FY 2010 Specialty Crop Block Grant Program - Farm Bill

Utah Department of Agriculture and Food

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2010-1. Utah Wolfberry Plant Nutrient Data and Information Enhancement

Final Report

PROJECT SUMMARY

A 2010 Utah Department of Food and Agriculture Specialty Crop grant initiated plant nutrient testing of Lycium barbarum, variety Phoenix Tears, fruit and leaves grown by Phoenix Tears Nursery, 1847 South 2400 West, Logan, UT 84321. The data from that research established the genetic make-up and basic nutrient profile of Phoenix Tears plants and played a major role in marketing plants for the 2011 growing season, with plants featured in six spring 2011 nationally distributed nursery catalogs.

As part of the 2010 grant, dried Phoenix Tears leaf material was tested for antioxidant and betaine levels, two key wolfberry nutrients. Values for these nutrients were exceptionally high, raising the possibility that leaf material may be an additional crop of value. The main purpose of this grant was to further document the nutrient value of wolfberry leaves.

Though the marketing of wolfberry fruit is very familiar to the health food market; nurseries and other consumers are largely unfamiliar with the propagation of wolfberry plants, berry and leaf use. Wolfberry leaf material for vegetables and tea is virtually unknown outside of China. The current project was designed to provide expanded coverage on wolfberry propagation and the use and value of both fruit and leaves.

PROJECT APPROACH

Dried Phoenix Tears leaf material was submitted to Brunswick Laboratories, Inc., for nutrient analysis.

Efforts to expand public awareness of wolfberry fruit and leaves as both a crop and food, were based on the assumption of positive nutrient testing results. If nutrient data was positive, then the information was to be incorporated into a website, shared in news releases, included in articles for publication, and included in a wolfberry cookbook.

GOALS AND OUTCOMES ACHIEVED

Objective One: Conduct a broad analysis of wolfberry leaf nutrients.

Nutrient data on Phoenix Tears dried leaves is summarized as follows:

PHOENIX TEARS DRIED LEAF NUTRIENTS
(In mcg/g unless otherwise noted)

Test	Results
Vitamin K	2.31
Folic Acid	5.97
Betaine	1540.00
Alpha-Carotene	1.58
Beta-Carotene	2.34
Lycopene	242.00
Zeaxanthin	84.00
Lutein	416.00
Vitamin C	1020.00
Catechin	2.00
Epicatechin	0.20
Epicatechin Gallate	0.10
Catechin Gallate	0.20
Gallocatechin	0.50
Epigallocatechin	0.20
Gallocatechin Gallate	0.10
Epigallocatechin Gallate	0.10
Vitamin B2	9.03
Vitamin B3	21.50
Vitamin B5	6.31
Alpha-tocopherol	567.86
Beta-Tocopherol	4.77
Gamma-tocopherol	12.03
Delta-tocopherol	0.95
Tocotrienol	Not detected
ORAC-hydro	522 micromole TE/g
Total Phenolics	30.50 mg/g
Total ellagic acid	Below quantifiable levels
Total Bioflavonoids	19.83 mg/g

Note: The above data is available on signed Brunswick Laboratories Certificates of Analysis.

Dried leaves and dried fruit were sent to NPA Laboratories to test for PQQ (pyrroloquinoline

quinone). The nutrient was not found in the leaves, but the fruit contained 17.9 mcg/g.

Nutrient data from the 2009 and 2010 Specialty Crop Grants are summarized as follows:

ORAC

ORAC (Oxygen Radical Absorption Capacity), is a valid measure of a food's antioxidant potential. It is a measure of the food's free radical absorption capacity. ORAC values for dried wolfberry fruit are characteristically higher than that of pomegranate. *Phoenix Tears* fruit tested in 2009 had ORAC values in the range of most reported wolfberry ORAC values. However, dried leaves tested in 2009 and again in 2010 had incredibly high scores. The 2009 leaves, which were harvested in the fall, had an ORAC value of 456 micromoles TE/ gram. The 2010 leaves were harvested early summer, and had a value of 522 micromoles TE/gram. These values are for only the water-soluble ORAC component. Two recent, high ORAC products introduced to the market are chokecherry at 160 and elderberry at 147. Pomegranate is about 100 on the ORAC scale. None of these is anywhere near the level of the *Phoenix Tears* leaves. The only other foods found with higher scores are spices such as turmeric, cinnamon, and oregano. Most high antioxidant foods such as blueberries and blackberries have an ORAC score of less than 100.

Clearly, dried wolfberry fruit and leaves have far more antioxidant potential than most foods, and have the potential to block the free radical damage that leads to cellular mutation and cancer.

Phenolics

The presence of polyphenols in wolfberries may compound their antioxidant roles. Blueberries, red grapes, and green tea are often referred to as having high phenolic content, contributing to their high antioxidant potential. The combination of ORAC, phenolics, and carotenoids in wolfberries, present a very compelling case for obtaining antioxidant action from a single food source. Among common fruit, the highest phenolic contents are found in plums and cherries (28 mg/g). Phoenix Tears wolfberry leaves tested in 2010 had a total phenolic content of 30.50 mg/g. Wolfberry and green teas have comparable phenolic content, but the wolfberries contain no caffeine.

Ellagic Acid

Ellagic acid is another important wolfberry fruit nutrient. Dried fruit tested in 2009 had an ellagic acid content of 11.92 mcg/g. Leaf tests in 2010 were negative for ellagic acid. There are some claims that ellagic acid can play a role in preventing some cancers.

Bioflavonoids

Phoenix Tears leaves were tested for total bioflavonoids in 2010, with a result of 19.83 mg/g. There are many different bioflavonoids. They are largely responsible for the colors of many flowers and

fruits. Bioflavonoids are water-soluble and have antioxidant and anti-inflammatory properties. They also can play a role in modifying the body's response to allergens, viruses, and carcinogens. Though there is no official RDI for bioflavonoids, one source recommends 30 mg/day. Two grams of *Phoenix Tears* leaves would supply more than that amount.

Carotenoids

Carotenoids occur as pigments in plants and microorganisms. Beta-carotene and alpha-carotene convert into vitamin A in metabolism. The standard food source for carotenoids is spinach, with 56 mcg/g of beta-carotene, 122 mcg/g of zeaxanthin, and 76 mcg/g of lutein. *Phoenix Tears* dried fruit tested in 2009 had 12.36 mcg/g of alpha and beta-carotene. Dried leaves tested in 2010 had 392 mcg/g; the leaves having values triple that of spinach.

Zeaxanthin and lutein values for dried fruit were 84 mcg/g and 41.44 mcg/g. Results for dried leaves were even higher at 84 mcg/g and 416 mcg/g, with the lutein value five times that of spinach.

Alpha and beta-carotene have anti-carcinogenic activity and zeaxanthin and lutein have been shown to protect the eyes from age related macular degeneration. A common source of zeaxanthin is egg yolk, with 200 mcg/g. Both dried wolfberry fruit and dried leaves would be an excellent cholesterol free source of these nutrients.

Lycopene is another carotenoid found in wolfberries. Lycopene is a powerful antioxidant, and may play a role in prostate cancer prevention. The common source of lycopene is tomato, with tomato juice having 86-100 mcg/g and ketchup with 124 mcg/g. *Phoenix Tears* dried fruit tested in 2009 had only .99 mcg/g of lycopene. This was unexpectedly low, as lycopene is usually associated with orange and red pigments in fruit. Even more unexpected, was the 2010 dried leaf results, with a lycopene content of 242 mcg/g, double that of ketchup, and with no sugar or high fructose corn syrup.

Lycopene is not water soluble, so dried leaf tea will not contain lycopene. Use of fresh and dried wolfberry leaves for vegetables would be an excellent source of lycopene.

Catechins

The least researched, but perhaps the most important nutrient found in dried wolfberry leaves, is catechin. Catechin is made up of seven subgroups, all of which are powerful antioxidants that can block the transformation of normal cells into cancerous cells. Studies show that catechins influence the breakdown of fats and the production of inflammatory materials that trigger hunger. Catechins are water-soluble and are best known for their benefits in green tea. All teas contain catechins, along with chocolate and some fruits.

Catechin test results for Phoenix Tears dried leaves are as follows:

Total Catechin	2.0 microgram/gram
Epicatechin	0.2 microgram/gram
Epicatechin Gallate	0.1 microgram/gram
Catechin Gallate	0.2 microgram/gram
Gallocatechin	0.5 microgram/gram
Epigallocatechin	0.2 microgram/gram

Gallocatechin Gallate	0.1 microgram/gram
Epigallocatechin Gallate	0.1 microgram/gram

Betaine

Betaine is also a wolfberry signature nutrient. Phoenix Tears fruit tested in 2009 had a betaine content of 2.19 micrograms/gram for fresh fruit, 2.24 micrograms/gram for frozen fruit, and 4.61 micrograms/gram for dried fruit. Incredibly, dried leaves tested in 2009 had 19.38 mg/gram. Dried leaves tested in 2010 also had a far higher betaine content than the fruit.

Vitamins

Dried *Phoenix Tears* leaves tested for vitamin C in 2010 contained 1,020 microgram/gram. Oranges have a vitamin C value of 530 micrograms/gram, about half the value of the wolfberry leaves. Dried leaves also contained 2.31 microgram/gram of vitamin K. This value is about ¼ that of kale and higher than amounts found in brussel sprouts and dandelion greens.

