FINAL PROJECT REPORT

Project Title: Decay control and management of fungicide resistance

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Cooperators: Selected packinghouses across the state

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Total Project Funding: $90,000

Budget History:

Item	**Year 1: 2007**
Salaries	50,000
Benefits	15,850
Wages	10,000
Benefits	1,150
Equipment	0
Supplies	10,000
Travel	3,000
Total	**90,000**

Objectives:

1. Develop preharvest fungicide and postharvest fungicide integrated programs for decay control.
2. Develop preharvest fungicide and postharvest biocontrol agent integrated programs for decay control.
3. Develop pre- and post-storage integrated programs for decay control.
4. Develop pre- and postharvest fungicide programs for control of Sphaeropsis rot.
5. Evaluate various programs that not only control decay but also minimize or control the development of resistance in *P. expansum* to pyrimethanil and fludioxonil.
6. Evaluate thermofogging-based programs for decay control.
7. Collaborate with Bruce Campbell in evaluating natural compounds for decay control.

Significant findings:

- Residual activity of Pristine in apple fruit was still evident 5 months after harvest. Preharvest Pristine in combination with postharvest Bio-Save was more effective than Pristine alone in reducing blue mold at storage temperature. More research to explore this strategy for blue mold control is needed.
- Residues of Penbotec in apple fruit can provide a long time protection against blue mold. Scholar drench applied prior to storage in combination with Bio-Save applied at packing could be a viable option for blue mold control.
- Similar to what we previously observed on Red Delicious, when Penbotec and Scholar were applied as drench treatments prior to storage, the residues of these two fungicides seemed to be stable in treated Fuji fruit in CA storage conditions. Even after 7 months in cold storage, the residues of Penbotec and Scholar in the drenched fruit still protected wounds from infection by *Penicillium expansum*. It appeared that Penbotec had a better residue protection than Scholar.
- Although infections of apple fruit by *Sphaeropsis pyriputrescens* occurs during the fruit-growing season in the orchard, a preharvest fungicide spray or a postharvest fungicide drench reduced Sphaeropsis rot incidence in storage and that a postharvest drench with one of the three apple-postharvest fungicides was highly effective in controlling this disease.
- Although pyrimethanil reduced blue mold incited by pyrimethanil-resistant strains of *P. expansum*, use of DPA in combination with pyrimethanil can compromise the efficacy of pyrimethanil for control of pyrimethanil-resistant strains. In order to avoid the development of resistance to pyrimethanil in *P. expansum* populations, strategies for fungicide resistance management, such as rotation among postharvest fungicides or use of preharvest fungicides instead of postharvest drench with fungicides, should be implemented.
- Thermfogging pyrimethanil or fludioxonil was able to reduce blue mold and gray mold. However, in commercial operations, a fungicide treatment applied by thermofogging to the fruit in a storage room may be delayed for 1-3 days after harvest until the room is filled with bins of fruit. A 1- to 3-day delay of the thermofogging treatment significantly compromised the effectiveness of the treatment, particularly for blue mold control.
- 2,5-DHBA or 2,3-DBAld as a chemosensitizing agent was not able to overcome fludioxonil resistance of *P. expansum* on apple fruit, though these two compounds in combination with fludioxonil controlled a fludioxonil-resistant strain in an in-vitro test. More research is being conducted in Campbell and Xiao labs to evaluate natural compounds as chemosensitizing agents to overcome fungicide resistance.

Methods:

In 2007, we set up a few experiments to evaluate various pre- and postharvest integrated programs for control of storage diseases in Red Delicious and Fuji apples before packing as well as decay after packing. Selected fungicides were applied within two weeks before harvest. Pre- and postharvest drench treatments had also been applied to the fruit. Various fungicides and biocontrol treatments were applied to the fruit 5 and 7 months after harvest. Fruit were evaluated for decay development.

Experiments were set up to evaluate various postharvest fungicide treatments applied in various combinations of pre-storage treatments and online treatments for control of decay. This experiment was to simulate commercial operations in which fruit are drenched with fungicides prior to storage and then treated again with fungicides or biocontrol agents on the packing line at packing. Various on-line fungicides and biocontrol treatments were applied to the fruit 5 and 7 months after harvest. Fruit were evaluated for decay development.

