d'Anjou trees with 708-36 rootstocks were significantly taller and had a larger branch spread than trees with OHxF 97 rootstocks.

Horner Mother Block Evaluation: Liners from the first 300 of the Horner selections were shipped to Fowler Nursery spring 2002. Several of the selections had insufficient numbers, or labeling problems that questioned their identity, and will be repropagated in 2003. Remaining selections were propagated in 2002 and will be delivered to Fowler Nursery spring 2003. Two trees of each selection will be planted beginning in 2004 in a 5' x 5' x 16' double-row planting. The remaining selections will be planted in 2004 and 2005. These trees will be initially evaluated for 5

years for dwarfing character, precocity, productivity, and fruit size. The goal will be to reduce the collection to the most desirable 15 to 20 selections for further evaluation.

Budding Height: D'Anjou trees budded at 9 inches as compared to 3 inches had a significantly larger increase in TCSA in 2002, were significantly taller by one foot, and produced significantly more fruit in their eighth leaf without a significant affect on fruit size. Yield efficiency, measured or either TCSA or CV, was not affected by budding height. Cumulative fruit numbers, yield, fruit size, and yield efficiency were not affected by budding height.

Fireblight: There were significant differences among clones in shoot length, lesion length, and mean proportional lesion length. Lesion length was greatest for the 1-year old Fox 11 liners and OHxF 40. Proportional lesion length, relating lesion length to shoot growth, was greatest in 708-36 and both sets of the Fox 11 liners, with most infections spreading into 1-year old wood. OHxF87 was the most resistant clone. OHxF 40 had the greatest shoot length and 708-36 had the shortest.

Budget:
Project title: Evaluation of Pear Rootstocks
PI: Eugene A. Mielke
Project duration: Long term
Current year: 2003-2004
Current year request: $27,816

Item	2002	2003
Salaries	14,917	**$13,434**
Benefits (42%)	5,673	**5,642**
Wages		**3,000**
Benefits (8%)		**240**
Equipment		**0**
Supplies	2,500	**5,000**
Travel	500	**500**
Miscellaneous		**0**
Total	23,590	**$27,816**

CONTINUING PROJECT REPORT **YEAR 3/3**
WTFRCP Project #: PR-01-90

Project Title: Northwest Pear Rootstock Trial

PI: Eugene A. Mielke

Organization: OSU – Mid-Columbia Agricultural Research and Extension Center

Co-PIs and affiliations: Dana Faubion, WSU, Extension Service, Yakima
Tim Smith, WSU, Extension Service, Wenatchee

Cooperators: Jim McFerson, WTFRC, Wenatchee
Tom Auvil, WTFRC, Wenatchee
Richard Bell, USDA, Kerneysville, WV

Research Assistant: Laurie Smith, OSU, MCAREC

Objectives: To develop a rootstock that is precocious, produces large crops of high quality fruit, and has some amount of dwarfing character. This is necessary in order to have orchards that can be efficiently managed from the ground or with short ladders and use newer equipment that is more environmentally friendly. Ideally the rootstock should be resistant (or at least tolerant) to the pests and diseases that plague Northwest growers.

1. Assess rootstocks for dwarfing and semi-dwarfing characteristics, precocity, production, and fruit quality under varying soil and climatic conditions in the Northwest utilizing conventional rootstocks and newly available rootstock material.
2. Determine the climatic adaptability of Concorde and Taylor's Gold with three rootstocks in the Pacific Northwest.

Significant findings:

- Rootstock played no significant role in tree survival in any of the plantings.
- Rootstock significantly affected root quality (number and size of roots) in the Hood River d'Anjou planting.
- Root quality was not related to initial or final trunk cross sectional area (TCSA).
- Few differences were noted in tree size as measured by trunk cross sectional area (TCSA) in the first year. D'Anjou trees with Pyro 2-33 roots and Bosc trees with Fox 16 roots had the smallest TCSA.
- There were no good correlations between initial and final TCSA.
- D'Anjou trees with Pyro 2-33 roots, Bosc trees with Fox 16 roots, and Bartlett trees with Pyrodwarf rootstocks produced the least number of lateral branches.

Methods:

Objective 1: Assess rootstocks for dwarfing and semi-dwarfing characteristics, precocity, production, and fruit quality under varying soil and climatic conditions in the Northwest utilizing conventional rootstocks and newly available rootstock material.

Maintain d'Anjou plantings in Hood River and Cashmere, a Bartlett planting in Parker, and a Golden Russet Bosc planting in Tonasket.

1. Maintain phase I planting of the Northwest pear rootstock trial. Rootstocks include: Pyrodwarf, Pyro II (2/33), Fox 10, Fox 11, 708-36, OHxF 87, OHxF 40 – planted in 2002, terminate 2011.
2. Prepare site for d'Anjou planting as second part of Northwest pear rootstock trial. Rootstocks will include: Brossier (28-152), Retuzier (OH11), Horner (H-4, H-10, & H-51), BM-200 (Australia), INRA P-2532, *Pyrus heterofolia*, and OHxF 87. – plant 2005, terminate 2014.

The experimental design will be a randomized complete block design with 10 blocks. Data to be collected annually will include: 1) Trunk cross sectional area (25 cm above bud union); 2) Canopy height, canopy spread (2 directions); 3) Flower clusters and fruit set (whole trees 1st five years); and 4) Yield (fruit number and total weight). Additional data to be collected: 1) Planting time root system rating (1 to 5, poor to excellent) and TCSA; 2) Any observations as to insect or disease preference (we are not going to scout the blocks every week); and 3) Reason(s) for tree loss, if any.

Objective 2: Determine the adaptability of Concorde and Taylor's Gold with three rootstocks in the Pacific Northwest.

Establish Taylor's Gold and Concorde pears on three rootstocks. Establish them in 2004 in conjunction with the rootstock trials as listed in objective 1. The procedures and data to be collected are the same as described above.

Results and discussion:

Rootstock played no significant role in tree survival in any of the plantings (data not shown). Rootstock significantly affected root quality (number and size of roots) in the Hood River d'Anjou planting (Table 1). D'Anjou trees with Fox 11 rootstocks had the largest mass of roots, and trees with OHxF 87 had the smallest root mass. The difference in root quality was not well correlated with either the initial (Table 1) or final (Table 2) trunk cross sectional area (TCSA), r^2 = 0.30 and 0.34, respectively.

Only the Tonasket Bosc planting exhibited significant differences in initial TCSA. Bosc trees with Fox rootstocks had the smallest initial (Table 1) and final (Table 2) TCSA. Bosc trees with Pyrodwarf roots had the largest initial TCSA (Table 1), while Bosc trees with OHxF 87 roots had the largest final TCSA (Table 2). Initial and final Bosc TCSA were not well correlated (r^2 = 0.49).

None of the rootstocks significantly affected initial TCSA in either d'Anjou planting (Table 1), and there were few significant differences in final TCSA (Table 2). D'Anjou trees with Pyro 2-33 roots had the smallest final TCSA, and d'Anjou trees with OHxF 40 roots had the largest final TCSA in both plantings. Initial and final TCSA were well correlated in d'Anjou (r^2 = 0.73).

No significant rootstock differences were found in either initial or final TCSA in Bartlett. Bartlett had the lowest correlation between initial and final TCSA (r^2 = 0.26). As three different Bartlett pollenizers were randomly utilized in the Cashmere d'Anjou planting, they were analyzed separately as a completely randomized design, and included. Significant differences did exist in initial TCSA between the rootstocks; however, as they came from different sources, and there was no significant difference in the final TCSA, the significance in initial TCSA may not be due to rootstock.

Table 1. Effect of rootstock on rootstock root ranking and initial TCSA.

Rootstock	Root[z] Ranking Hood River D'Anjou	Initial Trunk Cross Sectional Area (cm2) Cashmere D'Anjou	Hood River D'Anjou	Tonasket Bosc	Yakima Bartlett	Cashmere Bartlett
708-36	) ab	2.87	2.57	2.47 ab	2.52	-
Fox 11	4.30 a	2.44	2.51	1.68 c	2.19	-
Fox 16	-	2.29	-	1.74 c	2.29	-
Pyro 2-33	2.78 c	2.01	2.20	2.71 a	2.26	3.28 a
Pyrodwarf	4.05 ab	2.94	2.74	2.59 a	2.31	2.50 b
OHxF 40	3.20 bc	3.06	2.81	2.06 bc	2.06	-
OHxF 87	2.70 c	2.62	2.54	2.48 a	2.14	2.65 a
OHxF 97	-	-	2.73	-	-	-
Nellis	3.93 ab	-	2.91	-	-	-

[z] Means within a column followed by the same letter are not significantly different at p=0.05 – Tukey's test.

Rootstock significantly affected the number of lateral branches in three of the four plantings (Table 3). D'Anjou trees with Pyro 2-33 roots produced significantly fewer branches in the Cashmere planting, and while it also produced the fewest shoots in the Hood River planting, the differences in the latter planting were not significant. The other six rootstocks in the Cashmere d'Anjou planting had no significant effect on the number of lateral shoots. Bosc trees with Fox 16 roots produced the significantly fewest number of lateral branches, while Bosc trees with 708-36 roots produced the most lateral branches. Bartlett trees with Pyrodwarf and Pyro 2-33 produced the significantly fewest number of lateral branches, while Bartlett trees with Fox 11 roots produced the most lateral branches.

Table 2. Effect of rootstock on final TCSA.

Rootstock	Final Trunk Cross Sectional Area (cm2)[z] Hood River D'Anjou	Cashmere D'Anjou	Tonasket Bosc	Yakima Bartlett	Cashmere Bartlett
708-36	4.93 a	4.26 ab	5.27 ab	4.13	-
Fox 11	4.69 a	4.43 a	3.57 cd	4.53	-
Fox 16	-	3.44 b	3.24 d	4.08	-
Pyro 2-33	3.22 b	3.33 b	4.78 ab	4.84	4.83
Pyrodwarf	4.62 a	4.32 ab	4.39 bc	4.08	4.16
OHxF 40	4.84 a	4.96 a	4.56 b	3.49	-
OHxF 87	4.33 a	4.86 a	5.68 a	3.81	4.77
OHxF 97	4.43 a	-	-	-	-
Nellis	4.64 a	-	-	-	-

[z] Means within a column followed by the same letter are not significantly different at p=0.05 – Tukey's test.

Table 3. Effect of rootstock on the number of lateral branches.

	Number of lateral branches[z]				
Rootstock	Hood River D'Anjou	Cashmere D'Anjou	Tonasket Bosc	Yakima Bartlett	Cashmere Bartlett
708-36	9.8	9.3 a	8.5 a	11.7 ab	-
Fox 11	9.6	8.6 a	6.3 bc	13.1 a	-
Fox 16	-	8.8 a	4.1 d	10.3 bc	-
Pyro 2-33	6.9	5.5 b	7.7 ab	9.2 c	5.8
Pyrodwarf	10.8	8.2 ab	5.2 c	9.0 c	6.7
OHxF 40	10.6	9.9 a	7.7 ab	12.4 ab	-
OHxF 87	9.7	9.6 a	6.8 abc	10.5 bc	8.5
OHxF 97	8.7	-	-	-	-
Nellis	10.1	-	-	-	-

[z] Means within a column followed by the same letter are not significantly different at p=0.05 – Tukey's test.

Budget:

Project Title: Northwest Pear Rootstock Trial

Co-PIs: Eugene A. Mielke, OSU – Mid-Columbia Ag Res. & Ext. Center
Dana Faubion, WSU, Extension Service, Yakima
Tim Smith, WSU, Extension Service, Wenatchee

Project duration: Long term

Current year: 2003-2004

Mid-Columbia Ag Res. & Ext. Center			
Salary & Wages			
Research Assistant, 0.085 FTE (12 mos.)	$2,686		
OPE	1,128		
Sub-Total Salary and Wages		$3,814	
Service & Supplies		500	
Travel		500	
Sub-Total (Mid-Columbia Ag Res. & Ext. Center)			$4,814
Yakima County Coop Extension Service			
Salary & Wages			
Data (2 people, 2 days = 32 hr @ $12.50)	400		
Sub-Total Salary and Wages		400	
Service and Supplies		200	
Travel		200	
Sub-Total (Yakima County Coop Extension Service)			$ 800
Wenatchee County Coop Extension Service			
Salary & Wages		0	
Sub-Total Salary and Wages		0	
Service and Supplies		0	
Travel			
Sub-Total (Wenatchee Co Coop Extension Service)			$ 000
Total			$ 5,614

CONTINUING PROJECT REPORT **YEAR 3/3**

Project title: Pear Rootstock and Regulated Deficit Irrigation Trial

PI: Tom Auvil
Organization: Washington Tree Fruit Research Commission

Cooperator: Randy Smith, Cashmere

Advisory Committee: Bob Gix, Blue Star
Randy Smith, Cashmere
Fred Valentine, Stemilt Growers, Inc.
Tim Smith, WSU Cooperative Extension
Chris Peters, WTFRC Commissioner

Significant rootstock findings:
For all varieties:

- Commercial production (30 bins per acre) is possible by the fourth season. Some production on OHxF 87 may be possible in the third season
- Bartletts and Bosc on OHxF 40,69,87, and 97 all can achieve commercially acceptable yields at 518 trees per acre. .
- Anjou on OHxF 69,87, and 97 are acceptable at 389 trees per acre.
- OHxF 69 can have trees which lean.
- Yield and fruit quality should be efficiently maintained over time at these densities.

Anjou:

- OHxF 87 is clearly most productive, but tends to have smaller fruit.
- In 2001-2002, OHxF 87 was pruned and fertilized more aggressively to improve fruit size. This was accomplished, but yield was reduced
- Trees on OHxF 87 can become so heavily set the tops break out. Some crop reduction or tree support may be needed to prevent loss of the central leader.
- Sites with good to excellent soils may have difficulty containing trees on OHxF 97 to a 14 foot drive row. 16 foot centers may be more easily managed.

Bosc:

- The best performing rootstocks are OHxF 69 and 87.
- OHxF 40 has not perform well in this trial.
- OHxF 97 was a little biennial in 2002.
- Fruit size was acceptable (peak size 80's) across all rootstocks.

Bartlett

- OHxF 40 and 69 performed similarly, with better yields than OHxF 87 and 97.
- OHxF 87 consistently had about one box size smaller fruit.

The rootstock summary is developed from three year's (200-2002) data from the fully irrigated plots.

Variety Bosc	Root	Pounds/ Tree	Bins / Acre	Pears/ Tree	Grams/ Pear	Box Size	Cumlt Yield/ TCSA	Cumlt Yield Bins / Acre
	40	59 c	28 c	109 b	247 ab	81 ab	640 b	84 b
	69	79 a	37 a	146 a	249 ab	80 ab	740 a	112 a
	87	78 ab	36 ab	149 a	241 b	83 b	781 a	110 a
	97	71 b	33 b	124 b	261 a	76 a	627b	100 ab

Variety Anjou	Root	Pounds/ Tree	Bins / Acre	Pears/ Tree	Grams/ Pear	Box Size	Cumlt Yield/ TCSA	Cumlt Yield Bins / Acre
	69	88 b	35 b	168 b	236 ns	85 ns	583 b	104 b
	87	108 a	44 a	216 a	229	87	798 a	131 a
	97	92 b	36 b	175 b	237	84	772 b	107 b

Variety Bartlett	Root	Pounds/ Tree	Bins / Acre	Pears/ Tree	Grams/ Pear	Box Size	Cumlt Yield/ TCSA	Cumlt Yield Bins / Acre
	40	87 ab	41 ab	173 a	233 a	86 a	903 a	122 ns
	69	89 a	42 a	174 a	236 a	85 a	786 b	126
	87	73 c	34 c	159 ab	211 b	95 b	879 a	103
	97	75 bc	35 bc	148 b	233 a	86 a	772 b	106

Irrigation results:

The irrigation tables are developed from the 2002 data, with cumulative yield from 2000-2002.

	Irrigation Treatment	Pounds/ Tree	Bins / Acre	Tons/ Acre	Pears/ Tree	Grams/ Pear	Box Size	TCSA	Brix	Acids	Firmness	Cumulative Yield / TCSA	Cumulative Yield Bins / Acre
Bosc	25	71 ns	33 ns	18 ns	126 n	253 b	78 b	71 ns	14.4 a	0.20 ns	13.4 a	673 ns	96 b
	50	70	33	18	120	266 ab	75 a	75	13.3 b	0.2	13.0 b	719	107 a
	100	69	32	18	116	269 a	75 a	75	13.3 b	0.19	13.2.ab	682	101 ab

	Irrigation Treatment	Pounds/ Tree	Bins / Acre	Tons/ Acre	Pears/ Tree	Grams/ Pear	Box Size	TCSA	Brix	Acids	Firmness	Cumulative Yield / TCSA	Cumulative Yield Bins / Acre
Anjou	25	94 ns	37 ns	18 ns	184 n	232 b	86 b	84 ns	14.8 a	0.29 b	15.1 a	638 ns	107 ns
	50	110	43	21	194	255 a	78 a	81	13.8 b	0.31 a	14.5 b	700	113
	100	94	36	18	162	242 ab	82 ab	85	14.9 a	0.29b	13.2 ab	670	114

	Irrigation Treatment	Pounds/ Tree	Bins / Acre	Tons/ Acre	Pears/ Tree	Grams/ Pear	Box Size	TCSA	Brix	Acids	Firmness	Cumulative Yield / TCSA	Cumulative Yield Bins / Acre
Bartlett	25	71 b	33 b	18 b	147 ns	220 c	90 c	61 b	12.8 ns	0.37 ns	17.6 ns	825 ns	102 b
	50	83 a	39 a	22 a	148	255 a	78 a	65 a	12.4	0.38	17.2	821	105 ab
	100	84 a	39 a	22 a	162	234 b	86 b	67 a	12.7	0.36	17.6	858	114 a

Significant irrigation treatment findings:

- In the previous two seasons, the deficit treatments had no impact on size.
- Precocity, as measured by kilograms per centimeter of trunk cross sectional area varied by season and variety. Cumulative yield, when divided by trunk area indicates no significant differences over time due to irrigation.
- Fruit size was reduced in all varieties in the 25% irrigation treatments in 2002. The deficit treatments ended June 25. By July 1, the fully irrigated plots had received 6 inches, and the deficit treatments 5 inches net irrigation.

Conclusions:

- Rootstocks often influence tree size, precocity and fruit size. It is often difficult to separate the effects of crop load, rootstock and irrigation management on fruit size. In the case of OHxF 87, crop load is probably reducing fruit size. The tree circumference of OHxF 87 is not increasing as fast as the other rootstocks indicating more trees per acre should be planted.
- In many growing conditions, all varieties on OHxF 87 could be planted at high densities up to 700 (or more) trees per acre.
- OHxF 87 may not be suitable for interplanting or weak soils. Small increases in canopy volume are likely after fruiting has initiated.
- Irrigation did not seem to increase precocity.
- The 50% plots, especially with Bosc and Anjou, have had interesting spikes in fruit number per tree and/or fruit size. This seems to support the premise that cold wet soils may reduce fruit size.
- Selecting workable combinations of rootstock, scion, soil type and planting density can strongly impact the economics of new plantings for years following the orchard establishment. If the trees are too vigorous, significant cost increases maybe needed to control the unruly trees. Yields may be lower than if a more precocious rootstock is used. Weak trees can be excruciatingly slow in building production volume. Fruit size is often smaller. A vigorous rootstock may fill the canopy more quickly and grow better fruit size.

Budget

Title: Pear Rootstock and Regulated Deficit Irrigation Trial
PI Tom Auvil
Current year: 2003
Project total (3 years): $36,000
Original budget request: 12,000

Total	11380	12,150	**12,000**

Current year breakdown

Item	2001	2001	**2003**
Salaries			
Benefits (%)			
Wages	6,639	5,740	**7,000**
Benefits (%)	1,991	1,910	**1,750**
Equipment	0	0	**0**
Supplies	150	1,000	**1,000**
Fruit & leaf analysis	0	1,000	**1,000**
Fruit purchase	2,500	2,500	**1,250**
Total	11,380	12,150	**12,000**

CONTINUING PROJECT REPROT **YEAR2/3**
WTFRC Project # PR-02-228 **WSU Project # 13C-3655-3298**

Project title: Branch induction in pear trees with bioregulators

PI: Don C. Elfving, Horticulturist
Organization: WSU Tree Fruit Research and Extension Center, 1100 N. Western Avenue, Wenatchee, WA; (509) 663-8181 ext. 252; delfving@wsu.edu

Cooperators: Peter Van Well, Van Well Nursery, East Wenatchee, WA
Dwayne Visser, Agricultural Research Technologist II, WSU-TFREC, Wenatchee, WA

Objectives:
1. Assess potential for cyclanilide-induced shoot formation from buds on 1- and 2-year-old branch sections during the late dormant season prior to budbreak.
2. Assess potential for cyclanilide-induced shoot formation from buds on 1- and 2-year-old branch sections when natural budbreak occurs (early April).
3. Assess cyclanilide concentrations and timings for use after active shoot growth begins for enhancement of lateral branching and rapid canopy expansion in young trees in the orchard.
4. Assess cyclanilide concentrations for stimulation of feathering in pear trees in the nursery.
5. Evaluate the use of proprietary mixtures of 6-benzyladenine and gibberellins A_4 and A_7 (Promalin®) alone or in combination with cyclanilide for effects under both orchard and nursery conditions.

Significant findings:
1. Cyclanilide® effects (dormant) on budbreak in 'Kalle' (Red Clapps)/OHxF97 pear (Cashmere, WA): In early March, cyclanilide was applied in 50% latex paint at four concentrations (0, 500, 1000 or 5000 mg a.i./liter) to groups of buds in bands around the lower portions of 1-year-old and 2-year-old shoots to test whether lateral shoots could be induced from these buds with cyclanilide. In no case did any treated bud show any signs of activity during the growing season.

2. Cyclanilide effects (dormant) on budbreak in 'Bosc'/OHxF97 pear (Cashmere, WA): In early March, cyclanilide was applied in 50% latex paint at four concentrations (0, 500, 1000 or 5000 mg a.i./liter) to groups of buds in bands around the lower portions of 1-year-old and 2-year-old shoots to test whether lateral shoots could be induced from these buds with cyclanilide. In no case did any treated bud show any signs of activity during the growing season.

3. Cyclanilide effects (green-tip) on budbreak in 'Kalle' (Red Clapps)/OHxF97 pear (Cashmere, WA): In early April, cyclanilide was applied in 50% latex paint at four concentrations (0, 100, 500 or 1000 mg a.i./liter) to groups of buds in bands around the lower portions of 1-year-old and 2-year-old shoots to test whether lateral shoots could be induced from these buds with cyclanilide. In no case did any treated bud show any signs of activity during the growing season.

4. Cyclanilide effects (green-tip) on budbreak in 'Bosc'/OHxF97 pear (Cashmere, WA): In early April, cyclanilide was applied in 50% latex paint at four concentrations (0, 100, 500 or 1000 mg a.i./liter) to groups of buds in bands around the lower portions of 1-year-old and 2-year-old shoots to test whether lateral shoots could be induced from these buds with cyclanilide. In no case did any treated bud show any signs of activity during the growing season.

5. Cyclanilide and Promalin® effects on lateral branching in 'Kalle' (Red Clapps)/OHxF97 pear (Cashmere, WA): On 23 May, cyclanilide (0, 25 or 50 mg a.i./liter) and/or Promalin (250 mg a.i./liter) were applied by handgun as dilute sprays to 3rd-leaf trees when newly developing terminal shoots were approximately 25 cm in length. Cyclanilide at either concentration was equally effective in increasing the development of lateral branches on previous season's growth (2- to 3-fold increase in branches). Promalin, either alone or mixed with cyclanilide, had no effect. Both cyclanilide concentrations with or without Promalin increased the amount of secondary branch development (lateral shoots induced on current season's growth) up to 10-fold. Visual inspection of the trees suggested that cyclanilide at 50 mg/liter was too active on pear, and that the concentration could likely be reduced below 25 mg/liter for best results. Pear trees appear to be particularly sensitive to cyclanilide, far more so than either apple or sweet cherry.

6. Cyclanilide and Promalin effects on feathering of 'Bosc'/OHxF97 pear trees in the nursery (Quincy, WA): Cyclanilide (0, 25 or 50 mg a.i./liter) and/or Promalin (250 mg a.i./liter) were applied to vigorously growing 'Bosc' trees in the nursery with a hand-operated small sprayer on 5 July. The applications were made to wet only the upper portion of each tree. Initial observations indicated that all cyclanilide treatments produced feathering of the nursery trees. Unfortunately, no data were collected in this trial because nursery workers removed all the treatment identification flags in late summer and it was not possible to re-establish the exact location of each plot.

Methods:
Trials were carried out in suitable commercial pear orchards and in one commercial fruit tree nursery in Washington. Dormant and green-tip applications were carried out with small paintbrushes, applying product in latex paint to treated buds in bands on shoots. In-season applications were carried out with handgun or backpack applications. Single-tree plots in randomized complete-block designs were used in all the orchard trials; plots of 10-15 trees each were set up in a randomized complete-block design down a single row of 'Bosc' trees in the nursery. All treatments were applied in randomized complete-block designs to permit appropriate statistical analyses of data. Data were collected from all but one trial, which was lost due to removal of treatment flags.

Results and discussion:
As was reported for both cherries and apples, cyclanilide treatments made before budbreak or at the time buds began to grow were not successful in inducing pre-existing buds on previous season's shoot growth on pear trees to develop into lateral branches. When cyclanilide was applied to young, poorly branched 'Kalle' pear trees in active growth, additional shoots were formed from the previous season's growth and as secondary branching from newly formed buds on the new shoots themselves. The application of Promalin, either alone or in conjunction with cyclanilide, did not improve the development of new shoots. Pear trees appear to be very sensitive to cyclanilide; lower concentrations than the 25 mg a.i./liter used in this trial should be tested for effects on new shoot development. Cyclanilide appears to be a very effective tool for increasing lateral shoot development in vigorous, young pear trees. Further work is needed to determine whether increased lateral shoot development translates into more precocious production.

Acknowledgments:
The assistance and support of the following persons and organizations are gratefully acknowledged: Dick Cox, John Griffith, Daryl Harnden, Jeff Henry, Chris Ishida, Chris Olsen, Pete Van Well, Rick Van Well, Dwayne Visser, Bayer CropScience, Valent BioSciences, Van Well Nursery, Washington Tree Fruit Research Commission, WSDA Laboratory Division.

Budget:
Project title: Branch induction in pear trees with bioregulators
PI: Don C. Elfving
Proposed project duration: three years
Current year: 2003
Project total (3 years): **$**37,496
Current year request: $12,432

Year	Year 1 (2002)	**Year 2 (2003)**	Year 3 (2004)
Total	11,580	**12,432**	13,484

Current year breakdown:

Item	**Year 1 (2002)**	**Year 2 (2003)**	**Year 3 (2004)**
Salaries (Technical)[1]	4,500	**4,750**	5,000
Benefits (28%)	1,260	**1,330**	1,400
Salaries (Time-slip)[1]	2,000	**2,200**	2,400
Benefits (16%)	320	**352**	384
Equipment	0	**0**	0
Supplies[2]	1,500	**1,600**	1,800
Travel[3]	1,500	**1,700**	2,000
Miscellaneous	500	**500**	500
Total	11,580	**12,432**	13,484

[1] Technical and time-slip help to set up trials, apply treatments and collect data as needed.
[2] This category includes a variety of miscellaneous supplies, non-capital equipment, consumables, etc. that are needed to carry out the research project. Telecommunication charges are allowed on this grant.
[3] Treatment applications and frequent data collection in distant sites. Includes vehicle lease-to-purchase, operating and repair costs.

CONTINUING PROJECT REPORT **YEAR 2/3**
WTFRC Project No: PH-02-227 **ARS Project No.** 5350-43000-003-011T

Project Title: Quality and condition of winter pears as influenced by harvesting, handling, packing and storage

Principal Investigator: Stephen R Drake, Research Horticulturist
Organization: USDA, ARS, TFRL, Wenatchee, WA

Objectives:
1. Determine type and time of atmosphere (oxygen, carbon dioxide, temperature) establishment in conjunction with different maturity levels to optimize storage (loose packs) of pears (Anjou, Bartlett, Bosc, and Concord). Emphasis on both controlled atmosphere and modified atmosphere (packing) will be addressed.
2. Investigate alternative packing materials (paper type, pear floats) to aid in maintaining pear quality and the relationship of these alternative materials to various storage environment (conventional and organic).

Significant findings:

- Packed pears (*Pyrus communis* L. 'd'Anjou') were stored under four individual controlled atmosphere (CA) storage conditions: 1) 1.5% O_2 and <1% CO_2 at -1.5°C; 2) 1.5% O_2 and <1% CO_2 at +1.5°C; 3) 1.5% O_2 and 3.0% CO_2 at -1.5°C or 4) 1.5% O_2 and 3.0% CO_2 at +1.5°C. Increased CO_2 in the storage atmosphere improved peel color retention, reduced firmness loss and improved subjective quality scores for packed pears, particularly for finish and stem condition. Loose pears in bins were stored under three CA storage conditions: 1) 1.5% O_2 and <1% CO_2 at -1.5°C; 2):1.5% O_2 and 3% CO_2 at -1.5°C or 3) 1.5% O_2 and 3% CO_2 at +1.5°C. Pears stored loose in bins in atmospheres containing 3% CO_2 had better firmness retention, reduced scald and greatly improved subjective quality scores for appearance, finish and scuffing compared to pears stored loose at <1% CO_2 prior to packing in January. Using 3% CO_2 in the CA atmosphere allowed 'd'Anjou' pears to be stored loose in bins and packed in late January after storage with little or no quality losses compared to the standard pre-packing followed by 1% CO_2 CA storage program.

- Thirty bins of commercially harvested 'Anjou' pears from each of three growers were packed at Blue Star Growers, Cashmere, WA, using one of two pear float materials and wrapped in one of three paper wraps. Fruit had been held at 0C for 45 days in regular atmosphere (RA) before packing. Float materials used were potassium phosphate (XEDA-F, pH 11.3) or lignin sulfonate (Lignosite). Specific gravity of both floats was adjusted to ~1.025. The anti-fungal compound sodium ortho-phenylphenate (3,800 ppm) was added to each dump tank mixture. Standard applications of TBZ, Biosave and wax were applied on the line before packing. Paper wraps were impregnated with either Biox-A, 3% oil + copper and ethoxyquin (3%C&E), or 6% oil + copper and ethoxyquin (6%C&E). After commercial packing, 108 boxes of fruit (6 boxes of each float material, paper wrap and grower) were selected and stored. Thirty-six boxes were placed in regular atmosphere (RA) storage @ 1C. Seventy-two boxes were placed in controlled atmosphere (CA) storage (1.5% O_2 and 1.0 CO_2 @ 0°C). After 50 days (RA), 100 and 200 (CA) storage, fruit was removed and quality evaluated. Float material (Lignosite or XEDA-F) did not influence either objective or subjective quality during this entire study. Pear quality from either Lignosite or XEDA-F was very acceptable after both 50 days RA and 200 days of CA storage. Type of paper wrap did have a strong influence on pear quality, particularly for the amount of scald present and subjective pear

quality. Pears in paper with Biox A were not as acceptable as pears in paper with either 3 or 6% oil with C&E which were comparable in quality.

· Commercially packed pears ('Anjou' and 'Bosc') were exposed to radiation treatments using a gamma beam 650 source containing cobalt-60 at doses of 0, 150, 300, 600 and 900 Gy's. After radiation pears were stored for 30 and 90 days in regular atmosphere at 1C. Analysis of carbohydrate concentration of the fruit flesh was conducted after each storage. Radiation treatment did not influence the total or individual (sucrose, glucose, fructose, sorbitol) carbohydrate levels in pears, regardless of the cultivar. Carbohydrate levels changed in pears as storage time progressed and these changes were cultivar dependent. Total carbohydrates and fructose increased; whereas, sucrose, glucose and sorbitol concentrations decreased in 'Anjou' pears as storage progressed. Total and all individual carbohydrates decreased in 'Bosc' pears as storage progressed from 30 to 90 days.

Research: 2003-2004

1. Organic Paper Wraps.

Cultivar: 'Anjou'
Wraps: 3% C&E, Mint oil, Lemon oil, Citronella, Cinnamon
Storage: RA and CA
RA for 90 days only
CA (1.5% oxygen & <1% carbon dioxide and 1.5% oxygen)
Time in CA storage: 120 and 220 days.
Number of boxed (1/2) pears required: 5 wraps x 3 growers x 3 storage = 45 ½ boxes
Cooperators: Wrap Pack and Blue Star

2. MAP of Bartlett pears. (Blue Bird, Blue Star)

RA/CA storage
RA storage at 45, 90 and 120 days
CA storage for 45 days - then MAP boxed and storage for an additional 30 and 60 days in RA storage.
CA storage only at 90 and 120 days
Number of ½ boxes in MAP bags required: 12 boxes for RA storage, 6 boxes after CA storage for additional storage in RA and 6 boxes in CA only. Number of ½ boxes for control would be 24.

3. New pear floats

Compare new pear floats to sodium silicate with and without SOPP. At recommended concentrations treat pears for various periods of time (2, 4 and 6 minutes). Pack after treatment or after simulated washing, using 3% C&E, 6% C&E and Biox paper and box with a liner. Store in RA for 90 days and evaluate pear quality. Store in CA for 120 and 150 and 220 days evaluate pear quality. Total of 108 boxes required.

4. Pears stored in bins. (Hi Up)

Cultivar: 'Anjou'
Requirements: 2 CA rooms at Stemilt
1. 30.5F at 1.5% oxygen and <1% carbon dioxide
2. 30.5F at 1.5% oxygen and 3% carbon dioxide

Treatments, drench
1. Check
2. Ethoxyquin (2000 ppm)
3. Scholar
4. Ethoxyquin + Scholar

Bins (16) of loose fruit will be stored in the above rooms for late packing (Jan/Feb). After storage fruit will be commercially packed using 3% C&E paper. Samples of packed fruit from the above rooms will be stored in CA (1.5% oxygen and <1% carbon dioxide) and evaluated after 60 and 120 days of additional storage. Two growers, 6 bins each. Two bins from each grower will be placed in each room. Total # of bins in each room = 4. Scuffing and decay to be major considerations (2003 MCP treatment).

5. Pear tolerance to high carbon dioxide

Requirements: 27 Small CA chamber
Oxygen concentrations: 1.5, 2.0, and 4.0%
Carbon dioxide concentration: 1, 3, and 5%
Storage time: Anjou - 60, 120 and 180 days
Bartlett - 60, 90 and 120 days (harvested: 22 Aug using 3 grower lots)
Bosc - 60, 120 and 180 days
Pears required: 1440 pears per cultivar, or 500 pears from each of three growers, for each cultivar under consideration.

6. Maturity and storage of Concord pears.

Maturity: 2 harvest:
a. At commercial harvest for Anjou (4 September)
b. 10 days after commercial for Anjou (13 September)
Storage: RA and CA
RA storage for 45, 90, 120 and 150 days.
CA storage (1.5% oxygen & <1% carbon dioxide; 1.5% oxygen and 3% carbon dioxide
Time in CA storage 45, 90 and 180 days. This will require 6 CA chambers
Number of pears required: 720 pears for RA storage, 1080 pears for CA storage

7. EURO Box, use of ethoxyquin

Cultivar: 'Anjou'
Treatments: (trays impregnated with ethoxyquin)
1. Check
2. 1000 ppm
3. 2000 ppm
4. 3000 ppm

Storage:
1. RA @ 45 and 90 days
2. CA @ 120 and 180 days

Cooperators: Wrap Pack and Blue Star

Projects initiated in 2002 (1 thru 7) will be repeated for 2003. Project # 4 (bin storage) will be expanded to include the use of MCP, for long-term bin storage and late packing of pears. Projects # 1, 2 and 7 will be expanded to include Bosc and Bartlett pears.

Project title: Quality and condition of winter pears as influenced by harvesting, handling, packing and storage
PI: Stephen R. Drake
Project duration: 2002-2004
Current year: 2003
Project total (3 years): $119,138
Current year request: $ $46,500

Year	Year 1 (2002)	**Year 2 (2003)**	Year 3 (2004)
Total	$46,638	**$46,500**	$26,000
Current Year breakdown			
Salaries[1]	29,178	**31,500**	15,750
Benefits	12,460	**13,500**	6,750
Supplies	5,000	**1,500**	2,000
Miscellaneous	100		500
Equipment (repair)			1,000
Total	$46,638	**$46,500**	$26,000

[1]Salary for temporary technician (2 year term).

PUBLICATIONS:

Drake, S.R. 2002. The influence of paper wraps on the quality and disorders of 'd'Anjou' pears after controlled atmosphere storage. 17th Washington Tree Fruit Postharvest Conf., March, 2002.

Drake, S.R. and R.D. Gix. 2002. Quality of 'Anjou' pears from variable oxygen and high carbon dioxide controlled atmosphere storage. J. Food Qual. 25:155-164.

Drake, S.R. and D.C. Elfving. 2002. Influence of prestorage carbon dioxide treatments on the quality of 'd'Anjou' and 'Bartlett' pears. J. Food Proc. & Pres. 26:143-151.

Drake, S.R., L.G. Nevens and P.G. Sanderson. Carbohydrate concentrations of fresh apples and pears as influenced by irradiation as a quarantine treatment. Accepted: J. Food Pres & Proc.

Drake, S. R. and P.G. Sanderson. Influence of float materials on the quality of 'Anjou' pears after regular and controlled atmosphere storage. In review.

Drake, S.R. and D.C. Elfving. Quality of packed and bin-stored 'Anjou' pears as influenced by storage atmosphere and temperature. In review.

Sincere appreciation is expressed to: Blue Bird, Blue Star, Stemilt, Independent and Hi Up packing, for their cooperation, suggestions and interest in this project.

The special cooperation of Robert Gix is sincerely appreciated.

CONTINUING PROJECT REPORT **YEAR 3/3**

TITLE: Effects of New Insecticides on Natural enemies: Acute toxicity and sub-lethal effects

CO-PIS Tom Unruh, USDA-ARS Yakima
Dave Horton, USDA-ARS Yakima
Dr. E. Beers, WSU, Wenatchee
Richard Hilton, OSU, Medford
Helmut Reidl, OSU, Hood River
Dr. Nick Mills, U.C., Berkeley

COLLABORATORS Vince Jones, WSU, Wenatchee
John Stark, WSU, Puyallup

OBJECTIVES (2003):

1. Test acute toxicity of the next 5 new insecticides to 9 arthropods using a combined topical, residue and per-os exposure method
2. Develop bioassay methods to measure sub-lethal effects on beneficial insects
3. Test sub-lethal effects in those cases where acute effects are trivial or short-lived.
4. Model acute and sub-lethal toxicity data to provide field testable predictions of pesticide effects (New objective since 2002)

Significant Findings:

- Bioassay procedures were developed for 5 of the 9 target arthropods: *Forficula auricularia, Chrysoperla carnea*, *Galenodromus occidentallis,and Colpoclypeus florus* and *Anthocorus nemoralis* and is under development for a 6th *(Deraeocoris brevis)*.
- Acute toxicity from exposure to the first 5 new insecticides (Provado, Actara, Intrepid, Esteem, Success) was estimated for lacewing, predator mite and earwigs and for 3 and 2 insecticides for *Anthocoris* and *Colpoclypeus.*
- Sublethal bioassays have been done for all insecticides for egg, larval, and adult lacewings and adult predatory mite, and for one insecticide for Anthocoris bugs..
- *Galendromus occidentalis*: Provado and Actara both repelled and reduced fecundity. When these effects were combined, total egg production was reduced 0-66% by Actara and 0- 99% by Provado at field rates, depending on population tested. Surprisingly the lepidopteran insecticide, Success, caused a 44% reduction in total egg production. The IGRs Intepid and Esteem caused very moderate reductions total egg production. Fecundity loss was highly variable among populations and replicates as was the tendency of the mites to run off the treated surfaces.
- *Chrysoperla carnea*: Actara and Provado caused high mortality of larvae and adults at field rates (and Actara at 10% field rates) but had no effect on eggs. Intrepid, Esteem and Success were not acutely toxic to any stage tested but had sub-lethal effects. Intrepid reduced adult fecundity and egg hatch; Esteem prolonged development of the last larval stage. Success reduced adult fecundity.
- *Colpoclypeus florus*: Actara, Assail, and Provado caused 100% mortality at field rates and 56%, 65% and 25% at a tenth of field rates. Survivors of Actara show full fertility in preliminary trials.
- *Anthocoris nemoralis*: Actara and Provado were acutely toxic at field rate as was Provado at 10% of field rate. Actara caused 40% mortality after 2 weeks but survivors were nearly as fertile as control insects.

- *Forficula auricularia:* Provado, Guthion, and Imidan all showed acute toxicity to immatures at both 1 and 15 days. Success showed acute toxicity to adults after 15 days. Control mortality was highly variable and sub-lethal bioassays require 2-3 months.

Methods:
In lieu of rehashing methods as outlined in the first year proposal we describe the bioassay methods that were developed and used in 2002 as a major part of the results of year 1. These methods will continue to be used in the coming year, with improvements as required**.** Bioassay methods are species-specific and thus we present them by species.

Results and Discussion
Forficula: Earwigs began to hatch in artificial nests that had been maintained in the laboratory over the winter. When sufficient numbers of second and third instar nymphs were available, ten individuals were placed in a petri dish and treated in a Potter spray tower with 2 ml of the test materials. Treatments were replicated five times and the materials tested were: Guthion, Imidan, Intrepid, Esteem, Dimilin, AgriMek, Provado, and two controls—one treated with water and the other unsprayed. The materials were applied at the maximum label field rate and one-tenth the field rate. In the fall, adults were collected from a block where no insecticides had been applied and treated in a similar manner as described above but only five individuals were placed in a petri dish and only the maximum label rate was tested. Males (six replicates) and females (seven replicates) were treated separately. The materials used in the adult test were: Intrepid, Esteem, Dimilin, AgriMek, Provado, Assail, Danitol, Mitac, Success, and a water control. After 15 days ten surviving males and females from each treatment were paired and a single pair was then placed in an artificial nest. At present, ten pairs of individuals from each treatment (excluding the Success treatment where no females survived) are being maintained in artificial nests in the laboratory. Survival and fecundity will be assessed in the spring of 2003. Because of the long life history of earwigs, the sub-lethal studies will be less extensive than used in other taxa. Rolled corrugated domicile appears to be an effective method to assess earwig populations and to collect earwigs from the field and has many advantages over the beating tray which is inefficient for sampling earwigs. Field studies not presented here suggest that earwigs may be a useful biological indicator species for the effects of pesticides in the environment, especially in pears.

Chrysoperla: Experimental insects were purchased from an insectary (Buena Biosystems), as cocooned pupae. Larvae were fed on eggs of *Ephestia kuehniella*, obtained from Beneficial Insectaries, and adults were fed on an artificial . Three life stages, 0.5 day old eggs, 2 day old 1st instars, and 3-4 day old adults were tested and all *C. carnea* stages were kept in an environmental chamber set at 23°C, 70% R.H. and 16 hours of light. All sprays were carried out using a Potter Tower with an air supply set at 10psi and spray nozzle set at 4psi, using an amount of product calibrated to deliver 1.5mg of formulated solution per cm^2 of arena surface.

Eggs were sprayed in groups of 10, and subsequently separated into individual 2oz plastic cups with eggs of *E. kuehniella*. Acute mortality of hatched larvae was assessed 5 and 6 days later. Larvae were sprayed in groups of 10 and immediately transferred to individual 2oz plastic cups with eggs of *E. kuehniella*. Acute mortality was scored after 48h. Adults were sprayed in groups of five, immediately after immobilization with CO_2. They were transferred to individual 2oz plastic cups, provided with artificial diet and water saturated cotton wicks, and acute mortality scored after 48h.

At the full field rate Actara was 100% lethal to both larvae and adults of *C. carnea*, and Provado was 100% lethal to larvae and 73% lethal to adults. Substantial mortality also occurred at the 10% rate for Actara, but only for larval exposure in the case of Provado. Thus Provado proved more lethal to larvae than adults, while the reverse was true for Actara. There was no evidence for topical toxicity to eggs of *C. carnea* from any of the selective products

For studies of sublethal effects, larvae and adults were subjected to simultaneous topical, residue and oral exposure at the higher of the two dose rates in those cases where survival from acute toxicity tests was greater than 25%. In all cases, products were compared to distilled water controls. Larvae were sprayed in groups of 10 and transferred to individual Petri dishes with dry residue. Ephestia eggs, the arenas and *C. carnea* larvae were all sprayed on the same day and sprayed eggs were used over the first 5 days of the assay, followed by unsprayed eggs. Eggs were replaced every 2-3 days and lacewing larvae were provided a piece of cardboard in which to pupate. Pupae were isolated in 2 oz. cups and upon emergence adults were moved to 4 oz. cups with food water and mate. Egg production was monitored for 14 days. Larval assays were based on 30 replicates which were followed through to egg hatch of the subsequent generation to determine immature development time, immature and adult (first 14 days) survivorship, adult size (hind tibia length) and fecundity (first 14 days), and the success of egg hatch.

For adult exposure sublethal assays unmated females and adult male *C. carnea* were sprayed in groups of 6 within Petri dishes after immobilization with CO_2. 15 pairs of adults were transferred to adult arenas with dry residue, artificial diet and a small cotton wool wick in a glass vial. Eggs were collected every second day, and the artificial diet replaced. Two sets of 30 hatching larvae, approximately equal numbers from each surviving pair of adults, were collected on days 3-4 and 11-12 to follow their performance through the subsequent generation. Measurements noted were survivorship, fecundity (first 14 days) and egg hatch of the sprayed adults, and immature development time, survivorship, fecundity (first 6 days) and subsequent egg hatch of the F1 generation.

Chronic sub-lethal effects on population growth rates were observed for the two IGRs. Although there was no apparent effect on development time, growth (adults size) or survivorship to adult, Intrepid showed some reduction in adult fecundity over the first 14 days, and on the success of egg hatch (data not yet fully analyzed). A similar effect may also occur with Success (data not yet fully analyzed). In contrast, Esteem prolonged the 3rd larval instar, but showed no effects on survivorship, fecundity or egg hatch (data not yet fully analyzed).

The combined routes of toxicity for 10% field rate Provado had no effect on adult survivorship over a 14 day period was comparable to the results from topical exposure alone, suggesting that the addition of the oral and residual exposure had no effect on survivorship. No sub-lethal effects of 10% field rate Provado were detected. As in the larval bioassays, Intrepid reduced adult fecundity for both the adults that were directly exposed and the two sets of subsequent F1 adults. However, there was no apparent influence of Intrepid on egg hatch in these assays. Although Esteem prolonged larval development in the larval assays, this effect was not seen in the F1 generation when adults were the life stage sprayed. Considerable effort has been spent on developing projection matrices to estimate/simulate the combined effects of acute and sub-lethal effects of insecticide exposure.

Galendromus: Bioassays were conducted using a cohort of 20 adult female *G. occidentalis*, reared from eggs laid within a 48-h period. The arena used for both producing females for study and for bioassays consisted of lima bean disks 36 mm in diameter, placed lower surface facing up, on a pad of moist cotton in a 90-ml plastic cup. The edge of the leaf was ringed with Tangle Foot to keep the females from running off the leaf. Females were fed with mixed stages of twospotted spider mites *(Tetranychus urticae* Koch) and pollen. Test arenas were sprayed with two concentrations of various pesticides, plus a separate distilled water check for each pesticide using a Potter Spray Tower. There were five replications per concentration (completely randomized design). Pesticide concentrations corresponded to the concentration obtained using the highest rate allowed on the label, applied at 100 gpa. Where the rates were different between the apple and pear label, the higher rate was used. The second concentration was a 1 in 10 dilution of the first concentration. Two ml of each solution was used for each application (disks were treated separately). Females were present on the disks at the time of application, thus the method of exposure was both contact and through residues on the leaf

disk.

The disks were evaluated daily through the 7-d test, recording both the number of live females and the number of eggs produced. Eggs were removed each day as they were counted but females were left undisturbed. Females were fed daily with mites and pollen as described above, so that food was not limiting at any time during the test nor was it treated with insecticides. Variables analyzed were the total number of eggs produced during the course of the experiment; female-days=the number of females per day cumulated over the course of the experiment and fecundity=total eggs divided by female-days. Female-days represent residency on the leaf, whether attrition in the numbers were due to mortality or runoff. The total number of eggs laid integrates both residency and fecundity.