Dried fruit was tested for some B complex vitamins with B-1 (thiamin) at 2.4 micrograms/gram, and B-3 (niacin) at 10.4 micrograms/gram. Biotin was measured at 6.8 micrograms/gram. This value is higher than that found in yeast, egg, or liver. Folic acid in dried leaves tested at 5.97 micrograms/gram. This value is double that found in liver and wheat bran.

Vitamin E values were determined for dried fruit, with measurable amounts of alpha tocotrienol (0.12 microgram/gram), alpha tocopherol (13.44 microgram/gram), gamma tocopherol (1.99 micrograms/gram), and beta tocopherol (0.65 microgram/gram). Though not extremely high values, the dried fruit had a mixture of E vitamins, an advantage over many fruits and vegetables that are largely of one type. With a total tocopherol content of 1.62 microgram/gram, the dried fruit is comparable to corn meal (1.70) and oats (1.94), but lower than for kale (8.0) and parsley (5.5), two of the richest vegetable sources of vitamin E.

Dried leaves were also tested for vitamin E content with results as follows: alpha tocopherol (576.86 microgram/gram), beta tocopherol (4.77 microgram/gram), gamma tocopherol (12.03 microgram/gram), and delta tocopherol (0.95 microgram/gram), for a total vitamin E content of 585.61 microgram/gram. At 59 mg/ 100 grams, the total tocopherol in the Phoenix Tears dried leaves are higher in vitamin E than kale and parsley, and may be the richest vegetable source of vitamin E available.

PQQ, Pyrroloquinoline Quinone

Pyrroloquinoline quinone (PQQ), is a recently discovered vitamin-like nutrient similar to some B vitamins and plays a role in mitochondria health. Scientists have identified mitochondria dysfunction as a key factor in aging. Mitochondria dysfunction and death are now clearly linked in the development of all killer diseases associated with aging. Recent research has documented that mitochondria dysfunction can be reversed. PQQ not only protects mitochondria from oxidation damage, it also stimulates growth of new mitochondria. The number of mitochondria, and their function, are clearly related to longevity. PQQ has emerged as the nutrient that can safely trigger mitochondria biogenesis.

A healthy diet can contribute small amounts of PQQ, with natto (fermented soybeans), green tea, green peppers and parsley as examples of foods with some PQQ. Research at present has not identified how much PQQ is needed to influence mitochondria health. Nutrient analysis of Phoenix Tears wolfberries revealed a PQQ content of 17.9 mcg/g. When compared to natto, with a value of 61 ng/g, Phoenix Tears wolfberries have 17,900 ng/g of PQQ. Five dried Phoenix Tears berries far exceed the documented amount of PQQ needed for normal cell health and probably contribute to its reputation as an anti-aging food.

PQQ is becoming available as a supplement. PQQ levels in Phoenix Tears wolfberries are comparable to some supplements, and the berries also contain a rich whole food source of many other nutrients. For the first time in scientific history, a natural compound called PQQ is available in Phoenix Tears wolfberries, with amounts sufficient to increase the functionality of existing mitochondria and also promote the generation of new mitochondria inside aging cells.

Note: The original intent to include root nutrient analysis in this project was dropped due to the cost of leaf nutrient analysis and the inference that root material would not provide as cost effective a crop as that of the leaf material.

Objective Two: Publish, in hard copy and electronic form, expanded information on wolfberry nutrients (variety Phoenix Tears).

All Phoenix Tears dried leaf nutrient data was incorporated into a revised web site, www.phoenixtearsnursery.com. Additionally, two news releases on PQQ in dried Phoenix Tears fruit and betaine levels in leaves were distributed to a variety of media, nursery growers, and all persons seeking plant information from Phoenix Tears Nursery. As of spring 2011, the nursery is currently receiving from one to three inquiries daily, virtually none of whom have any knowledge of leaf usage.

The following articles were written and submitted to Countryside Magazine, Backwoods Home, Mother Earth News, and Urban Farm for publication:

Lycium barbarum: Variety Phoenix Tears
Wolfberries: As Good as it Gets, Getting Started with Goji Plants
How and Why of Wolfberry Harvest
Goji Leaf Salad
Goji-Wolfberry Plant Pruning

Objective Three: Improve farmers market grower, nursery grower, and personal grower understanding of wolfberries as a high nutrient food source.

In addition to the items discussed under Objective Two, a summary report will be emailed to about 300 farmers markets, nursery growers, and individuals.

Objective Four: Produce a set of recipes utilizing wolfberries.

Phoenix Tears Nursery published a recipe book with 91 recipes and some information on nutrients and cooking techniques. This material was reviewed by Tammy Vitale, a Utah State University

nutritionist, and is available to interested parties. This is a one of a kind super food cookbook utilizing fresh and dried wolfberry fruit and stem and leaf material.

BENEFICIARIES

Data and information from this project will enhance the expansion of wolfberries as a crop and food source. Immediate impact is measurable in the increase of nursery inquiries and plant orders. For example, spring 2010 inquiries were at a level of about one or two a week. Spring 2011 inquiries are running from one to three a day. Last years total plant orders were less than 1000. This years orders as of March 1, are already nearing 10,000 plants, reflecting the expanding interest in wolfberries as a commercial and garden use crop.

LESSONS LEARNED

First, there is always more to learn about this incredible plant. Second, without grant funds, this plant may never have become a crop outside of China. It has been an exciting venture to go from discovery in the Utah West Desert eight years ago, to establishing Phoenix Tears Nursery as a nationally recognized source of information on Lycium barbarum.

Nutrient data has clearly established the merits of Lycium barbarum, variety Phoenix Tears.

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2010-2. Identification and distribution of *Erwinia amylovora* strains resistant to streptomycin in apple and pear orchards in Utah

Final Report

PROJECT SUMMARY

The project was conducted at the request of apple and pear growers though the Utah State Horticulture Association. An initial survey for streptomycin resistance of *Erwinia amylovora* had been done from 2006-2008 after the first resistant isolates were found. Growers wanted to know if the resistant isolates were still present three years later and if resistant isolates had spread. Resistance to chemicals often results in a “cost of fitness” for the resistant organism such as slower growth that makes them less competitive with sensitive isolates once the chemical associated with the resistance is removed. Thus, after a few years sensitive strains should be dominant again.

Streptomycin is still the most effective chemical treatment available to Utah apple and pear growers who apply it based on a fire blight risk forecasting system in orchards with no known resistant isolates. In orchards with resistant isolates many growers switched to oxytetracycline, another antibiotic that is often not as effective in controlling fire blight. Streptomycin resistance can lead to substantial economic losses due to yield loss, cost for ineffective sprays and loss if trees. The survey provided the growers with information on the distribution of streptomycin resistant *E. amylovora* isolates in apple and pear orchards in Utah and if they could use streptomycin again in orchards that had resistant isolates during the first survey.

PROJECT APPROACH

Activities performed

In fall 2010 and spring/early summer 2011 and 2012, an undergraduate student assistant and I collected cankers and blossoms from symptomatic and non-symptomatic trees in a total of 25 individual orchards. 19 orchards (three of these orchards were visited again in 2012) were in Utah county, three in Cache county and one each in Box-Elder, Grand and Davis county. Two of the orchards revisited in Utah Co. had no fire blight in 2011 and were re-sampled in 2012. We isolated *E. amylovora* from samples from 15 of the Utah county orchards, two from Cache county orchards, one from Davis county and none from Box-Elder and Grand counties. The isolates from Cache county came from a pear isolate (the only pear isolate we obtained) and one apple orchard. All isolates were tested for their resistance to streptomycin at 0, 100 ppm, 1,000 ppm initially, and when they were resistant some isolates were also tested at 200,000 ppm. In 2011, two Utah county orchards had mixed *E. amylovora* populations containing both resistant and sensitive isolates, one orchard had only sensitive isolate and the other twelve orchards had only resistant *E. amylovora* strains. In the Davis county, I found only sensitive isolates in 2011 but I collected one resistant isolate among 10 total isolates from the same orchard in 2012. Both resistant and sensitive isolates were found on the same tree. This are the first resistant isolates detected outside of Utah County. The Cache county isolates were sensitive.

To test for resistance to streptomycin, a hole was punched with a cork borer into the agar and a streptomycin solution was pipetted into the well. The streptomycin solution diffused into the agar and a halo forms around the well when isolates are sensitive. All resistant isolates grew as well on 100 and 1,000 ppm streptomycin as they did on medium without streptomycin. To determine if the resistance breaks down at higher streptomycin concentrations we exposed several resistant isolates to concentrations of 200,000 ppm. The bacteria were still resistant and grew as vigorous as they did at 100 ppm. 200,000 ppm is 1,000 times the concentration used by growers in the field. We stopped at that 100,000 ppm because this demonstrated how strong the resistance was.

The survey results clearly show that streptomycin resistance is persistent in orchards even after the use of streptomycin was ended in these orchards in 2006 when resistance was detected. There was also no cost of fitness associated with the resistance. Both resistant and sensitive isolates grew vigorously which is probably the reason why streptomycin-resistant isolates are still dominant in orchards were growers indicated they stopped using streptomycin. The grower who owned the orchard in Utah county that had only sensitive isolates never used streptomycin.

To identify the mechanism for resistance in Utah *E. amylovora*, an undergraduate student as part of her Undergraduate Research class determined that the resistance was due to a mutation in *rpsl* gene that encodes a protein to which streptomycin binds. The mutation had been detected in resistant *E. amylovora* in other states previously and is highly stable and has no negative effect on the bacteria. The mutation results in a slight change of the protein which makes it impossible for streptomycin to bind. The mutation changes one amino acid from a lysine to an arginine. Other mutations have been observed in this gene in New York but in contrast to this mutation they were not stable. The undergraduate project was not part of this grant but I felt the information was important and should be added to the report. A manuscript on the survey and the resistance mechanism is in progress.