An experiment was conducted on Golden Delicious to evaluate effects of timing of infection of apple fruit by *Sphaeropsis pyriputrescens* on effectiveness of pre- and postharvest fungicide applications for control of Sphaeropsis rot. Apple fruit were inoculated with the pathogen at 5 and 2 weeks before harvest. Fruit were either treated with preharvest Pristine and Topsin M or drenched with postharvest fungicides. Decay development was assessed monthly for up to 7 months after harvest, starting 3 months after harvest.

Effects of DPA in combination with either Scholar or Penbotec in the drench solution on the control of fungicide-resistant mutants of *Penicillium expansum* on apple fruit were evaluated.

An experiment was conducted to evaluate thermofogging fungicides for control of postharvest diseases. Commercially harvested fruit were used for this experiment. Both fludioxonil and pyrimethanil as themofogging treatments were tested.

In collaboration with Bruce Campbell, an experiment was conducted to evaluate 2,5-dihydroxybenzoic acid and 2,3-dihydroxybenzaldehyde for management of fludioxonil-resistant strains of *Penicillium expansum* and for decay control.

Results & Discussions:

Preharvest Pristine in combination with postharvest biocontrol agent or fungicide for blue mold control.

Pristine was applied to Fuji apples 7 days before harvest. Fruit were stored in CA for 5 months, washed and brushed through a research packing line, wounded and inoculated with *P. expansum*. Inoculated fruit were stored at 32°F in air for 8 weeks and one additional week at room temperature.

Preharvest Pristine without any postharvest biocontrol or fungicide reduced blue mold incidence to 20% after 8 weeks at 32°F. Preharvest Pristine in combination with BioSave further reduced blue mold to only 2.5%. The effectiveness of Pristine and BioSave was diminished after the fruit were stored at room temperature for one additional week (Table 1). However, the size of decay on the fruit treated with preharvest Pristine and postharvest Bio-Save was significantly smaller than that on the fruit treated with preharvest Pristine without postharvest Bio-Save. Virtually no decay developed on the fruit that were treated with Scholar or Penbotec. Our results indicate that residual activity of Pristine in apple fruit was still evident 5 months after harvest. Preharvest Pristine in combination with postharvest Bio-save appears to be more effective than Pristine alone in reducing blue mold at storage temperature. More research to explore this strategy for blue mold control is needed.

Table 1. Preharvest Pristine in combination with postharvest fungicide and biocontrol agent for control of blue mold

Preharvest Treatment	Fungicide applied 5 months post drenching	8 weeks at 32F post inoculation		1 week at room temp after cold storage	
		% decay	Lesion (mm)	% decay	Lesion (mm)
Nontreated	No Fungicide	100.0a	30.0a	100.0a	64.1a
	Scholar	0.0e	0.0d	0.0d	0.0d
	Penbotec	0.0e	0.0d	0.0d	0.0d
	TBZ	100.0a	30.3a	100.0a	63.7a
	BioSave	31.7c	6.9c	92.4ab	23.1b
Pristine	No Fungicide	20.0d	14.1b	78.8c	23.2b
	Scholar	0.0e	0.0d	0.0d	0.0d
	Penbotec	0.0e	0.0d	1.3d	8.8c
	TBZ	47.5b	12.7b	95.0ab	31.1b
	Biosave	2.5e	0.9d	97.5ab	8.8c

Postharvest drench treatments in combination with postharvest biocontrol agent or fungicide for blue mold control.

Experiments were conducted on both Red Delicious and Fuji apples. Penbotec applied as a pre-storage drench treatment had an excellent residual activity in apple fruit against blue mold. No decay developed on Penbotec-drenched fruit that were inoculated with the pathogen 5 or 7 months after the drench treatment (Tables 2 and 3). Scholar also exhibited a very good residual activity in apple fruit against *P. expansum*, but the residual activity of Scholar was reduced after the fruit had been moved to room temperature. However, Bio-Save applied at packing provided additional benefits than Scholar drench without Bio-Save. Our results suggest that residues of Penbotec in apple fruit can provide a long time protection against blue mold and that Scholar drench applied prior to storage in combination with Bio-Save applied at packing could be a viable option for blue mold control.