The two chloronicotinyls,Actara and Provado, showed one or more effects on *T. occidentalis* in one or more tests. Two of the four tests with Actara showed a reduction (66%) in total egg production (lab colony) or residency (29%) (CRO). The inconsistency among populations tested may have been due to prior exposure to chemicals. The effect of Provado was more pronounced; in one test (Skeele population) there was a 99% reduction in overall egg production at the field rate, with corresponding reductions in residency and fecundity. There was also a 24% reduction in residency after exposure to 10% of the field rate, indicating that the effect might continue well beyond the time of application. The rate tested was the high label rate for pear, which at 20 fl oz was substantially higher than the high rate for apple (8 fl oz). On the latter crop, it is frequently used at a lower rate, but these results suggest that there may be an effect as low as 2 fl oz/acre.

The IGRs Intrepid and Esteem were tested against three populations each, and there was a detectable effect in one of the variables in one of the three tests. For Esteem, the Bench Rd. populations experienced a 52% reduction in total egg production, and a 35% reduction in female residency. For Intrepid, there was a 29% reduction in total egg production in the lab colony. The two miticides, Acramite (bifenazate) and Secure (etoxazole) had no effect on fecundity or residency of *T. occidentalis* at the high rate (year 2 priority materials).

Anthocoris: Virgin female *Anthocoris nemoralis* (2-4 days old) were treated with 2 ml of solution in small petri dishes using a Potter Sray tower. Females were immediately moved to small, psylla-infested pear seedlings in small, vented cages. An untreated male was added to each cage. Pairs were moved to new seedlings every 3-4 days until 2 weeks following treatment, at which time bugs were discarded. Mortality was checked each time the pair was moved. Eggs deposited into the seedlings were allowed to hatch, and the nymphs were counted on each plant. Both acute toxicity and sublethal studies are ongoing, but here we report results for Actara and Provado at 10% field rates.

Provado caused 100% mortality of adult females within 3 days of treatment. Mortality rates of Actara-treated bugs was lower than that caused by Provado (40% by 2 weeks), but was higher than that in control bugs. Production of nymphs by surviving females was slightly higher in control bugs (15 nymphs per female by 2 weeks) than Actara-treated bugs (13 nymphs per female by 2 weeks). Because eggs were not counted, results are highly conservative estimates of 2-week fecundity.

Colpoclypeus florus: For acute toxicity screens, five 3-5 day old female wasps greater than 0.4 mg wt, immobilized by chilling over ice, were placed in a small arena (4.5 cm Petri dish) with a damp piece of filter paper on the bottom. Pesticides were sprayed in a potters spray tower and insects were given 15 minutes to dry and the plate was covered. Mortality was scored at 24 and 48 hr. Actara, Assail, and Provado caused 100% mortality at field rates and 56%, 65% and 25% at a tenth of field rates. IGRs have not yet been tested.

For sublethal exposures adults were treated as above and , on the same day, leafroller retreats (apple leaves folded by and containing a 4^{th} instar leafroller larvae) and a streak of honey on wax paper were treated in the spray tower. After 2 hr drying time, a leafroller retreat, some of the sprayed honey, and a single surviving wasp were confined together in a clean petri plate. After 3 days, a second leafroller retreat (unsprayed) replaced the first retreat, and the wasp was confined for 4 additional days. Adult

survival after this 7 days was recorded and the wasp was retained for measurement of hind-tibial length (=size; used to estimate potential fecundity). Number of offspring emerging from each exposed host, and percentage of hosts parasitized (as estimated from silken webbing from both the first and second retreat were tallied after 14 days. Sublethal biassays are just getting started.
Survivors of Actara show full fertility in preliminary trials.

Proposed schedule of accomplishments:
Objectives (2003) 1 and 2 will be completed for all test insects by December 2003 for the first[t] 13 pesticides listed. Objective 3 has begun for all but one test species and should be completed for the first 5 insecticides in 12 months. Objective 4, has begun with the lacewings (Nick Mills) and model development should be completed in 12 months.

TITLE: Effects of New Insecticides on Natural enemies: Acute toxicity and sub-lethal effects

CO-PIs Tom Unruh, Dave Horton, Elizabeth. Beers, Richard Hilton, Helmut Reidl. Nick Mills

Current year request 2003: $50,000

Project total (3 years) $117,220

Budget:

Item	2001	2002[1]	**2003[1]**
Salaries		45,000	**45,000**
benefits		5,000	**5,000**
IFAFS Matching		86,000	**86,000**
Total (WRFRC)	17,220	50,000	**50,000**

[1] $10,000 per location; and funds should be sent to 5 locations as in 2002.

Funded $35,000 by Apple Entomology

Table 1. Pesticides tested or to be tested in program. Materials 1-5 have or will be tested in first round (2002), and materials 6-13 in the second round (2003; highlighted) with some variation among species being tested. (For example, miticides will get higher priority in the *Galendromus* work).

Priority	Compound/Form	Chem. Name	Class
1	Provado 1.6F	imidacloprid	Chloronicotinyl
2	Actara 25WDG	thiamethoxam	Chloronicotinyl
3	Intrepid 2F	methoxyfenozide	IGR: Molt accelerator
4	Esteem 0.86EC	pyriproxifen	IGR: JH analog
5	Success 2SC	spinosad	fermentation product
6	Assail 70WP	acetamiprid	Chloronicotinyl
7	Calypso 480SC	thiacloprid	Chloronicotinyl
8	Aza-Direct 0.0987	azadirachtin	Plant derived
9	Acramite 50W	bifenazate	
10	Savey 50DF	hexythiazox	
11	Secure 72WDG	etoxazole	
13	Surround WP (95%)	kaolin clay	
	Pyramite 60W	pyridaben	
new	Mesa	milbamectin	fermentation product
new	Piton	acequinocyl	
		Chlorthianidin	
	Agri-Mek 0.15EC	abamectin	fermentation product
	Apollo 4SC	clofentezine	
	Avaunt 30W	indoxacarb	
	Envidor 240SC	spirodoclofen	
	Orchex 796	petroleum oil	
	Guthion 50W	azinphosmethyl	organophosphate
	Imidan 70W		organophosphate
new		flonicamid	
new		buprofezin	

CONTINUING PROJECT REPORT **YEAR 3/3**
WTFRC Project # PR-01-88

Title: Use of Hexanal Vapor for Aroma Production and Decay Control

PI: Peter Sholberg, Paul Randall, AAFC-PARC, Summerland, British Columbia

Co-operator: Peter Sanderson, WTFRC, Wenatchee, WA

Objectives:
1. Identify optimal hexanal concentration, temperature, and duration required to control *Penicillium expansum* (blue Mold), *Botrytis cinerea* (grey mold), and *Mucor piriformis* (Mucor rot).
2. Determine optimum concentration and length of exposure required to fumigate pears in commercial storage rooms.
3. Determine effect of hexanal fumigation on stored pear aroma.
4. Evaluate the potential for combining hexanal with MCP to control post harvest decay and improve pear aroma.

Significant Findings:
1. Hexanal used as a surface fumigant eliminates grey mold on inoculated fruit at a range of temperature from 5^0C to 20^0C, while blue mold is eliminated at only 15^0C or 20^0C.
2. Hexanal reduces the amount of grey mold that develops in wounds. Most effective at 20^0C.
3. The best rates and duration to control post harvest pathogens are 2 mg/l for 24 hours or 4 mg/l for 18 hours at 15 or 20 ^{0}C.
4. Hexanal improves the aroma on stored pears.

Methods

1. **Large scale efficacy test.**

2001-2002 1. Two bins of d'Anjou pears, provided by Peter Sanderson (WTFRC) were split into 4 half bins. Two for fumigation in the Fumigation building at 4 mg/l for 48 hours at 2^0C, and two controls. The level of hexanal during the fumigation was monitored by using a Gas Chromatograph. After fumigation, the pears were hand packed in polylined boxes with top pad and lid, but no paper wraps was used, and placed into the 1^0C cold storage. A bin of Anjou pears from PARC was also split and fumigated as above.

2002-2003

WTFRC d'Anjou Pears. Two bins of d'Anjou pears from Wenatchee, Wash were divided into three replicates and hand packed in polylined boxes. The pears were placed in a 1 m^3 chamber at a temperature of 15^0C and fumigated at 4 mg/l for 18 hours. After fumigation the polyliner was closed up, with a top pad and lid. The pears were placed into a 1^0C cold room. A subsample was inoculated with both blue and grey mold and fumigated at 2 mg/l for 24 hours, or 4 mg/l for 18 hours.

PARC d'Anjou Pears. All PARC d'Anjou pears were treated two weeks prior to harvest with a preharvest application of Vangard 75WG (Cyprodinil, a systemic fungicide, registered on grapes for the control of *Botrytis*) using two different rates. This allowed for a control (no preharvest spray), Vangard 1 (3.1g /10 litres, approx. 1/2 the grape rate) and Vangard 2 (approx. recommended grape rate (300g/ac)). d'Anjou pears (3 boxes of each treatment) were harvested on the day of the fumigation. The harvested fruit, were immediately placed in the cold room and air cooled to 15^0C. The treated pears were then fumigated at 2mg/l for 24 hours or 4 mg/l for 18 hours. Following

fumigation, the pears were hand packed in polylined boxes with top pad and lid, and placed in the cold room at 1^0C.

2. **Small scale efficacy tests.** Tests to determine hexanal efficacy and phytotoxicity are done by inoculating with a set number of spores (1 x 10^4 CFU/ml) of a decay-causing fungus over the fruit surface, and allowing the inoculum to dry. The pears were either fumigating then wounded with a sterile wounding device (3mm diameter, 3mm deep) (IWF), or wounded after fumigation (IFW). The inoculated pears were placed in the 1 m^3 chamber. The humidity was adjusted to 80+% if necessary by evaporating water into the chamber. Laboratory Grade Hexanal liquid (Table 1) was evaporated by heating with a small electric heater. The hexanal concentration was monitored by withdrawing a 250 ml sample of air from the chamber via vacuum pump shortly after the start and at regular intervals during fumigation. The gas sample was injected into the Gas Chromatograph (GC Model 910, Questron Technologies Corp. Mississauga, Ontario) and within approx. 1 minute the concentration in the chamber was known. The GC was outfitted with an FID and fused silica capillary column Zebron ZB-FFAP (Phenomenex, Torrance, Ca). At the end of the fumigation, the chamber was vented and the fruit removed. The chamber used for fumigation was placed at 20^0C, 15^0C, 10^0C, or 5^0C. Fumigated fruit was placed at 20^0C for 7 days when decay and phytotoxicity were recorded. Results from last year showed that as the temperature decreases the effectiveness of hexanal also decreases. The amount of hexanal added at the lower temperatures were increased to 6 mg/ at 5^0C from the 4 mg/l at 20^0C (Table 1).

Table 1. Amount of hexanal added at the different temperatures.

Fumgiation rate	Fumigation Temperature (amount of hexanal added to 1 m^3 chamber)			
	20^0C	15^0C	10^0C	5^0C
0 mg/l	0	0	0	0
2 mg/l	2 ml	2.2 ml	2.4 ml	2.6 ml
4 mg/l	4 ml	4.4 ml	4.8 ml	6 ml

3. **Sensory Panel.** When d'Anjou pears are fumigated, there is a very fruity aroma present at the conclusion of the fumigation. A sensory panel was conducted to determine whether pears fumigated, stored for several months had improved aroma over control (non-fumigated) pears. A sample of stored d'Anjou pears, both fumigated and control, were removed from cold storage the previous evening and allowed to come to room temperature. Then the next day, a panel was asked to rate the pears for intensity of fruit aroma.

Results and discussion:

Large Scale Efficacy Test.

1. **2001/2002.** Half bins of d'Anjou pears (2 bins from Washington, and 1 bin from the research station) were fumigated (Sept 01) with hexanal at 4 mg/l for 48 hours at 2^0C. These pears were placed in polylined boxes and stored at 1^0C until May 02. The results indicated that hexanal reduced grey mold rot on WTFRC fruit (Pr>f = 0.0216 (Table 2). In this trial hexanal was not effective against blue mold, or stem contamination. This was the first preliminary experiment that was done and treatment conditions were estimated based on previous work with acetic acid fumigation and information found in the publication by Song et al. (1996). This preliminary experiment supports our belief that hexanal could reduce post harvest decay in stored fruit.

Table 2. The results of the half bins of d'Anjou pears fumigated with hexanal at 4 mg/l for 48 hours at 2^0C, and stored at 1^0C until May 02.

			(Grey mold)		(Blue Mold)		Mold Free
			Stem Mold	Rot	Stem Mold	Rot	
WTFRC	24 Boxes	Control	10%	63%	3%	14%	6%
		Fumigated	12%	7%	24%	48%	6.5%
	24 Boxes	Control	12%	55%	1%	15%	14%
		Fumigated	30%	16%	2%	4%	47%
PARC	24 Boxes	Control	44%	6%	3%	0.5%	32%
		Fumigated	53%	5%	10%	3%	29%

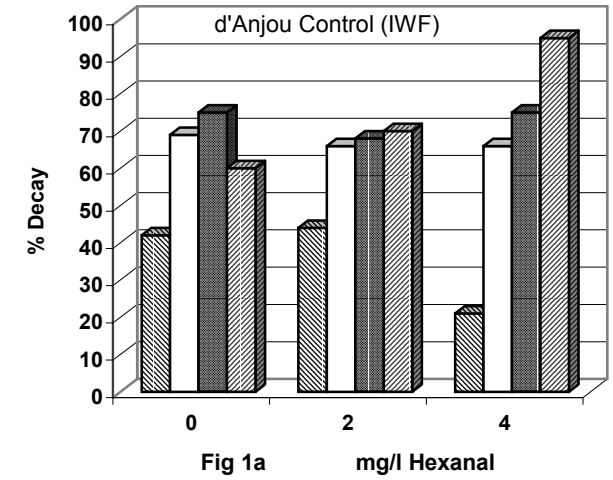
2. **2002/2003.** The bin quantity experiments were repeated this year but at a temperature of 15^0C using a rate of 4 mg/l for 18 hours. The pears were cooled to 15^0C then fumigated. The results from this experiment are to be evaluated in Feb/Mar 03. In another experiment, pears were inoculated with blue and grey mold, and then fumigated. As with all the large scale efficacy tests, after fumigation, the pears were hand packed in polylined boxes with top pad and lid, and placed in the cold room at 1^0C. This experiment is to be evaluated at the end of January 03 and results presented at the review.

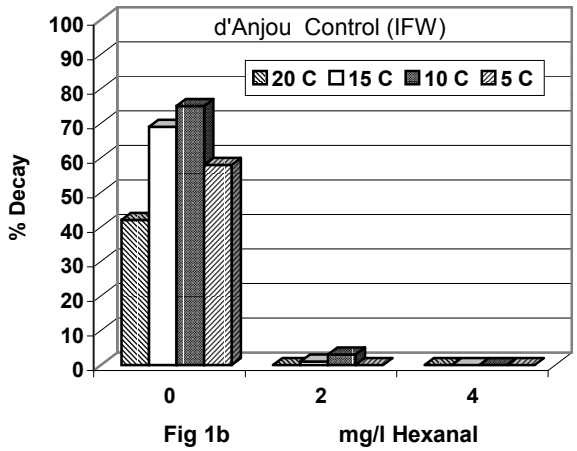
Small scale efficacy tests.

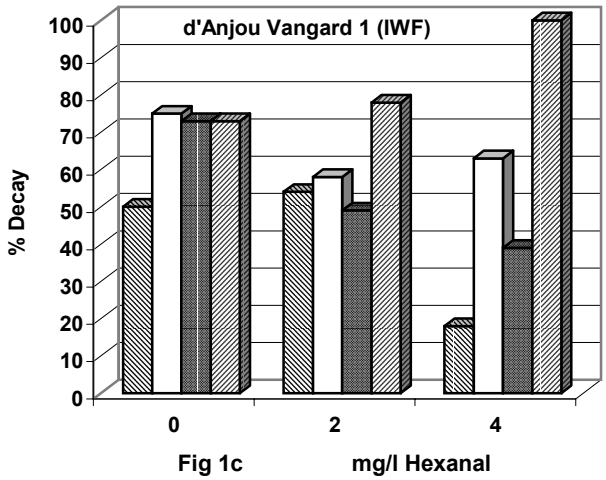
Botrytis (Grey Mold)

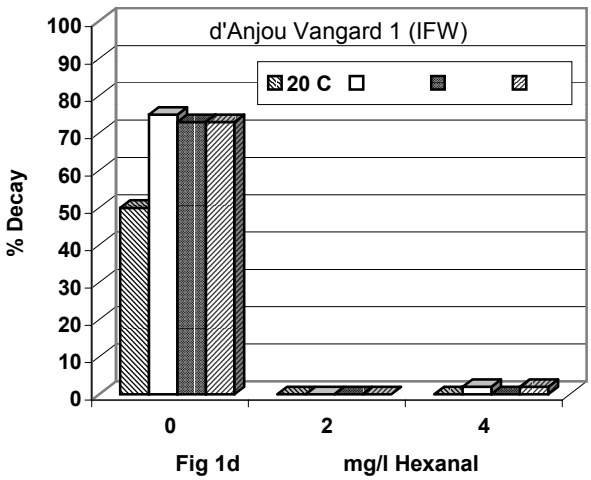
In an ideal world we would like to be able to eliminate 100% of the post harvest pathogens present in wounds. The results of d'Anjou pears which were inoculated, wounded then fumigated (IWF) at various temperatures and rates is shown is figure 1 (Left half of page Fig 1 a, c, e). Also shown is the effect of Vangard on wounds. Compared to the control (untreated) and Vangard 1 rate, the Vangard 2 treatment showed a significant reduction in the amount of rot that developed in the wounds. The fumigation rate of 4 mg/l at 20^0C also reduced the amount of decay when compared to the controls. Wounds were fresh when inoculated and hexanal would work better on dry wounds.

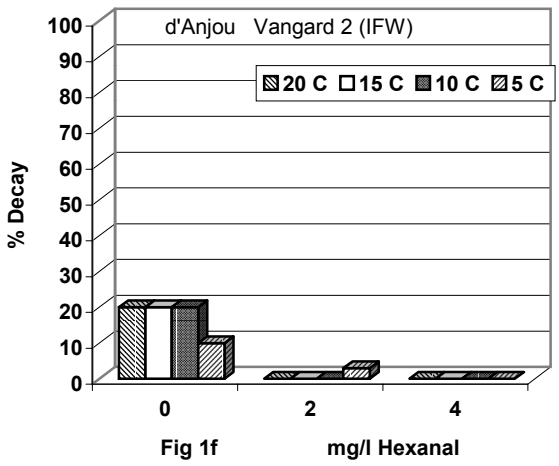
Hexanal used as a surface sterilent on d'Anjou pears, shows an almost total reduction of decay (Right half of page Fig 1b, d, f). Hexanal controlled grey mold at low (5^0C) and high (20^0C) temperatures with as low of rate as 2 mg/l for 24 hours. Note the effect of the higher rate of Vangard in the absence of hexanal (fig 1e & 1f).











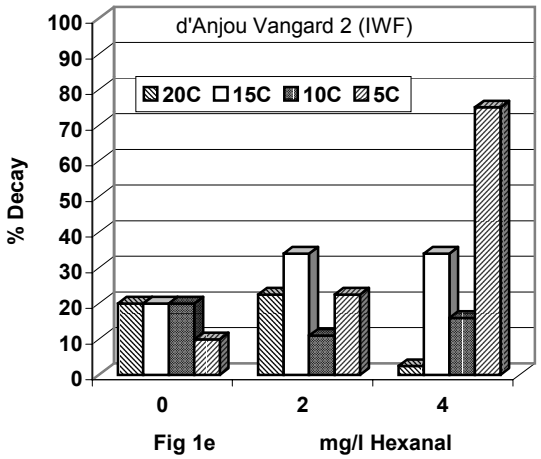
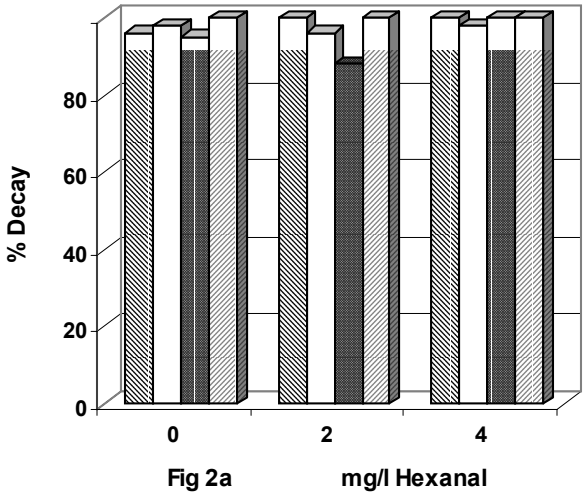


Figure 1. The effect of hexanal on (grey mold) inoculated, wounded, then fumigated d'Anjou pears (Fig 1a, 1c, 1e) vs inoculated, fumigated then wounded d'Anjour pears (Fig 1b, 1d, 1f).

***Penicillium* (Blue Mold)**

Hexanal research on blue mold was limited to apples but early indication are that the results would be the same on pears. Hexanal does not reduce blue mold in wounds. Hexanal will significantly reduce blue mold on the fruit surface but only at 20^0C and 15^0C. (Fig 2a, 2b).



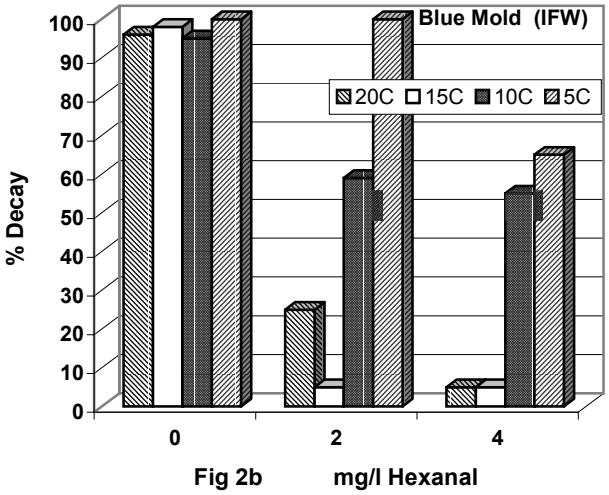


Figure 2. The effect of hexanal on (Blue mold) inoculated, wounded, then fumigated fruit (Fig 2a) vs inoculated, fumigated then wounded fruit (Fig 2b).

Sensory Panel. A sensory panel of 21 judges rated d'Anjou pears which had been fumigated and then stored for two months. The hexanal fumigated d'Anjou pears had a significantly fruitier aroma, then the nonfumigated pears (GLM procedure Pr>F 0.0002).

MCP and Hexanal. Rates of MCP for use on pears are presently unknown. MCP apple rates have been defined and an experiment is being conducted on apples only. Result to be determined in May 03.

Proposed Research:

1. Conduct large scale fumigation trial at Stemilt packing house in Wenatchee, WA, monitoring hexanal concentration with a portable GC.
2. Repeat the Vangard trial using the rate recommended for grapes.
3. The preliminary results indicated that hexanal reduces the amount of spores surviving in wounds. Unfortunately some spores still survive to cause rot. A series of experiments will be conducted in which exposed fruit will be subjected to a constant level of hexanal vapours for the duration of the fumigation. The two rates, (2 mg/l and 4 mg/l), will be used. The effect of the wound age on hexanal control will also be investigated.
4. To determine if hexanal can be used to sterilize different materials, such as wood and plastic bins, concrete floors, walls of cold rooms, expanding foam insulation, etc.

Budget Request:

Title: Use of Hexanal Vapor for Aroma Production and Decay Control
PI: Peter Sholberg
Project duration: 3 years
Project total (3 years): $22,500
Current request: $7,500

Year	**Year 1 2001-2002**	**Year 2 2002-2003**	**Year 3 2003-2004**
Salary	6,500	6,500	**6,500**
Materials and supplies[1]	500	500	**500**
Travel[2]	500	500	**500**
Total	7,500	7,500[3]	**7,500[3]**

1. Supplies include such items as Petri dishes, GC supplies, pears, boxes, packs and hexanal
2. Possible travel to Washington to treat pears at a packinghouse.
3. Funds to be matched by the Matching Investment Initiative Program of Agriculture and Agri-Food Canada,

References:

Song, J., Leepipattanawit, R., Deng, W., Beaudry, R.M. 1996. Hexanal vapor is a natural, metabolizable fungicide: inhibition of fungal activity and enhancement of aroma biosynthesis in apple slices. J. Amer. Soc. Hort Sci. 12: 937-942

CONTINUING REPORT **YEAR 3/3**

TITLE: Postharvest decay control

PI: Peter G. Sanderson, Plant Pathologist, WTFRC
WTFRC staff: Mark S. Aldrich, and Diane Fuller, WTFRC

OBJECTIVES:
Assess efficacy of new chemical and biological fungicides for control of postharvest decay
Assess new technologies for management of postharvest diseases and disorders

SIGNIFICANT FINDINGS (2001-2002):
Fungicide and SAR tests
Scholar

- Efficacy of Scholar line sprays against blue mold in wound inoculated Red Delicious apples
  - Scholar in combination with DPA effectively controlled decay (0.5%of wounds with lesions) compared to the untreated control (83.0% of wounds with lesions) at rates as little as 4oz/100 gal.
  - Combinations with TBZ, DPA, or wax did not affect efficacy at 16oz/100 gal.
  - DPA alone (1000 ppm) significantly reduced blue mold incidence
- Efficacy of Scholar line sprays against blue mold in wound inoculated d'Anjou pears
  - Scholar was most effective when applied alone at 16 oz/100 gal (0.5 % of wounds with lesions).
  - In combination with 2000 ppm ethoxyquin or wax (18%), efficacy was reduced 10 fold (about 5.0% of wounds with lesions).

JAN PH-066 (PL-40)

- Efficacy of JAN PH-066 against blue mold and gray mold in apples and pears
  - Disease in Red Delicious apples was effectively controlled by all concentrations and treatment methods (99.8% and 99.3% control of blue mold and gray mold, respectively) .
  - Best control of disease in Anjou pears was achieved either as a line spray or in wax (99% control of blue mold and 98.7% control of gray mold).
- Evaluation of formulations of JAN PH-066 for phytotoxicity on different varieties of fruit
  - Phytotoxicity was not affected by treatments

BAS 516

- Efficacy of BAS 516 line spray & dips against blue mold in wound inoculated Red Delicious apples and D'anjou pears
  - Best results with line sprays were at the highest rate tested (2000 ppm). Incidence was reduced from 79.5% to 1.0% of wounds with lesions in apples and from 68.5% to 2% of wounds with lesions in pears.
  - Dip applications reduced blue mold incidence at all rates tested and no differences in incidence were observed among rates. In Red Delicious blue mold incidence was reduced from 99.3% of wounds with lesions to 0.8%; in d'anjou pears from 95.8% to about 7.7%.

Fungicide resistance screening

- Scholar. About 5% of field collected isolates of *P. expansum* were insensitive to Scholar at up to 100 ppm.
  - Spores of 109 *P. expansum* isolates collected from the field in 2001 were seeded onto agar amended with Scholar. Spores of 78%, 56%, 52%, and 55% germinated and formed microcolonies (<0.1 mm diam) after 5 days on agar amended with 0.1 ppm, 1.0 ppm, 10 ppm, and 100 ppm Scholar, respectively.

- After 10 days, colonies of 61% of isolates continued to grow on agar amended with 0.1 ppm Scholar, whereas only about 5% continued to grow at the higher concentrations.
- Growth of isolates of *P. expansum* in the presence of 0.1 ppm Scholar was not an indication of resistance to the fungicide (EC_{50} □ 0.1 ppm).

- Imazalil. All field collected isolates of *P. expansum* were sensitive to Imazalil at 10 ppm and 100 ppm, and only about 1% were insensitive at 1.0 ppm.
  - Spores of 78%, 54%, 61%, and 53% of field isolates of *P. expansum* (n = 109) germinated and formed microcolonies (<0.1 mm diam) after 5 days on agar amended with 0.1 ppm, 1.0 ppm, 10 ppm, and 100 ppm Imazalil, respectively.

After 10 days, colonies of 77% of isolates continued to grow on agar amended with 0.1 ppm Imazalil, whereas only 0.9% continued to grow at 1.0 ppm, and none grew at either 10 ppm or 100 ppm Imazalil.

- Growth of isolates of *P. expansum* in the presence of 0.1 ppm Imazalil was not an indication of resistance to the fungicide (0.1 ppm < EC_{50} < 1.0 ppm).

Biological antagonists

- Efficacy of mixtures of yeast and bacterium biological antagonists on blue mold in Red Delicious apples and Anjou pears
  - All combinations of biological antagonists reduced blue mold incidence by about 35% in apple and about 36% in pear.
  - Fruit treated with CIM alone was significantly less effective (11% decay reduction in apples and 16% in pears) than Biosave alone and all other combinations of biological antagonists.

Dump tank sanitation

Pear Flotants

- Effects of pear float, paper and different storage regimes on Anjou pears
  - At 50 days of storage in regular air atmosphere, paper wraps had a significant effect (P = 0.028) on the incidence of calyx end browning. None of the other parameters evaluated (i.e., decay, phytotoxicity, scald, or color) were significantly affected by either float or paper wraps.
  - No effects of either floats or paper wraps on fruit were observed at 100 days of CA storage.
  - 200 days of CA storage, both color and scald were significantly affected by paper wraps (P = 0.013 and P = 0.003, respectively); float materials had no effect on fruit.
- Effect of potassium phosphate pear floats (Xeda-F and Xeda-FC) combined with either SOPP or chlorine
  - Blue mold incidence was lowest in fruit dipped in Xeda-FC (pH 7.3) combined with 100ppm chlorine and Xeda-F (pH 11) combined with 4000ppm SOPP.
  - Pears that remained in dip treatments of Xeda-F with 3500ppm or 4000ppm for 60 minutes had significantly higher phytotoxicity (Table 2) than other treatments.

Application technology

Thermofogging

- Efficacy of fungicides applied by thermofogging
  - Decay incidence in unwounded fruit was reduced from that in the untreated controls by all fungicides applied.
  - Lowest numbers of decayed fruit were found in bins of unwounded fruit treated with JAN PH-073, but on apples that treatment was not statistically different from Scholar and in pears it was not different from either Scholar or TBZ.

- JAN PH-073 was the most effective treatment against blue mold in wound inoculated apples and pears.

RESULTS AND DISCUSSION:

Fungicides and SARs

Efficacy of Scholar for postharvest disease control. Treatments were applied to commercially harvested Red Delicious and d'Anjou fruit as line sprays using a control droplet applicator (CDA) on a packing line. All treatments significantly reduced incidence of blue mold in both apples and pears. In apples, blue mold incidence was significantly lower in all fruit treated with Scholar than those treated with either TBZ with DPA or DPA alone. Interestingly, blue mold incidence was reduced by almost 90% by treatment with DPA alone. No differences in efficacy were observed among rates of Scholar or treatments with Scholar and either DPA, wax, or TBZ. Scald did not occur in any treatments.

In pears, the 16 oz rate of Scholar alone gave the best control of blue mold along with the combination of Scholar, TBZ, and ethoxyquin. Although treatment with ethoxyquin reduced decay incidence from that in the water control, it appeared to have an adverse effect on the efficacy of Scholar. Disease incidence was significantly higher in fruit treated with combinations of fungicides and ethoxyquin. No differences were observed among fungicide treatments when combined with ethoxyquin or wax. Superficial scald was reduced from that in the water control by all treatments including Scholar alone. Low rates of Scholar appeared to enhance the activity of ethoxyquin as did the combination of Scholar and TBZ. Fruit wax had no effect on scald.

Efficacy of Janssen PH-066 (=PL-40). Commercially harvested Red Delicious apple and d'Anjou pear fruit were treated with either as line sprays or by dipping. Line sprays were applied with a CDA. All fungicide treatments significantly reduced incidence of both blue mold and gray mold in both d'Anjou pears and Red Delicious apples. No differences were observed among treatments applied to Red Delicious, regardless of application method. In d'Anjou pears, significant differences were observed among treatments based primarily on application method. Dip applications were less effective than line sprays. Lines sprays with either 1000 ppm PH-066 alone or 2000 ppm PH-066 with wax gave best control of both blue mold and gray mold. In general, dip treatments of Mertect 340-F and JAN PH-066 were equally effective.

Evaluation of two formulations of JAN PH-066 for phytotoxicity. Treatments were applied to commercially harvested Red Delicious, Golden Delicious, Granny Smith, Fuji apples, Bosc, and Anjou pears as line sprays using a CDA. No evidence of phytotoxicity caused by either formulation of PH-066 was observed on either apples or pears.

BAS 516. Line spray applications of BAS 516 significantly reduced blue mold in both d'Anjou pears and Red Delicious apples at all rates tested. Rates ≥1000 ppm gave the greatest control. Similarly, dip applications reduced blue mold incidence by >91% from that in the untreated control in Anjou pears and >99% in Red Delicious apples. Fungicide concentration did not significantly affect blue mold disease incidence in either d'Anjou or Red Delicious fruits. Addition of Latron Ag-98 reduced blue mold incidence by 8.2% in dip treatments applied to d'Anjou pears, but this effect was not observed on apples.

Efficacy of combinations of biological antagonists. Treatments were applied to commercially harvested Red Delicious apple and d'Anjou pear fruit. Antagonist treatment rates used were calculated based on label recommendations for Biosave (1.65 g/L) and $2x10^8$ cfu/ml (6.67g/L) for *Cryptococcus infermo-mineatus* (CIM). Antagonists were mixed in CIM:Biosave ratios of 1:1, 0.5:0.5, 0.25:0.75, and 0.75:0.25. All antagonists significantly reduced blue mold incidence in both apple and pear fruits. Biosave was significantly more effective than CIM when each was applied alone. Combinations of Biosave and CIM were not better than Biosave alone. However, fruit treated with CIM was significantly less effective than all other combinations of biological antagonists. Similarly, lesions in CIM only treated Red Delicious were significantly larger than lesions in fruit

treated with either Biosave or combinations of antagonists. Lesion size was smallest in fruit treated with Biosave alone and the 0.25:0.75 CIM:Biosave combination.

Fungicide resistance in field populations of Penicillium expansum. Isolates of *P. expansum* were collected from fruit, soil, leaf litter, and fruit bins in seven orchards and grown on agar containing 0.0, 1.0, 10.0, 100.0, or 1000.0 ppm of either TBZ, fludioxonil, or imazalil. Of 252 isolates tested, none grew on agar amended with fludioxonil and imazalil at any concentration. However, 10.7% of isolates were insensitive to TBZ at all concentrations. Strong orchard effects were observed in which 18-20% of isolates were resistant in three orchards, 5% in one orchard and 0% in three orchards. Colony diameters of isolates resistant to TBZ were somewhat smaller when grown on agar with ≥ 10 ppm TBZ. TBZ sensitive isolates (no growth at 1.0 ppm) were also placed on agar containing 0.1 ppm TBZ. All isolates (119) grew at this concentration, but colony diameters were reduced compared to the 0.0 ppm control (21.0 mm diam vs. 24.9 mm diam, respectively. Only 36.1% of this group of isolates grew on media amended with 0.1 ppm imazalil (0.5-14 mm diam) after 5 days and only 3.4% of isolates grew (0.5-1.0 mm diam) on 0.1 ppm fludioxonil amended media after 5 days.

Dump tank sanitation

Effects of pear float, paper and different storage regimes on Anjou pear fruit. Thirty bins of commercially harvested Anjou pear fruit from each of three growers were packed at Blue Star Growers, Cashmere, WA, a commercial packing facility, using either of two pear floats and wrapped in one of three paper wraps. Fruit had been held at 0C for 45 days in regular atmosphere storage before packing. Floats used were potassium phosphate (XEDA-F, pH 11.3) or lignin sulfonate (Lignosite), the industry standard. Specific gravity of both floats was adjusted to about 1.025. The antifungal compound sodium ortho-phenylphenate (4000 ppm) was added to each dump tank mixture. Standard applications of TBZ, Biosave, and wax were applied on the line before packing. Paper wraps were impregnated with either Biox-A, 3% oil + copper and ethoxyquin (3%C&E), or 6% oil + copper and ethoxyquin (6%C&E). After packing, 3 boxes of fruit were each put into regular atmosphere storage at 0C for 50 days, and controlled atmosphere (1.5% oxygen & 1.0% carbon dioxide, 0C) storage for 100 or 200 days. Upon removal from storage, fruit color and phytotoxicity were rated on a 0-4 scale (0 = excellent and 4 = poor). Incidence of calyx-end browning and decay were also assessed. After a 6-day ripening period at room temperature, superficial scald was rated (0 = none and 4 = severe). Data were analyzed as a split plot design with the pear float as the whole plot and paper wraps as split plots.

At 50 days of storage in regular air atmosphere, paper wraps had a significant effect (P = 0.028) on the incidence of calyx end browning. Incidence was greatest in fruit wrapped with paper impregnated with Biox-A. No calyx-end browning was observed in fruit wrapped with 3%C&E. None of the other parameters evaluated (i.e., decay, phytotoxicity, scald, or color) were significantly affected by either float or paper wraps. Likewise, no effects of either floats or paper wraps on fruit were observed at 100 days of CA storage. However, after 200 days of CA storage, both color and scald were significantly affected by paper wraps (P = 0.013 and P = 0.003, respectively); float materials had no effect on fruit. Fruit remained greenest (least color change) when wrapped in the Biox-A impregnated paper and was yellowest (most color change) when wrapped in 3%C&E paper. Conversely, scald was greater in fruit wrapped with Biox-A than those wrapped in either of the C&E papers. No decay or phytotoxicity were observed.

Efficacy of SOPP or chlorine with potassium phosphate pear floats for control of blue mold. Treatments were applied to commercially harvested Anjou pears obtained from a packinghouse in North Central Washington. Fruit used to assess efficacy of SOPP or chlorine for control of blue mold were wounded (3mm diam x 3mm deep) a single time on the equatorial axis. All treatments were applied as dips to each of three 15 fruit replicates. Pears were dipped into a tub containing either Xeda-F (pH 11) with SOPP or Xeda-FC (pH 7.3) with chlorine and removed at specific times. Specific gravity was adjusted to 1.026. To inoculate fruit, aqueous suspensions of *P. expansum* were

mixed into each dip treatment. Inoculum density was adjusted to give 1000 conidia/ ml of *P. expansum* in the final dip mixture. Phytotoxicity was assessed on fruit that were not wounded or inoculated, but were otherwise treated as described above. Following each treatment the fruit were allowed to dry before being place in a standard tray pack apple box and placed in regular atmosphere at 31.5°F. Disease incidence and phytotoxicity were assessed 3 mo after treatment.

Blue mold incidence was lowest in fruit dipped in Xeda-FC with 100 ppm chlorine and Xeda-F with 4000 ppm SOPP (Table 1). Exposure period had no effect on blue mold incidence. However, exposure period did have an effect on phytotoxicity. Pears that remained in dip treatments of Xeda-F pH 11 and 3500 ppm or 4000 ppm for 60 minutes had significantly higher phytotoxicity (Table 2) than other treatments. No phytotoxicity was observed in any of the control treatments (Xeda-FC or Xeda-F alone) or the Xeda-FC with chlorine treatments.

Postharvest chemical application technology

Thermofogging Fungicides were applied with a XEDA thermofogging machine to each of three single replicate bins of commercially harvested fruit. In wound-inoculated apple and pear fruits, JAN PH-073 was significantly more effective at controlling blue mold than any other treatment. All fungicides significantly reduced blue mold incidence in wound-inoculated apples compared to the untreated control. However, neither imazalil nor TBZ were effective against blue mold in pears.

In unwounded Red Delicious apples, blue mold incidence and that of other postharvest diseases (e.g., bull's-eye rot and Alternaria rot) was very low (<0.12% of fruit affected) and were not affected by any treatments (data not shown). All treatments with exception of imazalil significantly reduced gray mold incidence in apples. Best gray mold and total decay control was from JAN PH-073 and DPA as well as Scholar. DPA has been reported to be effective against TBZ resistant isolates of *P. expansum*. This test appear to confirm that DPA has fungicidal effects, at least when applied as a fog treatment. In unwounded pears, incidence of gray mold was not significantly affected by any fungicides although there was a clear trend in which less decay developed in bins of fruit treated with JAN PH-073 than in bins given other treatments. All fungicides significantly reduced the amount of blue mold in unwounded pears and JAN PH-073 offering significantly better control than the other fungicides. Likewise, total decay in pears was significantly reduced by all fungicides with the exception of imazalil, which was ineffective.

PROPOSED RESEARCH:

Chemical and biological control remain mainstays of postharvest disease management programs. New chemicals from several companies are being developed for postharvest use and for preharvest application to control postharvest disease. We are continuing to provide data to registrants on the efficacy of these chemicals to promote their further development and registration. The use of biological antagonists for postharvest disease control is the only option for organic production and has been embraced as a supplement conventional disease management programs. Single organisms are typically developed for use as biological antagonists. However, combinations of antagonists that more effectively utilize space and nutrient resources may enhance their effectiveness.

The contribution of field bins to inoculum loading of drenches and packinghouse water systems has been established. Practical methods for sanitizing bins need to be developed and implemented. The fruit industry is adopting pressure washers to remove field residues such as Surround. Most systems use of recirculated water that can become heavily contaminated with pathogen spores and may increase the probability of incurring disease losses. Methods to minimize spore loading in those water systems need to be developed and tested.

Trials planned or currently underway include:

Fungicides and SARs

- Efficacy of BAS 516 against - dips and line sprays,
- Efficacy of Scholar against postharvest pathogens - drenches,

- Efficacy of JAN PH-066 against blue mold and gray mold - dips and line sprays,
- Efficacy of postharvest fungicides and antioxidants applied by thermofogging,
- Effect of preharvest Messenger applications on postharvest fruit quality
- Nutrient enhancement of field applied biological antagonists against postharvest pathogens.

Sanitation

- Bin sanitation to eliminate fungicide resistant and residual populations of postharvest pathogens.

BUDGET:

TITLE: Postharvest decay control
PI: Peter G. Sanderson
Project total (3 years): $36,000
Current year request: $18,950

Requested for 2003:	2001 WTFRC	2002 WTFRC	**2003 WTFRC**	Outside funding
Labor[1]	5,000	5,800	**13,200**	
Goods and services[2]	500	5,000	**5,000**	15,000 [3]
Travel[4]		750	**750**	
Total	5,500	11,550	**18,950**	15,000

[1] 1/2 FTE time slip worker
[2] Fruit, agric. chemicals, lab supplies
[3] Estimated from chemical companies
[4] In-state travel to orchard plots and packinghouse

CONTINUING PROJECT REPORT **YEAR 2/5**

Project Title: Evaluating Water Management Techniques to Optimize Fruit Production and Quality and Increase Profitability to the Grower

PIs: Clark Seavert, Steve Castagnoli and Roberto Nunez-Elisea
Organization: OSU-Mid-Columbia Agric. Res. and Ext. Center
3005 Experiment Station Drive, Hood River, OR 97031

Research Assistant: Laurie Smith, OSU, Mid-Columbia Agric. Res. and Ext. Center

CO-PIs: Helmut Riedl, Robert Spotts, Eugene Mielke, Paul Chen, Anita Azarenko, Tim Righetti and John Selker

OBJECTIVES FOR 2002:

- To quantify soil-water dynamics and tree growth responses of both Columbia Red d'Anjou and Green d'Anjou trees under a polypropylene fabric row cover vs. no row cover with the purpose of optimizing irrigation scheduling of pear orchards
- To determine the cost/benefit potential of optimizing pear yields with water management and fabric row cover technologies.

OBJECTIVES FOR 2003:

Same as for 2002.

SIGNIFICANT FINDINGS:

- During the first season after planting, Green d'Anjou exceeded Columbia Red d'Anjou for all growth responses measured. These differences in growth largely reflect differences in tree size at planting time. Fabric row cover increased the mid-summer and end of season TCSA compared to those of the no row cover treatment for Green d'Anjou. There was a trend toward increased tree height and canopy diameter for both varieties, but these differences were not statistically significant.
- A partial soil moisture characteristic curve has been generated for each grid. Additional measurements are needed to complete these.
- The first two year's costs to establish the weed free herbicide strip blocks are $10,929 per acre and $12,554 per acre for the fabric row covers. The total variable cash cost for 2002 was $9,455 per acre for the weed free herbicide strips and $11,080 for the fabric row cover. The fabric row cover cost $1,595 per acre to install, including labor, materials and equipment.

METHODS:

- **To quantify soil-water dynamics and tree growth responses of both Columbia Red d'Anjou and Green d'Anjou trees under a polypropylene fabric row cover vs. no row cover with the purpose of optimizing irrigation scheduling of pear orchards.**

  A pear research orchard was established at the MCAREC, Hood River in the spring of 2002 to carry out this project. Pear cultivars include Green d'Anjou, Columbia Red d'Anjou and Green Bartlett. Tree spacing is 10 by 16 feet. The research orchard is divided into16 grids with 24 trees in each grid. A central core of eight trees in each grid is used for data collection. The remaining trees in each grid serve as guard trees. The treatments consist of two ground cover treatments and two cultivars. The tree rows in eight grids are covered with a 30 inch-width woven polypropylene fabric row cover, the other eight grids have weed-free herbicide strips. In 2002, weed control was strictly by mechanical means and will include both chemical

and mechanical means in the future. There are four grids of each row cover treatment planted to Columbia Red d'Anjou and four grids of each planted to Green d'Anjou, with eight Bartlett pollinizers included in each grid. The four treatments are applied in factorial combinations and replicated four times in a randomized complete block design. The layout of the research orchard is diagrammed in Figure 2.

The trees were planted in early May 2002 and the fabric row cover laid down over the tree rows by the end of May. A tree support system, consisting of 6 inch-diameter treated posts, a single wire at 8 feet, and a ½ inch-diameter aluminum tree pole for each tree, was installed in June. A lower wire at 2 feet supports the irrigation line. The trees are being trained to a central leader system. Initial training in 2002 consisted of spreading the new growth with toothpicks and the older limbs with plastic limb spreaders.

Irrigation water is applied to each tree using Netafim microsprinklers delivering 9.3 gal/hour, with a wetted diameter of approximately 5 feet. The irrigation system was designed so that each grid can be irrigated independently in order to water individual grids based on soil water content. In 2002, irrigation was applied uniformly at 10 to 14 day intervals to all grids. Beginning in 2004, irrigation will be applied on the basis of soil water depletion for each grid independently when available water content drops to approximately 50%. Detailed orchard management costs are being recorded to conduct cost/benefit analyses for the irrigation management treatments.

Volumetric soil water content in the block is being measured with a portable probe (Sentek Diviner 2000®). The Diviner 2000® system measures soil water content via vertically placed PVC access tubes installed adjacent to a data tree in each grid, within the area explored by the root zone. The Diviner 2000® is manually operated and collects data at 10 cm intervals through the soil profile. This system allows the determination of tree water use based on the amount of water extracted by roots at different soil depths. One access tube was installed in each grid in June 2002. Watermark sensors were installed in each grid in August, at 30 cm and 90 cm depths adjacent to, and on either side of, each Diviner 2000® access tube. Watermark sensors are used to measure soil water tension, which is correlated to volumetric soil water content at 30 cm and 90 cm depths to generate in-situ soil water characteristic curves. We are interested in determining whether these curves can be used to better interpret readings obtained with Watermark sensors.

Soil moisture monitoring was conducted every other day, as well as pre- and post-irrigation, through the initial growing season and has continued weekly through the dormant season.

In 2002, data was collected to quantify tree growth and vigor. Trunk cross sectional area was measured both in the early part of the growing season and after leaf drop in the fall. Canopy height and spread were measured in the fall. Annual growth will be measured prior to the beginning of the 2003 growing season.

- **To determine the cost/benefit potential of optimizing pear yields with water management and fabric row cover technologies**.

  Detailed expense data has been recorded for each of the 16 grids in the block since preparation for planting began. Income and expense data will be tracked on an individual grid basis with the use of enterprise budgets. Enterprise budget analysis will determine the economic potential of Red d'Anjou and Green d'Anjou and row covers. Tree yield and fruit size and quality from each grid will be reflected in gross incomes. Labor costs as well as cash and machinery costs will be gathered. Thus, each grid will show a net projected return that will demonstrate the profit or loss of a particular treatment. Each treatment will be evaluated based on statistical and economic analysis.

Additional Data Collected:

Information will be gathered annually from each grid pertaining to soil and leaf nutrient levels, soil temperature, and soil biology factors. Soil pH, and macro- and micro- nutrient content were determined for each grid prior to planting in 2001 and in the fall of 2002. The soil will be sampled for bacterial, fungal, protozoan, and nematode activity and biomass in the spring of 2003 prior to shoot growth. Pest counts and disease levels will be correlated with levels of water use and ground cover treatments. It is anticipated that data loggers will be installed in each grid to continuously measure soil and air temperature in 2003. A soil quality kit will be used to obtain respiration, earthworm concentration, bulk density, water infiltration, and aggregate stability measurements.