Based on the results of the streptomycin resistance survey, the current recommendations are the use of oxytetracycline as the primary chemical management and only use streptomycin in orchards with no resistant *E. amylovora* as a last resort. Pruning infected branches as soon as possible after symptoms appeared can significantly reduce fire blight incidence.

GOALS AND OUTCOMES ACHIEVED

I accomplished outcomes 1, 2 and 3. We collected *Erwinia amylovora* strains from orchards in dominant fruit production areas in the state. The only regions we did not obtain any isolates from were Grand and Box Elder counties. We determined that streptomycin resistance was still a mjor problem in many orchards in Utah county where resistant *E. amylovora* were found during the first survey. WE also showed the occurrence of streptomycin resistant *E. amylovora* in Davis county which is over 80 miles to the north of Utah Co. Each grower (12 total) was notified about the resistance level in his orchards as soon as the results were available. I gave a brief talk at the Fruit tree field day in Santaquin, UT in August 2011 (42 participants) and I presented the results at the Utah Horticulture Association (USHA) meeting in January 2012 (50 participants). A second update will be given at the USHA meeting in January 2013. A fact sheet on streptomycin resistance of *E. amylovora* with management recommendations was posted on the Utah State University Extension website in November 2012.
Significant contributions were provided by Utah State University whose infrastructure I use and the Utah Horticulture Association who provides the venues to present the results of this project. The growers significantly contributed to this project by allowing me to collect samples in their orchards.

BENEFICIARIES

Beneficiaries were commercial apple and pear growers and small farms. The results of the survey allowed me to provide recommendations that lead to reduced losses due to application of ineffective chemical applications, yield loss and loss of trees to systemic infections.

LESSONS LEARNED

The most important lesson learned from this project was the fact that resistant populations still dominated many apple orchards years after growers quit using streptomycin. The resistant populations will be here for many more years making the use o f streptomycin as a management tool in many orchards in Utah useless.
A second lesson learned was the high levels of streptomycin the resistant *E. amylovora* populations could tolerate. Often times when microorganisms are resistant to a chemical they only tolerate certain concentrations and die at high concentrations. This was clearly not the case with resistant *E. amylovora* isolates who can at least tolerate 100,000 ppm.

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2010-3. Cherry Fruit Fly Control with GF-120 Killing Stations

Final Report

Project Summary

Western cherry fruit, *Rhagoletis indifferens*, is the key insect pest of cherries in Utah and western North America. Processed tart cherries have a zero tolerance for fruit fly larvae, and so strict prevention of fruit infestation must be maintained. A reduced risk bacterial insecticide, spinosad, has been formulated with a feeding attractant in an "attract-and-kill" product called GF-120 Naturalyte (Dow AgroSciences, Indianapolis, IN). GF-120 is registered for organic production (OMRI approved). GF-120 sprays have proven successful in suppressing cherry fruit fly populations in Utah tart cherry orchards, but GF-120 is not rainfast and breaks down under ultraviolet (UV) light. Testing and refinement of a killing station that combines a yellow visual attractant and protection of GF-120 spray droplets from UV and rain was initiated in 2010 with funding from the Utah Department of Agriculture and Food Specialty Crop Block Grant Program. In 2011, further studies were undertaken to determine the required density of killing stations to eliminate cherry fruit fly infestation in tart cherry orchards.

Killing stations sprayed with GF-120 did not completely prevent fruit infestation by western cherry fruit fly, but they did lower fruit infestation levels to no more than 0.3% when deployed at the medium and high densities (18 and 30 killing stations per acre). Killing stations show promise as a supplemental control method for cherry fruit fly in commercial orchards (e.g., place them along borders and in population "hotspots"), or as a stand-alone control method in smaller acreage cherry orchards with low fruit fly densities. Once placed in an orchard, they are relatively easy to maintain with weekly targeted GF-120 sprays. Sprays can be applied to killing stations with a directed nozzle from a hand-pump or electric sprayer mounted on an ATV.

Adoption of killing stations by the tart cherry industry would enable growers to manage cherry fruit fly more cost effectively with a reduced risk insecticide. GF-120 killing stations could expand organic marketing of Utah cherries.

Project Approach

Methods and results

1) Killing station density research trial

Yellow killing stations (36 cm diam and 5 cm deep plant pot saucers) sprayed with 40% GF-120 (10 ml each) were deployed at three densities in two tart cherry orchards at the USU research farm in Kaysville, UT, in 2011. Killing stations (KS) were deployed every 16th tree (low), every 8th tree (moderate), and every 4th tree (high) in 0.24 acre plots and replicated four

times each. Stations were placed on June 22 and removed on August 24. Freshly mixed GF-120 was reapplied weekly. Two yellow sticky traps with external ammonium carbonate bait boxes were hung in each plot. Each week, the number of western cherry fruit fly adults on each KS were counted and collected in each the morning and afternoon. Adult fruit flies caught on sticky traps were collected, and the traps replaced every 2-3 weeks before the sticky surface was compromised. Flies from KS and traps were sexed (male and female), and the females dissected to determine if their ovaries contained eggs (reproductively mature).

Killing stations sprayed weekly with GF-120 did not completely eliminate fruit infestation, but stations deployed at 18 and 30 per acre kept fruit infestation at or below 0.3% through fruit maturity and harvest in early August.

2) Outreach

In 2011 and 2012, the following Extension outcomes were achieved: one *Utah Pests News* newsletter article, three tree fruit grower advisories that included information on timing of management of cherry fruit fly and performance of killing stations (http://utahpests.usu.edu/IPM/htm/advisories/treefruit/), incorporation of killing station recommendations into the *2013 Utah-Colorado Commercial Tree Fruit Production Guide* (http://intermountainfruit.org/), one poster presentation at a national entomology conference, and presentation of project results at the 2011 and 2012 winter USHA conventions, one in-season grower field meeting, and the 2011 summer USHA field tour.

A project follow-up grower survey was conducted at the Utah State Horticultral Association (Utah tree fruit industry) convention in January 2012 to measure grower perceptions to GF-120 and pest management behaviors for cherry fruit fly. Respondents represented 46% of the state's tart cherry production (1,525 acres of 3,300 total acres planted in the state) and five fruit producing counties in the state. Sixteen percent of the survey respondents grew some organic cherries on their farm; however, 54% reported using GF-120 for cherry fruit fly management. The number of GF-120 applications per year ranged from 0 to 10 with a mean of 4.5. These findings indicate that a majority of cherry growers are using GF-120 even though only a minority is targeting organic markets with their fruit. A newer generation of spinosyn insecticide, spinetoram (Delegate), was currently used by 31% of cherry growers. Spinetoram has a longer residual and protection interval than spinosad. 2012 grower survey results indicate strong interest among Utah cherry producers in using reduced-risk insecticides with good human safety profiles to manage their key cherry pest, cherry fruit fly.

Conclusions and recommendations

The yellow color of the killing stations increased fruit fly attraction and mortality.
Killing stations deployed at the medium and high densities (18 and 30 stations per acre) did not prevent fruit injury, but greatly reduced it to 0.3% or less throughout the fruiting season. Deployment of killing stations treated with the GF-120 in addition to supplemental sprays of GF-120 or spinosad offers promise for sustainable organic cherry management. In addition, conventional growers showed high interest in GF-120 and a newer generation spinosyn, spinetoram, that provides longer protection of fruit, 14 as compared to 7 days. The deployment of killing stations along field borders with cherry fruit fly immigration pressure

and in "hot spots" in combination with reduced-risk organic and conventional insecticides can provide enhanced management of fruit fly and greater insurance to eliminate fruit infestation.

Presentations and Publications

Alston, D. G., J. C. Pinero, and C. R. Adams. 2010. Attract-and-kill stations for management of a temperate fruit fly pest, *Rhagoletis indifferens*, in cherry. Entomological Society of America 58th Annual Meeting, December 12-15, San Diego, CA.

Alston, D. 2011. Attract-and-kill stations for management of cherry fruit fly. Utah Pests News Vol. 5 (Spring): 9, Utah State University Extension and Utah Plant Pest Diagnostic Laboratory, Logan, UT. (https://utahpests.usu.edu/files/uploads/UtahPests-Newsletter-spring11.pdf)

Murray, M. and H Larsen (eds.). 2012. Utah-Colorado tree fruit production guide, 178 pp., Utah State University Cooperative Extension, Logan, UT.

Significant contributions and role of project partners

Diane Alston was the project director and oversaw all aspects of the research and outreach accomplishments. Because the project required that some fruits be allowed to be infested with cherry fruit fly, all research was conducted on a USU experimental farm. The outreach provided education on use of killing stations to fruit growers, Extension agents, Utah Department of Agriculture and Food field inspectors, and Natural Resource Conservation Service field agents.

Goals and Outcomes Achieved

Over 200 face-to-face contacts and 4,000 newsletter and tree fruit pest advisory subscribers received education about the potential of killing stations to improve cherry fruit fly management.