Table 2. Postharvest drench with Penbotec or Scholar in combination with Bio-Save for control of blue mold in Red Delicious apples

Drench treatment applied prior to storage	Fungicides applied at packing 5 or 7 months post drenching	5 months post drench treatments		7 months post drench treatments	
		% infected fruit at 8 weeks at 0ºC post packing	% infected fruit at one additional week at room temperature after storage	% infected fruit at 8 weeks at 0ºC post packing	% infected fruit at one additional week at room temperature after storage
		TBZ-R	TBZ-R	TBZ-R	TBZ-R
Nontreated	No fungicide	100.0a	100.0a	98.8a	98.8a
	Scholar	0.0c	10.0d	0.0c	0.0d
	Penbotec	0.0c	0.0e	0.0c	0.0d
	Mertect	100.0a	100.0a	100.0a	100.0a
	Bio-Save	25.0b	92.5b	35.0b	100.0a
Scholar	No fungicide	0.0c	20.0c	0.0c	36.3b
	Bio-Save	0.0c	10.0d	0.0c	25.0c
Penbotec	No fungicide	0.0c	0.0e	0.0c	0.0d
	Bio-Save	0.0c	0.0e	0.0c	0.0d

Table 3. Postharvest drench with Penbotec or Scholar in combination with Bio-Save for control of blue mold in Fuji apples

		5 months post drench treatments		7 months post drench treatments	
Drench treatment applied prior to storage	Fungicides applied at packing 5 or 7 months post drenching	% infected fruit at 8 weeks at 0ºC post packing	% infected fruit at one additional week at room temperature after storage	% infected fruit at 8 weeks at 0ºC post packing	% infected fruit at one additional week at room temperature after storage
		TBZ-R	TBZ-R	TBZ-R	TBZ-R
Nontreated	No fungicide	98.8a	98.8ab	98.8a	100.0a
	Scholar	0.0c	0.0e	0.0c	1.3c
	Penbotec	0.0c	0.0e	0.0c	0.0c
	Mertect	98.8a	100.0a	98.8a	100.0a
	Bio-Save	61.3b	96.3b	61.3b	97.5a
Scholar	No fungicide	0.0c	16.3d	1.3c	6.3b
	Bio-Save	1.3c	10.0d	0.0c	1.3c
Penbotec	No fungicide	0.0c	0.0e	0.0c	0.0c
	Bio-Save	0.0c	40.0c	0.0c	0.0c

Residual activity of Penbotec and Scholar in Fuji apple fruit against Penicillium expansum.

In a previous study, we reported that when applied as a pre-storage drench treatment, residues of Penbotec and Scholar in Red Delicious apple fruit were stable and can protect fruit from infection by *P.expansum*. In the current study, we evaluated whether or not this residual activity also occurs on Fuji apple fruit.

Table 4. Residual activity of fludioxonil and pyrimethanil in Fuji apple fruit against *Penicillium expansum*

		5 months post drench treatments		7 months post drench treatments	
Drench treatment applied prior to storage	Fungicides applied at packing 5 or 7 months post drenching	% infected fruit at 8 weeks at 0ºC post packing	% infected fruit at one additional week at room temperature after storage	% infected fruit at 8 weeks at 0ºC post packing	% infected fruit at one additional week at room temperature after storage
		TBZ-R	TBZ-R	TBZ-R	TBZ-R
Nontreated	No fungicide	98.8	98.8	100.0	100.0
	Scholar	0.0	0.0	0.0	0.0
	Penbotec	0.0	0.0	0.0	0.0
	Mertect	100.0	100.0	100.0	100.0
Mertect	No fungicide	98.8	100.0	97.5	97.5
	Scholar	0.0	1.3	0.0	0.0
	Penbotec	0.0	0.0	0.0	0.0
Scholar	No fungicide	1.3	5.0	0.0	10.0
	Mertect	8.8	55.0	6.3	35.0
	Penbotec	0.0	0.0	0.0	0.0
Penbotec	No fungicide	0.0	0.0	0.0	0.0
	Mertect	2.5	15.0	0.0	2.5
	Scholar	0.0	0.0	0.0	0.0

Similar to what we previously observed on Red Delicious, when Penbotec and Scholar were applied as drench treatments prior to storage, the residues of these two fungicides seemed to be stable in treated Fuji fruit in CA storage conditions (Table 4). Even after 7 months in cold storage, the residues of Penbotec and Scholar in the drenched fruit still protected wounds from infection by *Penicillium expansum*. It appeared that Penbotec had a better residue protection than Scholar. TBZ residue in drenched fruit did not provide a satisfactory protection after 7 months of CA storage, even against TBZ sensitive strain of *Penicillium expansum* (data not shown). An additional online treatment with either Penbotec or Scholar provided an excellent protection of the fruit from infection by either TBZ-R or TBZ-S strains of *P. expansum*.