RESULTS AND DISCUSSION:

- **To quantify soil-water dynamics and tree growth responses of both Columbia Red d'Anjou and Green d'Anjou trees under a polypropylene fabric row cover vs. no row cover with the purpose of optimizing irrigation scheduling of pear orchards**

  d'Anjou and Green d'Anjou trees under a polypropylene fabric row cover vs. no row. Through the 2002 growing season, data were collected with the Diviner 2000® system and the Watermark sensors in order to generate a soil moisture characteristic curve for each grid. A partial curve has been generated for each grid (data not shown), but additional measurements are needed to complete these.

  There were significant differences in all growth responses between the two cultivars during the first season (Table1). These differences in growth largely reflect the larger initial tree size of Green d'Anjou at planting time. The increase in TCSA from August to November for Green d'Anjou was, however, 22% greater than that of Columbia Red d'Anjou. This indicates that Green d'Anjou had a higher relative growth rate during that part of the season.

  Fabric row cover increased the mid-summer and end of season TCSA compared to those of the no row cover treatment for Green d'Anjou but not for Red d'Anjou (Table1). There was a trend toward increased tree height and canopy diameter for both varieties, but these differences were not statistically significant.

- **To determine the cost/benefit potential of optimizing pear yields with water management and fabric row cover technologies**. In 2001, pear trees were removed from a prior research block, the ground was ripped and disked and remaining roots were removed. The soil was sampled in each grid for pH and nutrient content and the block fumigated with Methylbromide and Chloropicrin. The first year total variable cash costs for both the weed free herbicide strips and fabric row cover was $1,474 per acre (Table 2).

  In 2002, the ground was roto-tilled after an application of 200 lbs per acre of 16-16-16. The pH was low in Grid 4, and 450 lbs (2.5 t/ac) of Dolomite were applied to that grid as well. The trees were planted, the fabric row cover was installed, irrigation and trellis support systems were installed, trees were pruned and training was accomplished by spreading limbs with toothpicks and plastic tree spreaders. A grass cover crop was planted in the fall. The total variable cash cost was $9,455 per acre for the weed free herbicide strips and $11,080 for fabric row covers (Table 2). The fabric row cover cost $1,595 per acre to install, including labor, materials, and equipment.

  One cost item related to weed control was changed in the budget. Due to concerns about potential herbicide damage to the young trees, the weeds in the tree row and at the edge of the fabric row cover were hand hoed to reduce the risk of injuring data trees. All row cover grids were hand hoed once, and the grids with herbicide strips were hoed an additional time. This procedure cost $1,392 for the weed free herbicide strips and $600 for the fabric row covers. The budget reflects costs of weed control practices that are more typical of industry standards. We will use chemical controls beginning in 2003.

The first two year's cost to establish the weed free herbicide strip grids is $10,10,929 per acre and $12,554 per acre for the fabric row covers. (Table 2)

BUDGET

Project Title: Evaluating Water Management Techniques to Optimize Fruit Production and Quality and Increase Profitability to the Grower

PIs: Clark Seavert, Steve Castagnoli and Roberto Nunez-Elisea

Project Duration: 2002-2006

Current Year: 2003

Project Total: **$154,197**

Current Year Request: **$ 30,481**

Year	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)	Year 4 (2004)	Year 5 (2006)
Total	28,268	30,481	30,818	31,803	32,827

Current Year Breakdown:

	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)	Year 4 (2004)	Year 5 (2006)
Labor - Salaries[1]	15,500	**16,670**	17,337	18,030	18,751
- OPE	6,568	**7,611**	7,281	7,573	7,876
Services & Supplies	5,600	**5,600**	5,600	5,600	5,600
Travel[2]	600	**600**	600	600	600
TOTAL	28,268	**30,481**	30,818	31,803	32,827

[1]1/2 FTE Faculty Research Assistant

[2]Oregon & Washington state travel

Table 1. The effect of variety and row cover on vegetative growth of pear trees.

Treatment	TCSAs[z] (cm^2)	TCSAf[y] (cm^2)	TCSA increase (%)	Tree height[x] (cm)	Canopy diameter[w] (cm)
Variety					
Columbia Red d'Anjou	-	-	16.9	147	46
Green d'Anjou	-	-	20.6	167	71
Row cover					
with Row cover	-	-	19.2	162	59
No Row cover	-	-	18.3	151	58
Var x RC Interaction					
Columbia Red d'Anjou w/Row cover	2.5	2.9	-	-	-
Columbia Red d'Anjou No Row cover	2.4	2.8	-	-	-
Green d'Anjou w/Row cover	4.3	5.3	-	-	-
Green d'Anjou No Row cover	3.6	4.3	-	-	-
Significant F					
Variety	***[v]	***	*	**	***
Row cover	***	***	ns	ns	ns
Var x RC	***	**	ns	ns	ns

TCSAs[z] = trunk cross sectional area measured in August 2002.

TCSAf[y] = trunk cross sectional area measured in November 2002.

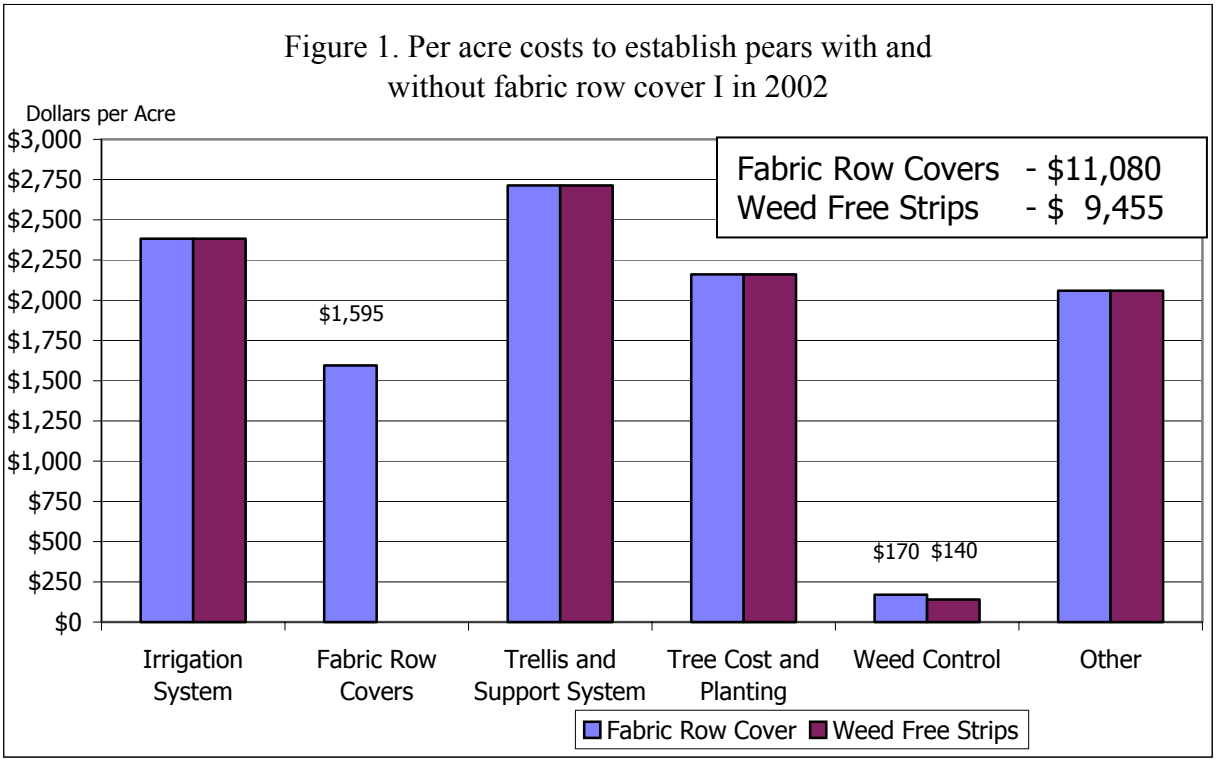
Tree height[x] measured in November 2002.

Canopy diameter[w] measured in November 2002.

[v] ns, *, **, and *** indicate not significant, and statistically significant at the 0.05, 0.01, and 0.001 levels of probability, respectively.

Table 2. Enterprise Budget for pear water management study - PER ACRE SUMMARY

VARIABLE CASH COSTS (per acre) Description	Total/Acre	Total-Row Cover	Total-Weed Free
GROSS REVENUES - YEAR 1	0.00	0.00	0.00
- YEAR 2	0.00	0.00	0.00
ACCUMULATED GROSS REVENUES	$0.00	$0.00	$0.00
VARIABLE COSTS - YEAR 1	1,474.23	1,474.23	1,474.23
- YEAR 2	10,267.51	11,079.86	9,455.17
ACCUMULATED VARIABLE COSTS	$ 1,741.74	$ 12,554.09	$ 10,929.39
NET RETURNS - YEAR 1	1,474.23)	(1,474.23)	(1,474.23)
- YEAR 2	0,267.51)	(11,079.86)	(9,455.17)
NET ACCUMULATED RETURNS	$ 1,741.74)	$ 12,554.09)	$ 10,929.39)



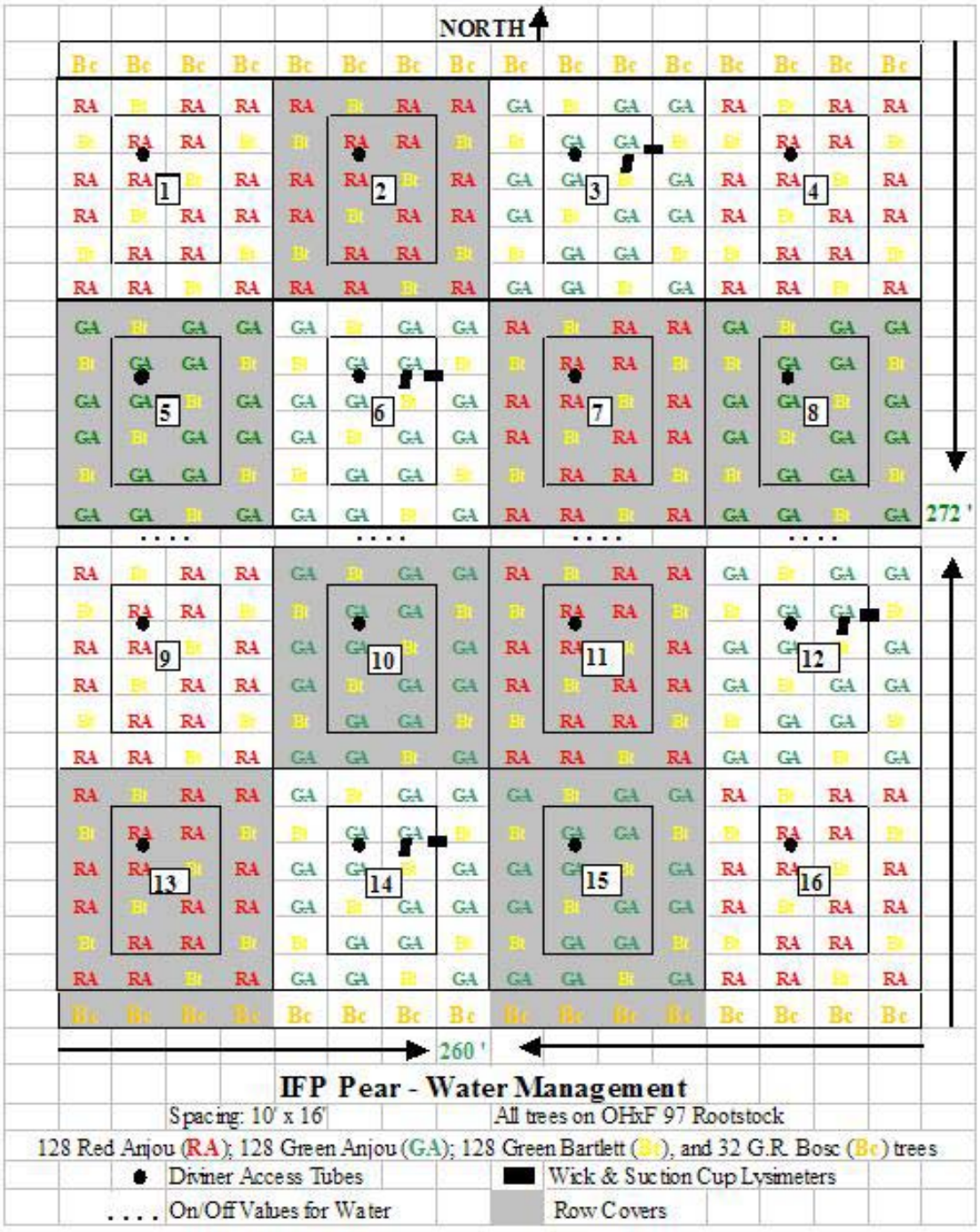


Figure 2. Diagram of the research orchard layout.

CONTINUING REPORT **YEAR 4/10**

Project Title: Evaluation of Harvest Maturity and Quality Aspect of Pear Cultivars in the Northwest

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Organization: OSU-Mid-Columbia Agric. Res. and Ext. Center
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OBJECTIVES FOR 2002:

- To establish new and maintain current pear varieties.
- To establish and maintain pear rootstock nursery.
- To establish and maintain two varieties of pear – Taylor's Gold and Concorde.
- To identify the optimum harvest maturity and storage life of 'Banjo' pear cultivar.
- To identify the optimum harvest maturity and storage life of 'Moore Red' pear Cultivar.

OBJECTIVES FOR 2003:

- To establish new and maintain current pear varieties.
- To investigate the storage life of US 71655-014.
- Determine consumer preferences for current pear varieties in Objective #1 and compare those to d'Anjou and Bartlett pears.

SIGNIFICANT FINDINGS:

- **To establish new and maintain current pear varieties.** First and full bloom data were collected on 21 varieties. The bloom span for the varieties ran from 4/7/02 for first bloom to 4/25/02 for full bloom. Limited quantities of fruit were available for display at the Washington State Horticultural Society meeting in December. In August 2002, seven flowering pear selections from the germplasm in Corvallis were budded onto OhxF97 rootstock in the variety block. The goal is to test these varieties for their ability to be used as more efficient pollinizers, than what is currently commercially available, for solid planted blocks of a particular pear variety.

  Pear Sensory Evaluations

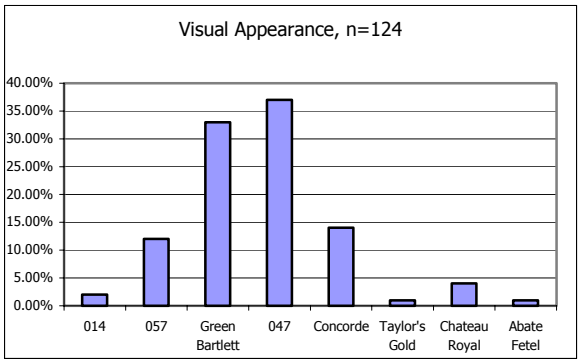
  A total of 253 consumers participated at Corvallis, Oregon (124 consumers on November 2) and Vancouver, Washington (129 consumers on November 30) in visual and taste evaluation test for fresh pears, mainly from Objective #1. Tables on the next page show the results from the two locations.

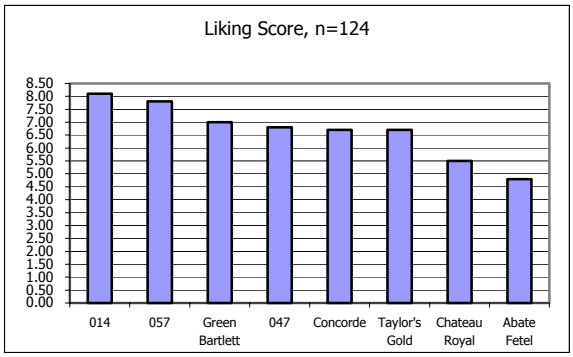
  In Corvallis, the varieties tested were Green Bartlett, Concorde, US 71655-014, US 78304-057, US 66170-047, Abate Fetel, Chateau Royal, and Taylor's Gold.

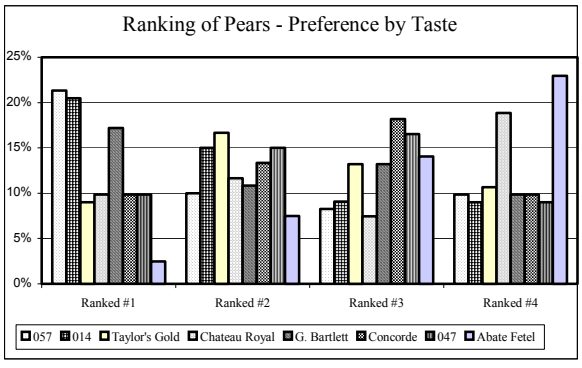
Corvallis, OR Survey Results

Pressures for Sensory Evaluation

Variety	No. Fruit	Max.	Min.	Average
Abate Fetel	17	5.0	3.0	4.3
US 66170-047	19	4.5	3.8	4.0
US 78304-057	14	4.3	3.0	3.4
Green Bartlett	17	4.3	3.0	3.6
US 71655-014	20	3.8	2.5	3.6
Taylor's Gold	15	4.5	2.3	3.3
Chateau Royal	15	5.0	3.3	4.2
Concord	15	5.0	3.5	4.3



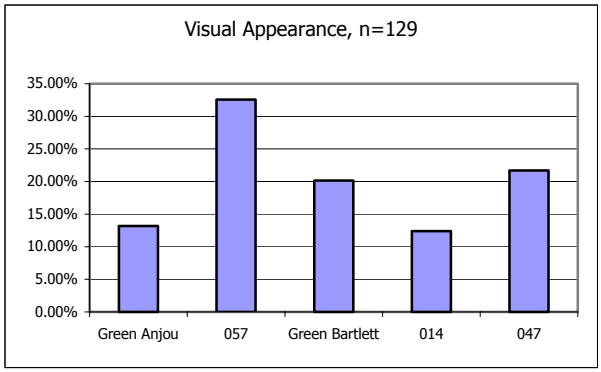


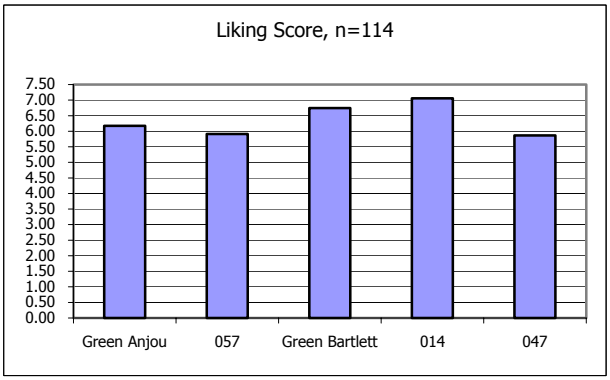


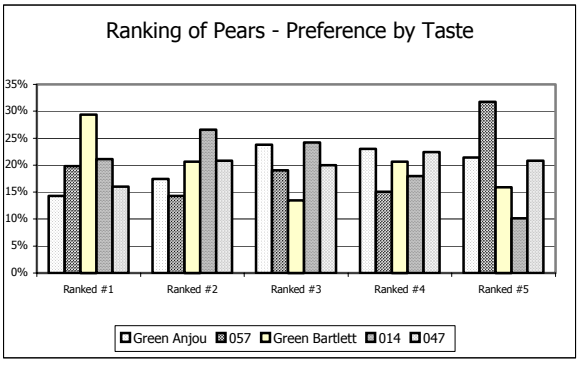
Vancouver, WA Survey Results

Pressures for Sensory Evaluation

Variety	No. Fruit	Max.	Min.	Average
Green Anjou	27	4.0	2.8	2.9
US 66170-047	25	4.5	2.3	3.3
US 78304-057	19	3.5	2.0	3.1
Green Bartlett	26	4.3	3.0	3.8
US 71655-014	20	4.0	2.0	3.0
Taylor's Gold	7	2.8	2.0	2.5







The results of the visual test showed US 66170-047 (36%) as the most appealing pear, followed by Green Bartlett (33%). The Concorde and US 78304-057 received about 12%followed by Green Bartlett (33%). The Concorde and US 78304-057 received about 12% each. The overall liking score showed US 71655-014 and US 78304-057 showed statistically higher than the other pears, while the Abate Fetel and Chateau Royal falling off as unacceptable (below a 6.0 rating). The results of the taste preference (ranking the pears from #1 to #4 after the liking score) showed US 78304-057 with 22% of the consumers ranking it first followed by US 71655-014 (21%) and Green Bartlett (17%). The pears ranked second were Taylor's Gold (17%), US 71655-014 and US 66170-047 (15%) and Concorde (14%). Pears ranked third were Concorde (18%) and US 78304-057 (16%).

In Vancouver, the varieties tested were Green Bartlett, Green d'Anjou, US 71655-014, US 78304-057, and US 66170-047. The results of the visual test showed US 78304-057 (32%) as the most appealing pear, followed by US 66170-047 (21%) and Green Bartlett (20%). The overall liking score showed US 71655-014, Green Bartlett and Green d'Anjou statistically higher than the other pears. The results of the taste preference (ranking the pears from #1 to #5 after the liking score) showed Green Bartlett with 30% of the consumers ranking it first followed by US 71655-014 (21%), Green Bartlett and US 78304-057 (20% each). The pears ranked second were US 71655-014 (26%), Green Bartlett and US 66170-047, each receiving 21% and Green d'Anjou 17%, respectively. Pears ranked third were Green d'Anjou and US 71655-014 and US 78304-057 receiving about 20% each.

In summary, the Green Bartlett remains very popular with consumers when it comes to visual apprearance and taste. However, the US 71655-014 pear seems to edge out the Green Bartlett for taste and the US 78304-057 and US 66170-047 are preferred over Green Bartlett as visually appealing. More survey work should be conducted to 1) better understand the chilling requirements of the pears in Objective #1, based on consumer liking scores and rankings, and 2) if pears from Objective #1 are superior to the industry standards of Green Bartlett and Green d'Anjou.

- **To identify the optimum harvest maturity and storage life of 'Banjo' pear cultivar.** In the 2001-2002 season, the results were basically the same as the findings in 2000-2001. We suggest that the optimum maturity of 'Lariza' pear is when the flesh firmness (FF) is decreased to between 10.5 lb and 12 lb and the optimum storage life of this cultivar is around 3 months in air at –1C. 'Lariza' was patented and re-named 'Banjo' in 2001. Data from previous and current reports assisted in the patenting process.

- **To identify the optimum harvest maturity and storage life of 'Moore Red' pear Cultivar.** In the 2001-2002 season, the results were basically the same as the findings in 2000-2001. We suggest that the optimum maturity of 'Moore Red' pear is when the flesh firmness (FF) is decreased to between 14 lb and 16 lb and the optimum storage life of this cultivar is around 4 months in air at –1C. Maximum days for ripening at 68°F have been determined to be 5 days. Based on finding from 2000, only one harvest date was necessary for 2002, when the pressure was between 14 and 16 lbs.

METHODS:

- **To establish new and maintain current pear varieties.**

A) Orchard maintenance: i) pruning, ii) training, iii) planting new varieties, iv) weeding, v) budding and grafting.

B) Data collection: i) bloom dates: first and full, ii) bloom count and fruit set, iii) harvest samples: up to 4 intervals during harvest season, iv) pressures at harvest, iv) TCSA cm^2, v)

canopy height and spread, vi) individual tree yield.

C) Fruit Storage: i) sorting and packing, ii) labeling, iii) evaluating ripening, tasting, and storage disorders.

D) Record keeping: i) mapping varieties for visitors, ii) identifying variety of tree with tags iii) harvest, bloom and tabular data

E) Reporting: i) display fruit at Washington State Horticultural Society meeting, ii) display and show variety trial at station tours and annual field day, iii) present current information with pictures on MCAREC web site (osu.edu/dept/mcarec)

- **To investigate the storage life of US 71655-014.**

A) Harvest 6 boxes of US 71655-014 fruit from the variety trial with a FF of 14-16 lbs. Sample 10 fruit at harvest for FF and SSC

B) Transfer fruit to 4/5 volume bushel boxes with polyliners and store at 30°F (±0.5°F).

C) After 2, months, 4 months, and every two weeks thereafter of cold storage at 30°F, transfer three boxes into a ripening room at 68°F.

D) On day 1, 5 and 7 of ripening, use 10 fruit per box for FF, EJ, TA and SS measurement.

E) On day 5 and 7 of ripening, assess the incidences of storage disorders including senescent scald and internal browning

F) On day 5 and 7 of ripening the dessert quality of ripened fruit including flesh texture and flavor will be rated on a nine point hedonic scale with 9=buttery and juicy texture and flavorful taste and 1=mealy, coarse and dry texture and off flavor.

- **Determine consumer preferences for current pear varieties in Objective #1 and compare those to d'Anjou and Bartlett pears**.

A) A test of 1,000 fresh pear consumers at 6 sites in Oregon and Washington will be surveyed during the fall of 2003.

B) The day before testing, penetrometer measurements will be taken on individual pears of each variety to select pears for testing that meet the firmness criteria between 3 and 6 lbs pressure.

C) The day of testing, each pear will be placed on sanitized plastic cutting boards just before slicing. Each cutting board is labeled by pear variety and by the sample 3-digit code number.

D) Pears will be sliced with stainless steel apple slicers, which core and cut each pear into 8 separate slices. Immediately after cutting, two slices of a given pear variety will be placed in a 5 oz. plastic cup that is coded with the 3-digit random code number.

E) Samples will then be placed on a plastic serving tray. Randomizing the order to which pears are to be evaluated will be predetermined on each survey form. All varieties will be presented together on one tray for each panelist. The pears will be served to consumers within 10 minutes of being sliced.

F) Before tasting any pears, consumers will be asked to select the pear they liked best based on appearance only, from a display of all pear varieties. Order of pear varieties displayed will be alternated throughout the test period. Consumers will chose only the one pear they liked best.

G) Liking scales, purchase intent and overall ranking will be used to evaluate consumer liking for each sliced pear sample. After tasting each pear, consumers will be asked how much they liked the pear overall.

H) Ratings will be based on a labeled 6 cm line scale. The three anchors used for the ballot will be as follows: the lowest=dislike, the midpoint=neither like nor dislike and the highest=like.

I) Consumers will be asked next if they would consider buying the pear where the choices will be no definitely not, possibly, and yes definitely.

J) Ranking all varieties tasted will determine which pear the consumer preferred. The following reasons for consumers' preference for a variety will be: juiciness, smell/aroma, sweetness, smooth texture, tartness/sourness, gritty texture and skin color. The reasons for consumers'

dislike of a variety liked least will be: juiciness, sweetness, skin texture, smooth texture, skin color, tartness/sourness and gritty texture.

K) Pear eating habit questions will be asked at the end of the ballot.
L) Consumers will be asked how often they eat fresh pears.
M) Consumers will also be asked what variety of fresh pears they eat most often.
N) Adults and children will be accepted to participate in the survey if they meet the following three conditions: a) They like fresh pears, b) They have no dietary restrictions for pears, c) They will voluntarily participate in the test.
O) Consumers will be compensated for taking the test with a free bag of Beaver Pears.

RESULTS AND DISCUSSION:

- **To establish new and maintain current pear varieties.** Twenty-one varieties deemed to have met the criteria for evaluation in the new variety trial and were moved in May 2000 from the old pear collection block. Trees in Phase I were planted, pruned, trained, weeded and some varieties were budded or grafted. Data collected for 2002 consisted of bloom dates: first and full; bloom count and fruit set; harvest samples: up to 4 intervals during harvest season; pressures and soluble solids first and full bloom dates, and flesh firmness pressures from the harvest sampling intervals. Fruit was ripened, displayed and tasted at the Washington State Horticultural Society meeting in December. A poster featuring the variety trial goals and results from the sensory evaluations were also displayed during the Poster session. First and full bloom data was collected on 21 varieties. The bloom span for the varieties ran from 4/7/02 for first bloom to 4/24/02 for full bloom (refer to Table 1).
- **To establish and maintain pear rootstock nursery.** A pear rootstock nursery was planted and maintained throughout the 2001-2002 season, consisting of 160 OhxF 97 rootstocks for grafting varieties that are difficult to purchase on appropriate rootstock.
- **To establish and maintain two varieties of pear – Taylor's Gold and Concorde.** Taylor's Gold on OhxF87 and Concorde on OhxF 97 were planted in Phase Two. The trees were pruned and trained. Data collection for 2001-2002 included: bloom dates: first and full; bloom count and fruit set.

Table 1

First and Full bloom dates, April 2002

Cultivar	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Green d'Anjou	X	X	X	X	X	X	X	X										
Potomac				X	X	X	X	X	X	X	X							
Tosca					X	X	X	X	X	X	X	X	X	X				
Bartlett					X	X	X	X	X	X	X	X	X	X	X			
Rosemarie						X	X	X	X	X	X	X	X	X	X			
US 76128-009							X	X	X	X	X	X	X					
US 71655-014							X	X	X	X	X	X	X	X	X			
Banjo							X	X	X	X	X	X	X	X	X	X	X	
Chateau Royale							X	X	X	X	X	X	X	X				
US 71660-045							X	X	X	X	X	X	X	X	X	X		
US 66125-035							X	X	X	X	X	X	X	X				
Angelys							X	X	X	X	X	X	X	X	X	X		
US 76115-010							X	X	X	X	X	X	X	X				
Cinnamon								X	X	X	X	X	X	X				
Moore Red								X	X	X	X	X	X	X	X	X		
US 67218-083								X	X	X	X	X	X	X	X	X		
Madeira								X	X	X	X	X	X	X	X			
Bautome-Serenade								X	X	X	X	X	X	X	X			
US 66131-021								X	X	X	X	X	X	X	X			
US 66170-047								X	X	X	X	X	X	X	X			
US 78304-057										X	X	X	X	X	X	X	X	X
H231-B1											X	X	X	X	X	X		
Taylor's Gold															X	X	X	X

- **To identify the optimum harvest maturity and storage life of 'Banjo' pear cultivar.** The most distinguishable indicators for evaluating the ripening activities of pear fruit in this project are flesh firmness (FF) and extractable juice (EJ) (Table 2-1). Normal ripening of 'Banjo' pear for Harvest 1 required up to 7 days at 20° C to reach the proper eating quality if harvested fruit had been stored at –1° C in air for 2 months or longer. Decrease of flesh firmness was steady from day 1 to day 7, yet reduction of EJ was not significant during ripening. (The reduction of EJ of ripened fruit indicates an increase in juice-binding capacity of pulp tissue, which results in juicy and buttery texture). Texture and flavor in the 'Banjo' for Harvest 1 was better on day 7 indicating this harvest required 7 days at 20° C or longer even though FF on day 5 and 7 of ripening was similar and was around 2.47lb to 2.31lb (Table 2-1). There were no differences in TA content before and after ripening 'Lariza" for 7 days. SSC in 'Banjo' pear did not change during 7 days of ripening at 20° C (Table 2-1).

Table 2-1.

Differences in flesh firmness (FF) (lb), extractable juice (EJ) (ml/100 g F.W.), titratable acidity (TA) (meq/100 ml), soluble solids concentration (SSC) (%), texture quality (score 1-9), and flavor quality (score 1-9) of 'Banjo' pear on day 1 (Unripened) and day 5 (Ripened), and day 7 (Ripened) of ripening at 20ºC. 'Banjo' fruit were harvested on August 21 (Harvest 1). Harvested fruit were stored in air at -1ºC for 4 months. (There was no fruit left to sample from subsequent harvests.)

Harvest	Days at 20 ° C	FF	EJ	TA	SSC	Texture	Flavor
1	1	5.56±.1.02	64.00±3.46	3.10±.41	12.47±.93	.	·
	5	2.47±.06	64.33±.58	3.25±.06	12.10±.66	6	5
	7	2.31±.17	63.67±1.53	3.19±.04	12.43±.81	7	6

Banjo 2000	**Harvest Date**	**Flesh Firmness at Harvest**
The flavor of Harvest One tended to develop an astringent flavor when ripened, possibly the result of harvesting too early.	8/21/00 **Harvest #1**	12.1
Harvest Two held up the best and had the best flavor, texture and overall marketability. It also had a substantial reduction in EJ from day 1 to day 7, indicating a buttery and juicy texture.	8/30/00 **Harvest #2**	10.77
The first sampling of Harvest Three at two months was good, but the fruit did not store well beyond that. It developed a soft and mealy texture after ripening at 4 months.	9/5/00 **Harvest #3**	9.26
Banjo 2001	**Harvest Date**	**Flesh Firmness At Harvest**
Fruit was blemish free at the 2 months sampling but developed storage scald and green stain for subsequent samples. Green stain may be related to a nutrient deficiency. Reduction in EJ was measurable, but not as good as the Harvest #2 sample.	8/21/01 **Harvest #1**	11.18
Fruit also developed scald and green stain after the 2 months sample, but it was less severe than Harvest 1. This harvest had a good reduction in EJ, coupled with favorable hedonic ratings at 2 and 4 months samplings. It is concluded that this is the better Flesh Firmness for harvest.	8/29/01 **Harvest #2**	10.37

Summary: This variety encompasses traits from both Bartlett and Anjou. The shape resembles Anjou with very little russet but it begins to turn yellow on the tree, and is a clean yellow color when ripe. Harvest is in late August, and the optimum harvest pressure is between 10.5-12 lbs. The fruit are medium to small in size, averaging .4lbs at harvest for both years. The harvest in August' 01 had problems with a "green stain", speckling that was unattractive. It was suggested that the problem might have been a nutrient deficiency. Flavor is sweet and mild, and very juicy. The flavor cannot be labeled as distinctly Bartlett or Anjou, but a combination of the two. Optimal storage life in regular air storage at -1ºC was 3 months.

- **To identify the optimum harvest maturity and storage life of 'Moore Red' pear Cultivar.** Normal ripening of 'Moore Red' pear usually required 5 days at 20° C to reach the proper eating quality if harvested fruit had been stored at –1° C in air for 4-4.5 months (Table 2-2). Decrease of FF was also associated with a distinct reduction of EJ in the 'Moore' Red' pear during ripening.

Table 2-2
Differences in flesh firmness (FF) (lb), extractable juice (EJ) (ml/100 g F.W.), titratable acidity (TA) (meq/100 ml), soluble solids concentration (SSC) (%), texture quality (score 1-9), and flavor quality (score 1-9) of 'Moore Red' pear on day 1 (Un-ripened) and day 5 (Ripened), and day 7 (Ripened) of ripening at 20ºC. 'Moore Red" fruit were harvested on August 15, 2002. Harvest pressure was 15.5 lbs. Harvested fruit were stored in air at -1ºC for 4 months, and 4.5 months.

4 months	Days at 20° C	FF	EJ	TA	SSC	Texture	Flavor
	1	14.32±.34	68.67±1.53	3.26±.31	11.75±.25	.	.
	5	3.51±.44	58.67±1.53	3.65±.17	11.92±.63	4.75	8
	7	2.2±.06	57.83±6.05	3.48±.05	11.67±.38	5.3	5.3
4.5 months	Days at 20° C	FF	EJ	TA	SSC	Texture	Flavor
	1	13.6±.25	69.67±2.08	3.4±.30	11.5±.25	.	.
	5	3.31±.22	65.00±2.65	3.22±.05	11.67±.29	3.75	6
	7	2.3±.21	62.83±1.89	3.54±.19	12.00±.50	4	4.5

Summary: Based on the findings from 2001, it was determined that 'Moore Red' fruit should be harvested only once in the 2002 harvest season, at 14-16 lbs pressure. Texture and flavor ratings for 'Moore Red' suggest that optimum storage is 4 months, and 5 days ripening as opposed to 7 days is preferable.

BUDGET

Project Title: Evaluation of Harvest Maturity and Quality Aspect of Pear Cultivars in the Northwest

PIs: Clark Seavert and Dr. Anna Marin

Project Duration: 2000-2009

Current Year: 2003

Project Total: **$250,397**

Current Year Request: **$ 27,500**

Year	Year 3 (2002)	Year 4 (2003)	Year 5 (2004)	Year 6 (2004)	Year 7 (2006)
Total	23,809	27,500	28,977	30,532	32,178

Current Year Breakdown:

	Year 3 (2002)	Year 4 (2003)	Year 5 (2004)	Year 6 (2004)	Year 7 (2006)
Labor - Salaries[1]	14,404	**14,700**	15,582	16,517	17,508
- OPE	6,893	**7,938**	8,414	8,919	9,454
- Salaries[2]	844	**2,541**	2,643	2,748	2,858
- OPE	68	**221**	238	247	257
Services & Supplies	1,000	**1,000**	1,000	1,000	1,000
Travel[3]	600	**1,100**	1,100	1,100	1,100
TOTAL	23,809	**27,500**	28,977	30,532	32,178

[1] 1/2 FTE Bio-Research Technician 3

[2] Temporary Workers

[3] Oregon & Washington state travel

FINAL REPORT
WTFRC Project PR-02-226 **Agricultural Research Foundation #3740**

Project Title: Introduction and propagation of pear rootstocks

PI: Dr. William M. Proebsting
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Oregon State University
Corvallis, OR 97331-7304

Cooperator: Dr. Gene Mielke
Mid-Columbia Research & Extension Center
Hood River, OR

Objectives: This project conducts research in propagation of pear, to: 1) help the flow of clonal rootstocks, from research programs towards commercial propagation, and 2) improve propagation of these clones.

Significant Findings:
1) **East Malling series**. Liners of clonal rootstocks 517-9 and 708-13 were sent to Hood River in spring, 2002. Multiplication of these clones is continuing.
2) **Horner series**.
●Softwood cuttings from 294 clones in the Horner collection at Hood River were propagated at Corvallis in July, 2001. Two or more liners of each were sent to Fowler Nursery in February, 2002 for grafting and return to Hood River for testing.
●The remainder of the Horner series, 148 clones, were propagated in July, 2002. Liners of about 130 will be sent to Fowler in February, 2003.
3) **Russian clones**. In February, 2002, we received budwood from three clonal rootstocks, Q29857, Q29858, Q29859, from Russia. These were initiated into tissue culture. Q29859 has multiplied very quickly, whereas the others are progressing slowly.

Methods:
Softwood cuttings. Horner series. Cuttings were collected from the original seedlings growing at Hood River. These trees were pruned hard to induce vigorous shoot growth. All available cuttings from each stock plant were collected on July 2. Cuttings were prepared by removing the expanding shoot tips and then making 10" cuttings, except for dwarf clones for which 6" cuttings were made. The cutting bases were dipped for 5 sec in 100 mM IBA dissolved in 0.25 M KOH and planted in medium (perlite:peat, 3:1) in bands 2 ¼" squares by 5" deep at 22^{o}C. The mist conditions were: 0700-0900 hours, 24 min interval, 0900 to 1000, 16 min interval, 1000 to 1700, 8 min interval, 1700 to 1900, 16 min interval and 1900 to 2000, 24 min interval. All mist applications were 10 sec duration.

During the last week of August, rooting was evaluated by tugging firmly on each cutting. The rooted cuttings were consolidated and moved directly outdoors to a shade structure.

Micropropagation. Budwood of Q29857, Q29858 and Q29859 was sent from Beltsville, Maryland in February and budded on seedling pear rootstocks in the greenhouse. Vigorous shoot tips were collected in late-April for tissue culture.

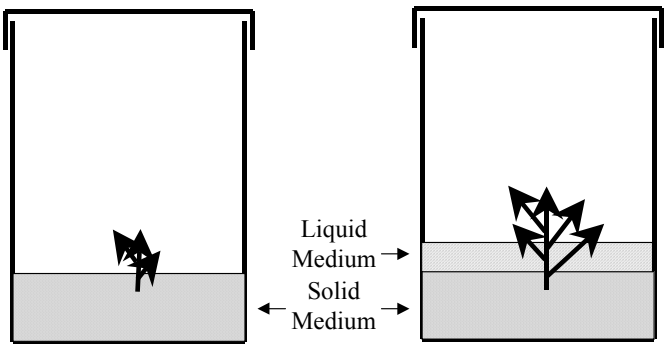


Figure 1. Single-phase vs. double-phase tissue culture.

The shoots were established in sterile culture by surface sterilizing actively growing shoots in 10% bleach solution and planting the shoots in individual tubes containing DKW medium consisting of 0.8% agar, 3% sucrose plus DKW salts and vitamins. Shoots which were sterile and still actively growing were transferred to a multiplication medium consisting of DKW medium plus 1 ppm benzylaminopurine (BAP). Every 4-6 weeks, shoot clumps were divided into single shoots and re-cultured on multiplication medium.

When liquid medium is used in double-phase culture, enough liquid is added, about 25 ml, to nearly cover shoots that had just been divided and transferred (Figure 1).

When a sufficient number of shoots are available, the surplus is treated with indolebutyric acid (IBA) to stimulate rooting. Rooted shoots are transplanted into clean potting medium, grown under intermittent mist for two weeks and then transferred to the greenhouse. In the greenhouse, the shoots are grown to liner size and transferred to other research programs.

For transfer to commercial micropropagators, shoot cultures are sealed in sterile, plastic pouches containing a small amount of DKW solid medium and mailed to the nursery.

Results and Discussion:

1) **Horner series.** Gene Mielke is interested in testing production characteristics of this group of over 400 open-pollinated 'Old Home x Farmingdale' seedlings. Further testing was warranted when preliminary studies found some promising rootstocks.

In this situation, tissue culture of 400 clones is inappropriate. Because these are seedlings, however, and have been maintained as small, heavily-pruned trees, rooting potential of softwood cuttings of each clone should be near its maximum. Furthermore, since only 2-5 liners of each clone were required for the rootstock trial, low rooting percentage is not a serious obstacle.

In 2001, the two liner minimum was met by 294 of the 304 clones we sampled. In February, 2002, these liners were shipped to Fowler Nursery, Newcastle, CA. They grew very well and were summer budded. John Ireland of Fowler Nursery remarked on how much variation there was among the clones. Two comparisons are pictured in Figure 2. Additional photos will be shown at the research review. The scions will develop this summer, 2003 and the trees shipped to Hood River for planting in 2004.

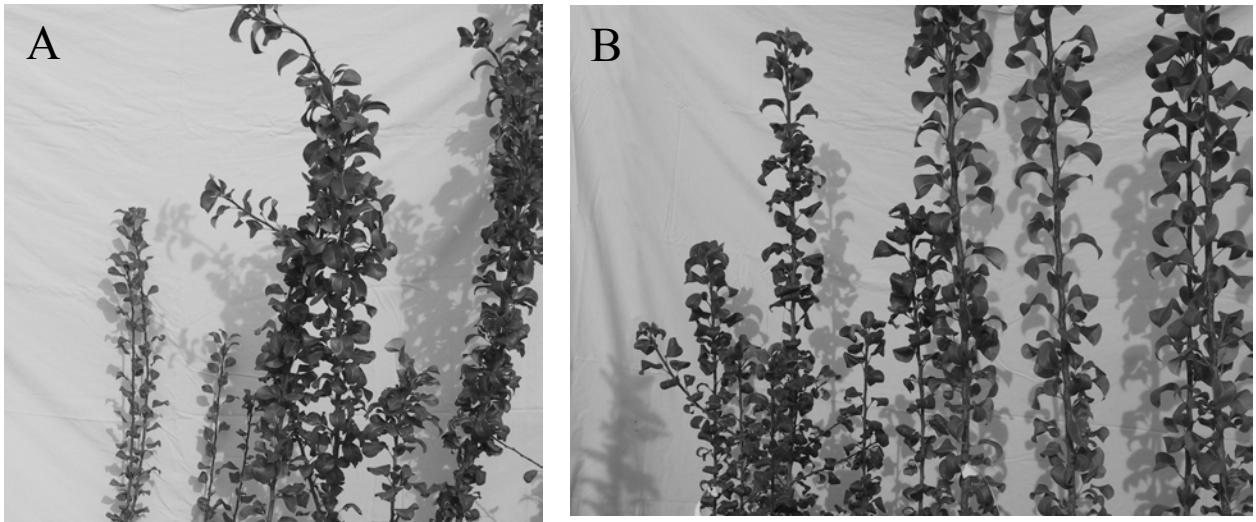


Figure 2. Variation in Horner liners. A. Left, Compact H-237, right H-324.
B. Left, compact H-87, right, H-234

In 2002, 133 out of 148 clones met the two liner minimum. In late August, the rooted cuttings were moved outdoors to a shade structure and entered dormancy. In January, 2003, 2-5 of each clone will be shipped to Fowler Nursery for growing on and grafting as the previous set were.

2) **East Malling series.** Two years ago, two additional clones, 708-13 and 517-9 were identified from the HRI rootstock breeding program. (Earlier, 708-2, 708-12 and 708-36 were propagated here and are presently being tested.) These were sent to NRSP-5, Bill Howell released them to OSU and we initiated them into tissue culture spring, 2000.

These clones multiply moderately well, though they are somewhat difficult to root. Liners were sent to Hood River spring, 2002 for testing.

Preliminary experiments with a chemical called azacytidine (AC) show promise for improved rooting. We will continue to test AC on these difficult-to-root clones.

3) **Russian rootstocks.** Several years ago, three clonal pear rootstocks were imported from Russia by Californians Larry Rogers and Jim LaRue. They are purportedly dwarfing. APHIS was willing to make these available for preliminary propagation. With the assistance of Gene Milbrath of Oregon Department of Agriculture to obtain the necessary paperwork, APHIS sent me budwood in February, 2002. We budded it on seedlings in the greenhouse and initiated cultures in late April, 2002.

Q29857 and Q29858 are multiplying slowly, but are healthy and clean. Q29859 has multiplied very quickly and we are ready to begin rooting. Liners of this clone would be ready to send to Hood River by fall, 2003. **However**, release depends on certification by APHIS.

Budget:
Project Title: Introduction and propagation of pear rootstocks
PI: Dr. William M. Proebsting
Project Duration: 2000-2003
Project total: $77,702

Year	2000-01	2001-02 (past)	2002-03 (current)
Total	$26,903	$26,903	$23,896

Details

	2000-01	2001-02	2002-03
Salary, Faculty Research Assistant[1]	12,999	$13,339	$11,373
OPE (53%)	6,889 (53%)	7,070 (53%)	6,028 (50%)
Student Wages[2]	1900	1900	1900
OPE (5%)	95	95	95
Services and Supplies[3]	4500	4,000	4,000
Travel[4]	500	500	500
Total	$26,903	26903	23896

[1]Luigi Meneghelli, Research Assistant
[2]Undergraduates maintain most of the cultures and field plots
[3]Tissue culture and greenhouse supplies
[4]Travel to plots at the Lewis-Brown Farm

FINAL REPORT

Title: Nitrogen Nutrition of Pears Grown Under Differing Soil and Environmental Conditions

Project leader: Timothy L. Righetti, Dept. of Horticulture, Oregon State University

Cooperators: Clark Seavert, Mid-Columbia Agriculture Research and Extension Center, Anita Azarenko, Dept. of Horticulture, Oregon State University.

Funding History: Three-year study, 1st yr $28,800 pear, $20,000 apple; 2nd yr $15,000 pear; 3rd yr $15,000 pear

Introduction:
Like many research projects, this effort has changed over time. Both the original justification and objectives and a description of how the project has been broadened over time are included in this final report.

Original Justification:
Many of us believe that as we strive to become more efficient, fertility programs will become more complex. We need to know how important the tree storage, non-fertilizer soil sources, and fertilizer N pools are for trees grown under different conditions. The most appropriate strategy for an orchard in a clayey soil in Wenatchee may be quite different than in a loam soil at Hood River. We believe that management strategies can be designed to meet the economic and environmental demands that face our industry, but there is not a one-size-fits-all solution.

A first step in the pursuit of developing management approaches for different soil and environmental conditions, is determining how much variability exists among and within different locations. We proposed to evaluate fertilizer efficiency, and the relative importance of tree storage, non-fertilizer soil sources, and fertilizer N pools at multiple Northwest locations under different soil environments. Trials on pears were conducted at Hood River and Medford, Oregon.

Specific hypotheses as originally proposed are listed below:

1) The ^{15}N estimates of fertilizer recovery may overestimate the real efficiency of plant uptake especially in high-organic matter systems.

2) Some pear growing systems can be defined as N saturated (more N available from fertilizer and soil mineralization than plants require). Under these conditions, increasing the efficiency of fertilizer or reserve utilization may decrease the use of N mineralized from the soil. Even though plants respond to N, we have more than we need.
3) The source of the N that can potentially contaminate groundwater varies for different pear growing systems and climates.

4) Mineralized N that is released from soil organic matter may be less efficiently used than fertilizer N, and the use of mineralized N will vary with pear variety, soil type and environmental conditions.

Original Objectives as Proposed:
1. Determine the relative importance of tree storage, soil and fertilizer N pools in meeting the nitrogen needs for pears grown under different soil and environmental conditions.