1. An *increase in use of GF-120 Naturalyte, a reduced risk and organically certified attract-and-kill insecticide product, by Utah cherry producers.* A 2012 post-project grower survey documented a high use pattern of GF-120 and related reduced-risk insecticides by the Utah cherry industry, 54% and 31%, respectively. Although only 16% of cherry growers in the 2012 survey were currently growing organic cherries, the high use patterns of organic and reduced-risk insecticides indicates a strong interest in improved worker safety, protecting the environment, and reducing off-target effects in killing beneficial insects. An informal survey conducted by D. Alston of 15 cherry producers in 2009 found that GF-120 made up only 20% of insecticide sprays in conventionally managed orchards, and 50-75% of treatments in organic orchards. An increase in use of spinosyn insecticides which include spinosad (GF-120, Success, and Entrust) and spinetoram (Delegate) from 2009 to 2012 indicate positive impacts of this and related projects on reducing the use of toxic, broad-spectrum insecticides in the Utah cherry industry.

2. *A change in organic cherry production in Utah that is linked, at least in part, to the use of GF-120 Naturalyte.* In the 2012 post-project survey, organic cherry producers indicated use of 7-

10 spinosad (GF-120 and Entrust) applications per season to protect fruit from cherry fruit fly. Spinosad is the only organically certified insecticide registered on cherry with efficacy for fruit fly. Adoption of killing stations to deploy GF-120 would decrease the amount of spinosad applied to orchards while extending the residual longevity of the insecticide.

Beneficiaries

Utah's cherry producers, pest management suppliers, and professional agency staff who work with the fruit industry, such as NRCS and Utah Department of Agriculture and Food were the primary beneficiaries of this project. All cherry acreage in the state (3,300 acres worth $5.8 mill in utilized production in 2010) was impacted by this project because cherry fruit fly is the key pest that must be managed in all commercial cherry orchards in order for them to be viable and successfully marketed. The integration of GF-120 killing stations into cherry fruit fly management programs has strong merit. For conventionally managed orchards that prefer to rely on insecticide sprays as their primary fruit fly control tactic, implementation of a lower density of killing stations could help reduce populations in the orchard and provide an effective pest monitoring tool. For organically managed orchards that must rely on spinosad as a primary fruit fly control tactic, an effective density of GF-120 killing stations could provide season-long control of fruit flies. An estimate of the price increase for organic over conventional cherries is at least 20%. The implementation of killing stations to reduce populations of cherry fruit fly could contribute to an increase of up to $1.9 million of added value for production of organic sweet and tart cherries in Utah.

Lessons Learned

The yellow killing stations were shown to be effective in protecting the GF-120 insecticide bait from UV radiation and rainfall. Use of killing stations alone did not prevent fruit injury, but reduced it to as low as 0.3%. Supplementation of the killing stations with an organic insecticide spray of spinosad, or a conventional insecticide for conventional orchards, may be adequate to completely prevent fruit injury.

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Additional Information

Publication

Alston, D. 2011. Attract-and-kill stations for management of cherry fruit fly. Utah Pests News Vol. 5 (Spring): 9, Utah State University Extension and Utah Plant Pest Diagnostic Laboratory, Logan, UT. (https://utahpests.usu.edu/files/uploads/UtahPests-Newsletter-spring11.pdf)

Murray, M. and H Larsen (eds.). 2012. Utah-Colorado tree fruit production guide, 178 pp., Utah State University Cooperative Extension, Logan, UT.

2010-4. Optimizing Winter Greens Production and Survival in High Tunnels

Final Report

Project Summary and Need:

Much of the work to develop high-tunnel production systems has been carried out in the Eastern (http://plasticulture.cas.psu.edu/H-tunnels.html) and Mid-western U.S. (www.hightunnels.org) where high humidity results in increased pressure from fungal pathogens. Foliar and fruit pathogens are generally not the limiting factor in the high-elevation arid climate of the Intermountain West. However, in high altitude desert climates like Utah, growth is often limited more by extreme day-night temperature fluctuations. This is particularly true in early spring when temperatures can fluctuate by more than 50F (10C). Growth problems from significant temperature variations within the tunnels are very common in the late fall through early spring period when one tries to grow crops when outdoor temperatures are very cold. In Utah, high light levels are common in winter, but short day lengths and low sun angles limit the amount of naturally occurring heat entering the tunnel. Cold night temperatures may be overcome by (1) using row covers or "crop blankets" inside the tunnel, (2) by creating secondary tunnels (fabric or plastic row covers) inside the high tunnels or (3) through modest heat additions like soil and targeted air warming. However, for lower value crops like winter greens, these may not be economical in all situations. In addition, for small fruits like blackberry which are moderately hardy under Utah conditions, one needs to both keep the temperature in the tunnel from getting too low (when extremely cold outside) which can damage the canes, and from getting too warm which can cause buds break too early in the spring.

Therefore, winter impacts on leafy salad greens and blackberry needs further study to develop cost effective production systems. With this information, growers will have additional production options and the detail horticultural and economic information needed to assess if this fits into their present production scheme. These finding can help small intensive fruit and vegetable producers in the intermountain region (CO, ID, NV, WY, UT) of the western US. The potential impact of this project would expand the production of selected crops throughout the winter months when locally grown produce is not available, and would allow for the production of high value crops not otherwise suited to harsh climate.

High tunnel season-extension technology has been demonstrated at Utah State University and extended to Utah's farmers and ranchers. More information is needed on potential uses of high tunnels during periods of the year when local produce may not be available or where climatic conditions are less conducive to growth. The main reason for growers failing to adopt winter production is that plant growth is slow and productivity levels are low in salad crops like spinach (when too cold) and early bud break in cold sensitive crops like blackberry (if too warm) hinder optimal productivity. Therefore the goals for this project were;

1. Assess growth and yield response of various winter salad greens to environment modification techniques
2. Devise improved survival strategies for overwintering blackberries.
3. Use generated information to draft enterprise and production guides.

Project Approach and Methodology:

Goal #1: Environmental Modification Techniques:

Six crop production systems were tested during the late fall - early winter of 2009-10 when outdoor environmental conditions are cold. Spinach (*Spinacea oleracea*) and Lamb's Lettuce (*Valerianella locusta*) were seeded in the greenhouse in late-September and transplanted in high tunnels (4 plants/ft^2 in early November and grown through to late-December (lower light levels and decreasing outside temperatures). The experiment was repeated in mid-January with plant growth and crop production monitored to mid-March (light levels and temperatures improving). To alter the environment around the plants, we used heating cables to warm the soil and row covers to alter the air temperatures around the leaves. The six growing systems were (see Figure 1);

1) Thermostatically controlled soil heating cables (programmed to heat when soil temperatures dropped below 50F); no row covers (heated control)
2) Soil heating cables plus low plastic tunnels (see Figure 1)
3) Soil heating cables plus floating row covers
4) Unheated soil, no additional covers (unheated control)
5) Unheated soil plus low plastic tunnels
6) Unheated soil plus floating row covers

Figure 1. The influence of row covers on spinach grown under plastic, under Reemay or without a row cover (control). Spinach planted on Nov. 3 and the photographs taken on Dec 21, 2009.

Spinach and lambs lettuce were harvested every 10 days (5 harvests) and plant fresh weight, leaf number, and the number of plants harvested recorded. Soil and air temperature at plant level and outside the high tunnels were monitored throughout the study.

Project Results:

The addition of soil heat generally increased the productivity of lamb's lettuce and spinach when compared to not heating the soil during both the fall and spring production periods (Table 1). Row covers (plastic or floating mulch) also increased final yield when compared to the uncovered controls. In general, lambs lettuce yield was greater when grown under low plastic tunnels than when gown under the floating row cover. The level of productivity between the fall and spring planted lambs lettuce were significantly different from each other. Due to the heat cable malfunctions in the fall planted spinach, we were not able to directly compare the fall crop to the spring crop. However, if we just compared the un-heat fall spinach to the spring spinach; yields were not different from each other.

Table 1. Yield response of lambs lettuce and spinach to various row covers and soil warming techniques (fall-winter 2009-10, 2010-11).

	Final Yield (lbs./ft2)			
Production Systems	December 2009		March 2010	
Lambs Lettuce	+soil heat	-soil heat	+soil heat	-soil heat
Low Plastic Tunnels	0.073 a	0.072 a	0.055 a	0.040 a
Floating Row Covers	0.048 b	0.033 b	0.037 b	0.024 b
Uncovered Controls	0.035 b	0.027 b	0.018 c	0.013 c
Sign. 0.05	0.052	0.044	0.037	0.026
Spinach	December 2009		March 2010	
Low Plastic Tunnels	-@	0.078 a	0.067 a	0.038 a
Floating Row Covers	-	0.064 b	0.059 a	0.025 b
Uncovered Controls	-	0.039 c	0.029 b	0.012 c
Sign. 0.05	-	0.060	0.052	0.025
Spinach	December 2010		March 2011	
Low Plastic Tunnels	0.179 a	0.125 a	0.426 a	0.374 a
Floating Row Covers	0.098 b	0.060 b	0.376 b	0.390 a
Uncovered Controls	0.077 b	0.040 c	0.384 b	0.335 a
Sign. 0.05	<0.0001	<0.0001	<0.0001	0.257

@ heat cable malfunction – data not different from non-heated
Values followed by the same letter are not different from each other

Air temperatures around the plants were significantly influenced by row cover treatment. Figure 2 illustrates the diurnal change in temperature for two very cold days in early February 2010. Outside temperature did not get above 0°C (32°F) during the day with an over-night low of -15°C (5°F). Plants grown without any row cover experienced a low temperature of -8°C (18°F) and then plants were exposed to a high temperature during the day of 25°C (77°F). In contrast, plants grown under the Reemay or Plastic row covers were subjected to a low night temperature of -1°C (30°F)

and warmed up to more than 30°C (86°F) during the day. The differences noted in final plant yield when spinach and lambs lettuce are grown under row covers is due to improved over night low temperatures and higher day temperatures which improves plant photosynthesis and thus plant growth.