Control of Sphaeropsis rot with pre- and postharvest fungicides.

Preharvest applications of Pristine and Topsin M and postharvest drench treatments with three postharvest fungicides were evaluated for control of Sphaeropsis rot. Two different timings of infection were included in the test to evaluate whether timing of infection affects the effectiveness of fungicide treatments (Table 5). Both Pristine and Topsin M significantly reduced Sphaeropsis rot compared to the nontreated control. The three postharvest fungicides statistically were equally effective, but Penbotec drench completely eradicated infections regardless of timing of infection before harvest. Ziram was effective, but Serenade was not effective in controlling Sphaeropsis rot.

Our results indicate that although infections of apple fruit by *Sphaeropsis pyriputrescens* occurs during the fruit-growing season in the orchard, a preharvest fungicide spray or a postharvest drench can still reduce Sphaeropsis rot incidence in storage and that a postharvest drench with one of the three apple-postharvest fungicides is highly effective in controlling this disease.

Table 5. Control of Sphaeropsis rot in Golden Delicious apples with pre- and postharvest fungicides

	Incidence of Sphaeropsis rot (%) 9 months after harvest	
Treatment	Fruit inoculated 5 weeks before harvest	Fruit inoculated 2 weeks before harvest
Nontreated control	75a	72.5a
Pristine 7d before harvest	46.3b	31.3b
Topsin 7d before harvest	66.3ab	47.5b
Ziram 14 d before harvest	43.8b	
Serenade 7 d before harvest		80.3a
Scholar drench after harvest	3.8c	1.3c
Penbotec drench after harvest	0c	0c
Mertect drench after harvest	6.3c	3.8c

Effects of Diphenylamine (DPA) on the control of blue mold on apple fruit incited by fludioxonil-resistant or pyrimethanil-resistant strains of Penicillium expansum.

DPA in combination with one of the three apple-postharvest fungicides was evaluated for control of blue mold on Red Delicious apple fruit incited by fludioxonil-resistant or pyrimethanil-resistant strain of *P. expansum*. The strain FR2 of *P. expansum* is resistant to fludioxonil but sensitive to pyrimethanil and TBZ. Fludioxonil alone or in combination with DPA was not effective in controlling blue mold incited by FR2. Pyrimethanil and TBZ almost completely controlled blue mold incited by FR2 (Table 6).

The strain PR2 is resistant to both pyrimethanil and fludioxonil but sensitive to thiabendazole (TBZ). DPA alone did not control this strain. Fludioxonil in combination with DPA provided a better control of blue mold caused by PR2 than fludioxonil alone, but the difference in the effectiveness between these two treatments was diminished after the fruit were stored at room temperature for an additional week after cold storage. TBZ alone and TBZ in combination with DPA were equally effective against blue mold incited by PR2. However, pyrimethanil in combination with DPA was less effective than pyrimethanil alone in controlling blue mold incited by pyrimethanil-resistant strain of *P. expansum* (Table 6), while pyrimethanil alone or in combination with DPA almost completely controlled blue mold incited by pyrimethanil-sensitive strains of *P. expansum* (data not shown).

Table 6. Effects of Diphenylamine (DPA) alone or in combination with postharvest fungicides on the control of blue mold on apple fruit incited by fludioxonil-resistant or pyrimethanil-resistant strains of *Penicillium expansum*

Strain	Treatment	12 wk at 32°F		12 wk at 32°F+7d at room temp
		Incidence (%)	Lesion (mm)	Incidence (%)
FR2 (fludioxonil-resistant strain)	CK	85.8 ab	5.0 b	100 a
	Diphenylamine	54.2 c	3.6 c	98.3 a
	Thiabendazole	0 d	0 d	0 b
	Diphenylamine +Thiabendazole	0 d	0 d	0 b
	Fludioxonil	70.8 bc	6.2 a	91.7 a
	Diphenylamine +Fludioxonil	89.2 a	5.7 ab	100 a
	Pyrimethanil	0 d	0 d	0 b
	Diphenylamine +pyrimethanil	0 d	0 d	3.3 b
PR2 (pyrimethanil-resistant strain)	CK	100 a	21.1 a	100 a
	Diphenylamine	100 a	16.0 b	100 a
	Thiabendazole	1.7 d	1.2 ef	5.0 c
	Diphenylamine +Thiabendazole	0.8 d	1.2 ef	8.3 c
	Fludioxonil	29.2 c	3.9 ed	88.3 b
	Diphenylamine +Fludioxonil	1.7 d	0.8 f	86.7 b
	Pyrimethanil	31.7 c	4.8 d	88.3 b
	Diphenylamine +pyrimethanil	86.7 b	8.0 c	100 a