2. Determine uptake efficiency for pears grown under different soil and environmental conditions.

3. Investigate how soil texture, site-specific weather conditions, and soil organic matter may modify the uptake storage and utilization of fertilizer applied N at different locations.

4. Develop possible management strategies that incorporate soil and environmental factors into N fertilizer recommendations.

Spatial Issues in Orchard Management:
As work proceeded, we took advantage of opportunities to broaden the scope of the original proposal. It appears that spatial variability with regard to N nutrition may be more important than an orchard's average N status. We hypothesized that N deficiencies and N excesses may occur within the same orchard and that differences in tree and canopy size could lead to large differences in the N status of different trees.

Early in the study it became apparent that large differences in tree size within an orchard were the major factor in a given tree's N uptake efficiency. We began to focus our research on how to incorporate tree size into N evaluations.

In our early studies, there was also a large amount of variability in canopy size and canopy density among different trees within our experimental orchards. Small canopies were either due to small trees or large trees with insufficient canopies. We utilized the canopy data acquired in the course of our nitrogen studies to develop procedures to quantify canopy status and determine if trees have sufficient or insufficient vigor. We explored different ways of expressing tree vigor to find ways that were not biased by differences in tree size.

We also initiated new studies to evaluate how canopy evaluations could supplement traditional N evaluations. Since our initial experiments suggested that canopy size was far more variable than N concentrations in leaf tissue, we hypothesized that without canopy information N concentration data would be misleading. Experiments were designed to determine if this was true.

As we documented the large variability in tree size, it became apparent that tree size is a dominant factor in determining yield potential in commercial orchards. Poor economic returns at specific locations within an orchard can be attributed to either small trees or large trees that are performing at a level far below their potential. With the information acquired in our N studies we are developing procedures to differentiate between size related and efficiency related constraints to maximizing yield or profit. We also hypothesized that the traditional measures of tree performance (yield/cross sectional area) or canopy efficiency (yield/canopy area) could be biased in favor of small trees. Therefore different approaches of quantifying tree or canopy performance were evaluated to determine if they were less biased than our traditional approaches.

Expanded Objectives:
The funding from the WTFRC has been pooled with other grant sources to expand the scope of the project. This has also allowed us to continue with apple research even though the WTFRC only funded pear research after the initial year. While the original proposal addressed the research topics listed below in categories 1), 7) and 8); all of the expanded areas of emphasis contribute to the overall understanding of interrelated topics. Technical publications in each of these categories are currently being prepared. A brief discussion of each of the following topics is presented with data examples where appropriate. Much of the ^{15}N analyses associated with category 1) and 8) are still underway, but sufficient data exists to comment on overall trends.

Although N research is an important part of our project, and finding more efficient ways of managing N is an ongoing process, our effort is now more broadly defined. We are convinced that there is more to be gained in managing the spatial variability within an orchard than there is in devising new and better management approaches to uniformly manage orchard blocks. This generalization applies to N management and many other aspects of tree fruit production. Developing an overall approach to spatial management has become our focus. This report discusses our findings and describes our current approach to implementing spatial management programs.

As our industry wrestles with an uncertain future, we do not believe that fine-tuning N management should be a high priority as researchers choose where to invest their time. None-the-less, since N management was the subject of the original proposal, the most important aspects of our N research program are presented in this final report.

Areas emphasized in this report are as follows:

1) Nitrogen Uptake Efficiency and Tree Size
2) Tree Size Variability and Orchard Performance
3) Yield or Profit Improvement Potential
4) Factors Limiting Tree Size
5) Canopy Variability and Canopy Improvement Potential
6) Quantifying Tree and Canopy Performance
7) Spatial Implications for Nitrogen Management
8) Replacement of Organic Nitrogen with Nitrogen Fertilizers

Materials and Methods:

Destructive Analysis of Entire Trees

For pears, data was collected at the Southern Oregon (Medford) and Mid Columbia (Hood River) Agricultural Experiment Stations. For apples, data was collected at OSU (Corvallis), the Mid Columbia Agricultural Experiment Station and at the University of Idaho Experiment Station in Parma, Idaho. At all four locations data was collected over a three-year period. Experimental designs varied slightly, but were generally similar. Labeled nitrogen was applied in the first year to a set of trees at all locations. In subsequent years trees that were previously treated with labeled N were treated with unlabeled N. At each location a new set of trees received labeled nitrogen fertilizer in the second and third years of the study. A portion of the trees was destructively harvested in each season. Fruit, leaves, and other above and belowground components were evaluated for dry weight, N concentration and isotopic N composition.

The destructive sampling allowed us to determine how much of the N in a tree comes from fertilizer and tree reserves. The amount of N not accounted for by either the fertilizer or tree reserves was assumed to come from soil sources (mineralization of N from organic matter). We could also determine how much variability exists in tree size, and canopy size (leaf weight/tree) at each location. Relationships between tree size (cross sectional area of the trunk or the dry weight of structural biomass) and yield were determined. Relationships between tree size and the amount of fertilizer N uptake and uptake efficiency were also evaluated.

Non-destructive Evaluations
At the Medford, Hood River, and Idaho locations yield and trunk cross sectional areas of a larger set of trees were evaluated over a two-year period. This larger data set was used to further evaluate the relationship between tree size and yield and better quantify the variability in tree size that occurs.

Additional data was collected for a 50-year-old pear orchard in Parkdale, Oregon. Yield and economic returns (ER) in dollars per tree collected in 1998, 1999, and 2000 Although evaluations at this site are ongoing, spatial treatments were implemented after the 2000 harvest so only the 1998-2000 time period is evaluated here. The 6.6-hectare (~16 acre) orchard was divided into 23 sampling units or cells. Each cell was approximately 2800 m^2 (0.7 acre; 0.5 acre if pollen source trees are excluded). At harvest, all bins from each cell were kept separate and tagged for tracking purposes. The cooperating commercial packinghouse tracked the bins through the processing facility and provided yield, fruit size, grade and cull information for individual cells. This information allowed us to determine the total yield, fruit value, and economic return for each cell. Economic returns (ER) were calculated as income minus total cost. The circumference of each tree trunk at a height of 30 cm above the ground was measured and used to calculate an estimate of tree trunk cross sectional area (CSA). The CSAs for individual trees were averaged to get representative values for each cell. Average canopy area and canopy density for each tree were estimated from an IR photograph. The canopy areas and densities for individual trees were averaged to get values for each cell.

Results and Discussion:

Nitrogen Uptake Efficiency and Tree Size
In Figure 1 tree size (structural biomass) is plotted against nitrogen recovery for pear trees in Medford Oregon. Although the strength of the relationship varies (r^2 values from 0.5 to 0.8) in various studies the results shown are typical of what is observed. Large trees simply take up more N than small trees. There is a limit to how much N a tree can take up. We would argue that unless differences in tree size are considered, there is little chance that efficiency can be improved. Fertilizer timing, fertilizer rate and the method of application (ground or foliar) are all important but these factors do not explain as much of the variability in uptake efficiency as tree size. We may have developed a nitrogen fertilizer program that results in the over fertilization of much of an orchard as we apply constant rates that meet the needs of our largest trees. The variability in tree size presented in this graph is typical of what is observed in our experimental plots. One hundred to 400 percent differences were observed at the Medford, Corvallis, Hood River, and Parma study sites in orchards that are considered to be relatively uniform with respect to tree size.

Tree Size Variability and Orchard Performance
If only standard regression statistics are used to evaluate these experimental results, one would conclude that there were not strong or consistent relationships between yield or profit and trunk cross sectional area (CSA) or structural biomass. The r^2 values for the 13 data sets from various orchards (three pear locations over three years; two apple locations over 2 years) varied from 0.05 to 0.80 but only one data set had an r^2 value greater than 0.45 and 9 were less than 0.15. However, in all orchards the data points were distributed in a manner similar to the distribution shown in Figures 2-5. For the sake of brevity, relative data has been pooled across years and sites for the apple orchards where the ^{15}N experiments were conducted (Figure 2) and across years at the pear site where 23 sample sites were evaluated over the three-year study (Figure 3). Figure 4 presents the same data that is presented in Figure 3 but average profit for the three-year evaluation period is presented. A single-year pear data set where a large number of individual pear trees were evaluated is presented in Figure 5. When data was pooled across years and sites for the pear orchards where the ^{15}N experiments were conducted the results are almost identical to the apple data in Figure 2 (data not shown).

In Figures 2 through 5, a boundary line approach has been utilized to define the upper limits of yield or profit for a given level of CSA or dormant biomass. Although the criteria used to define the upper boundary is beyond the scope of this summary, a visual evaluation of the boundary condition is informative. Although many factors can limit yield or profit and there are many points that are well under the upper limit, the maximum yield or profit obtainable is determined by CSA. Large trees can have low yield or profit, but small trees are never in high yield or profit categories. Points above the apparent upper boundary lines are rare. In individual years the upper boundary line will shift up or down as production and price change, but CSA defines the maximum return possible in any given year.

Since this relationship (a wedge shaped pattern) is consistently observed it suggests that it is possible to identify trees or regions within an orchard that are yielding less than their maximum potential. For example, many points in Figures 4 are on or near the upper boundary line presented. Locations represented by these points are performing at or near their maximum potential. It is unlikely that management changes would result in improved performance at these locations. Emphasizing corrective management treatments, in the areas of an orchard that are consistently represented by points below upper boundary lines, have the highest probability of short-term success.

Yield or Profit Improvement Potential

In Figure 6, a contour plot reveals areas of the orchard that were characterized in Figures 3 and 4 that are likely to respond to enhanced management in the short term. This map was created by calculating the relative distance between the three-year average ER for each cell and the CSA upper boundary line derived from the average data (Figure 4). This distance can be defined as an improvement potential with units of $/tree. The points slightly above the upper boundary line were given a value of zero. Points with greater relative distances from the upper boundary line have more potential to respond to enhanced management. Areas with a high improvement potential (light color) represent areas where low tree efficiency rather than small tree size limit profitability. Figure 6 gives a manager a visual representation of where responses are most likely to occur.

Better management for the orchard as a whole is of course well advised. However, if a manager is going to implement spatial management strategies, concentrating enhanced management efforts in areas most likely to be economically responsive would be a wise strategy. Managers and researchers may also be interested in identifying possible profit limiting factors and determining if management changes can improve economic return/tree. In this example the two areas with high improvement potential (the northwest and northeast corners of the orchard) were also lowest in soil pH.

Factors Limiting Tree Size

As previously discussed it is important to determine if small tree size or inefficient trees limit profit. The approach discussed above (Yield and Profit Potential section) can be used to identify possible limiting factors for areas of an orchard that are producing at less than their potential. Correcting factors that may limit tree size also has long-term advantages.

Attempts to correlate soil or tissue analyses with CSA were generally unsuccessful. This is to be expected since many factors can simultaneously limit CSA. Therefore, a boundary line approach that is similar to the procedures we used to define relationships between CSA and yield or profit (Tree Size Variability and Orchard Performance section) was used.

An example of this method is illustrated in Figure 7, where an upper boundary line is used to visualize the relationship between CSA and soil pH. Although other factors can limit CSA and there are points well below the boundary line, the maximum CSA obtainable for a given pH interval is

defined by the upper limit boundary. Even though there is not a significant relationship between soil pH and CSA an identifiable wedge shaped pattern and upper boundary line suggest that increased soil pH is associated with an increase in CSA.

Similar wedge shaped patterns and boundary lines were apparent for soil organic matter (OM) and cation exchange capacity (CEC). A negative relationship between leaf Mn and CSA was also apparent. In an effort to determine if wedge shaped patterns and boundary lines could be randomly created, simulations were conducted to randomly assign pH, CEC, OM and leaf Mn values to the real CSA data. None of the random simulations produced the statistically significant boundary conditions that were apparent in the real data.

Canopy Variability and Canopy Improvement Potential

One of our goals was to quantify canopy status. However, without data on tree size, it is difficult to determine if small canopies are due to small trees or large trees that suffer from some form of stress that is limiting canopy development. This distinction is important if we want to improve canopy management. Without having some way to incorporate tree size into canopy evaluations, canopy data is much less meaningful.

Attempts to correlate canopy size or leaf biomass with CSA produced weak statistical relationships. This is to be expected since many factors can simultaneously limit canopy development. Once again, a boundary line approach can be used to define relationships between CSA and canopy coverage or total leaf biomass. For the sake of brevity only a single example is discussed below, but similar relationships were apparent in most of the data sets. In some cases it was difficult to capture all the senescent leaves from individual trees. Therefore the remote evaluation of canopy size in the pear orchard that was divided into 23 zones is discussed below.

In Figure 8 remotely assessed canopy areas are plotted against CSA. The data suggests that although trees with large CSA can still have small canopy area the maximum possible canopy area is determined by the CSA of the trunk. The familiar wedge shaped pattern is evident. Canopy improvement potential maps can be created in a manner that is analogous to the yield or profit improvement potential maps discussed above. It is also possible to determine if achieving maximum canopy area is desirable.

It could be that the maximum canopy area represents excessive vigor. This is not the case in the example shown. Points marked with a circle are from the most profitable cells (highest third) within the orchard. In this instance high producing trees are near the boundary line and have close to the maximum possible canopy size. This suggests that excessive canopy area (related to vigor) is not a problem in this orchard. Estimates of canopy density (data not shown) may be more important than canopy area assessments when determining if trees are overly vigorous.

Quantifying Tree and Canopy Performance

The data in Figure 8 also demonstrates the biases that are apparent when using conventional expressions to quantify canopy efficiency. If canopy efficiency is expressed as yield or profit per canopy area some of the best performing zones are identified as the least efficient (dashed lines). This occurs because small trees are more efficient on a yield or profit per canopy area basis. It is well known that dwarf trees are more efficient, but their efficiency advantage is only useable if many more trees are planted per unit area. In our example, trees that have limited growth (small size) appear more efficient but do not have the capability of producing large profits. The paradox, apparent here,

is that if local soil or environmental conditions produce small trees and limit profit, these same trees will be rated the most efficient on a yield or profit per canopy area basis.

The same phenomenon occurs if tree efficiency is expressed on a yield or profit per trunk CSA basis. Since small trees are more efficient than large trees, conditions that stress trees and result in limited growth also produce trees that appear to be efficient when standard tree efficiency expressions are used (data not shown).

We have taken the approach that profit maps can be easily created and one can then determine if profit is limited by small tree size or large trees yielding less than their maximum potential. A profit improvement potential is the best way to integrate tree size into a profit assessment. Possible limiting factors associated with trees that are performing at less than their maximum potential can then be evaluated. If areas of an orchard that are performing at or near their maximum potential are significantly different than areas with a high improvement potential, this difference may warrant further exploration. It is also possible to evaluate factors that are associated with profit losses that are caused by small tree size.

A similar approach can be applied to canopy evaluations. Small canopies are often associated with small trees. Small canopies can also result from insufficient canopy development in large trees. A canopy improvement potential evaluation integrates tree size into a canopy evaluation. Possible limiting factors associated with trees that have smaller than optimum canopies can then be evaluated. It is also possible to determine if maximizing canopy area is advantages for a given orchard.

Spatial Implications for Nitrogen Management

Combining canopy assessments with N concentration data is essential to developing a nitrogen fertilizer strategy for an orchard. Our data suggests that low N concentrations can be a result of either insufficient N or the result of a healthy dilution of N in trees that have maximized the amount of leaves in their canopy. Since canopy sizes are much more variable than N concentration, the amount of leaves on a tree has more impact on the amount of total N in the canopy than the N concentration in the leaves. This generalization was observed in all of the data sets we evaluated. As an example, the relationships between canopy status and N concentration for the data points presented in Figure 8 will be discussed below.

Very low N concentrations were present at some locations within the orchard evaluated in Figure 8. Some of these locations have insufficient N in the tree canopies to optimize tree performance. Trees associated with the four points at the lower right in Figure 8 have less than optimum canopy size and are low in N. Adding more N may not solve their problem but there is clearly not enough N in the canopy to maximize production. At the same time, very productive trees with large canopies also have N concentrations that are also very low. As tree or canopy size increases the N in leaf tissue is diluted. This is apparent in the Figure 9. Large trees with large canopies have low N concentration even though the total N in the canopy is high.

Rather than attempting to interpret leaf N concentrations we would suggest calculating an N requirement based on whether or not canopy size is adequate. Canopy size and tree size can be used to estimate how much N a tree or orchard region will require. If a larger canopy is desired more N will be needed. We believe that both deficient and adequate or even excessive N conditions can be found in the same orchard.

Replacement of Organic Nitrogen with Nitrogen Fertilizers

Samples are still being analyzed but some preliminary trends are apparent. The amount of N derived from the fertilizer that is present in tree tissues after the growing season in which N is applied varies from a low of 12 to a high of 30 percent among the various sites we evaluated. The Medford site has the highest amount of N derived from the fertilizer. This site also has the coarsest texture.

We feel that these differences can be explained by differences in the amount of organic matter and potential N mineralization that occurs at the sites. There is likely more N available at our study sites than the trees need. The sandy site at Medford has more uptake from the fertilizer because there is less available from the soil.

We also now believe that ^{15}N data may overestimate the importance of fertilizer sources. For example a site that has 20% of its N derived from the fertilizer does not mean that fertilized treatments have 20% more N in the trees than unfertilized controls. Fertilizer N is readily available and quickly taken up resulting in substantial fertilizer N being present in the trees. However, the fertilized trees often have approximately the same total N content as unfertilized controls. This suggests that much of the N taken up from the fertilizer simply replaced N that would have eventually been taken up as the organic matter in the system slowly makes additional N available.

It is not as simple to quantify how the requirement for N fertilizer varies as soil and environmental characteristics differ as we expected. In very sandy, low organic matter soils the interpretation of ^{15}N data is more straightforward since replacement of mineralized N by fertilizer N is less important. However, many orchard sites have a substantial amount of N that is supplied by organic matter. Annual N applications are likely required to maintain profitable production, but the amount of fertilizer required to supplement organic sources is difficult to determine. The effect of annual N additions on the size of the organic N pool and how fertilizer N becomes available in future years is difficult to determine.

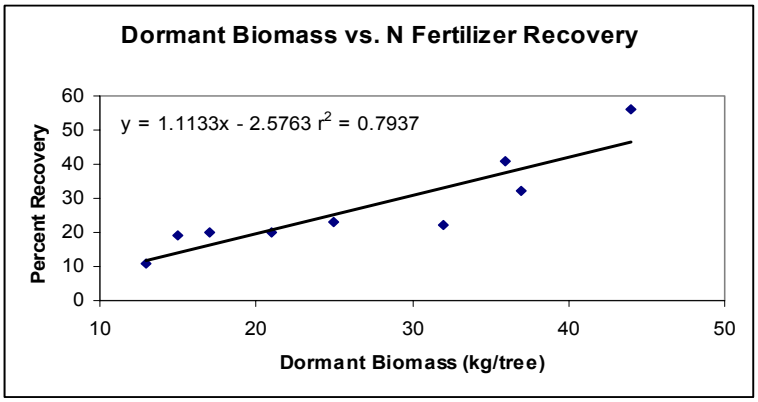


Figure 1. The relationship between tree size and N recovery in pear trees grown in Medford Oregon.

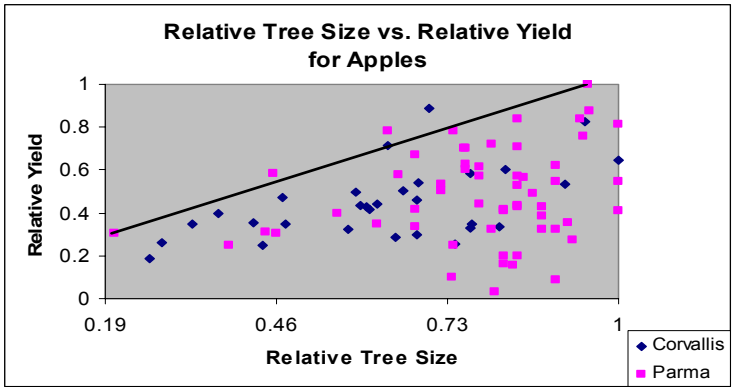


Figure 2. The relationship between relative tree size and relative yield for apple trees grown in Corvallis, OR and Parma, ID. The upper boundary line is hand drawn.

Figure 3. The relationship between relative trunk cross sectional area and relative economic return for pears grown in Hood River Oregon over a three year period. The upper boundary line is statistically derived.

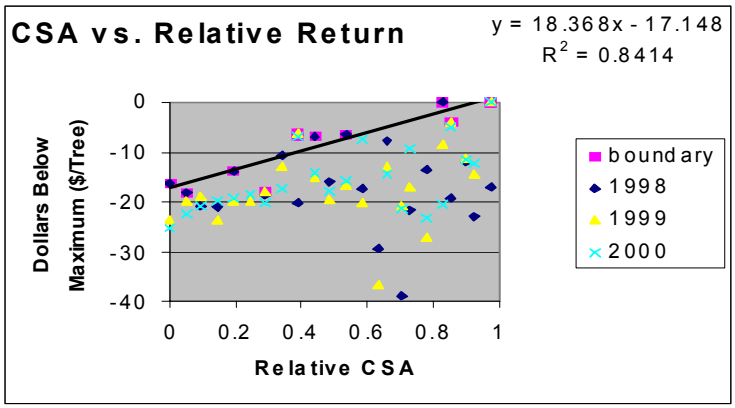


Figure 4. The relationship between trunk cross sectional area and average economic return for pears grown in Hood River Oregon over a three year period. The upper boundary line is statistically derived.

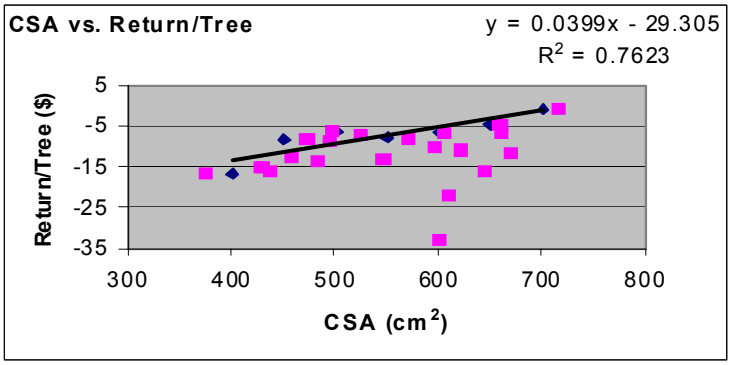


Figure 5. The relationship between trunk cross sectional area and economic return for pears grown in Hood River Oregon for a single season. An upper boundary line is not shown.

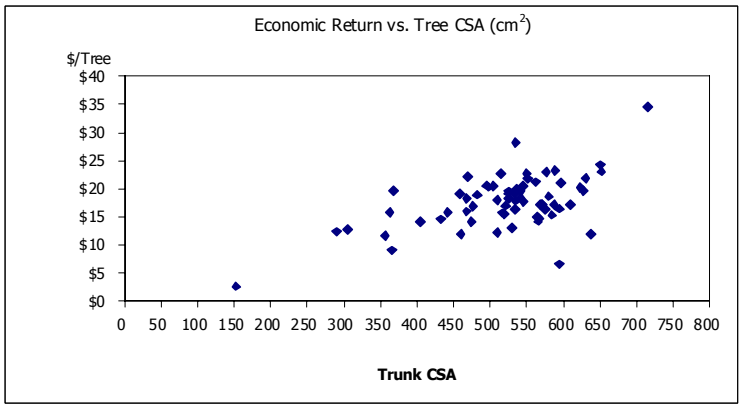


Figure 6. A contour map of a pear orchard showing regions of high, medium and low profit improvement potential. The light colored regions have high improvement potential. Dark colored areas have low improvement potential.

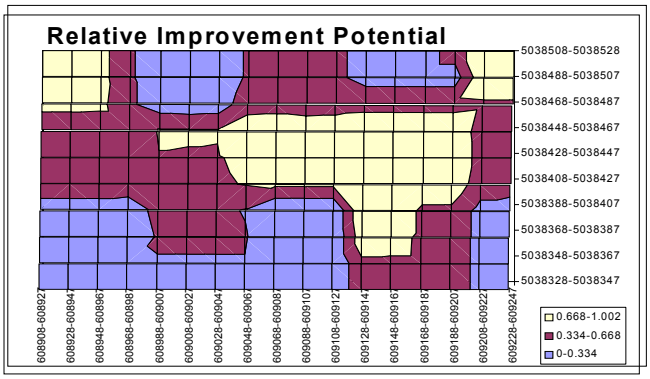


Figure 7. A scatterplot with a boundary line showing the relationship between an acidity index and trunk cross sectional area for a pear orchard. A pH or acidity index combines both soil pH and leaf Mn into a single value. A high acidity index corresponds to a high pH.

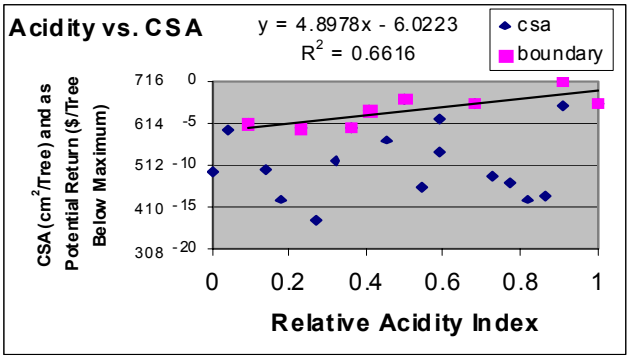


Figure 8. A scatterplot with a boundary line that demonstrates the relationship between trunk cross sectional area and canopy area for a pear orchard. The four points in the lower right of the plot represent large trees with small canopies. These trees are also low in N.

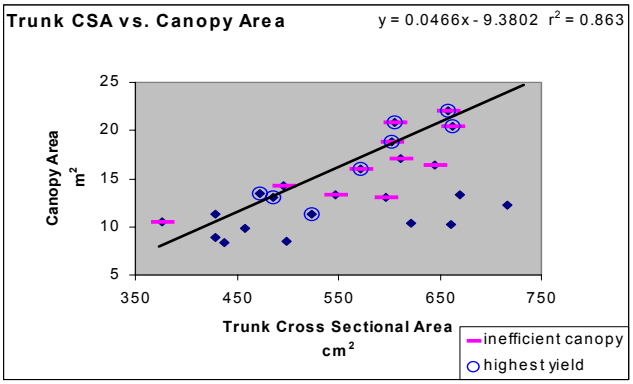
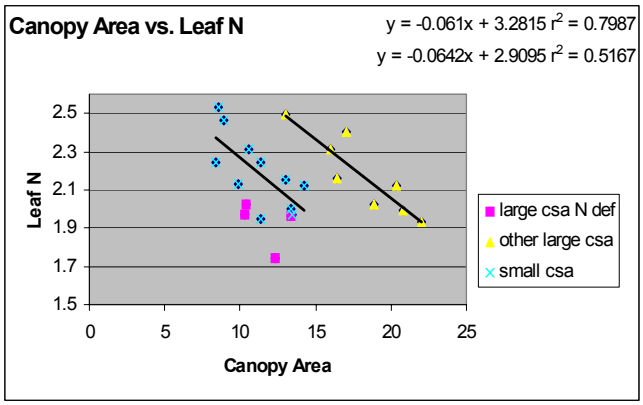


Figure 9. The relationships between canopy area and leaf N concentration for both large (right) and small (left) pear trees. The large trees with small canopies identified in Figure 8 (square points) have been excluded from the regression lines.



FINAL REPORT

Project title:	Improving fruit quality in Concorde pear as influenced by boron and pollination**.**
PI:	Eugene A. Mielke
Organization:	OSU – Mid-Columbia Agricultural Research and Extension Center
Co PIs and affiliations:	Steve Drake, USDA-ARS, Wenatchee, WA Michael Chaplin, Department of Horticulture, Iowa State University, Ames, IA Mike Morley-Bunker, Department of Horticulture, Lincoln College, Christchurch, NZ
Cooperator:	Paul M. Chen, OSU - Mid-Columbia Ag. Res. & Ext. Center
Research Assistant:	Laurie Smith, OSU – Mid-Columbia Ag. Res. & Ext. Center

Objectives:

1. Determine if color sorting and segregation at harvest can improve color appearance following storage.
2. Determine the role of pollination in fruit set and fruit quality of Concorde pears following harvest.
3. Determine if fall pre-harvest or spring full bloom applications of boron can correct the physiological problems affecting Concorde pears following storage.

Significant findings:

- Based on the first-year results, it appears that "at-harvest" color segregation of Concorde fruit may greatly reduce the lack of uniformity in color following storage.
- Concorde pears can set and mature fruit without cross-pollination.
- Cross- pollination dramatically increased set. Non-cross-pollinated fruit were greener at harvest, and had a greater percentage of the fruit fall below the median color value for the crop.
- Summer boron applications were not effective in correcting the postharvest disorders in Concorde as they had been in Conference (Haibo et al., 2000).
- Spring full-bloom and petal fall applications of foliar boron significantly improved yields in Concorde pear by increasing fruit numbers without affecting fruit weight.

Methods:

Objective 1: Determine if color sorting and segregation at harvest can improve color appearance following storage.

Concorde fruit were harvested from four random trees four weeks prior to anticipated harvest in 2001 and 2002. The fruit were passed thru the Greefa color-sorter. Color values were obtained for each fruit and a median color value determined for each year. The resulting median values were used to establish the mature color-sorting standard for their respective years.

Harvest maturity was previously determined to be two weeks following the onset of CA d'Anjou harvest. In 2001, fruit were collected from 14 randomly selected trees. Fruit from each tree were segregated into two lots by color by passing through the Greefa color sorter.

These were: less than the median color value, "green", or greater than the median color value, "yellow". The fruit were placed in regular air storage at 31F and held for 5 months. The amount of yellow, green and "yellow to green" fruit from each lot was determined following storage. In 2002, fruit from each of the 24 trees utilized in objectives 2 and 3 were segregated and stored as described for the 2001 fruit. These will be evaluated following 5 months of storage.

Objective 2: Determine the role of pollination in fruit set and fruit quality of Concorde pears following harvest.

In 2002, twelve uniform 6-yr-old Concorde trees were selected (four each in three rows). Two randomly selected trees in each row were covered with bee-proof cages from green tip to three weeks after petal fall. Thirty flower clusters were randomly selected on each tree and tagged. From first bloom (Ballard, et al.) to one week past petal fall, 15 of the tagged clusters were hand pollinated every other day with a mixture of d'Anjou and Bartlett pollen. Initial fruit set was determined in early July and final fruit set at harvest. The diameter of the resulting fruit was measured in early August.

At harvest, fruit from the pollinated and non-pollinated spurs were harvested separately. Each fruit was individually passed thru the Greefa color-sizer to determine diameter, color and weight. The remainder of the fruit on each tree were harvested and passed thru the Greefa color-sizer to determine fruit size in "yellow" and "green" color categories. The fruit were stored in regular air storage at 31 F. The samples will be evaluated for color and storage defects following five months of storage.

Objective 3: Determine if summer pre-harvest, or spring full bloom applications of boron can correct the physiological problems affecting Concorde pears following storage.

Twelve uniform 6-yr-old Concorde trees were selected in summer 2001. Four trees were treated with three pre-harvest foliar sprays in 2001 (4 lb Solubor/100 gal, 100 gpa, at 14, 24, and 34 days before harvest), four trees received two spring 2002 foliar sprays (1 lb Solubor/100 gal, 400 gpa, at full bloom and petal fall), and four trees served as controls.

At harvest, the fruit from each tree were collected, passed thru the Greefa color-sizer to obtain yield and fruit size, segregated as "green" or "yellow", packed into 42 lb cardboard boxes with polyethylene liners, and stored in regular air storage at 31F for five months (2001 fruit – 2002 fruit will be stored for 5 months).

Following storage, the 2001 fruit were ripened for five days at 68F, and evaluated for storage disorders. The 2002 fruit will be evaluated in February.

Results and discussion:

Objective 1: The color patterns developed for the pre-harvest samples followed similar patterns in 2001 and 2002. The median color values determined were 309 and 395 for 2001 and 2002, respectively. The color camera was replaced in the color sizer between the 2001 and 2002 seasons, and while every attempt was made to adjust it to the same standards, it is possible the difference in the 2001 and 2002 median color values is due to camera calibration and/or seasonal differences in the fruit itself.

Evaluation of the 2001 fruit, following five months of storage, revealed 8.8 % of the fruit classified as "yellow" to be yellowish-green, and 8.6% of the fruit classified as "green" to be greenish-yellow. The distribution for the "unsorted" sample would have been 50 %, 8.7 %, and 41.3%, respectively, for the yellow, yellowish-green, and green fruit.

Objective 2: Yield from trees within the cages was about 25% of that of the non-caged trees. The reduction in yield was due primarily to fruit numbers. Fruit size was reduced significantly in the open-pollinated trees; however, it is not possible to determine if the size reduction was due to cage effect or crop load.

Fruit from the caged trees had a significantly lower average fruit color. A greater percentage of the fruit from the caged trees was greener than the median color value.

Initial fruit set and final fruit numbers were increased three-fold by hand pollination within the caged trees. No significant effect of supplemental hand pollination was observed on non-caged trees. The significant increase in set by hand pollination inside the cages as compared to outside the cages may be due to reduced wind exposure or slightly elevated temperatures inside the cages.

Objective 3: Summer 2001 pre-harvest foliar boron applications had no effect on fruit number, fruit weight, or yield in 2001 or 2002. Spring 2002 full bloom and petal fall foliar boron applications significantly increased the number of fruit per tree in 2002 by 60%, and yields by 52%, without affecting fruit size.

Summer 2001 boron applications had no effect on storage disorder in the 2001 crop. Storage samples for the 2002 crop year will be evaluated in February.

References:

Ballard, James K., E. L. Proebsting, and R. B. Tukey. 1973. Critical temperatures for blossom buds: Pears. Washington State Univ. Ext. Circ. 373.

Haibo, X., J. Streif, and F. Bangerth. 2000. Does boron affect the occurrence of physiological disorders of 'Conference' pears during CA storage? Abstracts 8th Intern. Pear Symp. 281.

Budget: Project total summary

Project title: **Improving fruit quality in Concorde pear as influenced by boron and pollination.**

Co-PIs: Eugene A. Mielke, OSU – Mid-Columbia Ag. Res. & Ext. Center
Michael Chaplin, Iowa State University, Ames, IA
Mike Morley-Bunker, Lincoln College, Christchurch, NZ

Project Duration: 1999-2003
Current year: 2002-2003
Project total (3 years – Commissions): $15,950
Project total (4 years – Total): $56,183
Current year request $0

Item	1999-2000	2000-2001	2001-2002	2002-2003*	Total
Salaries	2,063	2,098	3,178	28,333	35,672
Benefits	887	902	1,447	11,900	15,136
Wages					
Benefits					
Equipment					
Supplies	750	2200	1,125	0	4,075
Travel	300	750	250	0	1,300
Miscellaneous					
Total	4,000	5,950	6,000	40,233	56,183
* Sabbatical salary contributed by Lincoln University (Christchurch, NZ) and Iowa State University (Ames).					

FINAL REPORT
WTFRC Project #PR-01-102 **WSU Project # 13C-3643-3225 -**

Project title: Development of a pesticide management program for pear psylla control

PI: John E. Dunley, Associate Entomologist
Organization: WSU Tree Fruit Research and Extension Center, 1100 N. Western Ave., Wenatchee, WA; (509) 663-8181 ext. 236; dunleyj@wsu.edu

Objectives:
1. Develop baseline tolerance levels for new psyllicides (2001).
2. Determine efficacy of new psyllicides at different timings throughout the season (2000-2002).

Significant findings:
2002
- In large-plot trials (4-acre plots), thiamethoxam (Actara) and acetamiprid (Assail) performed equally well.
  - No differences were found comparing clusterbud applications.
  - No differences were found comparing petal fall applications.
  - No differences were found comparing clusterbud to petal fall.
  - Control from each material was limited to first generation.
- In large plot trials, Actara and Assail …
  - effectiveness was improved significantly when used following kaolin (Surround).
  - residual activity decreased significantly for late-season applications.
  - did not increase mite populations enough to warrant additional miticides, relative to standard comparisons.
- In large-plot trials, azadirachtin formulations were found to be effective for pear psylla control following Surround use.
  - Neemix, Aza-direct and Ecozin all controlled the first generation.
  - Multiple applications were necessary.
  - High label rates were used, with different frequencies of reapplication, so no comparisons between materials were made.
  - Oil alone provided a moderate degree of control.
  - No differences were found in densities of natural enemies (which were very, very low).
- In small-plot trials (single and 9- to 16-tree plots), results were generally the same as previous years, although densities in untreated controls tended to be too low to make good comparisons.

Previous years
- Bioassays were developed for chloronicotinyl insecticides on pear psylla nymphs as well as adults.
- Baseline tolerances for psylla populations were established for chloronicotinyls.
  - imidacloprid (Provado).
    - Much variation in response in the field was found (baseline levels had previously been determined).
    - Potential for resistance appears high (resistance may already be in the field).
  - thiamethoxam (Actara).
    - Baseline tolerance levels were developed.

        - Some geographic variation was found (lower likelihood of resistance currently indicated).
    - acetamiprid (Assail).
        - Baseline tolerance levels were developed.
        - Less geographic variation in response was found than for Actara and Provado.
    - thiacloprid (Calypso).
        - Baseline tolerance levels were developed.
        - Geographic variation in response was not determined.
    - buprofezin (Applaud).
        - Baseline tolerance levels were determined.
- Insecticide timings were examined to optimize pear psylla control.
    - Provado.
        - Effective at clusterbud (not legal) and petal fall.
        - No synergism with Actara at half-rates in summertime.
        - Early nymphs are most susceptible.
    - Actara.
        - Effective at clusterbud and petal fall.
            - Equal efficacy at each timing.
        - No synergism with Provado at half-rates in summertime.
    - Assail.
        - Effective at clusterbud and petal fall.
            - Clusterbud more effective than petal fall.
            - Efficacy at two weeks post-petal fall (codling moth timing) is significantly less effective than clusterbud or petal fall.
    - Calypso.
        - Effective at clusterbud and petal fall.
            - Petal fall more effective than clusterbud.
        - Efficacy at two weeks post-petal fall (codling moth timing) is significantly less effective than clusterbud or petal fall.
    - Applaud.
        - Clusterbud timing very effective.
            - As good as chloronicotinyls.
            - Residual period appeared long (>= 3 weeks).
        - Efficacy in summer does not compare favorably to Agri-Mek or chloronicotinyls.
    - Surround / Raynox.
        - Prebloom period is best.
            - Postbloom applications of Raynox are associated with severe russeting of Bartlett.
        - Two applications of 50 lbs. equal to three applications of 50 lbs.
        - Pear psylla populations were synchronized for two generations after Surround use.
    - Dimilin.
        - Clusterbud timing appears most effective.
        - Petal fall timing has some efficacy.
        - Application at two weeks post-petal fall (codling moth timing) does not provide control of pear psylla.
    - Esteem.
        - Clusterbud timing appears most effective.
        - Petal fall timing is also effective but is less effective than clusterbud.
        - Application at two weeks post-petal fall (codling moth timing) provides a small degree of control of pear psylla.

- Chloronicotinyls appeared to increase spider mite populations in the absence of natural enemies.

Methods:
Bioassays: Bioassays of several new insecticides were conducted for pear psylla. Bioassays were conducted using several methods on different life stages of pear psylla. Adult pear psylla were bioassayed using a slide-dip method. Adult winterform or summerform were collected from the field by beat tray and aspirator. Psylla were anesthetized by CO_2 and placed dorsal side down on double-sided sticky tape affixed to microscope slides. Ten females were used per replicate, with four replicates per insecticide concentration. Five to seven concentrations of a test insecticide were used in each bioassay, and distilled water only served as the control treatment. Slides were dipped into the appropriate concentration for 5 seconds, allowed to air dry, and then placed in a vegetable crisper at 22^{o}C with moist paper toweling to maintain humidity.

For bioassays of psylla nymphs, psylla were collected from infested pear leaves and placed on pear leaf discs on moist cotton. Application method varied, including topical application on nymphs by Potter spray tower prior to placing them on leaf discs (topical-only treatment), topical application on nymphs by Potter spray tower after placing them on leaf discs (topical + residual), and placing nymphs on previously treated leaf discs (residual exposure only). Again, five to seven concentrations were used per insecticide and four replications of 10 nymphs each.
For all bioassays, mortality was assessed at 48 and 96 hours and was corrected for control mortality. Probit analysis was used to estimate population response to the insecticide treatments.

Timings: Small- (9-16 trees) and single-tree plots were established to examine the efficacies of various new psyllicides at several different timings. Applications were made by handgun approximating 200 gpa spray volume. Sampling occurred weekly to biweekly, depending on the time of year. Standard sampling protocols were used. Data were analyzed using ANOVA; mean separation was by FPLSD.

Large-plot trials: Large plots of greater than four-acre treatments were established to examine the efficacies of various new psyllicides at several different timings. In these trials, one replication of each treatment was made to an orchard, with different orchards serving as blocks. Applications were made by airblast sprayer (grower applied), with 80-100 gpa spray volume. Sampling occurred weekly to biweekly, depending on the time of year. Standard sampling protocols were used. Data were analyzed using ANOVA; mean separation was by FPLSD.

Results and discussion:
Bioassays: Bioassays of the chloronicotinyls established baseline data for tolerance to these compounds (Tables 1a and 1b present a summary). These baseline data will provide a reference in the future to determine the first occurrences of insecticide resistance. The data for Provado bioassays on psylla populations from around Washington show a high level of variation among populations (Table 2). This variation between populations indicates that there is a higher risk of resistance evolution with this compound. Bioassays are currently being conducted on the populations with the highest LC50s to determine whether resistance may have already occurred.

Table 1a. Bioassays of new insecticides on pear psylla nymphs, 48 hr

Compound	n	Exp hours	Slope	LC 10	LC 50	LC 90	% cont. mort.
Provado	208	48	1.85	2.77 (.21 – 6.95)	13.69 (4.54 – 23.73)	67.69 (39.07 – 203.1)	10.5
Actara	225	48	2.46	2.96 (.29 – 6.04)	9.52 (3.72 – 18.1)	31.66 (16.87 – 153.49)	6.2
Calypso	279	48	1.34	1.64 (9.26 – 4.20)	14.7 (6.3 – 27.21)	132.17 (67.36 – 403.1)	16.2
Assail	282	48	1.11	.536 (.09 – 1.46)	7.66 (3.39 – 15.23)	109.37 (48.1 – 435.1)	6.7
Agri-Mek	274	48	1.38	0.52 (.008 - .13)	.44 (.20 - .90)	3.71 (1.65 – 17.65)	1.7
Mesa	274	48	0.89	134.0 (19.28 – 351.12)	3665.17 (1641.74 – 12959.25)	100243.78 (23223 – 2879088)	3.4
Pyramite	283	48	2.41	37.24 (14.06 – 60.77)	126.50 (85.05 – 168.61)	429.74 (304.80 – 789.67)	5.2
Applaud	268	48	2.12	1.80 (1.05 – 2.60)	7.26 (5.5 – 9.53)	29.3 (20.62 – 48.51)	0.0

Table 1b. Bioassays of new insecticides on pear psylla nymphs, 96 hr

Compound	n	Exp hours	Slope	LC 10	LC 50	LC 90	% cont. mort.
Provado	197	96	2.01	3.92	17.03	73.90	28.1
Actara	278	96	1.98	.60 (.06 – 1.47)	2.67 (.92 – 5.37)	11.89 (5.87 – 47.16)	26.0
Agri-Mek	274	96	2.17	.021 (.003 - .05)	.084 (.04 – 1.4)	.33 (.20 - .83)	17.3
Applaud	269	96	1.23	42.8 (7.6 – 107.9)	475.43 (217.46 – 993.5)	5281.51 (2209.91 – 25741.58)	6.7
Calypso	272	96	2.07	6.51 (2.03 – 11.46)	25.25 (15.86 – 33.96)	97.99 (70.01 – 178.3)	21.5
Pyramite	279	96	2.04	10.40 (2.40 – 20.97)	44.14 (22.24 – 74.7)	187.31 (106.7 – 513.07)	17.5
Assail	268	96	1.80	1.02 (0.53 – 1.59)	5.26 (3.82 – 7.08)	27.12 (18.41 –47.39)	0.0

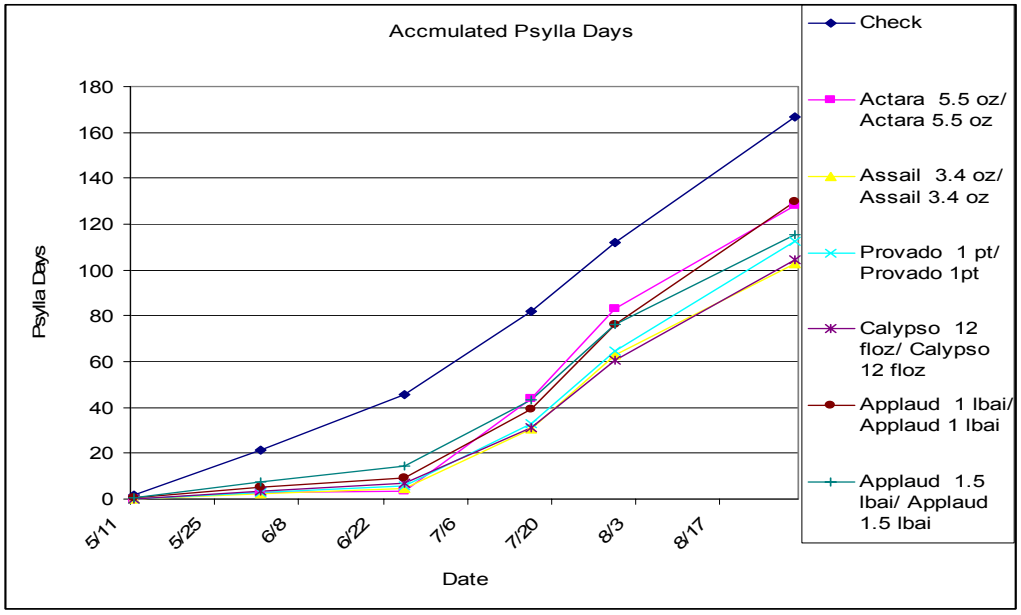
Table 2. Provado bioassays of adult pear psylla in Washington

Compound	n	Slope (se)	LC 10	LC 50	**LC 90**
Orondo	320	1.31 (0.15)	9.69 0.17-30.60	92.59 29.05-1118.62	884.87 195.74-1047199.94
N. Dryden	320	1.12 (0.16)	14.06 5.09-26.17	194.44 105.56-26.17	2688.65 863.35-26153.18
Dryden	320	1.26 (0.29)	30.34 7.37-55.98	316.82 181.88-1025.35	3308.22 1023.16-82401.36
TFREC	320	2.41 (0.43)	36.95 0.6-61.5	125.81 82.23-189.99	428.38 260.24-1438.13
Monitor	320	1.22 (0.15)	11.11 0.22-35.7	123.97 38.96-2342.16	1382.49 264.92-3992889.80
Peshastin	320	3.01 (0.51)	44.54 24.00-62.81	118.90 90.94-151.42	317.39 233.91-537.69
Okanogan	320	1.31 (0.15)	9.69 0.17-30.6	92.59 29.05-1118.62	884.87 195.74-1047199.94
Selah	320	3.37 (0.59)	32.25 14.44-47.52	77.33 54.46-101.55	185.42 136.26-327.17
N. Yakima	320	2.31 (0.5)	29.49 (4.45-55.33)	105.91 (57.27-160.4)	380.27 (230.92-1485.09)
Parker	320	1.88 (0.35)	27.09 10.63-44.44	129.78 90.73-190.01	621.79 366.68-1715.26
Hood River	320	3.53 (0.63)	39.81 (14.74-60.84)	91.88 (59.81-127.48)	212.06 (149.38-433.98)

Selection experiments will be conducted to determine the risk of resistance evolution. Lab colonies from populations from the Dryden area have been established and will be selected for resistance in the laboratory. This population will be compared to a laboratory susceptible population (from TFREC) and a susceptible population that will also be selected for resistance.

Timings: Results from the tests of new compounds identified all four chloronicotinyls as excellent for control of pear psylla (summary shown in Fig. 1; data are presented as accumulated pear psylla days, the number of pear psylla nymphs per leaf per day). There were no significant differences between the chloronicotinyls, although some differences will likely occur in large plots. Clusterbud and petal fall applications were clearly better than other timings (codling moth and summer timings); please note, however, that it is not legal to use Provado before petal fall. Applaud was equally effective as the chloronicotinyls at the clusterbud timing; however, it did not appear to provide as much control of nymphs after leaves developed (this was particularly true for summer applications).