Project Outcomes and Achievements: Goal #1

For winter production in high tunnels, there was a significant improvement in plant yield for both lambs lettuce and spinach due to better temperature management. Overnight temperatures never drop too low and day temperatures get significantly above the minimum temperature (5°C or 40°F) needed for growth for either lambs lettuce or spinach. One question of interest is "how rapidly does plant photosynthesis increase after plants are subjected to repeated cold-hot cycles?" This question is raised because yield levels are still quite low and do not achieve productivity levels that are considered economic. In 2010-11 we refined our production approach and had one fall treatment (heat + low tunnels) achieve productivity levels better than 0.15 lb/ft^2. In the winter (January-March) of 2011, better management and refined approaches to growing spinach showed that all heated and unheated treatments could achieve quite high yields. A production level of 0.15 lb/ft^2 (1 kg/m^2) is considered to be the break point for economic sustainability. For the fall planted crops which start production when temperatures outside are more mild, this may be achievable since yields only need to double to get more than 0.15 lb/ft^2. In the fall, plantings should be early enough to get good establishment and to ensure much of the growth occurs before the really cold weather of winter sets in.

However, other approaches may be needed for plantings occurring in early to mid-January when night temperatures are quite cold, light levels low, and establishment and early growth of either lambs lettuce or spinach is more adversely affected by these conditions. Differences in the relative growth rate (change in weight per unit time) for the first harvest interval in the fall planting were three times greater that during the same period in the winter planting (data not shown). Plants respond to the better growing environment in the fall and grow faster, thus achieve a higher final weight. One approach improving winter production would be to plant at higher densities which would increase yield per unit area even though it would not change the actual growth rate of the plants. Planting at higher densities would increase production costs since more plants need to be propagated and transplanting labor costs would be higher.

Growers can not start to use this information to grow a variety of crops both in the late fall and early winter before switching to their commonly grown crops in late March or early April.

Goal #2: We are beginning the evaluation of the effects of the following overwintering techniques on high tunnel and outdoor grown blackberries (various varieties). The following treatments were imposed on the plants in the late October 2009 and plant growth will be rated in late May 2010 for cane growth (number, length, weight, etc), date of bud break, first flowering and fruiting potential.

1) Plants will be covered or uncovered to assess extra winter protection to the canes.
2) Plants will be left standing upright (on trellis) then either covered or uncovered.
3) Prostrate trellises will be either covered with row cover or left uncovered.

Preliminary findings indicate that fluctuating temperatures in the tunnels results in incomplete dormancy and increased incidence of winter injury. As a result, cane damage is quite substantial and flowering is negatively affected which results in low yields. None of the production techniques tried

has been successful and additional protection methods are required before recommendations can be made to Utah growers. Since cane damage is too severe, we cannot recommend growing blackberries at this time.

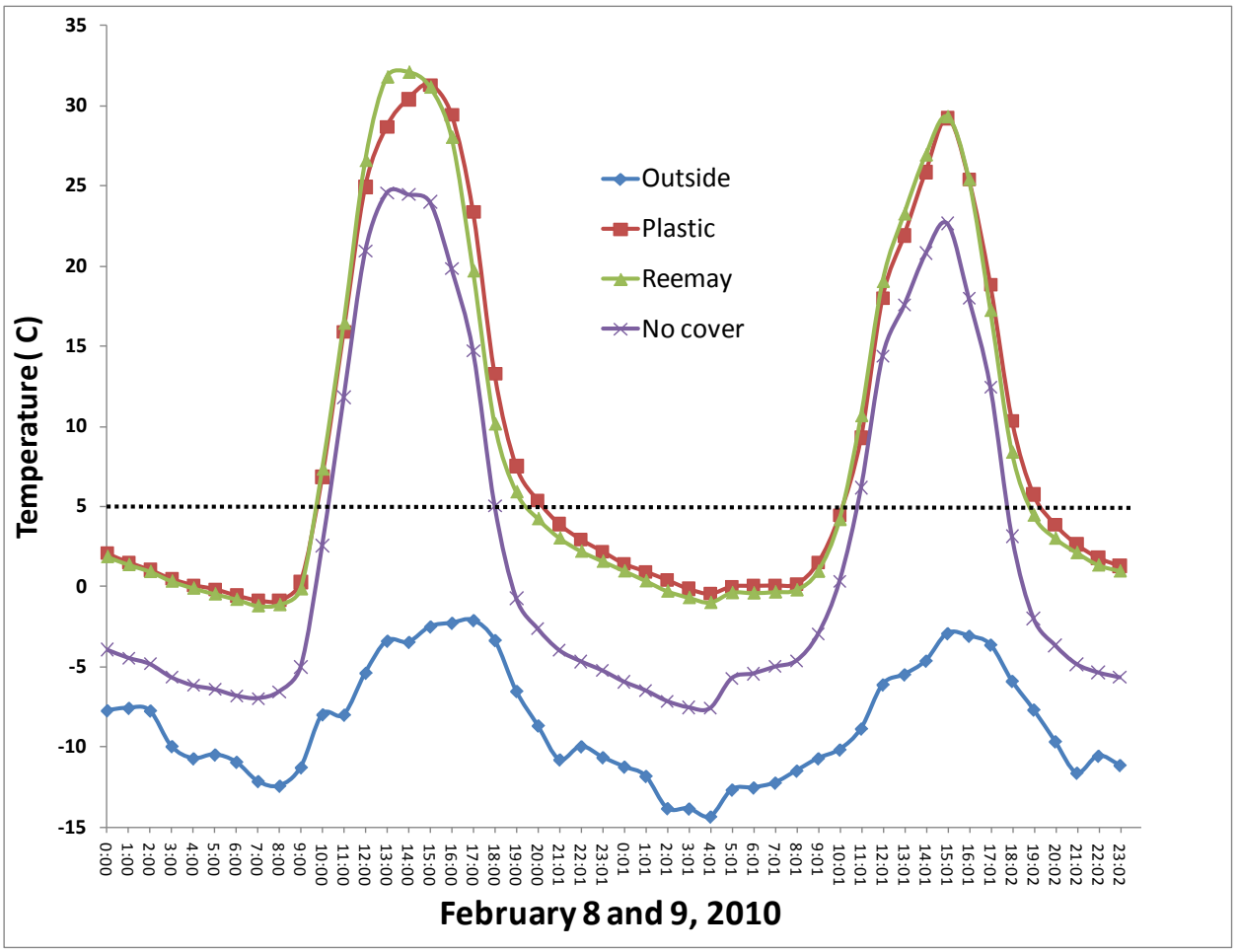

Figure 2. The influenced by different row cover treatments on air temperature (°C) over two days in early February, 2010. Row covers were the no cover control, a floating Reemay cover, or low tunnels covered with plastic inside the high tunnel. Outside air temperature is also shown. The dotted line shows the minimum temperature required for spinach or lambs lettuce growth.

Goal #3: Winter production guidelines are being written outlining plant establishment considerations (seeding or transplanting) and planting dates (fall vs. winter). While the preliminary data has been helpful understanding how plants perform in cold conditions, it should be noted that the systems employed do not generate yields that are yet considered economical. In June of 2010 we hired Ms Taunya Ernst (MS graduate student) who is researching the effects of changes in plant density (4, 9, 36 plants/ft2), comparing direct seeding to transplanting, and exploring if leaf clipping is more economical than selected leaf remove. If these alternative production methods increase yield if would offer a solution to the problem of low productivity. It would also allow the grower to harvest the same plants over a much longer growing period which would save reestablishment costs and the problems associated with slow winter growth. These studies were planted in late-October 2010 and will be grown until mid-March 2011. In addition, Ms Ernst is exploring how photosynthesis changes

as plants are exposed to repeated freezing-thawing cycles. This data may explain more fully the growth responses and highlight plant adaption to variable environments of high tunnels during the fall-winter period.

Beneficiaries:

Findings from these studies were presented to more than 200 growers, industry and government persons at national and regional meetings in Utah, Nevada, Idaho and California in 2010. These presentations highlighted findings from our studies and provided participants with up-to-date information on production approaches and market opportunities. In addition to more formal presentations, we hosted over 40 growers who came to tour the Utah State University research site in Logan.

Significant Outcomes, Accomplishments and Presentations – 2010-11

Presentations:

Drost, D and B. Black. 2010. High Tunnels and IPM: How Season Extension Technologies Impact Pests and Diseases. Western IPM Working Group. May 18. Logan, UT.

Drost, D and B. Black. 2010. Hoop House Construction and Season Extension Technologies. Nevada Indian Agriculture and Rural Summit. May 24-26. Fallon, NV.

Hunter, B, **D. Drost**, and B. Black. 2010. Frost Protection for Early High Tunnel Tomatoes. Amer. Soc. Hort Sci., Aug. 2-5; Palm Desert, CA.

Rowley, D, B. Black and **D. Drost**. 2010. High Tunnel Strawberry Systems for High Elevations. Amer. Soc. Hort Sci., Aug. 2-5; Palm Desert, CA.

Hudson, B. and **D. Drost**. 2010. Increasing Winter Salad Greens Yield in High Tunnels. Amer. Soc. Hort Sci., Aug. 2-5; Palm Desert, CA.