In a previous study, we found that if *P. expansum* develops resistance to pyrimethanil, the resistance can extend to fludioxonil and TBZ and thus the strains become multi-drug resistance. The results we reported here indicate that although pyrimethanil can still reduce blue mold incited by pyrimethanil-resistant strains, use of DPA in combination with pyrimethanil can compromise the efficacy of pyrimethanil. In order to avoid the development of resistance to pyrimethanil in *P. expansum* populations, strategies for fungicide resistance management, such as rotation among postharvest fungicides or use of preharvest fungicides instead of postharvest drench with fungicides, should be implemented.

Thermofogging postharvest fungicides for decay control.

In 2007, 24 bins of Red Delicious harvested from a commercial orchard were used for the evaluation. Eight replicate bins were either not treated as a control or thermofogged with pyrimethanil or fludioxonil. Decay was assessed 8 months after harvest. The decay from natural infections was relatively low. A thermofog treatment with pyrimethanil or fludioxonil was equally effective and reduced both total decay and gray mold as compared to the nontreated control (Table 7). Blue mold was very low, and no differences were observed among the treatments.

In the commercial situation, a thermfog treatment applied to the fruit in a storage room may be delayed for 1-3 days after harvest until the room is filled with bins of fruit. In 2007, we also used inoculated fruit to look at whether delay of themfog treatment compromises fungicide efficacy for decay control. After harvest, apple fruit were inoculated with either Botrytis or Penicillium, and part of the fruit received the thermofogging treatment with pyrimethanil or fludioxonil at 0, 1, 2, and 3 days after inoculation. Delay of the thermofogging treatment significantly compromised the effectiveness of the treatments, particularly for blue mold control (data not shown).

It appears that thermfogging fungicides could be a promising option for control of blue mold and gray mold. However, in commercial operations, delay of thermfog treatment can compromise the efficacy of fungicides.

Table 7. Effectiveness of pyrimethanil and fludioxonil applied as a thermofog treatment in controlling decay originating from natural infections in Red Delicious apples

Treatment	Total Rot (%)	Gray mold (%)	Blue mold (%)
Nontreated	2.22 a	1.79 a	0.08 a
Fog with Fludioxonil	0.69 b	0.40 b	0.04 a
Fog with Pyrimethanil	0.63 b	0.27 b	0.02 a

Evaluation of natural compounds for control of blue mold incited by fludioxonil-resistant strains of Penicillium expansum

This work was done in collaboration with Bruce Campbell at the USDA ARS, Albany, CA. Two natural compounds, 2,5-dihydroxybenzoic acid (2,5-DHBA) and 2,3-dihydroxybenzaldehyde (2,3-DBAld), were tested as chemosensitizing agents to overcome fludioxonil resistance in *Penicillium expansum* on apple fruit. These two compounds have been shown effective as chemosensitizing agents to overcome fludioxonil resistance in *P. expansum* in an in-vitro test conducted by Bruce Campbell's lab.

It appeared that 2,5-DHBA and 2,3-DBAld were not able to overcome fludioxonil resistance of *P. expansum* on apple fruit, though these two compounds in combination with fludioxonil controlled a fludioxonil-resistant strain in an in-vitro test (Table 8). In 2008, additional compounds were screened by Campbell's lab for potential of chemosensitizing agents to overcome fludioxonil resistance. Campbell's lab found that octylgallate could be a promising chemosensitizing agent to overcome fludioxonil resistance in *P. expansum*. On the 2008 crop, we set up a trial to evaluate octylgallate in combination with Scholar (fludioxonil) for control of blue mold caused by a fludioxonil-resistant strain. The fruit are currently in storage for decay development. Results will be forthcoming.