Figure 1. Efficacy of new insecticides on pear psylla nymphs, 2002, expressed in pear psylla days.



Applications of Surround were most effective during the prebloom period. Surround appears to reduce adult psylla densities and may repel psylla into adjacent orchards (Table 3). Mortality from Surround was greatly reduced once nymphs developed; the primary method of activity appears to be prevention of oviposition. Applications of Surround made the previous November maintained enough residue to significantly reduce adult psylla densities and oviposition the following year. Raynox also reduced pear psylla; however, we found that postbloom applications of Raynox were associated with high levels of fruit russeting. Therefore, Raynox should only be considered in the prebloom period for use as a control tactic of pear psylla.

Table 3. Mean (s.e.) adult overwintering pear psylla per beat tray sample, taken along a transect from Surround-treated pear orchards into adjacent conventionally treated pear orchards.

Orchard	Surround, 50 m from edge	Surround, 3 rows from edge	Surround, border row	Conv., border row	Conv., 3 rows from edge	Conv., 50 m from edge
Monitor1	2.1 (0.3)	0.9 (0.6)	1.8 (0.4)	8.1 (1.1)	16.3 (2.6)	8.2 (0.6)
Monitor2	0.4 (0.2)	0.0 (0.0)	0.0 (0.0)	18.3 (2.9)	10.7 (1.8)	9.2 (0.7)
Cash1	0.5 (0.4)	3.1 (0.5)	0.6 (0.4)	42.6 (5.8)	57.9 (6.3)	22.5 (3.2)
Cash2	0.7 (0.3)	0.9 (0.2)	1.4 (0.4)	28.6 (3.2)	29.5 (4.2)	17.9 (2.1)

Budget:
Project title: Development of a pesticide management program for pear psylla control
PI: John E. Dunley
Project duration: 2000-2002
Current year: Terminated (2002)
Project total (3 years): $80,880
Original budget request: $36,785 (2000)

Year	Year 1 (2000)	Year 2 (2001)	Year 3 (2002)
Total	$29,200	$15,000	$36,680

Current year breakdown

Item	Year 1 (2000)	Year 2 (2001)	Year 3 (2002)
Salaries[1]	29,200	15,000	27,050
Benefits (32%)	0	0	8,120
Wages[1]	0	0	700
Benefits (16%)	0	0	110
Equipment	0	0	0
Supplies[2]	0	0	200
Travel[3]	0	0	500
Miscellaneous	0	0	0
Total	29,200	15,000	36,680

[1] Bruce Greenfield at 75% appointment
[2] Slides, vials, solvents, etc.
[3] Cost of one vehicle for two months plus fuel and maintenance.

FINAL REPORT

Project title: Application of Radio Frequency Treatments to Control Spider Mites on Pears

PI: J. D. Hansen, Research Entomologist

Organization: USDA-ARS YARL, Wapato, WA
Co-PI and affiliation: J. Tang, Food Engineer, WSU, Pullman, WA

Objective: To investigate the feasibility of using radio frequency (RF) at 27.12 MHZ as a physical treatment to control spider mites on pears.

Significant findings*:*

- Radio frequency treatment insufficient in eliminating all spider mites when conductivity of water exceeded that of fruit, either with increased final water temperature or holding times up to 3 min.
- Treatment efficacy improved with the reduction of water conductivity when current was maintained at 2 amps.
- Addition of silicon-based materials at 0.05%, either a defoamer or a surfactant, to the water bath resulted in 50% removal of spider mites and nearly complete mortality of the remaining when used with radio frequency with final water temperature above 51°C and holding time of 1 min.
- Fruit quality not acceptable at temperatures above 50°C for any of the treatments.

Methods:

Considerable preparation was required before conducting efficacy tests. Previous research in the use of radio frequency as a postharvest phytosanitation and quarantine treatment was done on internal feeding pests, like codling moth larvae. Because ours were the first attempt in treating a surface pest, the initial equipment settings had to be accommodated. These variables included adjusting the length of the top electrode, determining the distance (or gap) between the top electrode and the target, and resolving the size of the target load.

To prevent arcing among pears during treatment, the fruits were treated in water. To assure that only the fruit surface was treated and not the fruit interior, the conductivity of water was adjusted by adding calcium chloride to exceed that of blended pears.

Early in the experimentation, it was discovered that the radio frequency field was not uniform below the top electrode. To compensate for this, a container system was designed and built at the University of California--Davis to rotate the fruits within a cylinder. Because certain materials sensitive to radio frequency could not be use, like metal and nylon, the container was made of polypropylene. Furthermore, the container needed to be narrow enough to occupy a space as small as possible, yet large enough to handle a sufficient number of fruits and the amount of water needed to move them. Also, internal ports were added to the container to allow for the directional flow of water. Finally, a pumping system had to be installed that was powerful enough to move the fruits (ca. 40 cycles/min), but not so strong as to form a vortex in the water. Then, all these factors had to be adjusted and test to assure the 2 amp treatment.

Four fiber optic sensors (UMI 8 Universal Multichannel Instrument, FISO Technologies Inc., Sainte-Foy, Québec) were installed through the walls of the container to measure water temperature, and temperature data were recorded on the computer. It was assumed that fruit surface temperature approached that of the surrounding water.

The field-infested fruits were obtained from a commercial packing house in Hood River, Oregon. The fruits were green d'Anjou pears (ca. 90 mm ht, 70 mm widest w, 200 g). Before

testing, the number of live diapausing spider mites were counted under a microscope, then returned to the cold room to chill down to about 4°C.

Treatment variables were the exposure duration to obtain the intended water temperature and the holding time at that temperature. When treatments were completed, the fruits were immediately hydrocooled in a water bath (≃ 15°C), then held for one day at room temperature (≃ 20°C) when the number of live diapausing spider mites were recounted under a microscope.

Treatment specifications:

1. Diapausing female adults of the twospotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) from field collected green d'Anjou pears near Hood River, Oregon.

2. Infested fruits were treated in a pilot-scale 27.12 MHZ RF Heater/Dryer (12 kW) procured from Strayfield International, Berkshire, England.

3. Standard procedure
   a. The number of live spider mites were counted on each of nine fruits before treatment.
   b. Fruits (initial fruit temperature ca. 4°C) were paced in specially constructed polypropylene container manufactured at the Univ. of California-Davis that uses water powered by an external pump to move fruits.
   c. Water temperature monitored with four fiber-optic temperature probes.
   d. Container (and plumbing) was filled with water to 9 mm below brim.
   e. Initial water temperature adjusted to 20°C.
   f. Water conductivity adjusted to 4 mS/m.
   g. Top electrode lowered to 250 mm above unit floor (bottom electrode).
   h. Operating current: 2 amps.

4. Treatment test #1--Efficacy with increased temperature
   a. Initial exposure of RF was 150 sec to increase water temperature to 52°C; then repeated with increased operating time to increase water temperature beyond 52°C.
   b. After treatment, allowed 1 min holding time for electrode to elevate so that fruits could be removed.
   c. Then immediately hydrocooled fruits
   d. Evaluated for spider mite survival the next day.
   e. Recorded surface condition of fruits.

5. Treatment test #2--Efficacy with increased holding time
   a. Used RF exposure of 150 sec to increase water temperature to 52°C.
   b. After treatment, allowed 1 min initial holding time in water; repeat but with 2 and 3 min holding times.
   c. Then immediately hydrocooled fruits
   d. Evaluated for spider mite survival the next day.
   e. Recorded surface condition of fruits.

6. Treatment test #3--Efficacy with Silwet
   a. Conducted same protocol as for test #1, but added an organosilicone surfactant, Silwet L-77 (polyalkyleneoxide modified heptamethyltrisiloxane, Helena Chemical Co., Memphis, Tennessee) to the water to make 0.05% solution.
   b. Evaluated as before.

7. Treatment test #4--Efficacy with silicon-based defoamer
   a. Conducted same protocol as for test #1, but added commercial silicon-based defoamer, dimethylsiloxane, to make 0.05% solution
   b. Evaluated as before.

8. Treatment test #5--Efficacy with reduced conductivity
   a. Conducted same protocol as for test #1, but conductivity of water bath at either 1 or 2 mS/m.
   b. Evaluated as before.

Results and discussion:

1. When the conductivity of the water bath was adjusted to 4 mS/m by adding calcium chloride, its conductivity was twice that of pears. The water temperature increased linearly with duration of exposure (Fig. 1) and can be accurately described (R^2 = 0.9989) by the equation

   $$T_w = 0.22t + 21.08$$

   where t is time in seconds and T_w is the resulting water temperature (°C). Thus, radio frequency exposures are a rapid, direct method for heating water.

2. Survival of diapausing spider mites decreased with increased final temperature with holding time of one minute, but there was considerable variability and complete efficacy was not obtained below 56°C (Fig. 2). Infrared temperature sensor indicated that the pear surface temperature was about 10°C below the water temperature. Perhaps water surface tension formed a barrier around each fruit, which impeded energy transfer or that the colder fruit interior served as a thermal sink that prevented the fruit surface from adequately heating.

3. Survival of treated diapausing spider mites did not decrease with increased holding time up to 3 min (Fig. 3). Thus, extending holding time did not increase efficacy.

4. In replicated tests, complete efficacy was obtained at 0.05% Silwet at 51°C with 1 min holding time (Fig. 4). Removal was about 50% (Fig. 5) and foaming was minimal. Similar observations were made with the silicon-based defoamer, dimethylsiloxane. Expanded studies could lead to a commercial treatment.

5. Decreasing conductivity to 1 or 2 mS/m resulted in an improvement in efficacy (Fig. 6). The relationship can be accurately described (R^2 = 0.9947) by the equation

   $$y = 0.0086x + 2.75$$

   where x is conductivity in mS/m and y is the percent alive. This model indicates complete efficacy when the water bath has no conductivity. Because the top

electrode was within 5 mm of the container to reach 2 amps, it is is beyond the capability of the our system to test the conductivity range. The container would need to be redesigned (enlarged) to compensate for the reduced mass caused by lowering the water conductivity.

6. Studies are continuing in the use of silicon-based adjuvants in agitated water systems where RF energy is not required. Initial results suggest that such a procedure can be easily adapted to commercial packing lines.

Budget:
Amount funded: $12,500
Project duration: 2000-2001
Current year: 2003

Final breakdown

Labor	$11,174
Travel (to Hood River, Pullman)	431
Supplies (including pears)	895
Total	$12,500

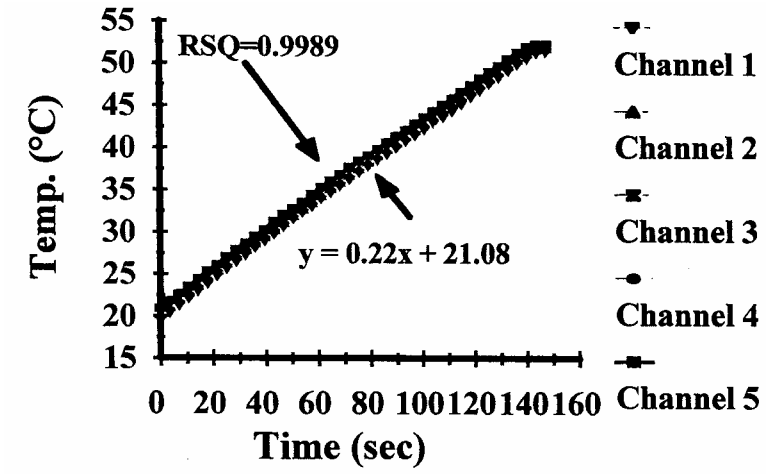


Fig. 1. Increase in water temperature with exposure time of 27.12 MHZ radio frequency at 2 amps. Temperature increased linearly with RF duration .

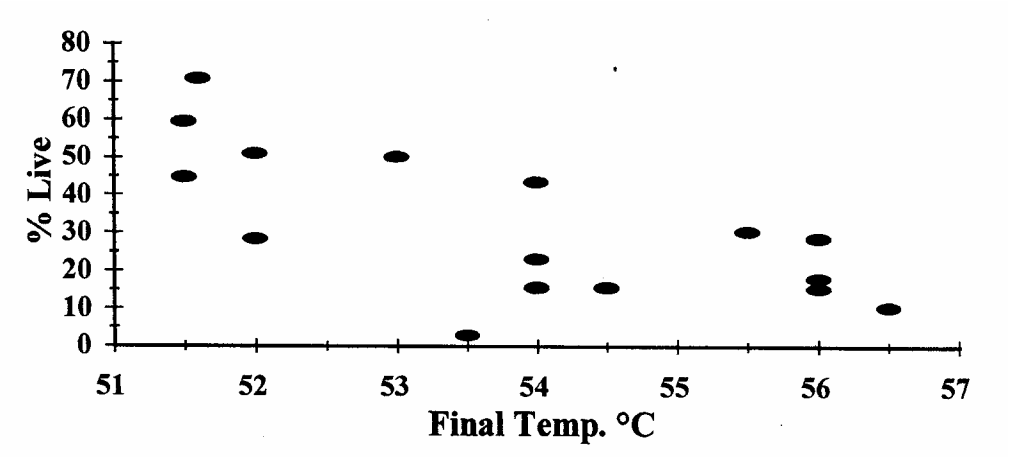


Fig. 2. Per cent survival of diapausing spider mites after reaching specific final temperatures and held for 1 min with RF exposures at 2 amps.

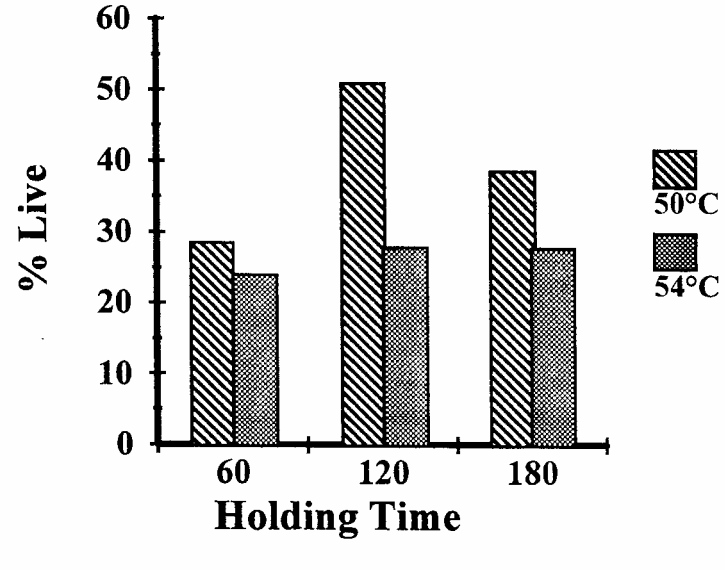


Fig. 3. Per cent survival of diapausing spider mites after reaching final temperatures of 50° and 54°C, then held for 1, 2, and 3 min.

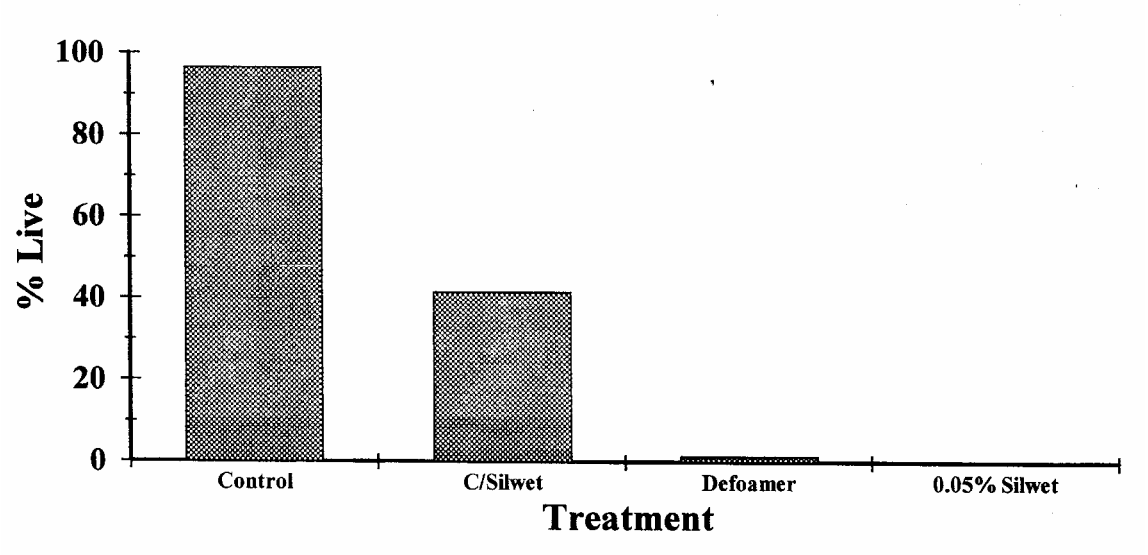


Fig. 4. Per cent survival of diapausing spider mites after exposure to Silwet at room temperature (C/Silwet) and in water with 0.05% Silwet or silicon-based defoamer with radio frequency treatment reaching final water temperatures between 51° and 53°C, then held for 1 min.

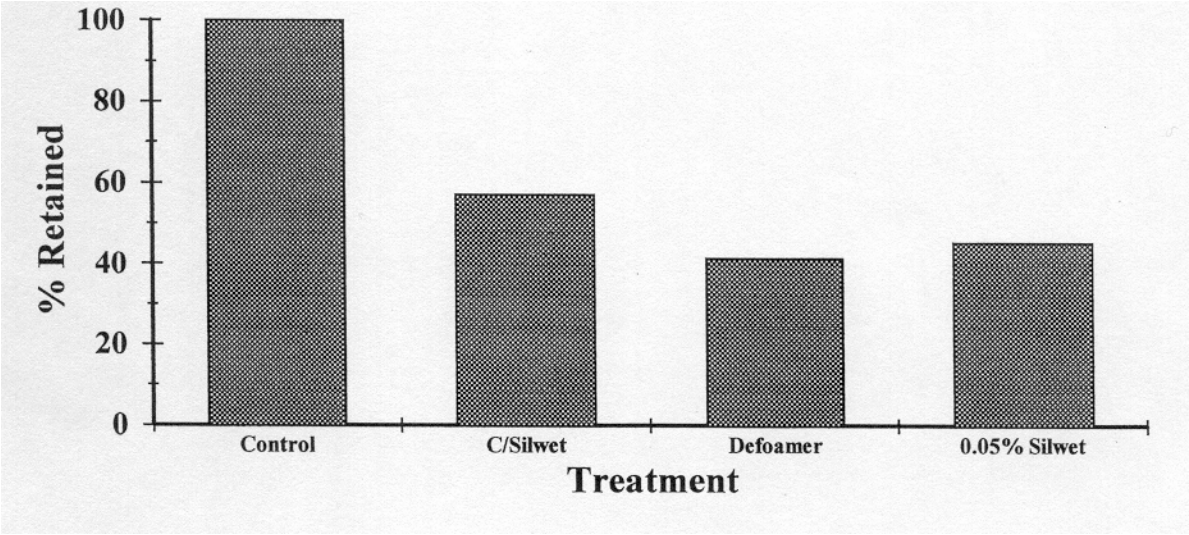


Fig. 5. Per cent retention of diapausing spider mites after exposure to Silwet at room temperature (C/Silwet) and in water with 0.05% Silwet or silicon-based defoamer with radio frequency treatment reaching final water temperatures between 51° and 53°C, then held for 1 min.

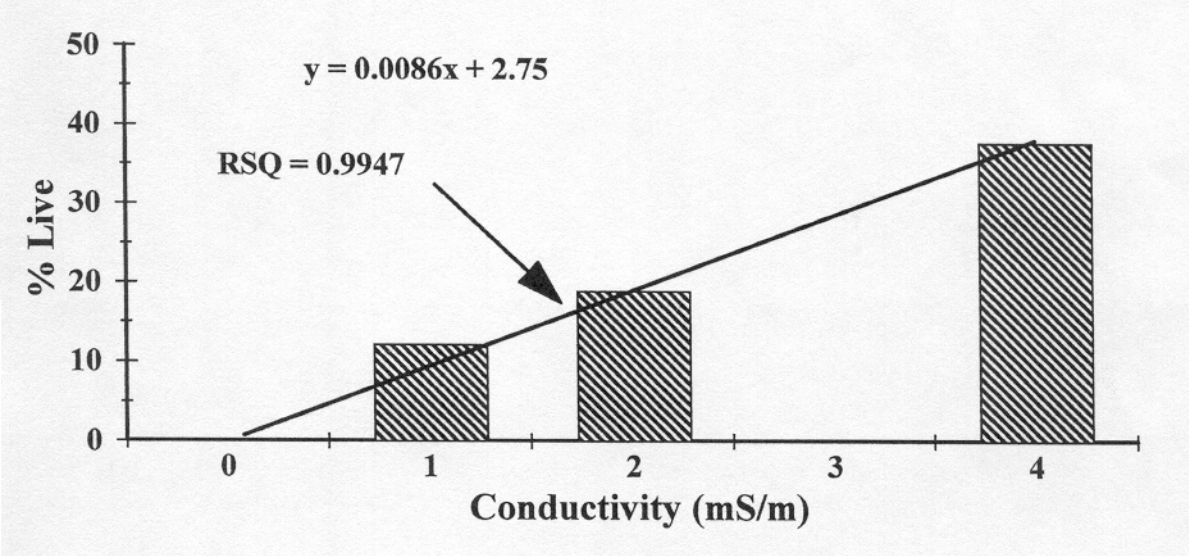


Fig. 6. Average per cent survival of diapausing spider mites after RF exposure of 150 sec at 2 amps in water of different conductivities; number of replicates $\geq$ 4; SEM $\leq$ 7% for all treatments.

CONTINUING REPORT/FUNDING REQUEST
WINTER PEAR CONTROL COMMITTEE

George Ing, WPCC Research Co-Ordinator

OBJECTIVES:

1. National and International interactions with activities, programs, scientists, administrators.

2. Sustaining office activities related to WPCC research.

3. Evaluating Varieties with potential.

2002 ACTIVITIES:

1. PROGRAM MAINTENANCE: office and travel, local, regional, national, international. Phone, fax, mail, mileage, lodging, personal contacts. Attended meetings with pear affiliation. visiting with and hosting researchers. Handling inquiries from Northwest growers regarding varieties and cultural practices.

2. INTERNATIONAL
   1. Continued contacts aimed at importing pear varieties from China. Nothing concrete at present.
   2. 2001 overture to import New Zealand varieties is on hold.
   3. Imported two varieties from a public breeding program in Italy. Established in test plot.
   4. Traveled 9 days in Turkey in mid June. While a cherry mission, I was headquartered in the principal pear growing region and picked up some information.
   5. During five days in England in late June visited more than 30 supermarkets in cities and towns. Several varieties of pears, principally from the Southern Hemisphere, were present. Noted price, appearance, condition, etc.
   6. Continued to interact with a private breeding program in Italy which has a pear of interest. They have agreed to let me plant one of their apples in 2003 for testing.

3. NATIONAL & LOCAL
   1. Pears established in test plot had good growth. Harvested 5 pears from a variety seen in Turkey in 1997, imported in 1998 and established in 1999. This is a long storage large fruit with very good flavor and very white flesh. These first 5 fruits are very ugly, rough, irregular and we hope for something much better looking in the future or else that one will be defunct.

   2. Visited Kearneysville, West Virginia ARS Pear breeding program in late January. They had ripened about 30 varieties. I sampled all and found none to be any better than anjou, which they also had in the samples. I wrote about the program for Goodfruit Grower. Copies are available upon request.

   3. Phytonutrient research. Explored various avenues at several sites. Each seems to have an obstacle. Pear Bureau funded work with phytonutrients, as a part of the Produce for Better Health is also behind schedule but is due to be reported in March, 2003.

A new and hopefully viable contact is a human nutrition lab at U. of Cal. Davis. Unfortunately the director and lead scientist who worked with phytonutrients are moving and retiring soon. Will continue to seek appropriate labs for this important work. When Pear Bureau funded data is released in March we will also know more about the next step.

GOALS FOR 2003---2004

1. Continue to pursue importation for testing of a FEW SELECTED varieties from other countries
2. Visit research entities in California, particularly those with potential for phytonutrient research.
3. Perhaps attend an international plant breeding/germplasm meeting in Angers, France, September, 2003.
4. Make plans to attend ISHS Pear Symposium in South Africa, February of 2004. Intent is to also spend extra time looking at pear plantings and the industry.
5. Visit the Wenatchee, Okanogan, Yakima and Medford Pear Districts during the growing season.
6. Continue to liaison with pear people world-wide.
7. Import and establish two more pears from Italian public breeding program.
8. Continue to interact with Private Italian breeding program with intent to test its most promising variety.

BUDGET: $ 6,000 in 2002

REQUEST $ 5,000 (Tentative) *

· A summary of expenses will be compiled prior to the pear research review to see where things stand· Final request will be based on those figures but will be no more than $ 5,000 and perhaps less.

PROJECT TITLE: Chemical ecology of pear psylla

PI: David Horton
USDA-ARS, Yakima Agric. Research Lab., Wapato, WA

CO-PI: Victoria Soroker, Volcani Center (Entomology), Israel

COOPERATORS: Peter Landolt, USDA-ARS, Wapato, WA
Ally Harari, Volcani Center (Entomology), Israel
Anat Zada, Volcani Center (Chemistry), Israel

CONSULTANT: Amos Naor, Golan Research Inst., Univ. Haifa, Israel

Comment: This project is part of a proposal submitted (with V. Soroker) to the Binational Agricultural Research and Development Fund (BARD). Funding request is $288,000 for 3 years, split 50:50 between Wapato and Israel. The original BARD proposal (summer 2001) was not funded. The proposal was rewritten and resubmitted (summer 2002), in response to comments by the reviewers. The new BARD proposal (as well as the current proposal submitted to the WSTFRC/WPCC) differs from the original BARD in three respects: (1) the mating studies have been eliminated; (2) we have added new objectives looking at tree-to-tree variation (within orchard) in chemistry, and in susceptibility and attractiveness to pear psylla (see **OBJECTIVES**); (3) we have added a study to look at the role of water and nitrogen stress on tree attractiveness (see **OBJECTIVES**). Copies of the revised BARD were sent to J. McFerson and G. Ing.

OBJECTIVES:
(1). To determine whether pear trees within an orchard differ in attractiveness to pear psylla and, if so, to see if the differences are conserved over the course of the season and between years (NEW OBJECTIVE);

(2). To determine whether variation among trees in infestation is due to variation among trees in host quality and chemistry, nitrogen or water stress (NEW OBJECTIVE), and/or to presence of other psylla;

(3). To isolate and identify psylla chemical attractants or repellents.

SIGNIFICANT ACCOMPLISHMENTS:
Funds obtained last year for this project from the Winter Pear Control Committee were to be used to partially fund a post-doc and to fund a temporary (GS-3) aide to assist the post-doc. The post-doctoral position was advertised. We received several applications from high-quality candidates, but all were from non-citizens. Because of new federal hiring rules, there is a temporary hold on hiring of non-citizens, so the position has not yet been filled. We hope to resolve the problem sometime this winter, as we will discuss at the research review.

The current proposal is a spin-off of a larger BARD grant, as noted above. Accomplishments in 2002 include completely rewriting the BARD grant in response to comments by reviewers of the original grant proposal. The new project will include a look at tree-to-tree variation (within orchard) in chemistry and attractiveness to pear psylla, and a look at nitrogen and water stress affecting colonization rates and establishment of pear psylla. Because of the new interest in tree stress, we added (as a consultant) a tree physiologist with expertise in pome fruits (Amos Naor, University of Haifa). Dr. Naor will assist with designing and interpreting the tree stress studies.

METHODS (2003):

(1). Tree-to-tree variation in quality and susceptibility. At two orchards, 100 trees randomly selected will be monitored for psylla density using beating trays between July and September 2003. From these 100 trees, the 20 trees having the highest levels of psylla infestation and the 20 trees having the lowest levels will be selected. The following two years (2004-2005), these 40 trees at both orchards will be monitored for psylla densities at 2-week intervals with beat trays and foliage samples. Tree vigor will be quantified by flagging 5 randomly chosen shoots per tree and measuring shoot length once per month.

In March 2004 and 2005, we will select the 5 trees having the highest densities from the previous year and the 5 trees having the lowest densities, for biochemical analysis. Five shoots will be selected randomly from each tree for analysis. At both orchards, in May, July, and September, 5 leaves will be collected from the tops of each of 10 terminal shoots per tree. Chemical composition will be quantified. Biochemical analyses of shoot and foliage samples will include quantifying protein, water, NPK, and phenolic levels, using standard methods.

Information obtained in Objective 1 will include: (1) whether trees within an orchard vary year-to-year in suitability and attractiveness to pear psylla; (2) if so, whether biochemical characteristics of the trees explain the differences in attractiveness.

(2). Role of tree quality, tree stress, or presence of other psylla on colonization of pear trees. Pear psylla are highly clumped in pear orchards, suggesting either: (a) that trees differ in suitability; or (b) that there is mutual attraction among colonizing psylla. To separate the effects of previous psylla infestation from other factors (including nitrogen and water levels in trees), we will compare colonization rates of psylla on 4 types of potted pear trees: (1) fertilized and irrigated, but previously infested; (2) fertilized and irrigated, but previously uninfested (controls); (3) uninfested, but reduced water; (4) uninfested but reduced nitrogen. Water stress is expected to affect solute concentrations potentially affecting psylla feeding rates, whereas nutrient stress will affect tree vigor and possibly tree defenses. Both may affect attractiveness of trees to pear psylla. Trees will be water-stressed by providing only enough water to avoid the onset of leaf senescence, based upon recommendations of the consultant Naor. Mid-day stem water potential will be used to measure stress. Nutrient stress will be applied by halving amount of nitrogen in the potting soil. To test effects of concurrent infestation on psylla colonization of trees, we will conduct tests in the laboratory (see below).

Field tests. Potted trees will be moved into orchards following one growing season of stress treatments. We will monitor colonization of trees beginning in March, during re-entry. The study will be repeated in mid-summer using a new set of trees (again stressed the previous year), by putting the trees in the orchard in July, and monitoring colonization by summerform psylla.

Laboratory tests. Treatments found to differ in the field will be assayed for involvement of volatile cues using Y-tube olfactometers (i.e., to test whether stress or previous infestation changes long-distance attractiveness of trees). Treatments showing attractiveness or repellency to pear psylla in the

olfactometer assays will be further studied, by collecting volatiles from the appropriate trees (using equipment developed by Landolt for collecting floral volatiles). The volatiles will be fractionated and analyzed using gas chromatographic methods, and fractions tested in olfactometers for biological activity, in OBJECTIVE 3 (below). Also, we will compare in olfactometers whether concurrent infestation affects attractiveness (as might be expected if psylla emit chemical signals) by comparing infested and uninfested pear clippings in an olfactometer.

(3). Isolate and identify biologically active volatiles. We will collect psylla, tree, and tree+psylla emitted volatiles in head-space collection chambers from isolated psylla, infested trees, uninfested trees, stressed trees, and non-stressed trees, for the treatments described above. Volatile samples will be trapped by solid phase methods. The volatiles will be eluted from the column with hexane and ether. Extracts will be fractionated with chromatography. Identification of volatiles will be done by comparison of their mass spectra to those in the Nist and Wiley Library. Subsequently, putatively active components will be tested in olfactometers with pear psylla to establish biological activity.

BUDGET
Title: Chemical ecology of pear psylla
PI: David Horton
Project duration: 2002-2004,
Current year: 2003
Project total: (3 years) $20,780
Current year request: $0

	Year 1 (2002)	**Year 2 (2003)**	Year 3 (2004)
Total	20,230	**0**	21,890
Current year breakdown			
Salary[a]	7875	**0**	8520
Benefits[b]	2375	**0**	2570
Wages[c]	9980	**0**	10,800

Comment: because the post-doctoral position has yet to be filled, funds received from WPCC in 2002 were not spent. Thus, no additional funds are requested for year 2 (2003).

[a] Partial support for GS-11 Post-doctoral Research Associate to work full time on this project at the Wapato laboratory, under the supervision of D. Horton. The remaining portion of the post-doctoral salary will be obtained from internal funds (unless BARD is funded) and the Oregon Bartlett Pear Commission ($10,000); [b] 30%; [c] 130-day, GS-3 technician to assist the post-doctoral associate.

PROJECT TITLE: Biology and Management of Pear Pests

PI: David Horton
USDA-ARS, Yakima Agric. Research Lab., Wapato, WA

COOPERATORS: Tom Unruh

OBJECTIVES

2002: (1). Determine pest and predators species associated with select orchard cover crops. ***(2).*** Monitor success of *Campylomma* as predator of pear psylla, caterpillar eggs, and spider mites. ***(3).*** Determine factors affecting overwintering densities of natural enemies in pear orchards, and describe emergence of overwintered predators in spring as a function of degree-days. ***(4).*** *Anthocoris antevolens*: Document reproductive isolation among and within populations of this important predator of pear psylla, and determine implications for psylla control.

2003: Test explicitly whether insects associated with cover crops in orchards move between cover crop and tree canopy, estimate impact on psylla densities, and estimate predation rates on sentinel eggs of a caterpillar.

SIGNIFICANT FINDINGS

- ***Cover crops*.** Obtained second year's data for select cover crops in terms of diversity and density of natural enemies associated with different crops. Data are to be used to select a cover crop for year 2003 objective (above).
- ***Campylomma***. Showed that *Campylomma verbasci* developed well on psylla eggs and nymphs, caterpillar eggs, and spider mites, illustrating highly generalized feeding behavior of this predator.
- ***Predator overwintering.*** (A). Factors affecting overwintering densities of predators in orchards. I set-out and retrieved cardboard bands in 28 pear orchards, to monitor overwintering pest and predators in ochards. Data obtained in this study and the same study conducted the previous year will be combined with data collected by Tom Unruh at these same orchards during the growing season on psylla densities, chemical spray records, tree vigor, and type of habitat adjacent to orchards. Data analysis is ongoing. We hope to determine what factors affect overwintering densities of natural enemies in orchards, as these predators are likely to be important sources of biological control in spring.
- (B). Emergence phenology. Confirmed degree-day model (developed in 2001) describing emergence from overwintering sites for 3 predator species in pear orchards.
- ***Anthocoris antevolens.*** Showed that this important predator of pear psylla is actually a complex (in Yakima valley) of at least 3 morphologically highly similar but reproductively isolated cryptic species. Preliminary evidence suggests not all three species occur commonly in pear orchards.

METHODS (2003):

My earlier studies with ground cover in orchards showed that these habitats may support extremely high densities of natural enemies. However, the research failed to resolve whether these natural enemies contribute to biological control in the tree canopy. The primary reason for not resolving this question is that it is unclear whether there is extensive movement by predators between the ground cover and the tree canopy. Especially for highly mobile predators, it is difficult to test effects of different ground covers on biological control, because predator mobility requires impossibly large plots to document the effects. I will use large cages over trees in combination with cover crops to determine explicitly whether specific predator species do move naturally between cover crops and tree canopy, affecting biological control and pear psylla density.

At the Moxee farm, plots composed of a vetch + mustard cover crop (from my work the last two years, these crops shown to support large numbers of predatory insects) will be established (see Figure 1 for plot design). Each plot (=dark shading in Figure 1) will consist of two aisles (3 tree lengths each). Control plots will also be established, consisting of a dirt understory. I will have 5 control and 5 treatment plots. The center tree in each plot will be eventually caged (Figure 1) following several weeks of pre-sampling (see next paragraph). Samples will be taken in the cover crop (sweep nets) and trees (beat trays, leaf samples) to determine densities of pests (emphasizing pear psylla, mites, leafminer) and predators before and after caging. All 3 trees in each plot will be sampled. Immature lacewings, ladybeetles, and damsel bugs (all difficult to identify to species and all comprising a complex of species) will be collected from both habitats during sampling, taken to the laboratory, and reared to the adult stage. This will allow me to determine whether a given species occurs both in the tree and the cover crop.
For instance, green lacewings occur in both habitats, but it is not known whether those inhabiting the tree canopy are the same species as those in the cover crop.

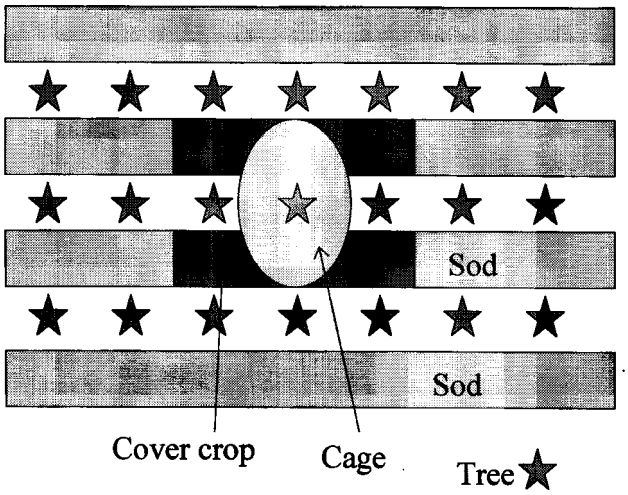


Figure 1. Design of study.

After several weeks of (pre-cage) sampling, the center tree in each 3-tree plot will be caged, using large cages constructed of PVC and organdy. The cages will be off of the ground enough to allow insects to move freely through the ground cover. The tree within each cage, however, can be colonized only from below the tree canopy. The trees will be sampled for several weeks following caging. Also, in each of the 3 trees within a plot, we will set out sentinel strips having cabbage looper eggs on them. These eggs will be checked at 2-3 day intervals to monitor predation.
If the ground cover is a significant source of biological control, and if (as hypothesized) predator mobility has made it historically difficult to show that cover crops do indeed enhance biological control, I expect the following results from this study:

- ✓ Predator species found in the cover crop will also be found in the tree canopy of both caged and uncaged trees;
- ✓ Predator densities in the trees in the control plots and cover crop plots will be fairly similar before caging has occurred (due to mobility of predators);
- ✓ After caging, trees within cages in the cover crop plots will have higher densities of cover crop-associated predators than will uncaged trees in the cover crops or any trees in the control plots. Moreover, if the effect is biologically significant, I anticipate effects on pest densities and on predation rates of sentinel eggs.

RESULTS AND DISCUSSION (2002):
(1) Cover crops. As with last year's work, legumes had higher counts of natural enemies (and pests such as *Lygus*) than grasses and grains. Predators were dominated numerically by minute pirate bug, damsel bugs, big-eyed bugs, ladybeetles, lacewings, and hover flies. Virtually all cover crops were infested with western flower thrips at flowering. *Lygus* was abundant in legumes and mustards. A variety of vetch and a species of mustard, found here to support extremely large numbers of predators, will be used in the 2003 cover crop study described above.

(2) *Campylomma* feeding trials. *Campylomma* survived well (>80% survival) from egg hatch to adult emergence when fed a diet of psylla eggs+nymphs, spider mites, or caterpillar (*Ephestia*) eggs. Development times were most rapid on caterpillar eggs (mean = 13.0 days at 70^{o} F), intermediate on psylla (mean = 15.3 days), and slowest on spider mites (mean = 19.0 days). Results re-emphasize that this bug is one of the more important generalist predators of pests in pear orchards, and efforts should be made to conserve this species in orchards.

(3) Overwintering of natural enemies. (A). Factors affecting overwintering densities of natural enemies in orchards. During the last 2 years, we (cooperator T. Unruh) collected data from 28 pear orchards in the Yakima valley on predator and pest overwintering densities (in cardboard bands), densities of pests and predators during the growing season, insecticide use patterns, size of orchard, tree vigor (rate of shoot growth), tree age (circumference of trunk), and type of neighboring habitat. We wish to determine explicitly which of these various factors affect predator overwintering densities in orchards, as overwintered predators are likely to be an important source of spring biological control in orchards. Data analysis has just begun. Densities of select natural enemies in each orchard are summarized in Figure 2, which shows wide orchard-to-orchard variation in counts, which this study hopes to eventually explain. Table 2 shows several of the initial significant correlations that we have obtained. Results suggest that we can predict overwintering densities of some natural enemies (spiders, green lacewings, *Deraeocoris*) by taking tray samples in September. Densities of green lacewings somewhat surprisingly were highest in orchards having psylla in the orchard late in the year, surprising in that lacewings tend not to be thought of as highly important psylla predators; similar results (less surprisingly) were noted for *Deraeocoris* and *Anthocoris*, both notable psylla predators. We will continue to analyze these data to determine effects of pesticide use, orchard characteristics, and surrounding habitat on predator overwintering densities.
(B) Phenology of emergence. Predator emergence from overwintering shelters (cardboard bands) was monitored to determine when in late winter and early spring predators became active and, thus, possibly susceptible to pre-bloom chemicals. Data were expressed as a function of cumulative degree days and showed for both years of study that brown lacewings and *Deraeocoris* emerged in February and March, and green lacewings emerged in May (Figure 3 shows emergence as a function of degree days; Table 3 shows estimated dates of emergence for 3 sites, based upon degree-day estimates). Results suggest that brown lacewings and *Deraeocoris* would be active at the time of delayed dormant sprays, but that green lacewings would still be in overwintering shelters at that time.

(4) *Anthocoris antevolens*. My laboratory studies with this important psylla predator have now shown that this species is actually a complex of at least 3 (in the Yakima valley) morphologically similar species. The best way to separate the species is by dissection of the male reproductive organ, which is found to differ in size among the three species (Figure 4). This has become an important observation, as *A. antevolens* moves into orchards from native plants surrounding orchards (especially willows, alder, cottonwoods, and poplars), but it appears preliminarily that not all "types" of the bug are equally likely to move into orchards. Specifically, I have yet to collect the oak "species" in pear orchards from western Yakima, despite the occurrence of this bug on oaks adjacent to pear growing regions of western Yakima (Figure 4). This result suggests that we may need to revise our thinking of the role of certain native habitats as a source of these important psylla enemies. Data showing that these are indeed reproductively isolated species will be presented at the research review.

BUDGET
Biology and Management of Pear Pests, David Horton
Project duration: 2001-2003, **Current year:** 2003

	Year 1 (2001)	Year 2 (2002)	**Year 3 (2003)**
Total	34,673	30,050	**15,970**

Current year breakdown

Salary	25,683	22,260	**12,700**[a]
Benefits	8990	7790	**1270**[b]
Materials			**2000**[c]

[a] Time slip for GS-5 130 day technician ($12.20 per hour); [b] 10%; [c] to purchase materials for cages

Comment: the budget request is smaller this year due to my receiving (with T. Unruh) a large grant from USDA-CSREES to pursue the *Anthocoris* studies.

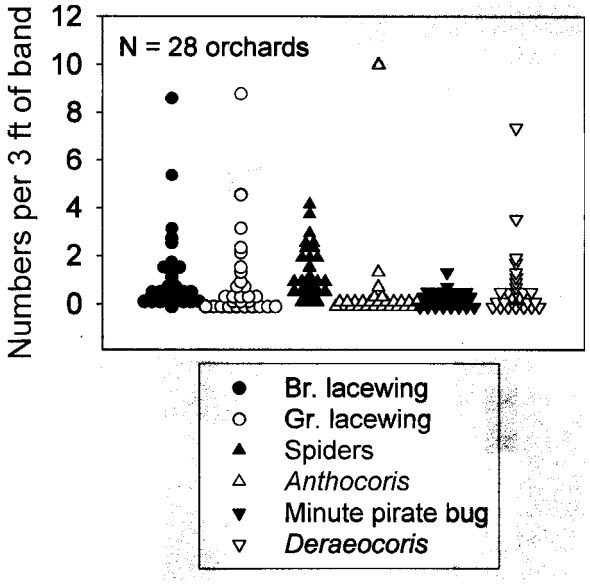


Figure 2. Densities of overwintering predators in cardboard band shelters. Each point a separate orchard.

Table 1. Significant correlations between overwintering densities of predators and various other factors.

Predator	Other factor	Correlation
Deraeocoris	Psylla tray count in Sept.	0.55
	Deraeocoris tray count in Sept.	0.74
Spiders	Spider tray count in Sept.	0.43
Green lacewings	Psylla egg densities in Sept.	0.61
	Green lacewing tray count in Sept.	0.38
Anthocoris	Psylla egg densities in Sept.	0.51
Predatory mites	Spider mite overwintering densities	0.38

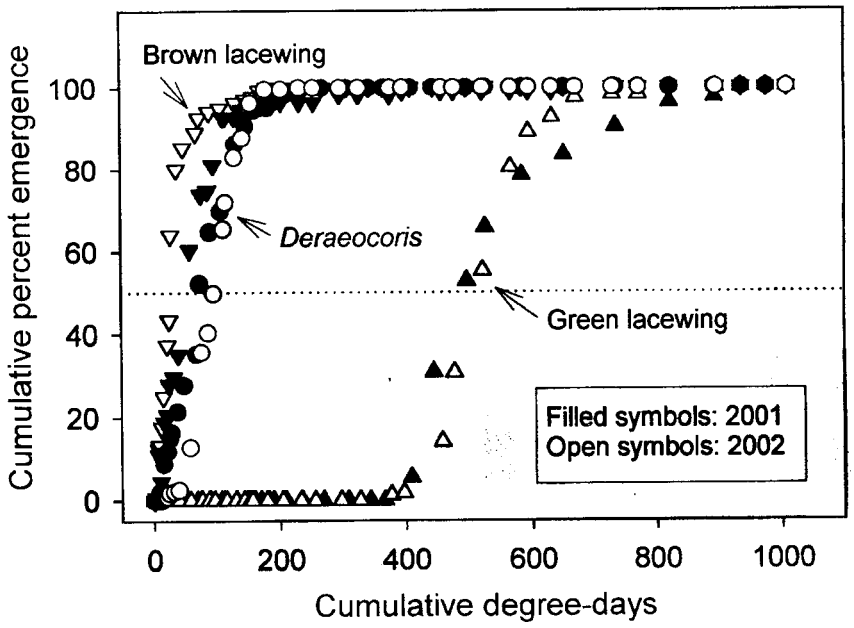


Figure 3. Cumulative emergence of 3 predator species from overwintering bands as function of cumulative degree-days (5 C base).

Table 2. Estimated date (from degree-day results) of 90% emergence at three sites.

	Hood River		Yakima		Wenatchee	
	2001	2002	2001	2002	2001	2002
Brown lacewing	Mar. 18	Mar. 9	Mar. 14	Mar. 3	April 1	Mar. 31
Deraeocoris	Mar. 30	Mar. 31	Mar. 30	Mar. 17	April 19	April 12
Green lacewing	June 6	June 10	May 29	May 8	June 11	June 11

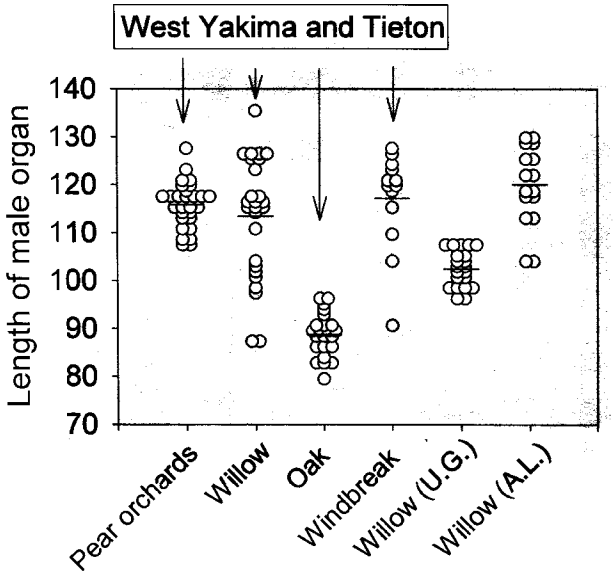


Figure 4. Length of male reproductive organ in *A. antevolens* collected from pear orchards, willow, oak and poplar windbreaks (West Yakima and Tieton), willow (Union Gap), and willow (Alder Lake, west of Cascades). Note that there is no overlap between pear orchard bugs, oak bugs, and willow-Union Gap bugs. Mating trials confirm that these three groups are reproductively isolated.

Project Title: A biochemical approach to quantifying pear psylla predation in the field

PI: Tom Unruh, USDA-ARS, Wapato WA 98951
509-454-6563 unruh@yarl.ars.usda.gov

CO-PI: Dr. Nina Bárcenas, Colegio Postgraduados, Texcoco, Mex.

Cooperator: Dave Horton

OBJECTIVES 2003

1. Complete digestion studies on Lacewings emphasizing short digestion times and evaluate longer amplicons for the bugs (near completion)
2. Describe daily rhythm of feeding by predators in laboratory microcosms to clarify molecular estimates of predation rates in the field.
3. Utilize PCR method to estimate predation rates of pear psylla by of *Anthocoris, Campylomma, Chrysoperla, Deraeocoris* and *Formica* in pear orchards.