Black, B. 2010. High tunnels for high elevation production. 116th Annual Convention of the Idaho State Horticultural Society. Nov. 22-23; Nampa, ID

Publications:

1) Rowley, Daniel, Brent L. Black, **Dan Drost** and Dillon Feuz. 2010. Early Season Extension Using June-Bearing 'Chandler' Strawberry In High Elevation High Tunnels. HortScience 45:1464-1469.
2) **Drost, D**. and R. Ward. 2011. High Tunnel Early Squash Budget 2011. USU Extension. http://extension.usu.edu/agribusiness/files/uploads/specialty/pdf/2011%20Early%20Squash%20High%20Tunnel.pdf
3) Hunter, B., **D. Drost**, and R. Ward. 2011. High Tunnel Early Tomato Budget 2011. USU Extension. http://extension.usu.edu/agribusiness/files/uploads/specialty/pdf/2011%20Early%20Tomato%20High%20Tunnel%20.pdf
4) Britney Hunter, **Dan Drost** and Brent Black. 2010. High Tunnel Lettuce Production. USU Extension Bulletin. http://extension.usu.edu/files/publications/publication/Horticulture_HighTunnels_2010-04pr.pdf
5) Brent Black and **Dan Drost**. 2010. Temperature Management in High Tunnels. USU Extension Bulletin.

http://extension.usu.edu/files/publications/publication/Horticulture_HighTunnels_2010-04.pdf

Lesson Learned:

High tunnels can effectively be used for the production of winter greens provided additional protection is used during the coldest periods of the year. Spinach and Lambs Lettuce grown in tunnels produced high yields when covered compared to uncovered. At present the benefits of additional supplemental heat with electric cables does not provide sufficient environmental modification to further increase plant production and thus is not advised. We were unsuccessful in achieving what has been reported to be a level of production that is economic. Other methods of production (higher plant populations, repeated harvesting of existing plants, and direct seeding) are being tested to see if fresh biomass levels of 0.15 lbs/sq ft can be achieved which have been reported to be a level of production deemed economic. These techniques are being used in the winter of 2010 and 2011 and will be reported on later.

A complete re-evaluation of blackberries grown in high tunnels is required to assess better plant protection approaches that ensure better levels of production. At this time, we cannot recommend high tunnel production of blackberry as levels of production are just too low.

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2010-5. Methods for Determining Water Stress in Tart Cherry Trees

Final Report

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Thor Lindstrom, Research Technician, Utah State University, Kaysville Research Farm

Project summary:
The availability of good quality irrigation water is a continuing limitation in Utah fruit production. Managing available water for optimum cropping is essential. The majority of the orchard acreage in Utah County has been converted to highly efficient micro-sprinkler and drip systems. However, irrigation scheduling is often calendar based, and is not always well correlated with tree needs. Often, insufficient irrigation near harvest has resulted in decreased fruit quality and yield. To avoid damage to the crop, some growers have over-irrigated to the point of detrimental effects on the orchard, such as the development of root and collar rot (Thomson, personal communication), and

increased iron chlorosis as was seen in 2008 and 2011. Additional detrimental effects of improper orchard irrigation may be trunk damage from mechanical harvest and subsequent decline of tart cherry trees.

Tart cherries are the number one fruit crop for the state of Utah, based on growing area. Since the late 1960s, tart cherries have been harvested mechanically. Harvesting equipment grips the trunk of the tree, shaking the fruit loose, to then drop on a padded catch surface and be collected in water-filled tanks for cooling and processing. Despite advances in shaker technology, harvesting often causes severe damage to the tree trunk. At the point where the shaker grips the trunk, the phloem and bark tissue may separate at the cambium layer. This results in cracks in the trunk that provide an infection site for plant pathogens. Even without pathogen infection, the resulting scar tissue makes the trunk more susceptible to southwest winter injury. The cumulative effects of trunk injury, coupled with southwest winter injury and pathogen infections dramatically reduces the commercial life of the orchard. Damaged and weakened trees require additional chemical inputs for addressing secondary insect and disease problems. Work with other mechanically harvested stone fruit crops, such as almonds, has shown that water status of the tree prior to, and during harvest affects the susceptibility of the trunk to damage (Gurusinghe and Shackel, 1995). Growers need to properly manage irrigation both to maintain orchard health and to conserve available water.

Regulated Deficit Irrigation (RDI) is the concept of applying less irrigation water than is needed for maximum plant growth, at a specific stage of crop development. We completed a 3-year study that demonstrated the effectiveness of RDI in not only conserving water, but also reducing the susceptibility of tree trunks to shaker injury (Papenfuss, 2010). However, we also found it difficult to apply the appropriate level of water stress without over-stressing the trees resulting in damage or death. During each of the three study years, tree stress was monitored through measurements of "mid-day stem water potential". This method was able to accurately quantify the level of tree stress. However, it is a cumbersome and slow process, requiring both specialized equipment and expertise in obtaining accurate readings. In order for irrigation scheduling to be improved, and water conserving practices such as RDI to be implemented, better methods are needed for growers to quickly and easily determine tree water status in the orchard. A study was carried out in 2011 to compare available methods for measuring tree water status.

Project approach:

The experimental orchard consisted of 4 rows of 32 trees established in 2003 at the Kaysville Research Farm. A specially-designed irrigation system was installed in 2011 to provide a water supply gradient to 4 replicate plots. Data were collected from the two middle rows, with the outside rows as guards. Each plot consisted of 10 levels of supplied irrigation water, ranging from 100% to 0% of evapotranspiration. Irrigation treatments began at pit hardening and continued through fruit harvest.

Since crop load and tree vigor differed among trees, a subset of trees in the two record rows was selected for detailed measurements. Trees were selected for uniformity of vigor and crop load, but to represent the widest possible range of supplied irrigation.

Multiple methods were used to quantify tree water status on these selected trees, including: (1) midday stem water potential (pressure chamber of acclimated leaf), (2) Midday leaf water potential, (3) Midday stomatal conductance (by diffusion porometer), (4) midday stomatal conductance as measured by a portable infra-red gas analysis system, and (5) canopy temperature using an infrared radiometer.

Dr. Scott Johnson from the University of California took oversight of day-to-day activities of this experiment. Dr. Johnson is a world-renowned expert in water relations and irrigation of temperate tree fruit, and was in Utah for the summer on a sabbatical leave. Due to an unusually wet cool spring in 2011, irrigation was not needed until later than normal, which delayed the development of treatment differences. Once tree stress differences began to appear, it quickly became apparent that methods based on individual leaf measurements (leaf water potential or stomatal conductance) were too variable to reliably indicate whole tree water status. This was because individual leaves on a tree can vary greatly in water status.

Much of Dr. Johnson's efforts in 2011 focused on refining methods for determining canopy temperature. He found that sensor angle and position were critical to the results from these measurements. One of the problems of the early prototype sensor was that the field of view was too wide, and resulted in measurement of both sky and ground temperature. However, if the sensor was properly positioned to minimize sky and ground in the field of view, early-afternoon canopy temperatures taken on sunny days were closely correlated to mid-day stem water potential (Figure 1). Additional funding was obtained through a USU Extension Internship program, and student intern Jeremy Crapo was employed during 2012 to continue the study. Also, based on Dr. Johnson's experience in 2011, the canopy temperature instrument manufacturer developed a new sensor with a slot aperture that could take a horizontal reading, while reducing background signal from the sky and ground (SI-1H1 Horizontal Field of View Infrared Radiometer; http://www.apogeeinstruments.com/infraredradiometer/#models). During 2012, Jeremy Crapo utilized these new sensors and continued measurements of trees in the Kaysville experimental plots. He was able to confirm Dr. Johnson's early results, and found that further refinement (sensor direction and angle) were critical to improving the accuracy of these readings. Data collected by Mr. Crapo is now being analyzed to further refine the accuracy and reliability of this technique.

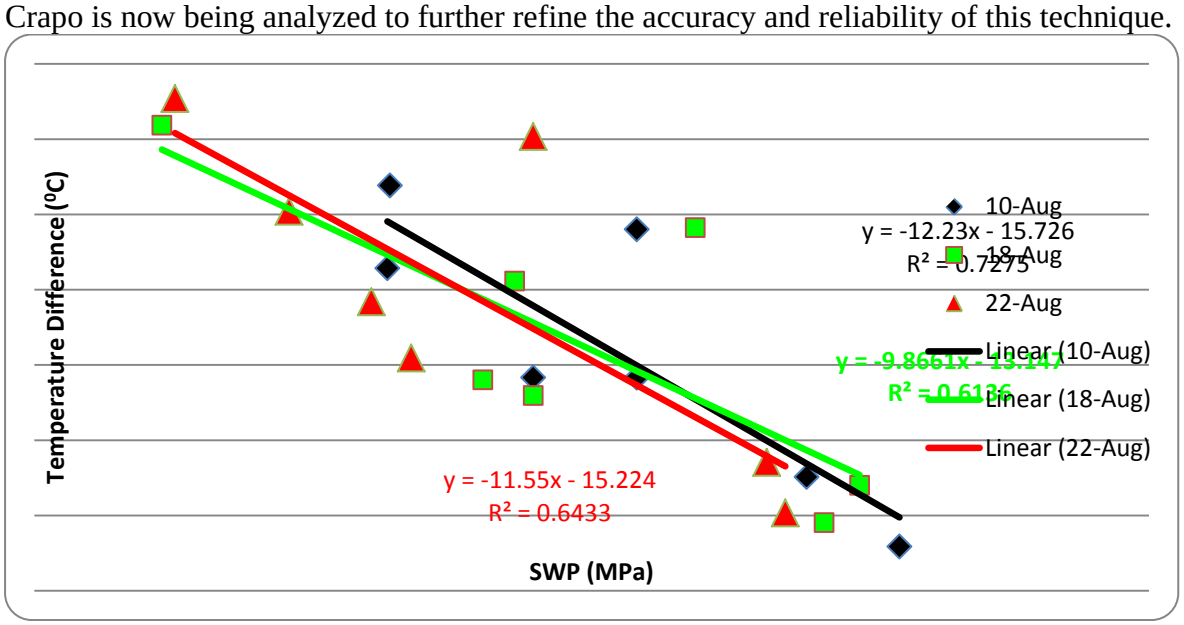

Figure 1. The relationship between canopy temperature (compared to air temperature) and stem water potential (SWP) of Montmorency cherries subjected to different levels of water stress. Canopy temperatures were measured for one hour foillowing solar noon and SWP taken at about the same time on three sunny days in August, 2011 at Kaysville, Utah.