Table 8. Effectiveness of 2,5-dihydroxybenzoic acid (2,5-DHBA) and 2,3-dihydroxybenzaldehyde (2,3-DBAld) as chemosensitizing agents to overcome fludioxonil resistance in *Penicillium expansum* on apple fruit

	Fludioxonil-sensitive strain		Fludioxonil-resistant strain	
Treatment	% of fruit Infected	Lesion size (mm)	% of fruit Infected	Lesion size (mm)
Untreated Control	100.0	42.3	100.0	8.6
2,5-DHBA 18 mM	100.0	47.7	100.0	12.9
2,5-Dbald 1 mM	100.0	40.3	100.0	7.3
2,5-DHBA 18 mM + Scholar	0.0	0.0	100.0	12.4
2,5-DbAld 1 mM + Scholar	0.0	0.0	97.5	7.7
Scholar 230 SC 12 fl oz/100 gal	0.0	0.0	100.0	8.0

Executive Summary

This report is a summary of a one-year project. The goal of the project was to develop integrated programs using recently registered reduced-risk fungicides and a biocontrol agent to control major postharvest diseases in apples.

Blue mold and gray mold are major postharvest diseases of apples. In previous studies, we found that new reduced-risk fungicides Pristine, as a preharvest treatment, or Scholar and Penbotec, as a postharvest drench treatment, were effective in controlling these two diseases. In the current project, we evaluated various pre- and postharvest integrated programs or pre- and post-storage integrated programs for decay control. We found that residual activity of Pristine in apple fruit against *Penicillium expansum* (the cause of blue mold) was still evident five months after harvest. Preharvest Pristine in combination with postharvest biocontrol agent Bio-Save was more effective than Pristine alone in reducing blue mold at storage temperature. Similar to what we previously observed on Red Delicious, when Penbotec and Scholar were applied as drench treatments prior to storage, the residues of these two fungicides seemed to be stable in treated Fuji fruit in CA storage conditions. Even after seven months in cold storage, the residues of Penbotec and Scholar in the drenched fruit still protected wounds from infection by *P. expansum*. It appeared that Penbotec had a better residual protection than Scholar. Scholar drench applied prior to storage in combination with Bio-Save applied at packing could be a viable option for blue mold control.

Pyrimethanil or fludioxonil applied as a thermfog treatment was able to reduce blue mold and gray mold. However, in commercial operations, a fungicide treatment applied by thermofogging to the fruit in a storage room may be delayed for 1-3 days after harvest until the room is filled with bins of fruit. We found that a 1- to 3-day delay of the thermofogging treatments significantly compromised the effectiveness of the treatmenst, particularly for blue mold control.

Sphaeropsis rot caused by the fungus *Sphaeropsis pyriputrescens* is another important postharvest disease of apples in Washington State. Although infections of apple fruit by *Sphaeropsis pyriputrescens* occurs during the fruit-growing season in the orchard, a preharvest spray with Pristine or Topsin reduced Sphaeropsis rot incidence in storage. A postharvest drench with one of the three apple-postharvest fungicides was highly effective in controlling Sphaeropsis rot.

Avoidance or management of resistance to new postharvest fungicides is important to postharvest decay control. In a previous study using laboratory-generated fungicide-resistant mutants, we found that pyrimethanil possesses a higher risk than fludioxonil in the development of resistance in *P. expansum*. In the current study, we evaluated whether DPA in the fungicide drench solution affects the effectiveness of fungicides against pyrimethanil- and fludioxonil-resistant strains of *P. expansum*. We found that although pyrimethanil reduced blue mold incited by pyrimethanil-resistant strains of *P. expansum*, use of DPA in combination with pyrimethanil can compromise the efficacy of pyrimethanil for control of pyrimethanil-resistant strains of *P. expansum*. In order to avoid the development of resistance to pyrimethanil in *P. expansum* populations, strategies for fungicide resistance management, such as rotation among postharvest fungicides or use of preharvest fungicides instead of postharvest drench with fungicides, should be implemented.

In collaboration with Bruce Campbell, we evaluated natural compounds as chemosensitizing agents to overcome fludioxonil resistance of *P. expansum*. We found that 2,5-DHBA or 2,3-DBAld was not able to overcome fludioxonil resistance of *P. expansum* on apple fruit, though these two compounds in combination with fludioxonil controlled a fludioxonil-resistant strain in an in-vitro test. More research is currently being conducted in Campbell and Xiao labs to evaluate natural compounds as chemosensitizing agents to overcome fungicide resistance in postharvest pathogens.