2002 Objectives not met

1. Develop a time budget for predator feeding behavior in the field (We could not do this in field settings because predators were not abundant enough and too difficult to see)
2. Apply method to field collected predators (Predators were collected both in 2001 and 2002 and frozen at –80C but have not been tested because this depends on completion of digestion rate studies)
3. Expand approach to mites (this objective has been postponed as overly ambitious)

Significant findings in 2002

(*Note**: Money for this project was not received until September2002 and Dr. Barcenas did not join us until mid-August. Hence, our results represent roughly 4 months of a half-time effort*)

1. Compared Monoclonal Antibody and DNA digestion rates in 4 predator species highlighting species differences
2. Demonstrated importance of size of DNA target for PCR on estimating predation rate and showed method superior to use of monoclonal antibodies

Results and Discussion

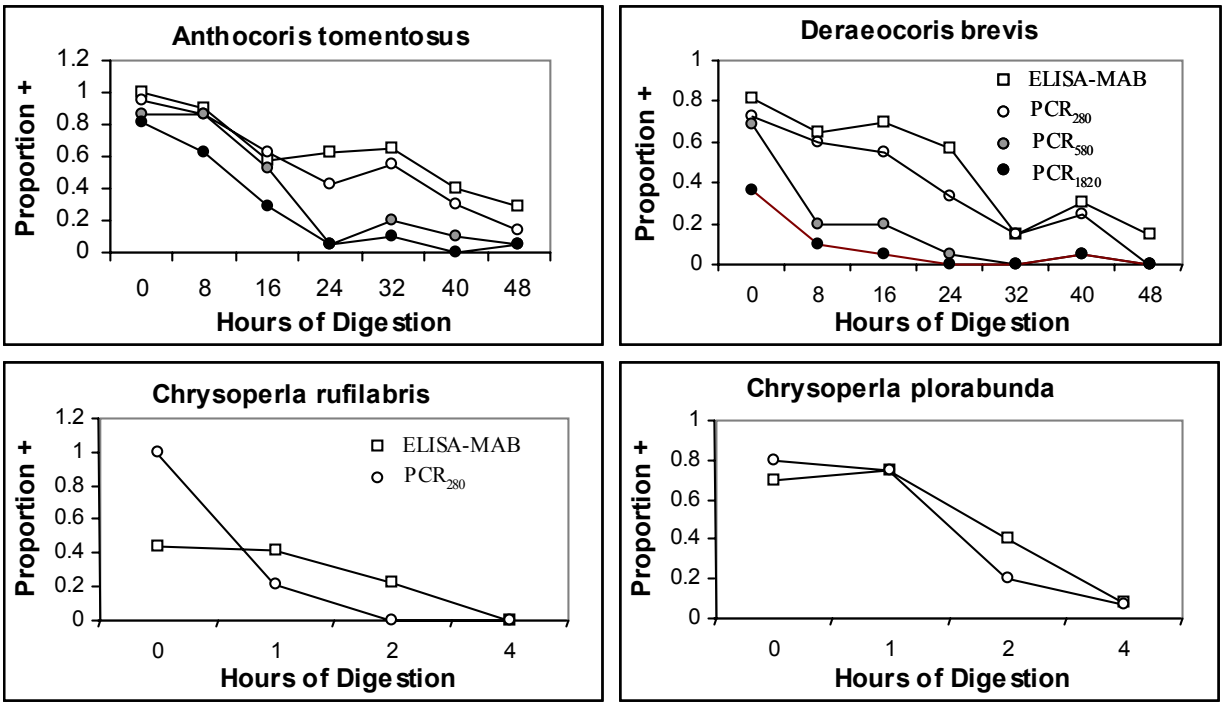
Introduction/justification: Many past studies have characterized psylla abundance from a combination of leaf counts and beat tray data and predator abundance from beat trays and from these data made inferences on predator importance. This includes some of my own data (see proposal by Dave Horton) and earlier data collected by Bob Fye and Brad Higbee at the YARL. Similarly there is a collection of studies of how many psyllas various predators can eat in the laboratory (Fye, Brunner, and others). Unfortunately, only a few studies conducted under very restrictive conditions have experimentally estimated predation of psylla by specific free-roaming predators in the field (Unruh and Higbee, 1994). In sum, we do not yet know which are the most reliable and important predators of pear psylla and when they are abundant enough to control psylla below damaging levels in the field.

Over the last 6 years we have been studying methods to detect if a predator has eaten a psylla -including specific monoclonal antibodies made against psylla proteins (Horton et al. 1997) and DNA primers that specifically amplify psylla DNA (Agusti, Unruh and Welter, in press). Dr. Nuria Agusti spent 4 months in my laboratory in the winter of 2000-20001. During that period we developed primers that specifically amplify DNA of pear psylla, which can be used to detect "forensic" evidence of psylla in the gut of predators. Nuria's primers amplified small pieces of psylla DNA (64- 280 bp).

After Dr. Agusti's departure in spring of 2001 we have discovered several primers that amplify larger stretches of DNA (amplicons 300-2,000 bp) as reported in February 2002. (Figure 1, reproduced below) From this work we have begun to learn details about the digestion biology of key predators.

We have completed comparisons between the monoclonal antibody (MAB hereafter) and 3 of the PCR amplicons (280, 560, and 1,800 base pairs, hereafter PCR300 etc.) for the predatory bugs, *Anthocoris* and *Deraeocoris* (See figures 2 and 3) and will have completed the comparisons for the lacewings within the month. Surprisingly, the retention time of psylla signal in the gut of the bug predators is quite long, more than 24 hr. Since making these observations we discovered that both protein and smaller pieces of DNA (PCR_{280}) is passed out in frass undigested, while larger pieces of prey DNA ($\geq PCR_{560}$) are digested before excretion.
More importantly, our results with the bugs show that larger segments of prey DNA are digested more rapidly than smaller segments of DNA. In other words, we can estimate the time since the last meal with greater precision using larger, more rapidly digested, target DNA. Please note that the inverse of time since last meal is a rough estimate of the predation rate. The value of short retention times of the prey signal is clear when you consider that some predators may eat more than 1 psylla per hour. A short pulse or signal life is required to have a realistic estimate of predation rate.

PCR_{280} and MABs show almost identical digestion rates within *Anthocoris antevolens, Deraeocoris brevis* and *Chrysoperla plorabunda* but digestion of protein and DNA seem different within *C. rufilabris*. More vivid in between species comparisons is the very rapid digestion in lacewings. Thus PCR_{280} is only 50% digested in 24 hours by *Anthocoris* or *Deraeocoris* but it is very nearly gone in one hour in lacewings. The digestion biology of the lacewings differs importantly from the predatory bugs. Both groups inject digestive enzymes into the prey but the lacewings have an incomplete digestive tract as nymphs thus no prey signal is excreted. Furthermore, exo-digestion of the prey, by injected enzymes, is much more thorough and rapid by the lacewings (as evidenced by cadaver examinations) and is especially notable in C. rufilabris which digests most of the protein before leaving the host. We are currently measuring digestion on a shorter time frame (0-1 hr) for the lacewings and testing even shorter primer/amplicons (65-300bp). This points out a key strength of the DNA-based method over monoclonal antibodies. Our 2002 data indicate that amplicon size must be appropriate the digestion biology of each predator species to be biologically meaningful. We can design DNA primers that best fit a species' digestion biology to more precisely estimate the time since last feeding. In contrasts psylla proteins (as antigens for the antibodies) are likely to be digested at roughly the same rate, independent of protein type.



Methods

1) In 2003 we will continue to develop primers for longer amplicons that will be digested within an hour in the two bug predators. In contrast, for the 2 lacewings studied here, shorter amplicons (75, 140, 202 bp) will be tested because larger ones are digested too quickly. For both groups we will collect more digestion profile data below 2 hours.

2) Two orchards with known psylla and predator populations will be sampled three times during the growing season (May, early July, late August). Psylla levels will be estimated from leaf samples and predator abundance from beat trays. Using beat tray collections we will accumulate and freeze in the field 100 or more individuals of the dominant predator species. Predators will be homogenized intact in Chelex (5%). We will use 3-4 size-dependent PCR primers to assay up to 100 individual predators collected on a given date orchard combination. We will specifically seek orchards having abundant *Deraeocoris* and lacewings. Predation rates will be estimated as time since last meal by predators and a log-linear regression model developed from laboratory data will be used to convert time estimates to hourly predation rate. We expect that these efforts will be focused on *Campylomma*, *Deraeocoris*, and lacewings the major predators we have observed in recent field studies, however, if Anthocoris or Formica are abundant we will sample and analyze them as well.

3) Use laboratory microcosms to describe time budgets for predator feeding and to verify feeding rate estimates using large nymphs of *Deraeocoris brevis* and *Chrysoperla plorabunda*. Time budgets will be created by directly observing individual predators in microcosms consisting of a 1 m^3 cage with a clear top and one clear side and housing a single, carefully pruned pear seedling. The plant will be placed on a "Lazy Susan" to facilitate moving the plant to better observe predator activities. Seedlings will be infested with 25 late stage psylla (5^{th} instars) and as the predator removes each prey a new prey will be placed on the plant. Predators will be condition in 2 ways: starved overnight or kept with excess prey overnight. Ten 4-hour observations will be conducted for each combination of predator species and predator conditioning type. Each predation event will be recorded for stop and start times and 2 or more

cages will be monitored simultaneously. Predators will be sacrificed at the end of the trial and tested using PCR with an array of primers. The most important information stemming from this study is the pace and frequency at which predators consume prey. We currently rear *Deraeocoris brevis* and purchase lacewings from commercial sources. To test diel periodicity of feeding predators will be combined with prey in Plexiglas arenas without plants, predator and 25 prey. Prey consumed will be examined every 6 hours and replaced. Ten replicates of this simple study will also be conducted for each predator species.

Proposed Schedule of Accomplishments:
Objective 1. Comparison between and optimization of primer pairs for different sized amplicons are ongoing and will be completed by spring or early summer.
Objective 2. Field-based predation estimates will begin with sample collection in the summer and lab analysis will begin in fall 2003 to be completed in early spring 2004.
Objective 3: Diel periodicity and feeding behavior studies in the lab will be completed by fall 2003.

BUDGET

Project Title: A biochemical approach to quantifying pear psylla predation in the field
PI: Tom Unruh
Project duration 2001-2003
Project total (3 years): $61200
Current year request: $28,600

Item	2001	2002	**2003**
Salaries	–0--	22,000[1]	**22,000[1]**
Benefits	4,000	6,600	**6,600**
Total	4,000	28,600	**28,600**

[1] Half of salary for visiting scientist (post- doc hired through WSU). This funding will pay for efforts through August of 2004.

Project title: Integrated management of fire blight of pear and apple

PI: Kenneth B. Johnson
Organization: Dept. Botany & Plant Pathology, Oregon State University, Corvallis,
Co-PI(s) and affiliation(s): Virginia Stockwell (OSU, Corvallis)
Cooperator(s): David Sugar (OSU, Medford), Joyce Loper (USDA-ARS, Corvallis)

Objectives:
In 2002:

1. Evaluate new products for fire blight suppression.
2. Field-test mixtures of beneficial bacteria optimized for compatibility of their biological mechanisms
3. (**New**) Evaluate potential for epiphytic growth of *Erwinia amylovora* on common flowers frequented by honey bees but which are not hosts of fire blight

Proposed In 2003 (all ongoing):

1. Evaluate new products for fire blight suppression.
2. Field-test mixtures of beneficial bacteria optimized for compatibility of their biological mechanisms, including refinement of use of iron with BlightBan A506
3. Evaluate potential for epiphytic growth of *Erwinia amylovora* on common flowers frequented by honey bees but which are not hosts of fire blight

Significant findings:

- A large field trial was conducted to evaluate alternative products for suppression of blossom blight. GWN-9200 (gentamicin sulfate), a mix of *Pseudomonas fluorescens* strain A506 Ecp-, *Pantoea agglomerans* strain C9-1 and Sequestrene 138 (FeEDDHA), *P. fluorescens* strain A506 (BlightBan) plus Sequestrene 138, Mycoshield, and *P. fluorescens* strain A506 (BlightBan) resulted in significantly ($P \leq 0.05$) fewer diseased blossom clusters compared to the water treated control.
- Two pear and two apple field trials were conducted to evaluate the effect of the iron chelate, Sequestrene 138 (FeEDDHA), on performance of *Pseudomonas fluorescens* A506 (BlightBan) for fire blight suppression**.** Overall, two applications of A506 alone reduced disease incidence by 42%; combining A506 with Sequestrene 138 decreased the incidence of fire blight by 54% compared to water-treated trees. A tank mix of A506 Ecp- and C9-1 with Sequestrene 138 added to the second application reduced the number of fire blight strikes by 63% relative to the water treated control.
- In growth chamber experiments, flowers from plants that are not hosts of fire blight disease were evaluated for their ability to support epiphytic growth of *Erwinia amylovora.* Plants of the rose family - peach, cherry, plum, blackberry, service berry – supported high populations of the fire blight pathogen. In addition, high populations of *E. amylovora* developed on flowers of big leaf maple, and scotch broom. In general, flowers of mustard, dandelion, clover and rhododendron were relatively poor hosts for epiphytic populations of *E. amylovora*.

Methods:
Objective 1. New chemical and biological agents with potential to control fire blight were tested (see results section). This experiment was conducted in a Bartlett pear block in Medford. Experimental treatments were arranged in randomized block designs with 5 replications of individual trees. Treatments included alternative products, a water-treated control and standard antibiotic products (streptomycin and oxytetracycline). Treatments timings were varied according to properties of the

product, but generally, two application of each product were made. Products were applied to near run-off a hand-directed backpack sprayers. Freeze-dried inoculum of the fire blight pathogen (strain *Ea*153nal, streptomycin sensitive) was applied near full bloom (7April). Beginning 22 April and ending 14, incidence of fire blight was evaluated weekly by counting and removing the diseased blossom clusters on each tree.

Objective 2. The iron-chelate FeEDDHA (Sequestrene 138) was selected, as it makes iron available to *Pseudomonas fluorescens* A506, but not the fire blight pathogen *Erwinia amylovora*. Field trials were conducted on mature Bartlett pear trees at the S. Oregon Research and Extension Center near Medford, OR and on Golden Delicious and Rome Beauty apple trees at the Botany and Plant Pathology Experimental Farm near Corvallis Oregon. Two applications of water, FeEDDHA (Sequestrene 138 at 1 pound/acre), A506 (1 X 10^8 CFU/ml), a tank mix of Sequestrene 138 and A506, or a tank mix of A506 Ecp- (protease deficient mutant), *Pantoea agglomerans* C9-1 and Sequestrene 138 (iron in second application only) were applied to 5 replicate trees as described above. Standard antibiotic products (streptomycin and oxytetracycline) were included as controls.

Objective 3. In a growth chamber, flower-bearing branches were collected from: willow, maple, *Prunus* spp. (cherry, peach, plum), clover, dandelion, mustard, blackberry, service berry, broom, rhododendron, and apple. Bouquets of flowers were inoculated with standardized suspensions of freeze-dried cells of *E. amylovora* strain 153Nal and incubated for 96 hours (15°C). Growth of *Ea*153Nal was monitored by washing the flowers dilution plating onto selective media. Eight blossoms were washed per non-host replicate; 2-4 replicates of each non-host species were conducted. Population sizes among various flower types were standardized by computing relative growth rate (% increase in bacterial populations per hour).

Results and discussion:

Objective 1. The chemical agents Agrimycin and Mycoshield (streptomycin sulfate 17% a.i. and oxytetracycline calcium 17% a.i. , respectively, Syngenta Crop Protection, Greensboro, NC), GWN-9200 (gentamicin sulfate 10% a.i., Gowan, Yuma, AZ), VacciPlant (defense elicitor from brown algae, Goëmar, Saint-Malo, France), and Cuprofix Disperss (copper sulfate 20% a.i., Cerexagri, King of Prussia, PA) were tested. The biological agents, QRD-137 (Serenade, a dried fermentation culture of *Bacillius subtilis* strain QST713, AgraQuest, Davis CA), *Pseudomonas fluorescens* strain A506 and its derivative A506ecp-, and *Pantoea agglomerans* strain C9-1 were tested, either alone or in a strain mixture.

Trees used in the study were large, averaging 700 blossom clusters per tree. Owing to favorable weather conditions for infection by *E. amylovora*, symptoms of fire blight developed on approximately one third of the blossom clusters on water-treated trees. Based on analysis of $\log_{10}$(strikes per tree), Agrimycin, Cuprofix Disperss then Agrimycin, GWN-9200 (gentamycin sulfate), the mixture of *P. fluorescens* strain A506ecp- and *P. agglomerans* strain C9-1plus Sequestrene 138, *P. fluorescens* strain A506 plus Sequestrene 138, Mycoshield, and *P. fluorescens* strain A506 resulted in significantly ($P \leq 0.05$) fewer diseased blossom clusters compared to the water treated control. Agrimycin applied at full bloom and again immediately following the pathogen inoculation resulted in the highest degree of fire blight suppression (89%). Four treatments - Cuprofix Disperss then Agrimycin, both rates of GWN-9200, and the mixture of P. *fluorescens* strain A506ecp- and P. *agglomerans* strain C9-1plus Sequestrene 138 – suppressed the incidence of disease by 60 to 80% relative to the water treated control. Analysis of variance based on % of blossom clusters blighted per tree revealed similar trends.

Table 1.

Treatment and Rate/100 gal of water	Date treatment applied 1 Apr	3 Apr	4 Apr	5 Apr	8 Apr	Mean number of blighted clusters per tree	Percent of blossom clusters blighted per tree
Water control	……..	X		X		…… 253 ab*	28.5 abc
VacciPlant.	7.2 fl. oz …… X			X		…… 184 abcd	31.8 abc
VacciPlant	14.4 fl. oz …….. X			X		…… 259 a	40.6 a
QRD-137(Serenade)	6.0 lb ……	X	X			…… 218 abcd	33.6 ab
QRD-137	6.0 lb ……	X	X		X	…… 234 abc	42.1 a
Cuprofix Disperss	1.3 lb ……..	X		X		…… 143 bcde	21.0 bc
A506	fresh ……	X		X		…… 130 cde	20.6 bc
Mycoshield	16.0 oz ……		X		X	…… 124 de	22.0 bc
A506 plus	fresh	X		X			
Sequestrene 138	16.0 oz ……..	X		X		…… 134 cde	23.4 bc
A506ecp- plus	fresh	X					
C9-1 plus	fresh	X					
then A506ecp-	fresh			X			
plus C9-1plus	fresh			X			
Sequestrene 138	16.0 oz ……			X		…… 87 ef	15.7 cd
GWN-9200	2.1 lb ……		X		X	…… 84 ef	15.1 cd
GWN-9200 (Gentamicin)	4.2 lb ……		X		X	…… 86 ef	14.9 cd
Cuprofix Disperss	1.3 lb	X					
then Agristrep	7.8 oz ……..			X		…… 56 f	8.8 de
Agristrep	28.8 oz ……..		X		X	…… 29 g	4.1 e

*Means followed by same letter are not significantly different according to Fischer's least significance difference at $P = 0.05$.

Objective 2.

Trees in the four orchards used in the study were moderate to large in size, averaging 350 to 1000 blossom clusters per tree. At both Medford and Corvallis, owing to favorable weather conditions for infection by *E. amylovora*, disease pressure was high and symptoms of fire blight developed on one third to one half of the blossom clusters on water-treated trees. In each of the four experiments, analysis of incidence of fire blight infections relative to the water treated control revealed that two applications of A506 combined with Sequestrene 138, A mix of A506 Ecp- and C9-1 with Sequestrene 138 added to the second application , or Agrimycin resulted in significantly ($P \leq 0.05$) fewer diseased blossom clusters. Agrimycin applied at full bloom and again immediately following the pathogen inoculation resulted in the highest degree of fire blight suppression (85%). A mix of A506 Ecp- and C9-1 with Sequestrene 138 added to the second application reduced the number of strikes by 63% relative to the water treated control.

The application of Sequestrene 138 alone had little effect on the incidence of fire blight compared to treatment with water. A506 alone reduce disease incidence by 42%. And combining A506 with Sequestrene 138 significantly decreased the incidence of fire blight 54% compared to water-treated trees. In one trial, the level of control obtained with the combination of A506 and Sequestrene 138 was similar statistically to that obtained with streptomycin.

In the coming year, we plan to refine recommendations on how to best utilize iron-enhanced biological control of fire blight with A506; to investigate forms of iron best suited for this technology, and to evaluate integration of iron-enhanced biological control with conventional, antibiotic-use recommendations for fire blight control.

Table 2. Relative incidence of fire blight in two pear trials and two apple trials conducted in 2002

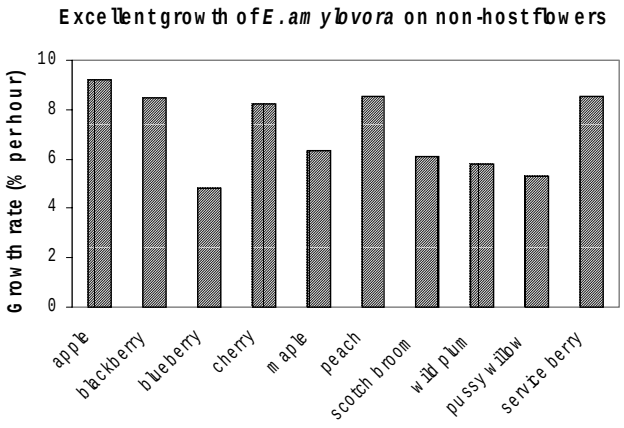
		Treatment[#]						
Trial/ Location	Number of strikes on water control	Water (relative disease)	Sequestrene 138	Mycoshield (oxytet)	A506	A506 & Sequestrene 138	A506 Ecp- & C9-1 & Sequestrene*	Streptomycin
Bart 1 /Mdfrd	253	100 A	-	49 B	51 B	53 B	34 C	11 D
Bart 2/ Mdfrd	168	100 A	93 A	80 AB	67 ABC	52 BC	39 C	15 D
Golden/Crvls	400	100 A	75 A	-	52 BC	21 D	34 CD	22 D
Rome /Crvls	135	100 A	83 AB	-	61 BC	59 BC	43 C	13 D

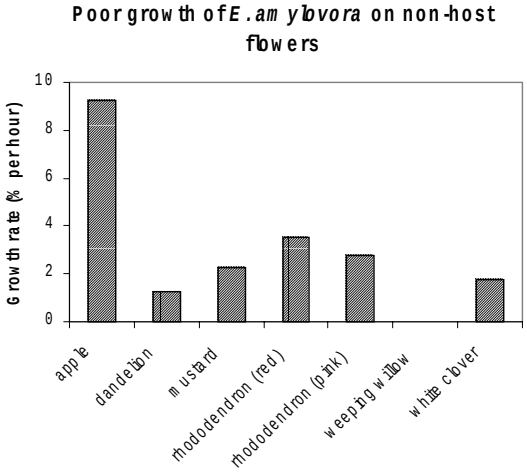
[#]Two applications of each treatment during bloom - *Sequestrene 138 added to second application only. *Means followed by same letter are not significantly different according to Fischer's least significance difference at $P = 0.05$.

Objective 3.

Growth of *E. amylovora* on floral surfaces of hosts of fire blight has been investigated widely, but the potential for *E. amylovora* to grow on surfaces of flowers that are not hosts of the disease has received little research effort. We believe of this kind of epiphytic growth may be significant in providing inoculum to pear and apple flowers during key periods in the season, and thus, may be an important but little understood risk factor in the initiation of fire blight epidemics.

Non-host plants of the rose family - peach, cherry, plum, blackberry, service berry – supported high populations of the fire blight pathogen. In addition, high populations of *E. amylovora* developed on flowers of big leaf maple, willow, and scotch broom. Conversely, flowers of mustard, dandelion, clover and rhododendron were relatively poor hosts for epiphytic populations of *E. amylovora*.





Reasons why these results are potentially important:

- Bees and other pollinating insects visit many kinds of flowers in the vicinity of apple and pear orchards (e.g., dandelions, cherries and blackberries). Thus. The data suggest that inoculum levels within a production region could increase on non-hosts plants as the spring progresses.
- In western production valleys, fruit orchards of different species occur at different elevations. The mix of hosts at varied elevations creates a drawn out period of bloom with the potential for insect and inoculum movement among pear and apple orchards and non-host flowers.
- Fire blight commonly fails to develop during the primary bloom, but many pear and some apple cultivars (e.g. Pink Lady) develop the disease during 'rattail' blooms that occur later in the spring/summer. Rattail infections could potentially arise from bacteria produced on non-hosts flowers.
- Knowledge that common, non-host flowers may support growth of *Erwinia amylovora* could lead to novel strategies to guide sampling for this pathogen with new, rapid diagnostic technologies.

Proposal for 2003:

Justification: The goals of our project are to understand to the biology and epidemiology of the fire blight pathogen, to develop and refine control methods for fire blight of pear and apple, and to integrate these technologies into commercial fire blight management. In recent years we have completed studies concerned with understanding how orchard environment affects growth and spread of bacteria on and among pear and apple blossoms. In addition, we have investigated and proposed a decision aid to modify fire blight forecasting models for use with softer control technologies. Our current activities include evaluating new chemical controls, and continuing to investigate, improve and optimize biological control of fire blight with beneficial bacterial. Our newest objective is concerned with evaluating the potential for epiphytic growth of *Erwinia amylovora* on common, abundant flowers frequented by honeybees but which are not hosts of fire blight disease. To our knowledge, increase and growth of pathogen inoculum on common, abundant nonhost flowers (maple, willow, peach, cherry, wild plum, dandelion, mustard, clover, and blackberry) has never been investigated. Knowledge of the potential for *Erwinia amylovora* to grow on flowers of non-hosts will provide further insight into seasonal dynamics of inoculum movement and availability, and will lead to improved indications as to when regional risks of fire blight epidemics are high.

Objectives (all ongoing):

1. Evaluate new products for fire blight suppression.
2. Field-test mixtures of beneficial bacteria optimized for compatibility of their biological mechanisms
3. **(2nd of 3rd year)** Evaluate potential for epiphytic growth of *Erwinia amylovora* on common flowers frequented by honey bees but which are not hosts of fire blight.

Objective 1 (ongoing): Evaluate new products for fire blight suppression. New chemical products with potential to control fire blight are being developed and tested (e.g. Serenade (*Bacillus subtilis* strain QST 713), Bloom Time Biological (*Panteoa agglomerans* strain 325), Starner (oxolinic acid), Agri-gent (gentamicin sulfate), Messenger (harpin), VacciPlant (algal derivative), Surround (kaolin clay), Mycosin (stone powder), Apogee (prohexidione-CA), Phyton 27 (copper in organic acid)). The mode of fire blight suppression differs among these products. Our emphasis in testing new materials will be on effectiveness, compatibility with other control products, and potential side effects (e.g. blossom browning, russeting). These experiments will be conducted in blocks of pear and apple located in Corvallis, OR, with treatments repeated in Medford if trees are available. Experimental methods and data collection will be as described above under Objective 1.

Objective 2 (ongoing): Field-test mixtures of beneficial bacteria optimized for compatibility of their biological mechanisms. As a focal point of our research, we have collected a volume of data showing that mixtures of bacterial antagonists on pear and apple blossoms are more effective than individual strains and, and perhaps more importantly, less variable in the degree of control obtained. In our recent efforts, we have discovered several ways to enhance the effectiveness of antagonist mixtures. One of these enhancements involved selecting a mutant of *P. fluorescens* A506 deficient in an extracellular protease (strain A506 Ecp-). In a mixture with *Pantoea agglomerans,* the loss protease production by A506 Ecp- prevents degradation of the antibiotic produced by *P. agglomerans*, resulting in a longer effective lifetime for the antibiotic and a greater level of disease suppression.

On another front, we have demonstrated that the addition of an iron chelate, FeEDDHA, to blossoms induces A506 to produce a previously unknown antibiotic, which also enhances disease suppression. [The iron related work is also the subject of a current and pending USDA WR-IPM grant to Stockwell, Johnson, and Loper – these grants fund Dr. Stockwell's salary.] In the coming year, we plan to refine recommendations on how to best utilize iron-enhanced biological control of fire blight with A506; to investigate forms of iron best suited for this technology, and to evaluate integration of iron-enhanced biological control with conventional, antibiotic-use recommendations for fire blight control. For example, in some trials, FeEDDHA has not enhanced fire blight control by A506 (Table 2). We suspect that part of the variation in control is due to insufficient coverage of flowers with the iron chelate. Our final applications of A506 with FeEDDHA occurred at 70% bloom, and while A506 can migrate to flowers that open later, the iron chelate cannot; thus, about a third of the flowers were not treated directly with the iron chelate. The purposes of these experiments will be three-fold: 1) determine if variation in efficacy can be diminished if iron is applied after all flowers are open, and 2) determine the persistence of iron chelates on flowers in orchard environments and 3) evaluate promising alternative iron chelates for disease control: FeDPTA (Sequestrene 330, Becker Underwood), FeEDTA, and Fe-amino acid chelate (Metalosate, Albion, Clearfield, UT). Experimental methods and data collection will be as described above under Objective 2.

[On other fronts (not related to this funding), we are beginning to investigate if the addition of avirulent (non-disease causing) strains of *Erwinia amylovora* to mixtures of beneficial bacteria enhances disease suppression. We also are working on ways to improve commercial formulations of gram-negative bacteria for cost effective delivery to the spray tank. Thus, with multiple strategies for improved fire blight suppression with mixtures of beneficial bacteria, each year we attempt to evaluate these strategies in various combinations.]

Objective 3 (2nd of 3rd year): Evaluate potential for epiphytic growth of *Erwinia amylovora* on common flowers frequented by honey bees but which are not hosts of fire blight.

Discussions on the development and control of the blossom blight phase of fire blight inevitably focus on the epiphytic growth of *E. amylovora* on floral structures, including stigmas and the hypanthium (nectary or floral cup). Stigmas, which are borne on the ends of the floral style, have been demonstrated to be the primary site epiphytic colonization by *E. amylovora* (1). Bees, and to a lesser extent other insects, are the primary vectors by which bacteria are introduced to stigmatic surfaces. Growth of *E. amylovora* on floral surfaces of important, rosaceous hosts of fire blight has been investigated widely, but the potential for *E. amylovora* to grow on surfaces of flowers that are not hosts of the disease has received little research effort. We believe of this kind of epiphytic growth may be significant in providing inoculum to pear and apple flowers during key periods in the bloom season, and thus, may be an important but little understood risk factor in the initiation of fire blight epidemics. For example, during key transition periods (e.g., from bloom of pear to apple, from low to high elevation, from primary to secondary rattail bloom), transport of the pathogen by honey bees to flowers of an abundant non-host (e.g., maple, alder, willow, or a cherry orchard) and back may provide an 'inoculum bridge' that increases the risk of fire blight in later blooming orchards. If this

were the case, the knowledge would contribute to our ability to model and predict the availability of *E. amylovora* inoculum within a district.

The book *Plants for Beekeeping in Canada and the Northern United States* (2) provides top ten lists of the most important nectar or pollen sources for bees in the major eco-regions across the continent. In the northwest, this list includes willow, maple, popular/alder, prunus, clover, dandelion, mustard, blackberry, broom, and rhododendron.

Methods: For this objective, we will collect flower-bearing branches of the above species. In growth chambers, bouquets of flowers will be inoculated with standardized suspensions of freeze-dried cells of *E. amylovora* strain 153Nal.. Population size of *Ea*153Nal will be monitored by dilution plating onto selective media. Population sizes among various flower types will be standardized on a per weight basis.

Literature Cited:

1. Johnson, K.B., and Stockwell, V.O. 1998. Management of fire blight: A case study in microbial ecology. Ann. Rev. Phytopathology 36:227-248.
2. Ramsay, J. 1987. Pages 139-143 in: *Plants for Beekeeping in Canada and the Northern United States*. Intl. Bee Research Assoc., London.

Budget:

Project title: Integrated management of fire blight of pear and apple

PI: Kenneth B. Johnson

Proposed duration of objectives: Objectives 1 & 2: Ongoing; Objective 3: 2nd of 3 year

Current year: 2003

Current year request: $17,605

Year	Last Year (2002)	**Year 2003**	Next year (2004)
Total	16,100	**17,605**	18,400

Budget specifics

Item	Last Year (2002)	**Current Request**	Next year (2004)
Salaries	9,000	**9,500**	10,000
Benefits (49%)	4,500	**4,655**	4,900
Wages			
Benefits (5%)			
Equipment			
Supplies	1,000	**1,500**	1,500
Travel	400	**450**	500
Plot Maintenance	1,200	**1,500**	1,500
Total	16,100	**17,605**	18,400

Salary is 3.5 months of a faculty research assistant

Support from other funding sources:

Oregon Agricultural Experiment Station

WPCC: Survival of *E. amylovora* on pear fruit (pending)

USDA Western Region IPM (pending): 2000-2001, $150,447 (Stockwell's salary and partial support for iron/A506 research).

USDA (pending): 2003-2005, $297,415 (pending) (Stockwell's salary and research on avirulent *E. amylovora*).

Occasional grants-in-aid of research from chemical companies.

Project title: Phacidiopycnis Rot of Pears

PI: Chang-Lin Xiao, Assistant Plant Pathologist
Organization: WSU-TFREC, 1100 N. Western Avenue, Wenatchee
509-663-8181 ext. 229; clxiao@wsu.edu

Cooperators: Bob Spotts, OSU Hood River
Dana Faubion, WSU Cooperative Extension, Yakima
Packinghouses in the Wenatchee River Valley, Yakima, and Hood River areas

Objectives:

1. Conduct packinghouse surveys to determine the occurrence of Phacidiopycnis rot and rots caused by other pathogens in storage.
2. Test *in vitro* sensitivity of the fungus, *Phacidiopycnis piri,* to various fungicides in order to develop a fungicide program for control of this disease.
3. Evaluate the effectiveness and timing of postharvest treatments with fungicides [thiabendazole (TBZ) and fludioxonil (Scholar)] and biocontrol agents for control of Phacidiopycnis fruit rot.

Significant findings:

- The two-year survey indicated that in addition to gray mold rot and blue mold rot, Phacidiopycnis rot was also an important component of storage decay in Anjou pears, accounting for approximately 30% of the decayed fruit.
- Phacidiopycnis rot was also found on stored Anjou pears that had been either drenched or presized prior to packing, indicating that this disease occurred under various postharvest fruit handling systems.
- The disease has also been found on other winter pear varieties, Bosc, Comice and red Anjou.
- Phacidiopycnis rot has three phases, i.e., stem-end rot, calyx-end rot, and wound-associated rot. Decays that originated from wound infections dominated during early storage before packing, whereas stem-end rot and calyx-end rot dominated on packed fruits during late storage. Approximately 80% of Phacidiopycnis rot originated from wound infection during early storage (before packing), whereas during late storage, from March to May, about 60 and 30% of the disease originated from stem and calyx infections, respectively. Different strategies should be implemented for control of decays under different postharvest fruit handling systems.
- Phacidiopycnis rot was found on fruits that were stored in cardboard boxes (field-packed) and in field bins without any postharvest treatments. This indicates that infections of fruit by the pathogen occurred in the orchard.
- Storage observations indicated that fruit-to-fruit spread by mycelia of the fungus occurred in storage. Laboratory experiments confirmed that *P. piri* has the ability to spread from infected fruit to surrounding healthy fruit through fruit-to-fruit contact.
- The fungus *Phacidiopycnis piri* has been recovered from all major pear production areas in Washington, including the Yakima area, the Columbia Basin, Wenatchee River Valley, Omak and Tonasket areas, and Hood River area in Oregon.
- Fungicides Captan, Dithane, Scholar, Mertect, and Ziram were effective in inhibiting mycelial growth on the agar medium. Procure was effective at label rates and less effective at $1/10^{th}$ the label rate. Two recently introduced fungicides, Flint and Vangard, were not effective in inhibiting mycelial growth of the fungus.

- In a preliminary test, TBZ and Bio-Save 110 were effective in controlling Phacidiopycnis rot originating from wound infections by the fungus. Aspire was not effective in controlling Phacidiopycnis rot.

Methods:

Surveys for postharvest decays. Surveys for postharvest diseases in Anjou pears were conducted during fruit packing from November 2001 to January 2002 (early storage before packing, i.e., pears are stored in field bins in cold storage) and during late storage (i.e., pears are stored in cardboard boxes after packing) from March to May in 2001 and 2002. Decayed fruits were randomly sampled from different lots from four packinghouses during packing or repackaging/repacking operations. Decayed fruits were sorted by symptoms, such as infection sites (stem end, calyx end, or fruit skin) and the presence of wounds. Isolations were made from decayed fruits to confirm causal agents. Photos of decayed fruits were taken before isolation in order to match causal agents with the disease symptoms they incited.

Sensitivity of the fungus *Phacidiopycnis piri* to selected fungicides. Nine fungicides, divided into four groups according to their use history, were selected to test *in vitro* for their effectiveness in inhibiting mycelium growth of the fungus. Each fungicide with three rates, i.e., label rate, one-half label rate, and $1/10^{th}$ the label rate, was amended in an agar medium to test fungicide sensitivity of *P. piri*. Plates were kept at 20ºC in the dark. Colony diameters were measured.

Control of Phacidiopycnis rot originating from wound infections. To evaluate the efficacy of fungicides and biocontrol agents for control of Phacidiopycnis rot, fruits were surface-disinfested in 10% freshly made bleach for 5 minutes, rinsed three times, air-dried and then wounded and inoculated. Three biocontrol agents, the *Cryptococcus laurentii* strain 87-108, Bio-Save 110, and Aspire, and two fungicides, thiabendazole (Mertect) and fludioxonil (Scholar), were tested.

Treatments were as follows:

(1) Control (Pha spore suspension only);
(2) Pha + Cryptococcus
(3) Pha + Aspire (at the label rate);
(4) Pha + Bio-Save 110 (at the label rate)
(5) Pha + TBZ (16 oz/100 gallons of water);
(6) Pha + Scholar (12 oz/100 gallons of water)

After inoculation, fruits were tray-packed and stored at 0ºC in air. The experiment was conducted two times. The new fungicide, Scholar, was only tested once in the second experiment.

Effects of timing of postharvest TBZ on Phacidiopycnis rot originating from stem and calyx infections. Experiments were conducted to evaluate whether postharvest treatments with TBZ can eliminate or reduce Phacidiopycnis rot originating from stem infections by the fungus. The stem and calyx of pears were inoculated with the pathogen, and the fungicide TBZ was applied either at the time of inoculation or at 1, 4 and 8 weeks after the inoculation. These pears were to be stored in RA and evaluated for decay development after three to five months in storage.

Results and discussion:

Survey of postharvest decays in pears.

1. Decays on pears stored in field bins before packing.

During November 2001 to January 2002, 33 sets of decayed fruits (from 33 different lots) were sampled during the packing operation. Gray mold rot and Phacidiopycnis rot were the two major decays on pears stored in field bins when fruits were not drenched with antiscald agents and fungicides, accounting for 61 and 18% of the decayed fruits, respectively. Blue mold rot accounted for 12% of the decayed fruits (Table 1). The other minor decays included Alternaria rot and sprinkler rot. The vast majority of decays in field bins originated from wound infections by these pathogens.

Phacidiopycnis rot was observed on fruits from 30 of 33 lots sampled during November 2001 to January 2002. Approximately 80% of Phacidiopycnis rot originated from wound infection during early storage (before packing). Stem-end and calyx-end rot caused by *P. piri* started showing symptoms in December (data not shown).

The data indicated that decay control should be targeted on gray mold rot and Phacidiopycnis rot if pears are not drenched and stored in field bins.

Table 1. Mean incidence (%) of postharvest fruit rots caused by different pathogens in the total decayed fruits sampled from mid-Nov. 2001 to early Jan. 2002 (early storage before packing).

Sampling period [1]	Gray mold	Phacidiopycnis rot	Blue mold	Mucor rot	Bull's eye rot	Sprinkler rot	Alternaria rot
November	52	12	20	1	0	0	5
December	63	25	5	0	0	2	0
January	64	18	11	0	1	1	1
Average	61	18	12	0.3	0.3	1	2

[1] Ten, 13, and 10 sets of decayed fruits were sampled in November, December 2001, and January 2002, respectively.

2. Decays on pears stored in cardboard boxes after packing.

In 2002, 39 sets of decayed pears were sampled. Gray mold rot, Phacidiopycnis rot, blue mold rot, and Mucor rot accounted for 27, 20, 37, and 8% of the decayed fruits from conventional orchards, respectively, and 26, 42, 8, and 1% of decayed fruits from organic orchards, respectively. Bull's eye rot accounted for 2 and 7% of the decayed fruits from conventional and organic orchards, respectively. Phacidiopycnis rot was prevalent. The disease was observed on fruits from 36 of 39 lots sampled during March to May 2002 (Table 2 and Fig. 1). Approximately 60 and 30% of Phacidiopycnis rot originated from stem and calyx infections, respectively (data not shown).

The incidence of decays caused by these pathogens varied from orchard to orchard. Approximately 45% of the lots had Phacidiopycnis rot incidence ranging from 20 to 50%, and 22% of the lots had less than 10% Phacidiopycnis rot. The incidence of blue mold varied greatly from lot to lot. About 33% of the lots had blue mold incidence less than 10%, but 25% of the lots had more than 50% of the decays caused by blue mold (Fig. 1).

Table 2. Mean incidence (%) of postharvest fruit rots caused by different pathogens in the total decayed pear fruits sampled from March to May 2002[1].

Production system	Gray mold	Phacidiopycnis rot	Blue mold	Mucor rot	Bull's eye rot	Others[2]
Conventional	27	20	37	8	2	6
Organic	26	42	8	1	7	16
Average	27	31	23	5	5	11

[1] Pears were stored in cardboard boxes after packing. Samples were collected when repackaging or repacking was in operation. Thirty-nine sets of decayed fruits were sampled.

[2] Include Alternaria rot, Cladosporium rot, rot caused by unknown pathogens and a fruit rot caused by an undescribed fungus.

3. Decays on pears that had been either drenched or presized prior to packing.

Four sets of decayed fruits were sampled in early April from four different packinghouses in the Hood River area. These pears had either been drenched or presized before packing. Phacidiopycnis rot was found in these four lots, accounting for approximately 16% of the decayed fruits. The other two common decays were gray mold rot and blue mold rot, accounting for approximately 60 and 13%, respectively (Table 3). Although only a limited number of samples were collected, the data indicated that Phacidiopycnis rot occurred as well under different postharvest handling systems in different pear productions regions in the Pacific Northwest.

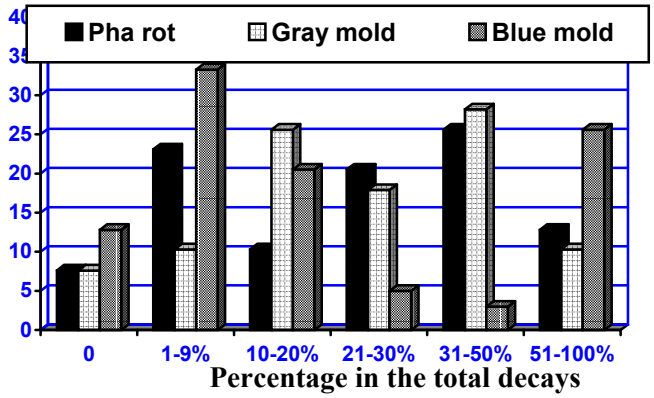


Fig. 1. Frequency of sampled lots (orchards) affected according to incidence level in the decayed fruits.

Table 3. Incidence of postharvest fruit rots (%) caused by different pathogens in the total decayed pear fruits sampled from the Hood River area on April 10, 2002.

Lot	Handling system	Gray mold	Phacidiopycnis rot	Blue mold	Mucor rot	Bull's eye
1	**Drench**	30	23	17	0	9
2	**Drench**	90	9	0	0	0
3	**Presize**	51	12	28	0	6
4	**Presize**	69	19	5	2	3

In summary, the survey study indicated that gray mold, Phacidiopycnis rot, and blue mold were the three major postharvest diseases on Anjou pears. Decays originating from wound infections dominated during early storage before packing, whereas stem-end rot and calyx-end rot dominated on packed fruits during late storage. Different strategies should be implemented for control of decays under different postharvest fruit handling systems.

Sensitivity of *Phacidiopycnis piri* isolates to selected fungicides.

Eighteen isolates of *P. piri* recovered from four pear production areas in the Pacific Northwest were tested for sensitivity to nine selected fungicides. At 1/10th label rate, fungicides Captan, Dithane, Scholar, Mertect (TBZ), and Ziram were very effective in inhibiting mycelial growth on the agar medium (Table 4). Two recently introduced fungicides, Flint and Vangard, were not effective in inhibiting mycelial growth of the fungus. Although a representative number of isolates were tested, the data may indicate that:

1. Reduced use of some fungicides in pear orchards could potentially increase populations of some fungi, including decay-causing pathogens such as *Phacidiopycnis piri*. In recent years, fungicide usage in pear orchards has been considerably reduced. For example, the number of applications of Dithane during a single growing season in the Wenatchee River Valley area is less than in the past.

2. Procure (DMI fungicide) and Flint (Strobilurin) are common fungicides used to control powdery mildew. Because Procure is more effective than Flint in inhibiting mycelial growth of the fungus, use of Procure to control powdery mildew may be also beneficial in reducing population levels of Phacidiopycnis in the orchard.

Table 4. Efficacy of nine selected fungicides to inhibit growth of *Phacidiopycnis piri* isolates recovered from different pear production areas in the Pacific Northwest.

Fungicide	Rate[1]	% Inhibition of mycelial growth					
		Pear production area from which isolate recovered					
		Omak (orchard)	Wenatchee[2] (orchard)	Wenatchee (decayed fruits)	Wenatchee (ascospore)	Yakima[3] (orchard)	Hood River (decayed fruit)
		Number of isolates					
		2	6	2	2	1	5
Captan	**0.1x**	99	100	100	100	100	100
	0.5x	99	100	100	100	100	100
	1.0x	99	100	100	100	100	100
Dithane	**0.1x**	100	100	100	100	100	99.8
	0.5x	100	100	100	100	100	100
	1.0x	100	100	100	100	100	100
Flint	**0.1x**	50	28.3	23	39	25	19
	0.5x	44	41.3	31.5	48	42	23
	1.0x	41.5	48.7	40.5	46.5	48	19.2
Procure	**0.1x**	97	86	84.5	89.5	96	83
	0.5x	100	100	100	100	100	96.2
	1.0x	100	100	100	100	100	100
Rovral	**0.1x**	85	75.2	79.5	74.5	89	80
	0.5x	98.5	88.7	99	89	97	94.8
	1.0x	98.5	87.5	100	87	94	96.6
Scholar	**0.1x**	98.5	97.7	94.5	100	89	98.8
	0.5x	100	99	96	99	93	98.4
	1.0x	98.5	98	95	98	91	99.2
Mertect	**0.1x**	100	99.5	99	96	100	99.2
	0.5x	100	99.5	100	99	100	99
	1.0x	100	99.2	100	97.5	100	98.8
Vangard	**0.1x**	52.5	22.7	36	64	39	6.6
	0.5x	61	30.5	56.5	67	48	10.4
	1.0x	54.5	33.7	49	58.5	58	12.8
Ziram	**0.1x**	100	100	100	100	100	97.6
	0.5x	100	100	100	100	100	100
	1.0x	100	100	100	100	100	100

[1] Relative to label rate.
[2] Wenatchee area includes Leavenworth, Peshastin, Dryden, and Monitor.
[3] This isolate was recovered from a Bartlett pear orchard.

Mertect (TBZ) is currently used as a postharvest treatment to control storage decay on pears and apples. The preliminary test indicated that this fungicide was also effective against Phacidiopycnis rot. Our observations also indicated that wound infection by *P. piri* occurred at harvest. Commercially, pears may be drenched with fungicides within several hours of harvest. Whether the delay of fungicide applications would reduce the control efficacy is unknown. Postharvest treatment with Mertect to control different phases of Phacidiopycnis rot needs to be further evaluated.

Control of Phacidiopycnis rot that originated from wound infections.
The experiment was set up shortly after harvest. The first decay evaluation was done at 11 weeks after fruit inoculation. As of December 9, 2002, 43% of Phacidiopycnis-inoculated fruits (control) developed decay. No decay developed on fruits treated with TBZ and the biocontrol agent Bio-Save 110, and 5% decay developed on fruits treated with the *Cryptococcus laurentii* strain 87-108. The biocontrol agent Aspire was not effective in controlling Phacidiopycnis rot in this experiment (Fig. 2). The data indicated that TBZ and Bio-Save 110 were effective in controlling Phacidiopycnis rot originating from wound infections by the fungus. Decay development will be evaluated again. More research is needed to confirm these results.