Goals and outcomes achieved

The goal of this project was to compare methods for measuring tree water status. Following are the methods that were employed, and our conclusion regarding their effectiveness for use in tart cherry.

1. Midday stem water potential (pressure chamber of acclimated leaf). *This is the most reliable and repeatable method for determining tree water status. However, the specialized equipment and expertise makes it unlikely that this method would be widely employed by orchard managers.*
2. Soil volumetric water content. *Although this provides a quick and reliable determination of soil water content for a small defined area, it isn't a very reliable predictor of tree water status, as tree roots spread both in the tree row and under the alleyway cover crop. It is still a useful tool for determining the amount of water that will be needed to recharge the soil profile, but should be used in conjunction with a method to directly measure tree water status.*
3. Midday leaf water potential (pressure chamber of non-acclimated leaf). *Tart cherry trees have very large leaf-to-leaf variation in leaf water content. Results from this method do not represent tree water status.*
4. Midday stomatal conductance (by diffusion porometer). *Unreliable due to large leaf-to-leaf variation.*
5. Midday stomatal conductance (by portable infrared gas analyzer). *Also unreliable due to large leaf-to-leaf variation.*
6. Canopy temperature (Infra-red thermometer). *After midday stem water potential, this appears to be the most promising method. Of particular advantage would be the ability to attach a sensor to a weather station and remotely monitor tree water status. More work is needed to refine this method and provide consistent results.*

Preliminary results from this study were presented at the annual meeting of the Utah State Horticulture Association on February 1st, 2012. Registration for this meeting was approximately 120, with 90 attending this presentation. The irrigation plots and sensors were also displayed at the Kaysville Farm Field Day on August 16th, 2012. Attendance at the 2012 field day was very low, due largely to the unusual weather conditions that accelerated fruit harvest during this period. Typical attendance at this field day is between 50 and 80. The attendance in 2012 was about 15 individuals, with most of these representing NRCS, USU Extension and industry consultants. Information on orchard irrigation strategies was also featured in one of the Box Elder fruit grower twilight meetings, with approximately 15 farm managers in attendance. Based on the attendance at these three venues, the information was presented to owners and farm managers representing at least 80% of Utah's commercial fruit industry.

USU Extension fact sheets on orchard irrigation were previously developed. During the course of this project, a "Production Horticulture" website was developed and launched, where commercial growers could quickly and easily access and download these fact sheets (http://fruit.usu.edu). Hard copies of these fact sheets were also distributed at each of the meetings discussed above. One of our goals in this process was to revise these fact sheets with information on using canopy temperature to monitor orchard tree water status. However, results from 2012 indicated that additional research would be needed to address some of the variability in this approach before specific recommendations could be developed and incorporated in these fact sheets.

Beneficiaries

Ultimately, this research benefits commercial tree fruit producers and orchard managers in determine when and how to best utilize irrigation water. Tart cherries are Utah's most important fruit crop with

3,300 producing acres, with 2009 production of 34 million pounds valued at $8.16 million (NASS, 2010). Improving irrigation strategies inprove the long-term health of these orchards, and optimize the use of Utah's most limited natural resource. Secondary benefits of the research are to populations living in or near Utah's fruit growing areas that compete for the same limited water resources.

Also benefiting from this research are instrument manufacturers that are seeking to develop equipment that can be utilized for orchard management. One early conclusion of this research resulted in a modification to commercially available sensors. As we continue to analyze data collected from this project, we anticipate further refinements in techniques and calibration to improve the reliability of this instrumentation.

Lessons Learned
A number of commercial instruments are sold to assist growers in irrigation scheduling. Our results indicate that any method that is based on single leaf readings will not be reliable for use in tart cherries. Soil based-readings will be useful to determine the quantity of water to apply, but have very little correlation with tree water stress. If growers are to optimize irrigation based on actual tree needs, direct measurements of tree water status are required. Stem water potential remains the most reliable approach. However, our results show that with further refinement, measuring tree canopy temperature with an infrared radiometer may be a very powerful and labor-saving method for monitoring water status of orchard trees.

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2010-6. "Breeding and Selecting Saskatoon Serviceberries (*Amelanchier alnifolia* Nutt.) for Improvement and Increased Use in Utah".

Final Report

Project Summary: The purpose of the project is to select and breed improved cultivars of Saskatoon serviceberries for use by commercial producers and for homeowners to use in edible landscapes. Saskatoon serviceberry is a shrub native to vast areas in the Intermountain West. It was highly sought after and has been an important food item of Native Americans and early settlers in this region. It is also considered to be an important shrub for many classes of wildlife. The species can be found growing on semi-arid ranges receiving 12 or more inches of annual precipitation, including being found throughout the Quaking Aspen (*Populus*

tremuloides L.) zone in Utah. It can be a large shrub attaining heights of up to 14 feet on some sites, while on other sites ecotypes can reach maturity at only a few feet. Serviceberries have significant genetic diversity and a high potential for improvement through selection and breeding. Improving Perennial Plants for Food and Bioenergy, Inc. (IPPFBE) is a 501.c.3 non-profit organization, founded by plant breeders, Dr. C. Reed Funk, Dr. Clarence Funk, Dr. Tom Molnar, Carol Petersen and Tim Ford. IPPFBE, (www.ippfbe.org) was established in 2005 with the objective to further scientific selection and improvement of underutilized perennial plants for the production of food, timber, and energy as well as the preservation and enhancement of soil and increased global carbon harvest. IPPFBE has eight research locations in northern Utah and southern Idaho. It includes a large geographical area and represents even more potential regions of high potential semi-arid rangelands and marginal croplands, unsuitable for the production of annual crops around the world. These areas represent over 50% of the earths terrestrial surface.

IPPFBE didn't purchase any of this germplasm. Though our relationships with Dr. Bob Bors at the University of Saskatchewan (which is near the center of origin or diversity for *Amelanchier alnifolia)*, we were able to travel to their large research farm and were able to collect berries from selections made from their entire collection. The collection there is the result of many years and many millions of dollars to collect and assemble in their research fields. They released a few varieties for use in their region and other nearby Prairie Provinces. I had unfettered access to all of this germplasm, even their most advanced selections. Out of the thousands of serviceberries amassed there, I selected 63 based on overall plant vigor, yield, berry taste and size, freedom from disease, etc. The berries were then cleaned and the seed extracted for each collection. The seed was then tested and the government officials from Canada issued a phyto-sanitary certificate for import into the United States. These 63 collections were then stratified at 36 degrees F for 3 months in a peat/sand moist medium and not allowed to dry out. This resulted in exceptional germination, we planted the seed in our research greenhouse roughly 98 plants for each collection. They were planted in 'conetainers' in greenhouse potting medium in late January and allowed to grow in our greenhouse. The plants were then allowed to grow and the best seedlings based on overall health, vigor, freedom from chlorosis, and disease from each collection were planted in late April at IPPFBE research locations into evaluation nurseries at Thatcher, Utah, near Richmond Utah, near Huntsville, Utah and at Dayton, Idaho. This represents the largest collection and diversity of serviceberries ever assembled in the United States. Having this extensive germplasm in evaluation nurseries is a gold mine for Utah and the Intermountain West. During the establishment year the trees were rated for establishment and vigor. As the nurseries mature they will be evaluated for yield, consistency, berry size and flavor, freedom from disease and overall plant vigor and health. They should start to produce berries in about 4 to 5 years. As we determine and identify the best potential plants to release as a variety or varieties, after Plant Variety Protection and Registration, we will do so through local and regional

nurseries, or possible other outlets and the varieties will be made available for the general public to utilize for edible landscapes and commercial industries. IPPFBE has spent much of our own money, perhaps close to double or more of our grant request to make this project happen, all for the future benefit of Utahans, the Intermountain West and perhaps other similar regions of the world. It is our belief that collecting berries/seeds and growing them in our greenhouse would fall into the category of plant materials. We have reached our initial goal of getting the best *Amelanchier* germplasm planted into evaluation nurseries. In fact, due to the excellent germination, we were able to establish four nurseries instead of one. Additionally, the Utah State University fruit extension specialist Dr. Brent Black along with the Garfield county extension agent are going to plant some of our material this coming spring for evaluation in Garfield county for potential use there. Unfortunately, tree and shrub breeding projects take time, some more than others. But they have high potential to produce food and harvest atmospheric carbon as edible landscapes and commercial orchards, particularly in their rapid growth phase. IPPFBE may charge a small royalty on the released varieties to further perennial plant breeding research at IPPFBE. We did hold two field days with extension agents from around the state to show them our research farm in Thatcher, Utah. The serviceberry project was discussed along with all of our other plant breeding projects.