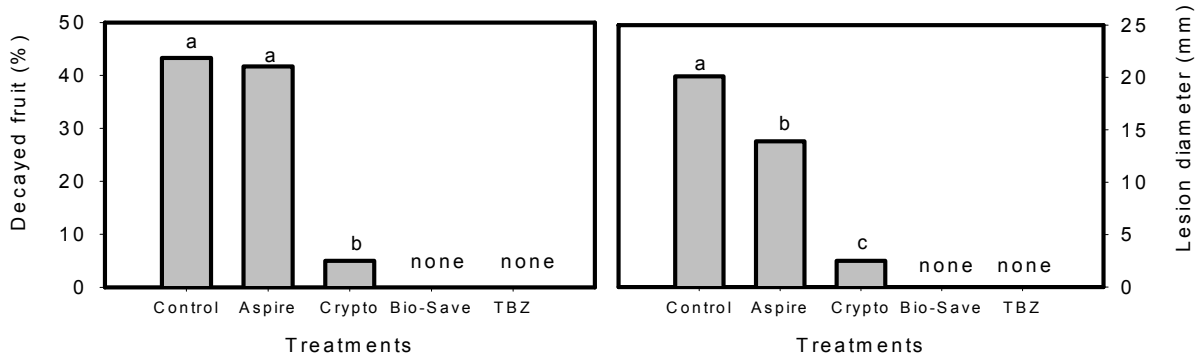


Fig. 2. Efficacy of TBZ and three biocontrol agents, the *Cryptococcus laurentii* strain 87-108 (Crypto), Bio-Save and Aspire in controlling Phacidiopycnis rot originating from wound infections by *Phacidiopycnis piri*.

Effects of timing of postharvest TBZ on Phacidiopycnis rot that originated from stem and calyx infections.
Two experiments were conducted. At the time of writing this report, the pears are still in storage. Decay development data will be forthcoming, and experimental results will be reported later.

Proposed research for 2003:
Objectives:
1. Determine when *Phacidiopycnis piri* inoculum is available for fruit infection in the orchard.
2. Determine when fruits are infected in the orchard by the fungus *P. piri.*
3. Evaluate effects of selected fungicides on the fungus *P. piri.*
4. Evaluate effectiveness of fungicides and biocontrol agents to control Phacidiopycnis rot.

Justification:
Postharvest decay is an ongoing concern for the long-term storage of winter pears. Several decay-causing pathogens are commonly associated with Anjou pears in the Pacific Northwest. The two-year survey of postharvest decays in Anjou pears indicated that Phacidiopycnis rot is an important component of storage rot in pears. Our research also indicated that Phacidiopycnis rot has three separate phases: stem-end rot, calyx-end rot, and rot originating from wound infection. Stem and calyx infection by the fungus occur in the orchard. The disease can also spread among fruits by the

mycelium of the fungus in field bins through fruit-to-fruit contact. Different phases of the diseases are due to different mechanisms of infection by the fungus. In order to develop an effective program for control of the disease, the following questions need to be addressed:

1. When viable inoculum of the fungus is available for fruit (stem and calyx) infection in the orchard.
2. When stem and calyx infections occur in the orchard. Because the disease symptoms do not appear at harvest, most likely the fungus survives on infected fruits as latent infections. Understanding when fruit infections occur would help further develop fungicide spray programs for disease control.
3. Whether pre- and/or postharvest fungicides and biocontrol agents would control or reduce Phacidiopycnis rot in storage.
4. Whether preharvest fungicides designated for control of other orchard diseases would be beneficial in reducing inoculum levels of *Phacidiopycnis piri* in the orchard. Effectiveness of fungicides in inhibiting spore germination of *P. piri* needs to be evaluated.

In this proposed study, we will address these critical issues related to disease control.

Methods:

1. Pear orchards with a history of Phacidiopycnis fruit rot have been identified. The fruiting body, pycnidia of the fungus, has been found in the bark of twigs and branches on the trees. To determine when the fruiting bodies of the fungus form on the tree, inoculum availability will be monitored periodically during the pear growing season, from early spring to harvest in two commercial orchards. Weather data will also be recorded in these two orchards. At each sampling time, 10 trees will be selected and 10 pieces of dying or dead bark tissue and 10 dying or dead fruit spurs will be collected from each tree. Samples will be examined under a stereomicroscope. Presence of pycnidia or apothecia of the fungus will be recorded. Viability of pycnidia or spores will also be determined by plating them onto an agar medium.
2. Experiments will be conducted in a research block. To determine whether or not infections of floral parts (resulting in calyx-end rot) and stem occur at different times during the pear growing season, pear flowers will be inoculated with the fungus during bloom, and fruit at different growth stages will be inoculated with the fungus. All fruits will be harvested and stored at 0˚C in air for decay evaluation. At each inoculation time, four replicate trees will be used for inoculation with the pathogen.
3. Currently labeled fungicides for pears, including Captan, Dithane, Mertect, Ziram, other fungicides for preharvest applications, and the new postharvest fungicide fludioxonil (Scholar), will be tested for their effectiveness in inhibiting spore germination of *Phacidiopycnis piri*.
4. To evaluate effectiveness of preharvest fungicides in controlling Phacidiopycnis rot originating from stem and calyx infections, fruits will be inoculated with the fungus during the pear growing season. Part of inoculated fruit will be sprayed with Ziram (at 14 days before harvest) and the rest without Ziram. All fruits will be harvested and stored at 0˚C in air for decay evaluation.

   Experiments will also be conducted to evaluate effectiveness of postharvest fungicides and biocontrol agents for control of Phacidiopycnis rot originating from wound infections. Fruits were surface-disinfested in 10% freshly made bleach for 5 minutes, rinsed three times, air-dried and then wounded. Two biocontrol agents (the *Cryptococcus laurentii* strain 87-108 and Bio-Save 110), and two fungicides, thiabendazole (Mertect) and fludioxonil (Scholar), will be tested. Fruits will be inoculated with spore suspensions of *P. piri*. Biocontrol agents and fungicides will be applied into the same wounds either at the time of inoculation with the pathogen or at 7 hours after inoculation with the pathogen. Fruits will then be stored at 31˚F in air and evaluated for decay development.

Budget:
Project title: Phacidiopycnis Rot of Pears
PI: Chang-Lin Xiao
Proposed project duration: 2002-2004
Current year: 2003
Project total (3 years): $62,281
Current year request: $24,420

Year	2002	**2003**	2004
Total	12,780	**24,420**	25,081

Current year breakdown:

Item	2002	**2003**	2004
Salaries [1]		**14,000**	14,560
Benefits (18%)		**2,520**	2,621
Wages [2]	8,000	**2,500**	2,500
Benefits (16%)	1,280	**400**	400
Equipment			
Supplies [3]	2,500	**4,000**	4,000
Travel [3]	1,000	**1,000**	1,000
Miscellaneous			
Total	12,780	**24,420**	25,081

[1] Salary for a 0.49 FTE technical helper (Associate in Research).
[2] Wages for time-slip in summer and during harvest.
[3] Culture media, chemicals, petri dish plates, cryogenic vials and other supplies for ultra-low temperature storage of fungal isolates, and fungicides. Cost of fruit bought from commercial orchards.
[4] Travel to Hood River, Wenatchee, and Yakima areas is required for sampling. We will be using a leased vehicle.

Title: Control of decay of pear

Project Leader: Robert A. Spotts

Cooperators: Paul Chen
David Sugar
Henrik Stotz

REPORT

Significant Findings:

Gray mold, blue mold, and total decay were less in punctured fruit that were run through dump tank water containing copper/silver ions than water without these ions. Total decay was reduced about 35%. The incidence of gray mold and Mucor rot were reduced when inoculated fruit were treated with 40° C water than with cold (5.5° C) water. Results were mixed for blue mold since 50° C reduced decay but 40° C increased decay. Heat injury was observed on fruit treated with 50° C water. Spore reduction was not simply a water dilution effect but an effect of the heat. A drench treatment with fludioxonil gave excellent control of blue mold and gray mold, even at the lowest rate of 4 oz per 100 gal. However, some injury at lenticels of d'Anjou fruit was observed with fludioxonil plus ethoxyquin treatments. Application of Flint, Ziram, or Ferbam 14 days before harvest did not reduce the incidence of blue mold or total decay. In controlled inoculations, percent stem end gray mold was closely related to the dose of *Botrytis* spores in the air and on the fruit surface. Survival of *Botrytis cinerea* was highest on quackgrass and annual bluegrass and lowest on dandelion and sweet clover. It appears that while sclerotia may be a minor source of *Botrytis* spores in the orchard, infected blackberry fruit are an important source of spores of *Botrytis*. Anjou fruit harvested at under 13 lbs pressure had the most Mucor rot and fruit under 12 lbs the most gray mold. No clear relationship was observed between fruit maturity and blue mold.

Objectives:

1. Chemical, heat, and biological control of decay of pear.
2. Studies on decay pathogens.

Procedures:

1. Chemical, heat, and biological control of decay of pear

A. Copper/silver ion generator evaluation.

Copper and silver ions are well-known biocides and have been used in a variety of applications, including Apollo space flights and commercial swimming pools.

A generation system capable of producing copper and silver ions was installed in the dump tank of the commercial packingline at MCAREC. About 14 bins of fruit were processed without operating the generator, then the same quantity of fruit from the same lot was processed with the generator turned on. Throughout each run, 6 boxes of punctured cull fruit were collected, stored at 30° F, and decay evaluated monthly. Dump water temperature, pH, specific gravity, and concentrations of copper were monitored throughout the study.

B. Evaluation of a hot water pressure washer system for decay control.

This research is part of a larger cooperative study with USDA personnel and is partly funded by an APHIS grant. The pathology component is as follows:

Evaluation of the effect of a hot water/pressure system (HWS) on fruit decay. d'Anjou pear fruit were puncture-inoculated with spores of the main decay pathogens, *Botrytis*

cinerea, *Mucor piriformis*, *Penicillium expansum*, and a sterile distilled water control. Fruit were run through the packingline with and with the HWS in operation. HWS operating conditions were those determined in preliminary tests to give the maximum temperature and time of fruit exposure without injury to the fruit. Treated fruit were stored at 30° F and decay evaluated after 1, 2, and 3 months for *M. piriformis*, *B. cinerea*, and *P. expansum*, respectively. Fruit also were evaluated for heat injury. The experiment was repeated three times, using a total of 72 boxes of fruit.

Evaluation of populations of decay spores in water. Effect of the HWS on populations of decay spores in the water system of the MCAREC packingline was determined by dilution plating of spore-containing water onto acidified potato dextrose agar. Dilution of system water was determined by measuring the intensity of blue food coloring added to the system. Replicate samples were taken from 1 minute after addition of spores and food coloring up to 2 hours at 86 and 104° F.

C. *Evaluation of fludioxonil (Scholar) for control of blue mold and gray mold and compatibility with ethoxyquin and Mertect.*
d'Anjou pear fruit were harvested at commercial maturity and surface-sterilized but not wounded. Fruit were treated in a recirculating drencher with the following treatments (all rates per 100 gal):

1. Scholar at 16 oz + ethoxyquin
2. Scholar at 4 oz + ethoxyquin
3. Scholar at 4 oz + Mertect at 16 oz
4. Scholar at 4 oz
5. CIM
6. Water control

Drench solutions also contained conidia of *Penicillium expansum* or *Botrytis cinerea*. Fruit were drenched, stored at 30° F in air, and evaluated after 2 and 3 months of storage for *B. cinerea* and *P. expansum*, respectively.

D. *Preharvest fungicides for decay control.*
Flint, Ziram, and Ferbam were applied 14 days before harvest. Control trees received no fungicide. At harvest, fruit were drenched with spores of *P. expansum*, then stored at 30° F. Decay was evaluated after 3, 6, and 8 months.

2. Studies on decay pathogens

A. *Airborne spore inoculum dose:disease incidence for stem end gray mold of pear.*

This was the second year of this study. Pear fruit were inoculated in an aluminum tower. Fruit were placed in the bottom of the tower with the stems up. Conidia/talc mixtures were used to obtain a range of inoculum sizes from 0.01 to 0.5 mg of conidia. Each mixture was forcefully blown into the top center of the tower. Spores were allowed to settle for 20 minutes, then fruit were removed. After 3, 6, and 8 months of storage at 30° F, stem end infection will be determined. Density of conidia of *B. cinerea* settling onto the surface was determined by placing glass microscope slides coated with a thin layer of silicone grease at different locations on the trays. Conidia on slides were counted under a microscope. Density

of conidia of *B. cinerea* in the air inside the tower was determined by sampling with a portable air sampler for agar plates through a port on the side of the tower.

B. Survival of Botrytis in weeds in orchard plots.

This study examined the importance of common orchard weeds as a source of *Botrytis cinerea*. The following weeds and additional organic matter sources were collected from a pear orchard in spring:

White sweet clover
Annual bluegrass
Common chickweed
Common mallow
Quackgrass
Dandelion
Dead pear leaves
Pear blossom petals

Leaves, stems, and flower parts of each species (when present) were sterilized and cut into pieces. Weed pieces were inoculated with spores of *B. cinerea* and incubated in petri dish moist chambers for 3 days.

"Starched" cheesecloth pieces were used to make envelopes, then filled with pieces of colonized weeds and placed on the ground in the orchard. Colonization and survival were determined monthly by plating weed pieces on agar.

C. Importance of sclerotia in the epidemiology of Botrytis.

Sclerotia are hard resting bodies of the fungus that are resistant to unfavorable conditions, may remain dormant for long periods of time, then germinate upon the return of favorable conditions. Their importance in the epidemiology of gray mold of pear has never been studied. Information on survival, germination, and spore production of sclerotia will help us understand the importance of these structures as related to the level of gray mold. This is the second year of this study.

D. Role of blackberries in the epidemiology of Botrytis.

B. cinerea infects many hosts, including pear fruit and blackberry fruit. Blackberries are common weeds near many orchards, especially in the Mid-Columbia district of Oregon and Washington. This study determined if gray mold spores from blackberry can infect pear fruit. In addition, the time of spore production on blackberry in relation to pear harvest was determined.

E. Harvest maturity in relation to decay susceptibility.

From limited data, it appears that overmature pear fruit are more susceptible to decay than less mature fruit. In this study, we tried to quantify this relationship. Eighteen boxes of d'Anjou pears were harvested weekly beginning one week before commercial harvest. Immediately after harvest, six boxes of orchard-run fruit were drench-inoculated with spores of *B. cinerea*, *M. piriformis*, or *P. expansum*. Fruit were stored at 30°F and decay evaluated after 1, 2, and 3 months for mucor rot, gray mold, and blue mold, respectively. In addition, fruit at harvest were analyzed for soluble solids, firmness, and polygalacturonase inhibitor protein (PGIP, thought to be related to decay resistance). The relationships between pressure, PGIP, and decay were determined.

Results:

1. Chemical, heat, and biological control of decay of pear

A. Copper/silver ion generator evaluation (Fig. 1).

Gray mold, blue mold, and total decay were less in punctured fruit that was run through dump tank water containing copper/silver ions than water without these ions. Total decay was reduced from 58% to 38%. The concentration of ions in the water was 1.2 ppm for copper and 0.08 ppm for silver. These levels were somewhat higher that desired but still within safe limits. Additional trials are planned.

B. Evaluation of a hot water pressure washer system for decay control (Tables 1 and 2).

The incidence of gray mold and Mucor rot were reduced when inoculated fruit were treated with 104° F water than with cold (42° F) water. Treatment with water at 122° F also reduced gray mold but not Mucor rot. Results were mixed for blue mold since 122° F reduced decay but 104° F increased decay. Heat injury was observed on fruit treated with 122° F water.

In a separate experiment, spores of *Penicillium* added to the water system were killed at both 86 and 104° F, primarily because the water had to be heated to 140° F in the contact loop at both temperatures. Within 5 minutes after addition of spores and blue food coloring, the water had been diluted about 57% at both temperatures as indicated by absorbance of the dye, but 90 and 95% of the spores had been killed at 86 and 104° F, respectively. Thus, spore reduction was not simply a water dilution effect but an effect of the heat.

The hot water pressure system has potential for decay control and merits further study.

C. *Evaluation of fludioxonil (Scholar) for control of blue mold and gray mold and compatibility with ethoxyquin and Mertect (Table 3).*

A drench treatment with fludioxonil gave excellent control of blue mold and gray mold, even at the lowest rate of 4 oz per 100 gal. However, when either rate of fludioxonil was combined with ethoxyquin, phytotoxicity was observed as burned areas, primarily at lenticels on d'Anjou pear fruit. Additional studies are underway to further evaluate fludioxonil/ethoxyquin combinations for phytotoxicity.

D. Preharvest fungicides for decay control (Table 4).

Neither Flint, Ziram, nor Ziram + Ferbam reduced incidence of blue mold or total decay compared to the unsprayed check. Generally, a preharvest fungicide application will reduce decay by at least 20%, and the reason for lack of control in this trial in unknown.

2. Studies on decay pathogens

A. Airborne spore inoculum dose:disease incidence for stem end gray mold of pear (Fig. 2).

Percent stem end gray mold was closely related to the dose of *Botrytis* spores in the air and on the fruit surface. The relationship was different from last year, and more decay occurred at each spore dose in 2002 than in 2001. This difference may be related to increased susceptibility of fruit in 2002 since the same isolate of *Botrytis* was used both years and conditions for infection and fruit storage were the same. The goal of this study is to be able to predict which spore loads on fruit surfaces at harvest indicate high decay risk in storage.

B. *Survival of Botrytis in weeds in orchard plots(Table 5).*
Colonization of various weeds by *Botrytis* was initially high, between 77 and 96%. After one month, survival ranged from 21 to 67% and further decreased to 13 to 30% by mid-September. Survival was highest on quackgrass and annual bluegrass and lowest on dandelion and sweet clover. Another pathogen of pears, *Pseudomonas syringae*, the cause of blossom blight and canker, also develops the highest populations on orchard grasses and the lowest on clovers. These results suggest consideration of alternative cover crops for pear orchards.

C. *Importance of sclerotia in the epidemiology of Botrytis (Table 6).*
Percent of d'Anjou fruit on the orchard floor after harvest with gray mold appears to vary each year but ranged from about ¼ to ½ of the fruit by mid December. Sclerotia were present on only a few of the infected fruit in November, but sclerotial production increased greatly in December. Although these structures are abundant and assure survival of *Botrytis* for several months, very little germination and sporulation have been observed during the growing season. Thus, sclerotia appear to be a minor source of *Botrytis* spores in the orchard.

D. *Role of blackberries in the epidemiology of Botrytis(Table 7).*
Blackberry fruit were infected by *Botyrytis cinerea*, and spores from infected blackberry fruit infected pear fruit. Infection of blackberry fruit occurred after pear harvest during the last two years. The infected blackberry fruit remained attached to the canes and were covered by large numbers of *Botrytis* spores at the time of pear harvest, almost a year after the blackberries were infected. It is likely that infected blackberry fruit are an important source of spores of *Botrytis*. Blackberries growing at the edges of pear orchards should be removed, when possible.

E. *Harvest maturity in relation to decay susceptibility(Tables 8 and 9).*
In the 2001-2 season, d'Anjou pear fruit increased in susceptibility to gray mold and Mucor rot as the harvest date was extended past the normal commercial harvest. Fruit under 13 lbs pressure had the most Mucor rot and fruit under 12 lbs the most gray mold. No clear relationship was observed between fruit maturity and blue mold. Significant correlations were found between Mucor rot and pressure, Mucor rot and PGIP (polygalacturonase inhibitor protein)/ug protein, and blue mold and PGIP. It appears that 14 lb d'Anjou pears are generally as resistant to decay as 15 lb pears, but more study is needed to be certain of this relationship.

PROPOSAL – New approaches to decay control of pears
Objectives:
1. Effect of MCP and CIM, silver ions, and heat on control of decay of pear.
2. DNA techniques for rapid, accurate detection of decay spores
3. Studies on decay pathogens.

Procedures:
Effect of MCP and CIM, silver ions, and heat on control of decay of pear.

A. *MCP and CIM treatment and effect on stem end gray mold.*

Stem ends of d'Anjou pears will be dipped in a suspension of Botrytis spores combined with the biocontrol yeast CIM. Stem ends of control fruit will be dipped in Botrytis spores without yeast. Fruit will be exposed to the following MCP concentrations: 0, 10, 30, 50, 70, and 100 ppb. After MCP treatment, fruit will be stored at 30° F, and stem end gray mold evaluated after 3 and 6

months. In the second year of this study, Mucor and Penicillium stem end decay will be included.

The effect of MCP and fungicides that are applied as fumigants will be studied in cooperation with Peter Sholberg and Paul Randall, Pacific Agri-Food Research Centre, Summerland, BC. Initial hexanal fumigation will be done at Summerland but expanded later to include MCP/hexanal trials at Hood River with both Anjou and Bosc pears.

B. Copper/silver ion generator evaluation.

Copper and silver ions are well-known biocides and have been used in a variety of applications, including Apollo space flights and commercial swimming pools.

A generation system capable of producing copper and silver ions was installed in the dump tank of the commercial packingline at MCAREC and reduced decay by about 35% in the first year of testing. In continued testing, fruit will be processed without operating the generator, then the same quantity of fruit from the same lot will be processed with the generator turned on. Throughout each run, punctured cull fruit will be collected, stored at 30° F, and decay evaluated monthly. During each run, dump water samples will be removed hourly, and the concentration of decay spores determined. Dump water temperature, pH, specific gravity, and concentrations of copper will be monitored throughout the study.

C. Evaluation of a hot water pressure washer system for decay control.

This research is part of a larger cooperative study with USDA personnel and is partly funded by an APHIS grant. One year of study has been completed and a second year is planned, pending APHIS support. The pathology component is as follows:

d'Anjou pear fruit were puncture-inoculated with spores of the main decay pathogens, *Botrytis cinerea*, *Mucor piriformis*, *Penicillium expansum*, and a sterile distilled water control. Fruit were run through the packingline with and with the HWS in operation. HWS operating conditions were those determined in preliminary tests to give the maximum temperature and time of fruit exposure without injury to the fruit. Treated fruit were stored at 30° F and decay evaluated after 1, 2, and 3 months for *M. piriformis*, *B. cinerea*, and *P. expansum*, respectively. Fruit also were evaluated for heat injury. The experiment was repeated three times, using a total of 72 boxes of fruit.

2. DNA techniques for rapid, accurate detection of decay spores

It is extremely important to packinghouse personnel to have a rapid, accurate method to determine the concentration of decay spores in dump tank and flume water and to know if the level is above or below the threshold for serious decay problems. The current methods require dilution plating of water, and results are not know for several days. In addition, identity of fungal colonies on plates often is uncertain. New techniques are being developed that are based on recognition of the unique DNA of each specific pathogen (*Penicillium, Mucor, Botrytis*, etc.). Results can be available in less than 48 hours.

Research will be done to adapt these techniques for use in postharvest water handling systems. Three key questions need to be resolved before the PCR (polymerase chain reaction) technique can be used. First, does the DNA of dead spores in the water break down rapidly enough so that they will not be counted along with live spores? Second, can the PCR

methods be quantitative enough to compare with dilution plating? Third, is the sensitivity of PCR adequate to detect critical threshold levels of decay spores?

Studies initially will be done under controlled lab conditions with spore suspensions of *B. cinerea* (gray mold), *P. expansum* (blue mold), *M. piriformis* (mucor rot), and *N. perennans* (bull's-eye rot) and several water temperatures. Clean distilled water will be used initially, then spores will be suspended in dirty dump tank water and the experiments repeated.

3. Studies on decay pathogens

A. Air, litter, and fruit surface Penicillium and Botrytis spore levels and fruit decay.

This epidemiological study was initiated to collect data on the concentrations of spores of *P. expansum and B. cinerea* in orchard air, soil, litter, and on fruit surfaces preceding and during harvest. This study will be expanded to several orchards and focus on the relationship between spores on the fruit surface and the amount of decay developing in stored fruit.

In orchards with a history of gray mold, spores will be washed from fruit surfaces and counted by standard dilution plating and also analyzed for *Botrytis* with new DNA identification techniques. Stems will be plated to determine presence of decay fungi, and fruit will be stored at 30° F and evaluated for decay after 3, 6, and 8 months.

B. *Airborne spore inoculum dose:disease incidence for stem end blue and gray mold of pear.* This will be the second year of this study for P. expansum and the final year for Botrytis cinerea. Pear fruit will be inoculated in an aluminum tower. Fruit will be placed in the bottom of the tower with the stems up. Conidia/talc mixtures will be used to obtain a range of inoculum sizes from 0.01 to 0.5 mg of conidia. Each mixture will be forcefully blown into the top center of the tower. Spores will be allowed to settle for 20 minutes, then fruit will be removed. After 3, 6, and 8 months of storage at 30° F, stem end infection will be determined. Density of conidia of *B. cinerea* settling onto the surface will be determined by placing glass microscope slides coated with a thin layer of silicone grease at different locations on the trays. Conidia on slides will be counted under a microscope. Density of spores of *P. expansum* on the surface will be determined by placing three petri dishes containing APDA on the trays. Density of conidia of *B. cinerea* and *P. expansum* in the air inside the tower will be determined by sampling with a portable air sampler for agar plates through a port on the side of the tower.

C. Survival of Botrytis in weeds in orchard plots.
This study (second year of data collection) will examine the importance of common orchard weeds as a source of spores of *Botrytis cinerea*. The following weeds and additional organic matter sources will be collected from a pear orchard in spring:

White sweet clover	Quackgrass
Annual bluegrass	Dandelion
Common chickweed	Dead pear leaves
Common mallow	Pear blossom petals

Leaves, stems, and flower parts of each species (when present) will be sterilized and cut into pieces. Weed pieces will be inoculated with spores of *B. cinerea* and incubated in petri dish moist chambers for 3 days.

"Starched" cheesecloth pieces were used to make envelops, then filled with pieces of colonized weeds and placed on the ground in the orchard. Colonization and survival will be determined monthly by plating weed pieces on agar.

D. Role of blackberries in the epidemiology of Botrytis.

B. cinerea infects many hosts, including pear fruit and blackberry fruit. Blackberries are common weeds near many orchards, especially in the Mid-Columbia district of Oregon and Washington. This study will determine the time of spore production on blackberry in relation to pear harvest.

E. Harvest maturity in relation to decay susceptibility.

From the previous two years, it appears that overmature pear fruit are more susceptible to decay than less mature fruit. In this study, we will continue to quantify this relationship. Eighteen boxes of d'Anjou pears will be harvested weekly beginning one week before commercial harvest. Immediately after harvest, six boxes of orchard-run fruit will be drench-inoculated with spores of *B. cinerea*, *M. piriformis*, or *P. expansum*. Fruit will be stored at 30°F and decay evaluated after 1, 2, and 3 months for mucor rot, gray mold, and blue mold, respectively. In addition, fruit at harvest will be analyzed for soluble solids, firmness, and polygalacturonase inhibitor protein (PGIP), thought to be related to decay resistance. The relationships between pressure, PGIP, and decay will be determined.

F. Prediction of bull's-eye rot of bosc pear fruit.

Bosc fruit from Oregon and Washington will be inoculated with spores of the *Neofabraea alba* and *N. perennans*, the two most common fungi causing bull's-eye rot in Oregon and Washington. Half of the fruit will be stored at 50°F and half placed in air storage at 30° F. The amount of decay that develops at each temperature will be compared. The goal is to obtain equal amounts of decay in both groups, but to see bull's-eye rot develop in the fruit at 50° in five weeks rather than in the normal five months that is common at 30°F.

Estimated duration:

This will be the final year for silver ion and heat experiments. MCP studies be done for three years and will include hexanal fumigation studies in cooperation with Agriculture Canada. The DNA rapid pathogen identification work will include development of methods the first year, then application during the second and third years. Use of the concentration of spores in fruit surfaces to predict decay in storage requires addition of new orchards and 2-3 years of data to develop a reliable prediction model. Spore tower work will be completed this year for Botrytis and in one more year for Penicillium. Importance of weeds and blackberries in gray mold epidemiology will be complete in one year. This will be the final year of the harvest maturity study. Prediction of bull's-eye rot requires multiple years in multiple orchards to develop a reliable prediction tool.

Funding History: Initiated: 1979 Funding in 2002-2003: $38,044

Budget requested:

Item	Amount
Salaries and wages	$38,220
Service and supplies	1,043
Travel	493
TOTAL	$39,756

Title: Storage Decay Research

Principal Investigator: David Sugar, Professor
OSU, Southern Oregon Research and Extension Center

Cooperators: R.A. Spotts, P. Sanderson

Objective:
The goal of this research is to develop a storage decay control program for winter pears in which diverse, independent decay control practices contribute to dependable reduction of postharvest diseases.

Significant Findings:
1. New and previously available pear flotation materials were evaluated their potential effects on fruit injury risk and decay control. Only an ammonium sulfate product combined with Steri-Seal caused fruit injury from short exposure to solutions at 40^{o}F. Injury was more frequent at warmer temperatures and was associated with specific materials, influenced in part by pH.

2. Setting the stage for Scholar: Scholar fungicide has provided consistently high levels of decay control at 8 oz./100 gallons of solution, whether applied alone or in combination with ethoxyquin, biocontrol agents, or in water laden with dirt and debris. Application of Scholar at the earliest postharvest opportunity appears to be the most beneficial. *Penicillium* isolates from late-season re-pack showed high frequency of resistance to TBZ, and no resistance to Scholar, although some isolates were less sensitive than others.

3. Potential new biocontrol agents BioCure and BioCoat reduced gray mold incidence but were not as consistent as the yeast CIM. Various combinations of biocontrol, fungicides, baking soda, chlorine, and Messenger are being evaluated as line sprays.

4. Both naturally occurring and inoculated decay were reduced in LifeSpan MAP bags. Decay reduction was associated with higher levels of CO_2 in the bags.

5. Orchard decay control programs targeted for specific markets are being identified by comparing different sequences of fungicide + calcium in the orchard and biocontrol or fungicide postharvest.

Results and Discussion:
1. Available pear flotation agents were evaluated for potential fruit injury and for their influence on pear decay. Flotation materials primarily affect fruit injury via their influence the phytotoxicity of SOPP. This can be associated with pH, since the more phytotoxic form of SOPP increased with lowering of pH. However, there are exceptions to the pH association, as has been found with lignosite. Furthermore, the phytotoxicity was found to be highly influenced by the temperature of the flotation solution (Table 1). Combinations of flotation agents may alter the fruit injury risk, both through effects on pH and through intrinsic properties of the materials (Table 2). Decay results will be evaluated in early 2003.

2. Scholar has previously been shown to be highly effective in controlling various types of fungi causing pear decay. As of 2003, Scholar has been registered for postharvest use on stone fruits. The product producer anticipates registration on pears in 2004 or 2005. Registration of Scholar will open the possibility of two fungicide treatments (Scholar and TBZ) where logistically feasible. Experimental applications at harvest and/or at three weeks after harvest indicated that the greatest benefit was from application of Scholar, and that if Scholar and TBZ are to be applied in sequence,

Scholar should be applied at the earliest opportunity (Table 3). Isolates of *Penicillium* spp. were cultured from blue mold decay on Bosc pears during repack in March, 2002, and tested for sensitivity to TBZ and Scholar. A large portion of this population was not inhibited by TBZ, while the same isolates were suppressed by Scholar (Fig. 1). Variability in the levels of sensitivity to Scholar were noted, however, indicating the risk of resistance development and the need for proper management.

3. Evaluations of the yeast CIM (*Cryptococcus infirmo-miniatus*) continue in preparation for potential registration. Candidate biocontrol products BioCure (*Candida saitoana* + enzyme) and BioCoat (*C. saitoana* + chitosan) reduced gray mold incidence but were not as consistent as CIM (Table 4). Various combinations of biocontrol, fungicides, baking soda, chlorine, and Messenger are currently being evaluated as line sprays. New fungicide PH066 (Janssen Pharmaceutica) provided equivalent control of blue and gray molds when applied in water- or wax-based solutions (Table 5).

4. Naturally-occurring decay was suppressed in Anjou pears stored in LifeSpan MAP bags for seven months. Bags containing hydrated lime sachets to absorb CO_2 had decay levels similar to pears in standard liners, indicating a key role for the elevated CO_2 accumulation in LifeSpan bags (Fig. 2).

5. Various combinations of calcium, ziram, and Flint in the orchard, and biocontrol agents or TBZ as postharvest line sprays, were applied to Bosc pears in 2002. The goal is to identify the potential decay control of various programs targeted to various markets or grower objectives. Decay will be evaluated early in 2003.

Table 1. Injury (phytotoxicity) rating on Comice pears floated in various solutions at specific gravity 1.05, with or without Steri-Seal or chlorine. All fruit were thoroughly rinsed with fresh water following flotation for the indicated length of time. Temperatures indicate initial solution temperatures. Fruit were maintained at ~32 F before and after flotation.

Injury rating: 0= none, 1= slight, 2 = moderate, 3= severe. [a] = darkened lenticels only.

		Flotation temperature and time (min.)							
		40 F				**68 F**			
	pH	15	30	45	60	15	30	45	60
1. Water	6.9	0	0	0	0	0	0	0	0
2. Water + Steri-Seal 0.5 %	10.8	0	0	0	0	0	0	0	0
3. Water + Steri-Seal 1%	11.2	0	0	0	0	0	0	0	0
4. Water + chlorine 100 ppm	6.9	0	0	0	0	0	0	0	0
5. Sodium carbonate	11.2	0	0	0	0	0	0	0	0
6. Sodium carb. + SS 0.5%	11.3	0	0	0	0	0	0	0	0
7. Sodium carb. + SS 1%	11.3	0	0	0	0	0	0	0	1[a]
8. Sodium carb. + chl 100 ppm	11.8	0	0	0	0	0	0	0	0
9. K-Float	12.2	0	0	0	0	0	0	0	0
10. K-Float + SS 0.5%	12.4	0	0	0	0	0	0	0	0
11. K-Float + SS 1%	12.2	0	0	0	0	0	0	0	0
12. K-Float N	7.0	0	0	0	0	0	0	0	0
13. K-Float N + chl 100 ppm	7.0	0	0	0	0	0	0	0	0
14. Lignosite	7.1	0	0	0	0	0	0	0	0
15. Lignosite + SS 0.5%	8.9	0	0	0	0	0	0	0	0
16. Lignosite + SS 1%	9.6	0	0	0	0	0	0	0	0
17. Xeda F	11.0	0	0	0	0	0	0	0	0
18. Xeda F + SS 0.5%	11.2	0	0	0	0	0	2	3	3
19. Xeda F + SS 1%	11.3	0	0	0	2	2	3	3	3
20. Xeda FC	7.7	0	0	0	0	0	0	0	0
21. Xeda FC + chl 100 ppm	7.7	0	0	0	0	0	0	0	0
22. Calcium chloride	6.8	0	0	0	0	0	0	0	0
23. Calcium chloride + SS 0.5%	10.6	0	0	0	0	0	0	1	2
24. Calcium chloride + SS 1%	11.3	0	0	0	0	0	0	0	2
25. Calcium chl. + chl 100 ppm	6.9	0	0	0	0	0	0	0	0
26. Sodium sulfate	7.5	0	0	0	0	0	0	0	0
27. Sodium sulfate + SS 0.5%	10.9	0	0	0	0	0	0	0	2
28. Sodium sulfate + SS 1%	11.7	0	0	0	0	0	2	3	3
29. Sodium sulf. + chl 100 ppm	8.4	0	0	0	0	0	0	0	0
30. GS-150 (Amm. sulfate)	6.5	0	0	0	0	0	0	0	0
31. GS-150 + SS 0.5%	8.0	0	2	3	3	2	3	3	3
32. GS-150 + SS 1%	8.3	2	3	3	3	2	3	3	3
33. GS-150 + chlorine 100 ppm	6.5	0	0	0	0	1	1	3	3

Table 2. Injury (phytotoxicity) rating on Comice pears floated in combination solutions at specific gravity 1.05 with 1% Steri-Seal. All fruit were thoroughly rinsed with fresh water following flotation for the indicated length of time. Temperatures indicate initial solution temperatures. All fruit were maintained at ~32 F before and after flotation. Lig = lignosite (calcium lignosulfonate).
Injury rating: 0= none, 1= slight, 2 = moderate, 3= severe

Flotation material combination		Flotation temperature and time (min.)							
		40 F				**68 F**			
	pH	15	30	45	60	15	30	45	60
1. 10% Lig + 90% K-Float	11.7	0	0	0	0	0	2	3	3
2. 25% Lig + 75% K-Float	11.3	0	0	0	0	2	3	3	3
3. 50% Lig + 50% K-Float	10.7	0	0	0	0	2	3	3	3
4. 10% Lig + 90 Xeda F	11.0	0	1	3	3	3	3	3	3
5. 25% Lig + 75 Xeda F	10.3	0	0	0	0	2	3	3	3
6. 50% Lig + 50 Xeda F	9.9	0	0	0	0	0	1	2	3
7. 10% K-Float + 90% Xeda F	11.3	0	0	1	2	3	3	3	3
8. 25% K-Float + 75% Xeda F	11.4	0	0	0	0	3	3	3	3
9. 50% K-Float + 50% Xeda F	11.6	0	0	0	0	2	3	3	3
10. 10% Xeda F + 90% K-Float	12.0	0	0	0	0	0	0	2	3
11. 25% Xeda F + 75% K-Float	11.8	0	0	0	0	0	2	3	3

Table 3. Effect of fungicide treatment timing and sequence on postharvest decay in Bosc pears.

		% of wounds infected			
Treatment at harvest	Treatment at + 3 wks	Blue mold	Gray mold	Side rot	Total
Water	-	26.2 a	21.4 a	43.8 a	85.2 a
TBZ	-	11.4 b	1.2 b	16.8 a	29.4 b
Scholar	-	0.0 c	2.4 b	1.0 b	5.2 c
TBZ	Scholar	3.0 c	1.6 b	3.8 b	11.0 c
Scholar	TBZ	0.2 c	0.8 b	0.4 b	2.4 c

Table 4. Effects of biocontrol treatments on gray mold in Bosc pears. Inoculation with *Botrytis cinerea*; treatments applied by linespray.

	Lesion diameter (mm)		% wounds infected	
Treatment	Inoculation 24 hr before treatment	Inoculation < 2 hr before treatment	Inoculation 24 hr before treatment	Inoculation < 2 hr before treatment
Check	20.8 a	20.8 a	61.6 a	61.6 a
BioCure	6.0 b	5.9 b	22.0 b	19.2 b
BioCoat	4.7 bc	1.1 b	17.6 b	3.2 c
CIM	0.8 c	1.3 b	3.6 c	4.0 c
TBZ	2.9 bc	2.3 b	7.6 c	6.0 c

Table 5. Effect of new fungicide PH066 (Janssen Pharmaceutica) on incidence of blue and gray molds in Bosc pears.

Conc. (ppm)	% of wounds infected		Conc. (ppm)	% of wounds infected	
Water base	Blue mold	Gray mold	**Wax base**	Blue mold	Gray mold
check	25.6 a	62.4 a	check	37.0 a	14.8 a
500	14.0 b	44.0 b			
750	7.0 c	17.0 c	1000	12.8 b	2.8 b
1000	6.8 c	5.0 cd	1500	6.6 c	1.2 b
1500	2.0 c	2.4 d	2000	4.2 c	0.6 b
TBZ standard	4.2 c	8.2 cd	TBZ	3.6 c	2.6 b

Fig. 1 Fungicide Sensitivity in *Penicillium* spp. Isolates

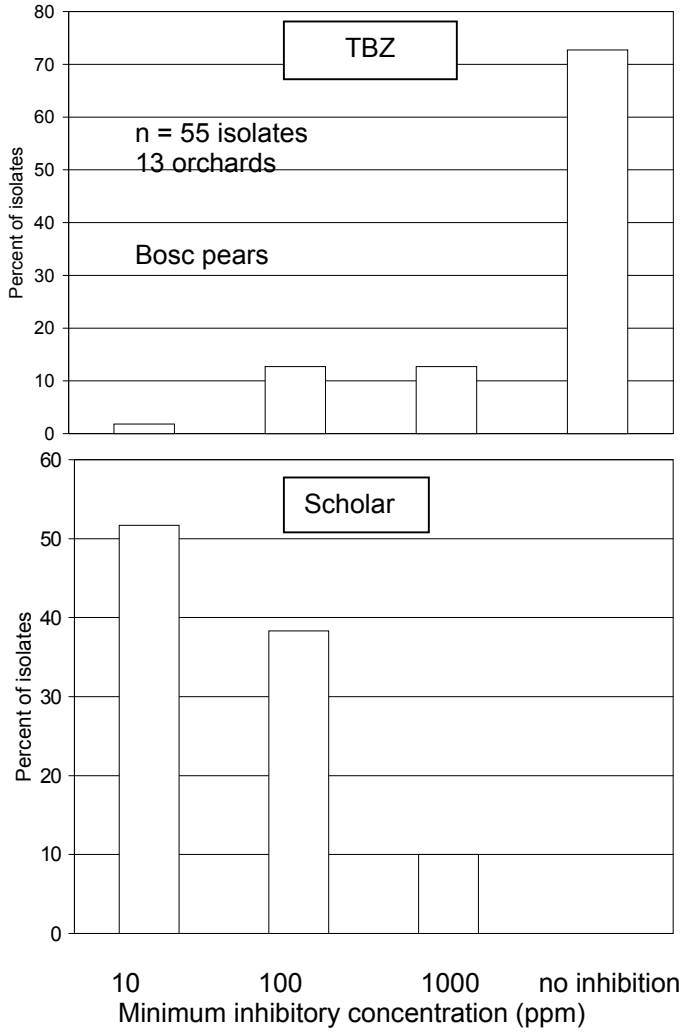
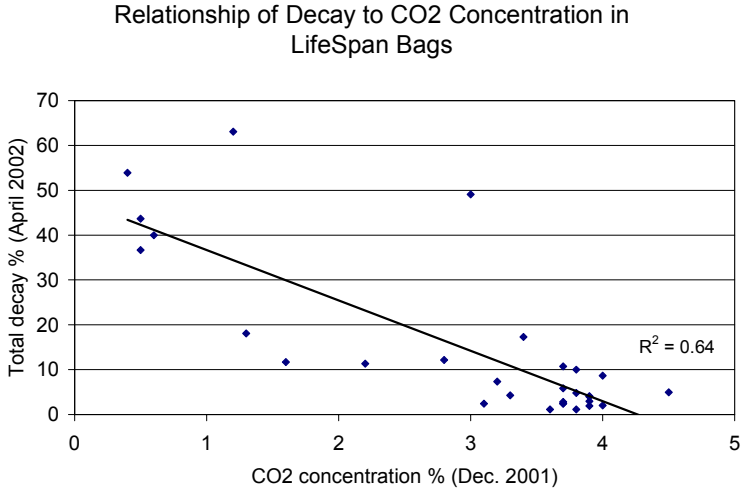


Fig. 2.



Objectives: This research will blend 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.

Justification for Proposed Research: Postharvest decay continues to cause significant economic losses in the pear industry. This research program has been focused on the development and evaluation of control tactics for pear decay. However, because of the importance of fruit quality in helping the pear industry meet their objectives, research will expand to include new technologies and opportunities for quality enhancement.

Procedures: The research will be conducted in the orchards and laboratories of the Southern Oregon Research and Extension Center in Medford, and in commercial orchards and packinghouses where appropriate. These areas will be emphasized:

1. Explore strategies to improve postharvest quality of pears. Techniques will include MCP treatments, ethylene management, packaging materials, new products and atmospheres, and combinations of treatments to achieve maximum benefits.

2. Evaluate products, dosages, and timing of chemical applications to maximize benefit for control of postharvest diseases. Test integrated strategies to optimally manage postharvest decay.

3. Continue studies of biocontrol agents and how they may be used most effectively in different types of pear handling and storage systems.

Estimated Duration: 1 year.

Budget Requested:

Title: Storage Decay Research
Principal Investigator: David Sugar, Professor

Item	Amount
Salaries and Wages	24,000
Services and Supplies	5,600
Travel	400
Total	30,000

Title: Epidemiology of Bull's-Eye Rot in Pear

Project Leader: David Sugar, Professor
Oregon State University, So. Oregon Research and Extension Center

Robert A. Spotts, Professor
OSU, Mid-Columbia Research and Extension Center
James E. Rahe, Simon Fraser University, B.C.

Cooperator: Andre Levesque, Agri-Food Canada

Objective: To understand the disease cycle of bull's-eye rot in pear, so that vulnerable points can be identified and corresponding control measures implemented effectively.

Significant Findings:
1. In an extensive sampling of bull's-eye rot from around the Pacific Northwest, approximately 500 isolates have been accumulated for species identification by combining PCR analysis of the fungus DNA with microscopic examination. To date, all isolates collected in 2002 have been identified as either *Neofabraea alba* or *N. perennans*, in roughly equal proportion. In western British Columbia, the species identified have been *N. alba* and *N. malicorticis*.

2. Monthly inoculations of wounded pear bark with the bull's-eye fungi indicate that pear wood appears to be susceptible from September through April; inoculations from May through August have not resulted in canker development.

3. Spore production by *N. alba* and *N. perrenans* from pear tree cankers follows a seasonal pattern, rising substantially in spring and again in autumn during later winter pear harvest.

4. In fruit covered with bags during the growing season and unbagged for sequential two-week "windows", there was an increase in incidence of bull's-eye in the later half of the growing season. In one orchard, peak bull's-eye incidence was associated with exposure during late June and also with exposure in late August

5. Fruit infection can take place with only 30 minutes of sustained wetness on the fruit surface. Infection was favored by cooler temperatures; the highest amount of infection occurred of 50 F, while infection decreased sharply at 68 and 86 F.

6. Fruit from 19 orchards were evaluated for decay incidence during re-packing in March 2002. Thirteen of the orchards used over-tree irrigation, while six used under-tree irrigation. Overall incidence of bull's-eye rot was low, but was five times greater in fruit from orchards using over-tree irrigation.

7. In tests on inoculated fruit, Mertect effectively controlled all three species of bull's-eye rot fungi. Flint and ziram were moderately effective against *N. alba* and *N. malicorticis* but less effective on *N. perennans*. Ziram was the most effective fungicide tested for suppression of spore production on tree cankers and suppression of spore germination. Copper treatments also reduced spore production, especially with *N. malicorticis*.

8. During two seasons, the incidence of bull's-eye rot developing after 6 weeks at 50° F was not significantly different than after 5 months at 30° F. This is a promising method for predicting the risk of bull's-eye rot development in long-term storage lots.

Results and Discussion:

1. *Identity of fungi causing bull's-eye rot*. In an extensive sampling of bull's-eye rot from around the Pacific Northwest, approximately 500 isolates have been accumulated for species identification by combining PCR analysis of the fungus DNA with microscopic examination. To date, all isolates collected in 2002 from Oregon and Washington have been identified as either *Neofabraea alba* or *N. perennans*, in roughly equal proportion. This has been the case for all growing districts, though the number of samples available from central Washington was small. Thus in our experience the species assumed to be a major pathogen of both apple and pear, *N. malicorticis*, has been found only rarely in pear. The presence of *N. alba* in the Northwest had not been noted prior to this study.

2. *Tree susceptibility to canker development*. Monthly inoculations of wounded pear bark with bull's-eye fungi indicate that pear wood appears to be susceptible from September through April; inoculations from May through August have not resulted in canker development. Cankers resulting from inoculations in October through February developed acervuli (spore-producing structures). Later inoculations through the spring produced fewer acervuli. *N. alba* differed from the other two species causing bull's-eye in showing a lack of virulence on dormant shoots and in having slightly higher virulence on actively growing shoots of pear than of apple.

3. *Spore production on cankers*. Spore production by *N. alba* and *N. perrenans* from pear tree cankers follows a seasonal pattern (Fig. 1). While spore production does not disappear completely during mid-summer, spore production rises substantially in spring and again in autumn during later winter pear harvest. Splash dispersal of spores from tree cankers provides inoculum for new infection of trees and for the fruit infection which appears as lesions after long-term storage.

4. *Timing of fruit exposure to bull's-eye spores*. In two Bosc pear orchards with histories of bull's-eye rot, a large number of fruit were covered with paper bags. Bags were then removed from sequential replicate sets of fruit for two-week "windows" of exposure over the course of the growing season. Bull's-eye rot appeared in fruit from every exposure window from petal-fall through harvest, probably due to the use of frequent over-tree irrigation in both orchards. However, there was an increase in incidence of bull's-eye in the later half of the growing season. In one orchard, peak bull's-eye incidence was associated with exposure during late June and also with exposure in late August (Fig. 2). In another experiment, half of the sprinkler risers in an orchard block were brought to ground level, while half were left as over-tree. Fruit were bagged and sequentially exposed in both treatments. Bull's-eye development will be evaluated in early 2003.

5. *Effect of wet period duration and temperature*. Results of fruit inoculations inside of controlled-temperature limb cages at MCAREC showed that fruit infection can take place with only 30 minutes of sustained wetness on the fruit surface. Infection was greatly favored by cooler temperatures; the highest amount of infection occurred of 50 F, while infection decreased sharply at 68 and 86 F (Fig. 3).

6. *Effect of irrigation method*. Several aspects of our study have implicated frequency of rainfall or over-tree irrigation as important factors in bull's-eye rot severity. The fungi that cause bull's-eye rot produce spores in a gelatinous matrix that appears to release spores into splashing water droplets rather than into dry air. The persistence of bull's-eye rot on the trees, as well as the probability of fruit infection are likely to be influence by the frequency of tree wetting, either through rainfall or irrigation. In the southern Oregon growing district, the traditionally worst orchards for bull's-eye have over-tree irrigation, and in the Mid-Columbia district severe bull's-eye year have been associated with high rainfall during the growing season. During re-packing at a cooperative packinghouse in Medford in March 2002, fruit from 19 orchards were evaluated for decay incidence. Thirteen of the orchards

used over-tree irrigation, while six used under-tree irrigation. Overall incidence of bull's-eye rot was low, but was five times greater in fruit from orchards using over-tree irrigation.

7. *Fungicide effects*. (1) Anjou fruit were inoculated with 50 µl per wound of water containing 10,000 conidia per ml of *Neofabraea alba, N. malicorticis,* or *N. perennans*. Conidia were harvested from lesions on Anjou pear fruit that had been incubated 21 days at 10° C in the dark. Three replicates of 20 fruit per replicate were treated with each fungicide for each species. Treated fruit were place in fiberboard trays in cardboard fruit boxes with perforated polyliners, stored at 10° C, and evaluated after 15 days. Mertect effectively controlled all three species (Table 1). However, while some bull's-eye rot infection probably occurs after harvest, postharvest Mertect applications are too late for infections begun in the orchard, believed to be the principal infection type. Flint and ziram were moderately effective against *N. alba* and *N. malicorticis* but less effective on *N. perennans*. Thiram and Dithane were the least effective fungicides. (2) Ziram, Flint and copper fungicides were tested for their effect on the production of spores (conidia) by established cankers of *N. alba* and *N. perrenans*, and on subsequent germination of spores of these fungi. Spore production by both species was suppressed most by ziram (Fig. 4). Spore production by *N. alba* was also suppressed by Flint and copper, but spore production recovered more quickly following copper treatment than with ziram or Flint. Germination of spores from treated cankers of both species was suppressed by ziram, with a lesser effect of Flint on germination of *N. alba*. Suppression of spore production and germination are important since the probability of successful infection increases with greater numbers of viable spores.

8. *Bull's-eye rot prediction*. We have tried to predict the amount of bull's-eye rot in pear fruit by freezing a sample of the fruit, then holding it at 50° F to speed up the development of the disease. The method has been successful with d'Anjou but not Bosc. In this study, we inoculated Bosc fruit with spores of the pathogen, then held half of the fruit at 50°F without freezing and half in air storage at 30° F, then compared the amount of decay that develops at each temperature. The goal is to obtain equal amounts of decay in both groups, but to see bull's-eye rot develop in the fruit at 50° in six weeks rather than in the normal 16 weeks that is common at 30°F. During two seasons, the incidence of bull's-eye rot developing after 6 weeks at 50° F was not significantly different than after 5 months at 30° F (Table 2). This method for predicting bull's-eye rot is promising and needs to be evaluated with Bosc pears from other growing districts. The incubation time at 50° F may be changed from 6 to 5 weeks since decay results appeared similar but problems with breakdown of fruit were less.

Table 1. Postharvest fungicide dips for control of bull's-eye rot of Anjou pear

		Percent infection			
Fungicide	Rate per 4 liters	*N. alba*	*N. malicorticis*	*N. perennans*	Avg
Mertect 340F	5.0 ml	5	0	10	5
Flint 50WG	0.445 gm	37	20	73	43
Ziram 76DF	19.2 gm	25	42	65	44
Thiram Granuflo	16.0 gm	87	87	93	89
Dithane DF	7.2 gm	95	85	100	93
Control		100	100	100	100

Table 2. Prediction of bull's-eye rot of Bosc using 50º F short term storage

	Percent fruit infected		
Season	50ºF/6 wk.	30ºF/5mo.	*P*
2000-1	64a	84a	0.08
2001-2	83a	79a	0.40

Fig. 1. Seasonal spore production from cankers of *N. perrenans* strain MA-001 on Bosc pear trees.

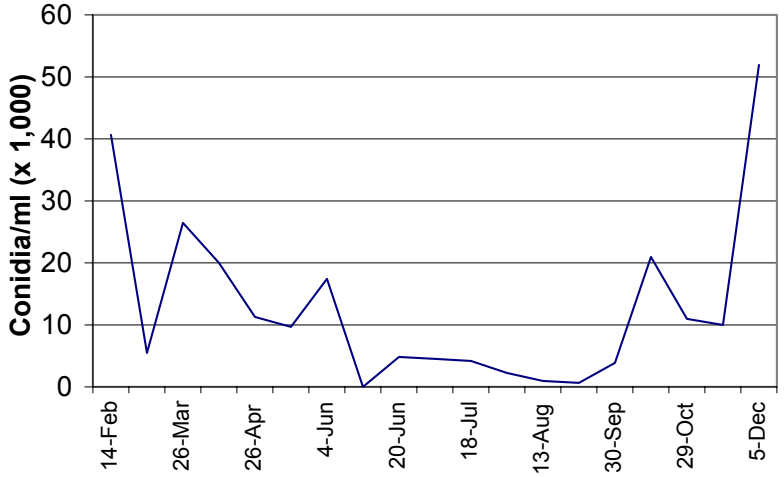


Fig. 2. Incidence of bull's-eye rot in Bosc pears in a commercial orchard near Medford, Oregon. Fruit were covered with paper bags from late fruit set until harvest (W0), or exposed for sequential two-week periods. W1 = mid-June through early July; W5 = mid-to late August.

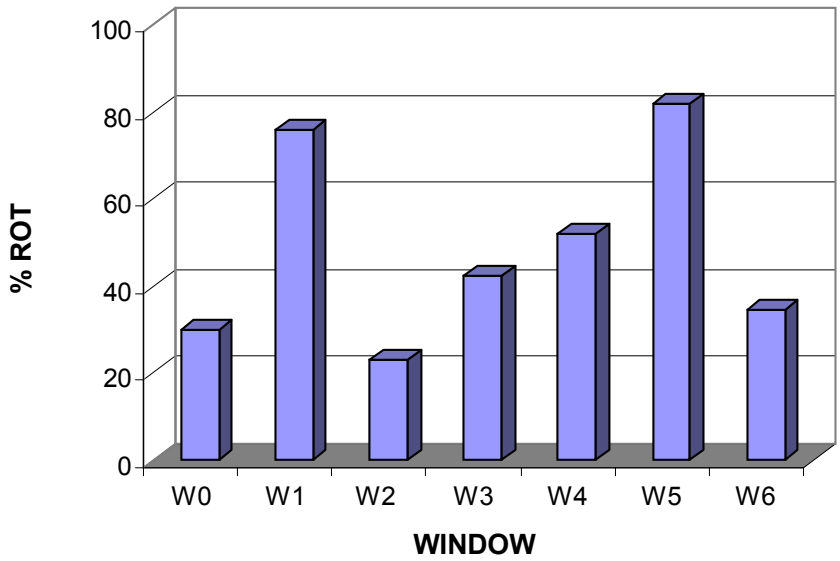


Fig. 3. Effect of wetness period duration and temperature on development of bull's-eye rot (*N. perrenans*) on Anjou pears at MCAREC. Disease index = incidence x severity.

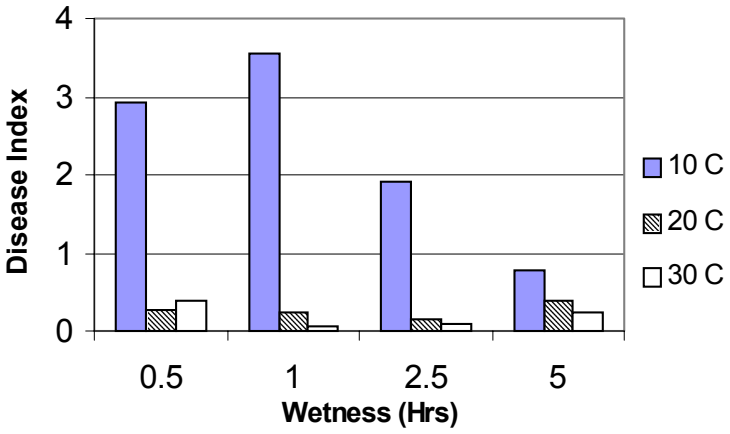
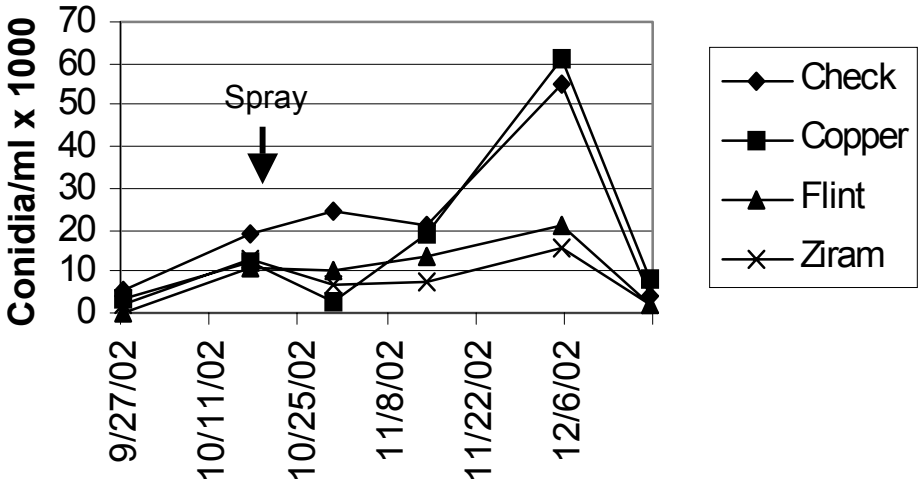


Fig. 4. Production of conidia (spores) by *N. alba* strain MB-0128 from cankers following orchard sprays with various fungicides.



Justification for Proposed Research: Growers in Washington and Oregon periodically suffer from severe outbreaks of bull's-eye rot in stored pears. In part, this project arose from the frustration of the project leaders in attempting to control bull's-eye rot in pear fruit. Although we have conducted many spray trials, there is a sense of "shooting in the dark" without a more fundamental knowledge of the cycle of events which describe this disease. This project has linked scientists at OSU and a graduate student at OSU working on the bull's-eye rot problem with scientists in Canada who have recently made important progress in understanding perennial canker disease in apple, and have developed molecular techniques for precise identification of fungus species involved in cankers and fruit rots.

Budget Requested for 2002-2003:

Title: Epidemiology of Bull's-Eye Rot in Pear
Project Leader: David Sugar, Professor

Item	Amount
Salaries and Wages	4,100
Services and Supplies	300
Total	4,400

Estimated Duration: 3 months (July – Sept. 2003).

Procedures: This project is close to completion. A large amount of information has been generated, and preliminary conclusions have outlined the understanding of bull's-eye rot in pear that the data have indicated. Limited support is requested through September, 2003 in order to evaluate of experiments initiated in 2002 and early 2003, and to complete analysis and summarization of data.

Project title: Manipulation of Pear Fruit Ripening by Control of Ethylene Action

PI: James Mattheis, Plant Physiologist
Organization: USDA, ARS, Wenatchee, WA

Co-PI(s) and affillation(s): Paul Chen, Professor
Oregon State University, Mid-Columbia Experiment Station

Cooperator(s): Rodney Roberts, Plant Pathologist
USDA, ARS, Wenatchee, WA
David Rudell**,** Biological Science Technician
USDA, ARS, Wenatchee, WA

Objectives:
A primary objective of postharvest management of pears is to prolong storage life by reducing the rate of fruit ripening. The combination of optimum maturity, refrigeration, postharvest chemical treatments and controlled atmosphere storage slow ripening and reduce physiological disorders and decay. Controlled atmosphere storage in particular reduces ethylene production as well as the capacity of fruit to respond to ethylene, responses that provide the residual effects of CA after fruit is removed from storage. Because of the importance of ethylene in regulating the processes of fruit ripening, practices that interfere with its production and/or action are useful in the commercial storage of pears.

Researchers at North Carolina State University, Dr. Ed Sisler and Dr. Sylvia Blankenship have identified a compound that interferes with fruit ethylene metabolism. This compound, 1-methylcyclopropene (MCP), inhibits ethylene perception and shows great potential as a tool for postharvest management of pears. MCP is a volatile compound that can be applied as a gas treatment without drenching fruit. Results with a number of fruit crops have demonstrated MCP treatment can reduce the rate of climacteric fruit ripening as well as development of a number of physiological disorders.

SIGNIFICANT FINDINGS: 2000-2002

- MCP treatment of 'Bartlett', 'Bosc', 'Comice' or 'd'Anjou' pears with MCP at concentrations between 0.1 to 1 ppm delays ripening and development of physiological and pathological disorders. 'Bosc' responses to MCP treatment are similar to those of 'd'Anjou', 'Comice' responses are intermediate between 'Bartlett' and 'd'Anjou'.

- Treatment of commercially packed boxes of 'Bartlett' or 'd'Anjou' results in typical MCP responses (reduced respiration, ethylene production, slowed loss of quality, delayed onset of decay and development of physiological disorders).

- The window for delaying MCP treatment of 'Bartlett' is 2 weeks after harvest to achieve maximum response. For 'd'Anjou', treatment can be delayed up to 4 weeks depending on the MCP treatment concentration.

- Fruit temperature (32 to 68 ^{o}F) during MCP treatment is not a critical determinant of fruit response.

- The long-term effects of MCP for slowing ripening of 'Bartlett' pear are inconsistent between production seasons.

- Partially ripe ‘Bartlett’ or ‘d’Anjou’ fruit treated with MCP ripen at a reduced rate compared to non-treated controls. The magnitude of MCP responses is dependent on fruit maturity when MCP is applied. This trend is evident when fruit are riper due to delayed harvest or delayed MCP treatment after harvest. Previous storage in CA increases the likelihood of success of ripening delay with a post-storage treatment.

- Ethylene treatments up to 10,000 ppm do not result in full recovery of the capacity to ripen in ‘Bartlett’ fruit treated with 0.1 to 0.5 ppm MCP.

- The duration of MCP responses for ‘Bartlett’ fruit is dependent on storage temperature after treatment. Fruit treated at 0.5 ppm and stored at 68 ^{o}F ripen within one month of treatment.

- Storing ‘Bartlett’ or ‘d’Anjou’ fruit in CA following treatment with MCP prolongs the inhibition of ripening compared to RA storage. MCP concentration for ‘Bartlett’ can be lower for fruit stored in CA compared to RA.

- MCP treatment does not increase sensitivity of ‘Bartlett’ or ‘d’Anjou’ fruit to CO_2 during CA storage.

- Storage of MCP treated ‘d’Anjou’ at 4.5% O_2 with 0.5% CO_2 may be optimum for long-term (8-9 months) storage.

- Low (30-50 ppb) MCP rates slow ‘Bartlett’ ripening and may prevent ‘d’Anjou’ superficial scald with minimal delay of ripening.

Methods:

1. Determine treatment conditions to maximize responses of pear cultivars to MCP.

2. Determine duration of responses when treated fruit are stored in RA or CA conditions.

3. Determine the impact of MCP treatments on fruit physiological disorders and decay.

Procedures:

Pears were obtained from commercial orchards. Fruit were held at in air at 68 or 33 ^{o}F or CA (1.5% O_2, 0.5% CO_2) until MCP treatments were conducted. The treatments were applied to fruit in sealed steel or plastic chambers at 70 ^{o}F for 12 h.

MCP was generated from SmartFresh powder provided by Agrofresh, Inc, a subsidiary of the Rohm and Haas Company. Target MCP concentrations, monitored by gas chromatography were reached within 10-15 minutes after initiation of gas generation.

Fruit firmness was measured using a Mohr Digi-Test instrument (Mohr and Associates, Richland, WA). Titratable acidity (TA) was determined by titrating fresh juice to pH 8.2, and soluble solids content (SSC) was measured with a refractometer (Atago, Tokyo).
Fruit respiration and ethylene production were determined using gas chromatography.
Fruit visual assessments. Peel color was rated 1:green to 5:yellow. Superficial and senescent scald were rated as 1:none, 2: 1 to 33%, 3: 34 to 66%, 4: 67 to 100% fruit surface with light brown discoloration, 5: 1 to 33%, 6: 34 to 66%, 7: 67 to 100% fruit surface with dark brown discoloration. Internal breakdown and core browning (browning within the core line) were rated as 1: none, 2: slight, 3: moderate, 4: severe.

Scuffing was rated as 1: absent, 2: present. Objective measures of fruit color were performed using a Minolta colorimeter.

Results and discussion:
Bartlett 2002-03

B1. Fruit maturity and response to MCP. 'Bartlett' pears were harvested on three dates from a commercial orchard. Fruit firmness at harvest was 19.4, 17.5 and 15.4 lbs, respectively, for harvests 1, 2 and 3. Fruit were treated the day of harvest with 50 or 300 ppb MCP for 12 h at 68 ^{o}F, then stored at 32 ^{o}F in air or CA (1.5% O_2, 0.5% CO_2). After two months in storage plus 7 days at 68 ^{o}F , fruit from all 3 harvests treated at 50 ppb then stored in air ripened but remained firmer than untreated controls. Fruit treated at 300 ppb, or both MCP treatments stored in CA did not ripen sufficiently during the 7 days at 68 ^{o}F . After 4 months plus 7 days ripening, all harvest 1 controls had decay, senescent scald and/or internal breakdown. Both MCP treatments stored in air had high (>95%) incidence of decay or internal breakdown after 7 days ripening, however, treated fruit stored in CA did not soften. Additional results will be presented at the research review.

B2. Pre-conditioning of MCP treated fruit. 'Bartlett' pears harvested at 16.6 lbs were treated the day of harvest at 300 ppb MCP. Fruit were stored at 32 ^{o}F in air with up to 15 days at 68 ^{o}F after 1, 3 or 5 months, then return to 32 ^{o}F for 8 or 10 weeks. Initial results indicate 5 days at 68 ^{o}F enhances the capacity for subsequent ripening after return to cold storage. Additional results will be presented at the research review.

B3. Post-storage MCP treatment. 'Bartlett' pears were obtained from a local packer ~1 week after harvest. Fruit were stored at 32 ^{o}F in air, and after 0, 3 or 6 weeks, treated with 1 ppm MCP, then held at 32 ^{o}F for an additional 0, 2 or 4 weeks plus 7 or 14 days ripening. At the time of MCP treatment, fruit stored 0, 3 or 6 weeks at 32 ^{o}F averaged 14.9, 15.2 and 12.0 lbs, respectively. MCP treatment applied after no additional storage (1 week after packing) was effective for delaying ripening and onset of physiological and pathological disorders for an additional 4 weeks cold storage plus 14 days ripening. MCP applied 4 weeks after packing when firmness averaged 15.2 lbs was effective for controlling ripening for an additional 2 weeks cold plus 14 days at 68 ^{o}F or 4 weeks cold plus 7 days at 68 ^{o}F. MCP treatment applied 7 weeks after packing when firmness averaged 12 lbs delayed ripening for an additional 7 days at 68 ^{o}F, however, all fruit returned to cold for 2 or 4 weeks then allowed to ripen developed internal breakdown and decay.

d'Anjou 2001-02

A1. Interaction of MCP and CA composition. 'd'Anjou' pears treated the day of harvest with 100 or 500 ppb MCP. Fruit were then stored up to 9 months at 32 ^{o}F in air or CA with 1.5, 3 or 4.5 % O_2 with 0.5 or 1.5% CO_2. Quality was determined after 3, 6 or 9 months plus 7 days at 68 ^{o}F . No influence of MCP dose was observed. MCP treated fruit stored in air ripened after 6 and 9 months storage with no (6 months) or low (9 months) incidence of physiological disorders,however, considerable decay was present after 9 months. MCP treatment prevented softening of fruit stored in all CA combinations until 9 months for pears stored in 4.5% O_2 with 0.5% CO_2. Fruit stored at 4.5% O_2 with 0.5% CO_2 were greener and had almost no decay compared to MCP treated fruit stored in air. Some CO_2 injury (internal breakdown) was observed in fruit stored at 1.5%, however, the primary impact of higher CO_2 was prolonging the MCP effect of delaying softening.

A2. MCP/storage environment/days to ripen. 'd'Anjou' pears treated the day of harvest with 100 or 500 ppb MCP were stored at 32 ^{o}F in air or CA (1.5% O_2, 0.5% CO_2). After 3, 6 and 9 months, fruit were removed from storage and held at 68 ^{o}F for up to 21 days to determine the duration necessary for ripening to occur. No effect of MCP rate was observed. After 3 months, MCP treated fruit did

not soften in 21 days regardless of storage environment. After 6 months, MCP treated fruit stored in RA softened to 8 lbs in 14 days, and all MCP treated fruit (RA and CA) were less than 5 lbs after 21 days with no decay or other disorders. After 9 months, MCP-RA fruit were soft after 7 days but had high incidence of decay. MCP-CA fruit had softened after 14 days with low decay incidence and good retention of green peel color.

A3. MCP dose response and storage environment. 'd'Anjou' pears were treated the day after harvest with 0, 10, 50, 100, or 500 ppb MCP for 12 h at 32 ^{o}F, then stored at 32 ^{o}F in air or CA (1.5% O_2, 0.5% CO_2). All MCP treated fruit stored in CA exhibited delayed ripening after removal from storage through 8 months plus 7 days at 68 ^{o}F . All MCP doses delayed ripening of RA-stored fruit, however, effects differed with dose and storage duration. After 3 months, fruit treated at 10 ppb ripened but slower compared to un-treated controls. Higher doses resulted in insufficient softening. After 6 months, all fruit ripened during 7 days at 68 ^{o}F but had less decay and physiological disorders (internal browning, core browning, splits) than un-treated controls. No superficial scald developed on controls or MCP-treated fruit.

'd'Anjou' 2002-2003

A1. MCP rate study. 'd'Anjou' pears from 3 grower lots were treated the day after harvest with 0, 30, 140 or 280 ppb MCP, then stored in air at 32 ^{o}F . Initial results after 3 months storage indicate treatment at 30 ppb was sufficient to prevent superficial scald without delaying softening (controls in only one lot developed superficial scald).

A2. Pre-conditioning of MCP treated fruit (similar to B2 above). 'd'Anjou' pears harvested at 14.3 lbs were treated the day of harvest at 300 ppb MCP. Fruit were stored at 32 ^{o}F in air with up to 15 days at 68 ^{o}F after 2, 4 or 6 months, then return to 32 ^{o}F for 8 or 10 weeks. Up to 15 days at 68 ^{o}F after 2 months storage then return to cold storage did not enhance the capacity for subsequent ripening. Additional results will be presented at the research review.

A3. Post-storage MCP treatment (similar to B3 above). 'd'Anjou' pears previously stored at 32 ^{o}F in air or CA will be treated at 1 ppm MCP, then returned to cold storage for up to 4 weeks followed by up to 14 days at 68 ^{o}F . Results thus far (through Dec 02) indicate previous storage in CA enhances the impact of post-storage MCP treatment. This effect is due in part to higher firmness at the time of MCP treatment of pears stored in CA compared to RA.

Procedures: 2003-2004

1. Optimization of treatment and post-storage conditions. Factors to be evaluated include 1-MCP concentration including low rates, delay after harvest, and pre-conditioning during storage at temperatures above 40 F. Pilot tests at low (30-50) ppb for 'Bartlett' and 'd'Anjou' are proposed. These tests should be conducted using fruit from multiple lots with 'd'Anjou' lots having a high probability for developing superficial scald. Costs for this part of the project are not included in the budget.

2. Response of treated fruit stored in RA or CA. Storage temperature and CA gas composition (particularly at higher O_2 concentrations) will be evaluated with focus on long storage durations.

3. Efficacy of treatments of partially ripe fruit based on fruit firmness will be conducted using fruit from multiple harvests and after various storage durations in RA and CA.

4. 1-MCP effects on metabolism of pigments and other phytoactive compounds will be continued.

Project title: Manipulation of Pear Fruit Ripening by Control of Ethylene Action
PI: James P. Mattheis
Project duration:: 2002-2003
Current year: 2003
Project total (2 years): $54,238
Current year request: $28,163

Year	Year 1 (2002)	**Year 2 (2003)**
Total	$26,075	**$28,163**
Current year breakdown		
Salaries[1]	$17,904	**$19,664**
Operations (lab supplies, fruit)	$ 2,800	**$ 2,600**
Employee benefits	$ 5,371	**$ 5,899**
Total	$26,075	**$28,163**

[1]GS-9 biological science technician, 0.5 FTE

This project was started under ARS Project #5350-43000-003-06T in 2000. Due to administrative contract changes it is now under ARS Project #5350-43000-003-08T.

FINAL REPORT

Project Title: Postharvest Physiology of Winter Pears

PI: Paul M. Chen

Cooperators: J. P. Mattheis; R. A. Spotts; S. R. Drake

Objectives:

1. To extend the marketability of 'd'Anjou' pears by combination of MCP and ethylene treatment.
2. To investigate the dosage effect of MCP treatment on inhibiting ripening capacity and superficial scald disorder of 'd'Anjou' pears after air storage.
3. To investigate the dosage effect of MCP treatment on inhibiting ripening capacity and internal breakdown disorder of 'Bartlett' pears after air storage.
4. To develop innovative procedures for freeze-drying fruit bits of 'd'Anjou' Pears as "value-added" commodities.

Significant findings:

1. To extend the marketability of 'd'Anjou' pears by combination of MCP and ethylene treatment.

   We find that conditioning 'd'Anjou' pears in air enriched with 100 ppm ethylene at 20°C for 3 or 4 days followed by the treatment with 1 ppm MCP at 20°C for 24 hours could extend the shelf-life of "ready-to-eat" 'd'Anjou' fruit for up to 14 days at 20°C. Therefore, 1ppm-MCP treatment provides a powerful tool for extending the marketability of partially ripened 'd'Anjou' pears.

2. To investigate the dosage effect of MCP treatment on inhibiting ripening capacity and superficial scald disorder of 'd'Anjou' pears after air storage.

   We find that pre-storage treatment of 'd'Anjou' pears with 10 to 20 ppb MCP did not inhibit normal ripening process but inhibited the development of superficial scald disorder. It is concluded that pre-storage treatment of 'd'Anjou' pears with 10 to 20 ppb MCP could be used as an alternative method of scald control measure of 'd'Anjou' pears.

3. To investigate the dosage effect of MCP treatment on inhibiting ripening capacity and internal breakdown disorder of 'Bartlett' pears after air storage.

   We find that pre-storage treatment of 'Bartlett' pears with 50 ppb MCP extended storage life in air at -1°C for 4 months and 50ppb-MCP-treated fruit ripened with juicy texture without developing any internal breakdown disorder. It is concluded that pre-storage treatment of 'Bartlett' pears with 50 ppb MCP can extend the storage life of 'Bartlett' pears without inhibiting normal ripening process.

4. To develop innovative procedures for freeze-drying fruit bits of 'd'Anjou' Pears as "value-added" commodities.

   We find the ripe 'd'Anjou' pear slices can be vacuum-infiltrated with soluble-solids solution; subjected to "individually quick freezing" (IQF) process; and then freeze-dried. We identified that one kind of soluble solids can increase the crisp texture of the freeze-dried pear slices. This procedure may provide the pear industry with a potential to turn "Cull-grade" fruit into a profitable "value-added" product.

Methods:

Objective 1. To extend the marketability of 'd'Anjou' pears by combination of MCP and ethylene treatment.

'D'Anjou' pears were harvested at commercial maturity with FF of 14.0 lb (±0.5 lb) on September 12, 2002. Harvested fruits were transferred into 40-lb wooden boxes with polyethylene liner and stored in air at -1°C. After 2 and 4 months of storage, fruits were conditioned in air enriched with 100 ppm ethylene at 20°C for 0 (no conditioning treatment), 1, 2, 3 and 4 days. After conditioning treatment, fruit were treated with 1 ppm MCP at 20°C for 24 hours. MCP-treated fruit were then held in air at 20°C. Changes in flesh firmness (FF) were determined daily for 7 days.

Objective 2. To investigate the dosage effect of MCP treatment on inhibiting ripening capacity and superficial scald disorder of 'd'Anjou' pears after air storage.

'D'Anjou' pears were harvested at commercial maturity with flesh firmness (FF) of 14 lb (±1.0 lb) and held in air at -1°C for 5 days. When the core temperature of fruit reached -1°C, fruit were treated with different dosages of MCP at 20°C for 24 hours. The dosages of MCP were: 0 (Control), 10, 20, 30, 50, 70 and 100 ppb. Treated fruit were stored in air at -1°C for 3, 4, and 5 months. After each storage interval, fruit were held 20°C in a ripening room enriched with 100ppm ethylene (±20 ppm) for 14 days. Changes in flesh firmness (FF), extractable juice (EJ), titratable acids (TA), and soluble solids (SS) were determined on day 1, 7 and 14 of ripening. Incidences of superficial scald disorder were assessed on day 7 and 14 of ripening. Ethylene productions (EP) were determined daily for 15 days at 20°C

Objective 3. To investigate the dosage effect of MCP treatment on inhibiting ripening capacity and internal breakdown disorder of 'Bartlett' pears after air storage.

'Bartlett' pears harvested at optimum maturity (FF of 18 lbs) (H-1) and late maturity (FF of 16 lbs) (H-2) were treated with 50 ppb and 300 ppb MCP within 2 days after harvest. Another group of untreated fruit for each harvest maturity were used as control. Both control and MCP-treated fruits were stored in air at -1°C for 2, 4, and 6 months. After each storage interval, both MCP-treated and control fruit were held at 20°C in air for 14 days. Changes in flesh firmness (FF), extractable juice (EJ), titratable acids (TA) and soluble solids (SSC) were determined on day 1, 7 and 14 of ripening. Incidences of internal breakdown (IB) disorder were assessed on days 7 and 14 of ripening. Ethylene productions (EP) were determined daily for 15 days at 20°C.

Objective 4. To develop innovative procedures for freeze-drying fruit bits of 'd'Anjou' Pears as "value-added" commodities.

'D'Anjou' pears stored in either air or CA storage were ripened in at 20°C until flesh firmness (FF) softened to 6 lb. Fruit were sliced into 16 sectors and then separately vacuum-infiltrated with three different kinds of soluble-solids solutions. Treated fruit sectors were subjected to "individually quick freezing" (IQF) process and then freeze-dried. Freeze-dried fruit sectors were organoleptically tasted for the crispness of its texture.

Results and discussion:

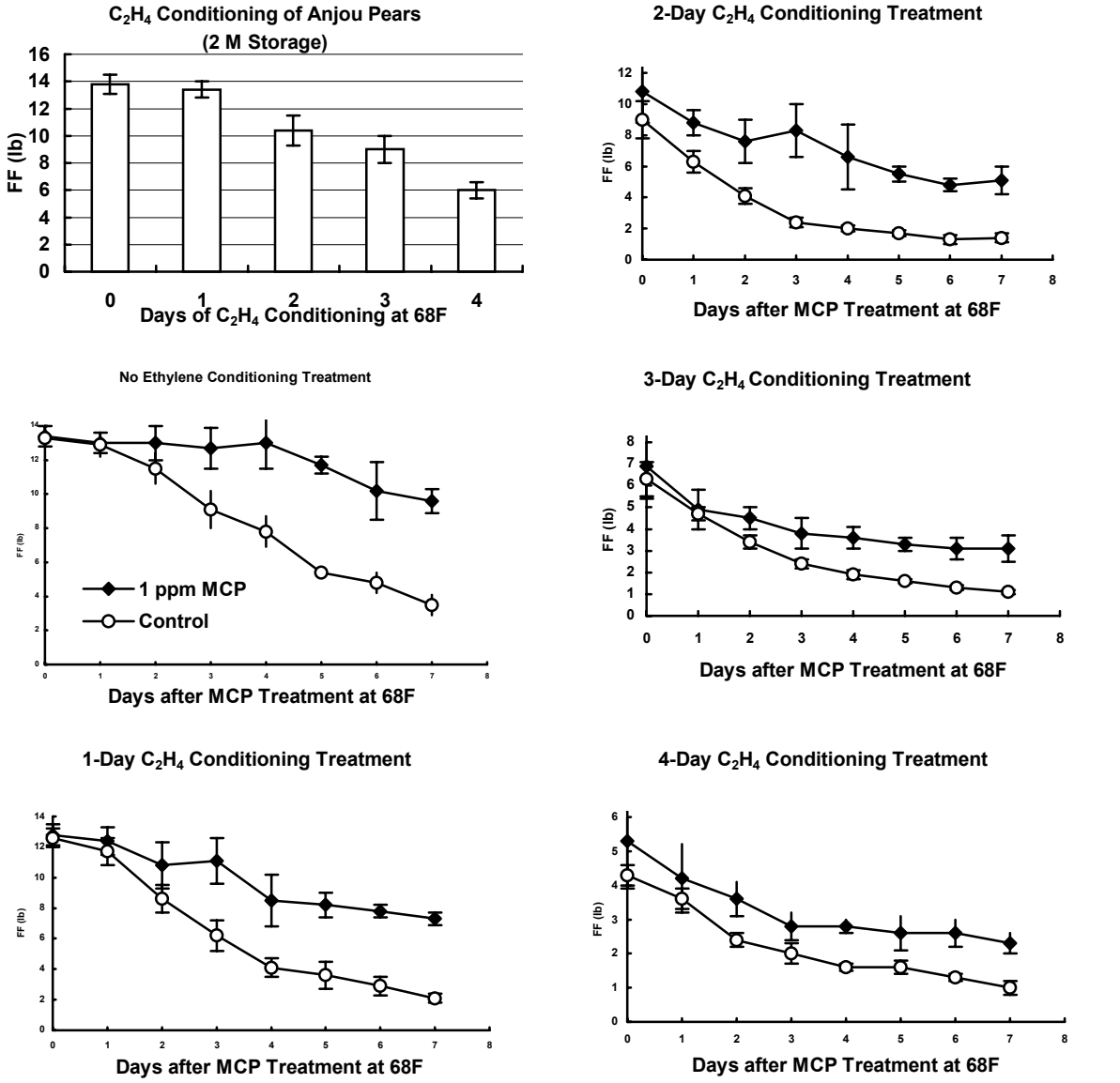
Objective 1. To extend the marketability of 'd'Anjou' pears by combination of MCP and ethylene treatment.

Figure 1 shows the changes in flesh firmness (FF) of 'd'Anjou' pears during 4 days of ethylene conditioning after fruit had been stored in air at -1°C for 2 months. Fruit conditioned for 0, 1, 2, 3 and 4 days softened to flesh firmness of 14, 13.5, 10.5, 9 and 6 lb respectively. After 24 hrs of MCP treatment at 20°C, fruit softened further and decreased by about 1 lb for each conditioned category. MCP-treatment of ethylene-conditioned fruit slowed down the softening process on the

shelf life at 20°C (Fig. 1). Fruit conditioned for 3 and 4 days followed by 1ppm MCP treatment softened to no less than 3 lb on day 7 after MCP treatment (Fig. 1). We find that conditioning 'd'Anjou' pears in air enriched with 100ppm ethylene at 20°C for 3 or 4 days could reach the state of "ready-to-eat" ripeness in the retail markets. Treatment of "ready-to-eat" 'd'Anjou' fruit with 1 ppm MCP at 20°C for 24 hours could extend the shelf-life for up to 14 days at 20°C. Therefore, 1ppm-MCP treatment provides a powerful tool for extending the marketability of partially ripened 'd'Anjou' pears.

We continue to investigate 1ppm-MCP treatment of partially ripened 'd'Anjou' pears when they have been stored in air for 4 months and in CA for 6 months. The results will be presented in the next annual report.

Fig. 1. Fruit softening patterns of 'd'Anjou' pears after 0, 1, 2, 3 and 4 days of ethylene conditioning at 20°C and during 7 days of holding on the shelf at 20°C after 1ppm MCP treatment. 'D'Anjou' fruit had been stored in air at -1°C for 2 months and then conditioned in a ripening room enriched with 100ppm ethylene for 1, 2, 3 and 4 days at 20°C followed by 1ppm MCP treatment at 20°C for 24 hour.

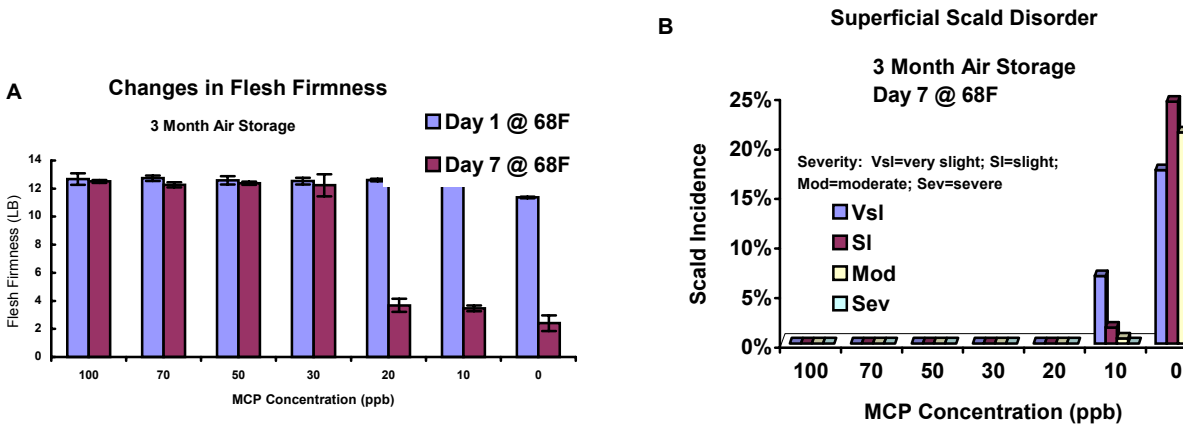


Objective 2. To investigate the dosage effect of MCP treatment on inhibiting ripening capacity and superficial scald disorder of 'd'Anjou' pears after air storage.

After 3 months of storage, 'd'Anjou' fruit treated with 30, 50, 70 and 100 ppb MCP were incapable of softening to the proper ripeness but did not develop any incidence of superficial scald disorder after 7 days at 20°C (Fig. 2, A & B). Fruit treated with 10 and 20 ppb MCP ripened normally and softened to FF of 3-4 lb after 7 days at 20°C (Fig. 2, A). Fruit treated with 10 ppb MCP developed minor incidence of superficial scald disorder on day 7 at 20°C while those treated with 20 ppb MCP were completely free from superficial scald disorder (Fig. 2, B). Control fruit reached the proper ripeness with FF of 2.5 lb on day 7 at 20°C (Fig. 2, A). Ripened control fruit developed very high incidence of superficial scald disorder on day 7 at 20°C (Fig. 2, B). The results indicated that MCP dosage of 10 and 20 ppb could effectively control superficial scald disorder without inhibiting ripening process of 'd'Anjou' pears after 3 months of air storage.

We continue to investigate MCP-treated 'd'Anjou' pears after 4 and 5 months of air storage. The results will be presented in the next annual report.

Fig. 2. Changes in flesh firmness (FF) (A) and incidence of superficial scald disorder (B) of 'd'Anjou' pears after 3 months of air storage at -1°C plus 7 days of ripening at 20°C. Fruit had been treated with different concentrations of MCP within 14 days of storage after harvest.



Objective 3. To investigate the dosage effect of MCP treatment on inhibiting ripening capacity and internal breakdown disorder of 'Bartlett' pears after air storage.

Regardless of harvest maturity, 'Bartlett' pears treated with 300 ppb MCP did not ripen normally and softened to 5.9 lb or firmer during 14 days at 20°C after 2 or 4 months of storage (Tables 1-4). After 2 months of storage, fruit treated with 50 ppb MCP did not ripen properly on day 7 at 20°C (Table 1 and 3). After 4 months of storage, 50ppb-MCP-treated fruit ripened properly on day 7 at20°C regardless harvest maturity (Table 2 and 4). MCP-(50 ppb)-treated fruit also ripened to proper flesh firmness of 2.5 lb and developed minimal incidence of internal breakdown (IB) disorder after 14 days at 20°C regardless of harvest maturity and storage length (Table 1-4). Control fruit softened to below 0.5 lb and developed unacceptable incidence of IB disorder on day 7 or 14 of ripening after 4 months of storage regardless of harvest maturity (Table 2 and 4). It was concluded that pre-storage treatment of 50 ppb MCP did not inhibit normal ripening of 'Bartlett' pears and extended the shelf life for 14 days in the retail markets.

Table 1. Differences in flesh firmness (FF), extractable juice (EJ), soluble solids (SS), and titratable acids (TA) in **optimum mature** 'Bartlett' pears after 1, 7 and 14 days of ripening at 20 C. 'Bartlett' pears had been treated with 300 ppb, 50 ppb, or 0 ppb (Control) MCP within 2 days after harvest (8-18-02) and stored in air at –1 C for **2** months.

Days at 20C	MCP (ppb)	FF	EJ	SS	TA	**IB**
1	300	**18.8 ±0.2**	70.5 ±0.5	12.6 ±0.1	5.5 ±0.4	**0**
	50	**15.7 ±0.2**	66.8 ± 0.8	12.2 ±0.2	4.7 ±0.1	**0**
	Control	**14.7 ±0.3**	65.2 ±0.8	12.1 ±0.1	4.7 ±0.2	**0**
7	300	**13.0 ±0.9**	64.7 ±0.3	12.4 ±0.2	4.8 ±0.1	**0**
	50	**8.5 ±0.6**	56.3 ±1.5	12.6 ±0.3	4.5 ±0.1	**0**
	Control	**1.9 ±0.1**	30.3 ±2.5	13.0 ±0.2	4.0 ±0.1	**8.4**
14	300	**11.7 ±0.6**	60.8 ±3.3	12.4 ±0.2	4.8 ±0.1	**0**
	50	**2.4 ±0.2**	32.5 ±2.8	12.9 ±0.1	4.3 ±0.2	**0**
	Control	**0.7 ±0.1**	44.0 ±3.6	12.5 ±0.1	3.8 ±0.4	**100**

Unit: FF (lb per square inch of force); EJ (ml juice per 100 g fresh weight pulp tissue); SS (%); TA (meq per 100 ml juice); IB (internal breakdown, %).

Table 2. Differences in flesh firmness (FF), extractable juice (EJ), soluble solids (SS), and titratable acids (TA) in **optimum mature** 'Bartlett' pears after 1, 7 and 14 days of ripening at 20 C. 'Bartlett' pears had been treated with 300 ppb, 50 ppb, or 0 ppb (Control) MCP within 2 days after harvest (8-18-02) and stored in air at –1 C for **4** months.

Days at 20C	MCP (ppb)	**FF**	EJ	SS	TA	**IB**
1	300	**17.6 ±0.4**	67.3 ±1.0	12.2 ±0.2	4.4 ±0.2	**0**
	50	**16.0 ±0.2**	66.8 ± 0.8	12.2 ±0.2	4.1 ±0.1	**0**
	Control	**14.1 ±0.5**	65.7 ±1.5	12.1 ±0.1	3.6 ±0.1	**0**
7	300	**15.8 ±0.9**	67.5 ±0.7	12.3 ±0.2	4.0 ±0.2	**0**
	50	**2.3 ±0.1**	41.7 ±3.1	12.5 ±0.2	3.9 ±0.2	**0**
	Control	**1.2 ±0.1**	44.0 ±4.6	12.5 ±0.2	3.6 ±0.1	**94**
14	300	**10.6 ±0.3**	54.0 ±3.6	12.5 ±0.1	3.7 ±0.1	**0**
	50	**1.6 ±0.1**	40.0 ±4.0	12.4 ±0.2	3.4 ±0.1	**11.6**
	Control	**0.5 ±0.1**	43.7 ±1.5	12.2 ±0.1	3.0 ±0.1	**100**

Unit: FF (lb per square inch of force); EJ (ml juice per 100 g fresh weight pulp tissue); SS (%); TA (meq per 100 ml juice); IB (internal breakdown, %).

Table 3. Differences in flesh firmness (FF), extractable juice (EJ), soluble solids (SS), and titratable acids (TA) in **late mature** 'Bartlett' pears after 1, 7 and 14 days of ripening at 20 C. 'Bartlett' pears had been treated with 300 ppb, 50 ppb, or 0 ppb (Control) MCP within 2 days after harvest (8-28-02) and stored in air at –1 C for **2** months.

Days at 20C	MCP (ppb)	**FF**	EJ	SS	TA	**IB**
1	300	**14.8 ±0.2**	68.0 ±1.0	12.9 ±0.4	4.8 ±0.3	**0**
	50	**14.0 ±0.6**	68.3 ± 1.5	12.9 ±0.2	4.6 ±0.2	**0**
	Control	**13.8 ±0.3**	65.6 ±2.1	13.2 ±0.2	4.4 ±0.1	**0**
7	300	**12.6 ±0.2**	66.8 ±0.3	13.0 ±0.1	4.7 ±0.4	**0**
	50	**6.7 ±0.2**	51.8 ±5.1	13.4 ±0.3	4.5 ±0.1	**0**
	Control	**2.2 ±0.1**	45.3 ±3.5	13.4 ±0.2	4.1 ±0.1	**14.4**
14	300	**6.9 ±0.2**	62.7 ±2.5	13.1 ±0.2	4.7 ±0.4	**0**
	50	**2.4 ±0.1**	37.0 ±4.0	13.0 ±0.3	4.5 ±0.4	**2.7**
	Control	**0.3 ±0.0**	50.0 ±2.0	12.4 ±0.2	3.1 ±0.1	**100**

Unit: FF (lb per square inch of force); EJ (ml juice per 100 g fresh weight pulp tissue); SS (%); TA (meq per 100 ml juice); IB (internal breakdown, %).

Table 4. Differences in flesh firmness (FF), extractable juice (EJ), soluble solids (SS), and titratable acids (TA) in **late mature** 'Bartlett' pears after 1, 7 and 14 days of ripening at 20 C. 'Bartlett' pears had been treated with 300 ppb, 50 ppb, or 0 ppb (Control) MCP within 2 days after harvest (8-28-02) and stored in air at –1 C for **4** months.

Days at 20C	MCP (ppb)	**FF**	EJ	SS	TA	**IB**
1	300	**14.4 ±0.2**	67.8 ±1.1	12.9 ±0.1	4.1 ±0.3	**0**
	50	**13.8 ±0.4**	67.3 ± 1.5	13.0 ±0.2	3.6 ±0.2	**0**
	Control	**12.6 ±0.7**	67.6 ±2.1	13.1 ±0.2	3.4 ±0.1	**0**
7	300	**12.2 ±0.2**	66.8 ±0.3	134 ±0.1	4.1 ±0.2	**0**
	50	**4.7 ±0.2**	45.8 ±5.1	13.1 ±0.3	3.5 ±0.3	**0**
	Control	**1.2 ±0.1**	38.3 ±3.5	13.2 ±0.2	3.1 ±0.2	**100**
14	300	**5.9 ±0.5**	55.7 ±2.8	13.3 ±0.2	3.6 ±0.4	**0**
	50	**1.5 ±0.3**	45.4 ±3.5	13.0 ±0.2	3.3 ±0.4	**25.1**
	Control	**0.3 ±0.0**	50.6 ±2.8	12.2 ±0.2	2.7 ±0.1	**100**

Unit: FF (lb per square inch of force); EJ (ml juice per 100 g fresh weight pulp tissue); SS (%); TA (meq per 100 ml juice); IB (internal breakdown, %).

Objective 4. To develop innovative procedures for freeze-drying fruit bits of 'd'Anjou' Pears as "value-added" commodities.

'D'Anjou' pears stored in either air or CA storage were ripened in at 20°C until flesh firmness (FF) softened to 6 lb. Fruit were sliced into 16 sectors and then separately vacuum-infiltrated with three different kinds of soluble-solids solutions. Treated fruit sectors were subjected to "individually quick freezing" (IQF) process and then freeze-dried. One kind of soluble solids was identified to increase the crisp texture of freeze-dried fruit sector. This procedure may provide the pear industry with a potential to turn "Cull-grade" fruit into profitable "value-added" product.

Budget:

Project Title:	Postharvest Physiology of Winter Pears
PI:	Paul M. Chen
Projection duration:	2002-2003
Current year:	2002
Project total (1 year):	$40,000
Current request for 2003:	$0