Project Approach: The commercial production of serviceberries is a fast growing industry in southern Canada. Additionally, there is a breeding program at the University of Saskatchewan. A number of improved, direct selections have been released for use in Canada. Serviceberry orchards in some areas of Canada can yield over 5 tonnes per hectare. The current demand exceeds supply, making serviceberries a highly profitable crop for producers. We have contacted Dr. Bob Bors at the University of Saskatchewan who oversees the small fruit-breeding program there. He has agreed to work with us and has provided seeds from their most promising serviceberry germplasm.

The seed that Dr. Bors sent in 2011 did not germinate, 0% of 30 collections. In July/August 2012 during serviceberry harvest I traveled to Saskatoon, Saskatchewan and was allowed complete access to all of their germplasm and plots to collect berries/seed. I was selective based on plant vigor, berry taste, freedom from disease, etc. I cleaned the seed, didn’t let it dry out and stratified the seed for 6 weeks at 36 degrees F in a mixture of peat and sand. 2012 germination percent approached 100%. This is in the serviceberry grower’s manual. For land reclamation and wildlife habitat improvement and whenever possible, keep the seed from drying out, the seeds be stratified for 6 weeks at 36degrees F and planted as soon thereafter as possible.

I was able to selectively harvest seed/germplasm from the entire collection at the University of Saskatchewan research farm. The collection had cost the Canadian government over $10MM to accumulate according to Dr. Bors and the program was cut in 2007 and has been mothballed ever since. He has kept the plantings going with minimal inputs. I think we have the largest, most productive germplasm base in world planted for future breeding and selection work. The planting of the evaluation blocks were rated and selected for seedling establishment and plant vigor. They should start to produce fruit in about 4 to 5 years, and then we can evaluate all of our nurseries based on fruit quality, yield, overall plant health and vigor, and freedom from disease for further testing at other sites to confirm the productivity for the eventual release of new serviceberry varieties for Utah and the Intermountain West. IPPFBE didn't purchase any of this germplasm. Through our relationships with Dr. Bob Bors at the University of Saskatchewan (which is near the center of origin or diversity for *Amelanchier alnifolia*, we were able to travel to their large research farm and were able to collect berries from their entire collection. The collection there is the result of many years and many millions of dollars to collect and assemble in their research fields. They released a few varieties for use in their region from this material. We had unfettered access to all of this germplasm, even their most advanced selections. Out of the thousands of serviceberries amassed there, I selected 64 based on overall plant vigor, yield, berry taste and size, freedom from disease, etc. The berries were then cleaned and the seed extracted for each collection. The seed was then tested and the government officials from Canada issued a phyto-sanitary certificate for import into the United States. These 64 collections of seed were then stratified at 36 degrees F for 3 months in a peat/sand moist medium and not allowed to dry out. This resulted in exceptional germination, we planted the seed in our research greenhouse roughly 98 plants for each collection. They were planted in 'conetainers' in greenhouse potting medium in late January and allowed to grow in our greenhouse. The plants were then allowed to grow and the best seedlings based on overall health, vigor, freedom from high pH induced iron chlorosis, and disease from each collection were planted in late April at IPPFBE research locations into evaluation nurseries at Thatcher, Utah, near Richmond Utah, near Huntsville, Utah and at Dayton, Idaho. This represents the largest collection and diversity of serviceberries ever assembled in the United States. Having this extensive germplasm in evaluation nurseries is a gold mine for the people of Utah and the entire Intermountain West.

IPPFBE would like to develop the genetic material and release varieties in the future that would spawn or enhance commercial industries and, additionally, provide an attractive landscaping shrub for Utah homeowners that could produce an abundance of highly nutritious berries with limited agronomic inputs, including water and fertilizer. Out of the thousands of serviceberries amassed at the University of Saskatchewan, I selected 64 based on overall plant vigor, yield, berry taste and size, freedom from disease, etc. The seedlings were then allowed to grow and the best seedlings based

on overall health, vigor, freedom from chlorosis, and disease from each collection were planted in late April at IPPFBE research locations into evaluation nurseries at Thatcher, Utah, near Richmond Utah, near Huntsville, Utah and at Dayton, Idaho. This represents the largest collection and diversity of serviceberries ever assembled in the United States. Having this extensive germplasm base in evaluation nurseries is a potential gold mine for Utah and the Intermountain West, as IPPFBE releases varieties in the future for use as edible landscapes and possible cottage type commercial Industries. There were numerous cottage type serviceberry industries throughout Saskatchewan from jams and syrups to pick your own orchards, frozen berries, pies, etc. Inferior plants were not collected or rouged out of the nurseries. While the few weaker, diseased plants have been rouged out, the majority of data will come in the future as the plants mature and the fruit can be evaluated.

Goals and Outcomes: We have planted out several serviceberry plants in evaluation nurseries near Richmond, Thatcher, and Huntsville, Utah and Dayton, Idaho. A few of the more productive types from the Intermountain Western United States and tissue cultured clones of all of the named varieties from Canada have been planted out in evaluation nurseries as well. Dr. Bob Bors from the University of Saskatchewan who oversees the small fruit-breeding program there, sent us several seed samples from their large breeding program, unfortunately none of the seed germinated which could have been caused by a number of possibilities such as seed age, seed storage, temperatures during delivery, etc. During late July-early August of 2011, I traveled to the University of Saskatchewan and was given the freedom to select and collect berries from their large collection nurseries. The program spent several millions of dollars to obtain the best possible germplasm from the Prairie Provinces. These berries were promptly cleaned, cold stratified, all under optimum conditions. They were planted in the greenhouse around the first part of February 2012 and then planted in evaluation nurseries at all of the above locations in the spring starting in April 2012.

We also collected a great deal of information and visited several Saskatoon farms and learned about the commercialization of Saskatoon berry. This region appears to be the center of origin for the species. I also learned a little bit about the names Saskatoon berry and serviceberry. There is a statue in the center of the town of Saskatoon, Saskatchewan that portrays the naming of Saskatoon, both the town and shrub. An early white settler was visiting with a native people and pointed to a large group of teepees by the Saskatoon River and asked, “what’s that”? The native person thought he was pointing at the shrub and according to native lore thought this is a pretty smart white person who realizes the value of this shrub. Hence the name, Saskatoon Berry. Serviceberry on the other hand has a fragrant white flower during the spring. It was the flower and wreath of choice for funerals during the early 1900’s, hence the name serviceberry.

Saskatoon or serviceberry is a large shrub native to Utah. It is found from south central Canada or basically the Prairie Provinces of Canada (there are limited plants British Columbia) to the mountainous regions of the southwestern United States. The species has a high degree of genetic diversity and has high potential for genetic improvement through breeding. The plants can be high yielding, produce large, nutritious berries that are very high in antioxidants. Saskatoon or serviceberry is also an attractive, low-maintenance shrub with beautiful white spring flowers that could form both the basis for commercial industries and edible landscapes throughout Utah and the intermountain Western United States. It could also potentially replace some of the small fruit production in Utah where production problems such as winter injury and high input costs are common.

I'm not sure if the seed collection trip would fall into the plant material category. I had thought it probably would. However, with just the stratification, greenhouse, soil, containers, etc., we have spent almost 5 times the amount of the grant for plant material and about 5 times the grant amount on Labor.

The initial selection at the University of Saskatchewan was based on fruit productivity, size, flavor, plant vigor, and freedom from disease. This resulted in the collection of 63 maternal genotypes open pollinated, out of over 5,000 evaluated. The plants for each maternal genotype were selected from the greenhouse based on overall vigor for each of the collections. This resulted in the planting of 4 evaluation blocks. This resulted in the selection of about 1200 plants from the nearly 4,000 seedlings in the greenhouse for planting in the greenhouse. This selection was based primarily on freedom from disease and seedling vigor. The seedlings were rated once last fall for establishment.

We have the large selected germplasm base in evaluation nurseries to select the best serviceberries for varietal release for use as commercial industries and edible landscapes in Utah and the Intermountain West. The possibility also exits in the future to make selected crosses based on performance data.

While tree and shrub breeding projects take some time and are longer term than annual crops. As soon as we are able to release a variety to the nursery industry, anyone who wants to start a serviceberry farm or plant in an edible landscape in Utah or the entire Intermountain West will benefit with adapted, highly productive, tasty serviceberries for fresh eating, Jams, Jellies, syrups, pies, etc. It could also replace some of the cane berry production, where blight and high pH induced iron chlorosis is a problem. It is highly probable that our varietal releases will spawn numerous cottage industries in

Utah and the Intermountain West. It will also produce significant sales not only to orchardists but also to homeowners interested in planting edible landscapes. The initial goal of any plant-breeding project is to establish as broad of a germplasm base as possible. This work and grant has allowed us to do that. Unfortunately, tree and shrub breeding projects take time, some more than others. But they have high potential to produce food and harvest atmospheric carbon as edible landscapes and commercial orchards, particularly in their rapid growth phase on land unsuitable for many annual crops. We did hold two field days with extension agents from around the state to show them our research farm in Thatcher, Utah. The serviceberry project was discussed along with all of our other plant breeding projects. The real benefit of this project will come as the plants mature and begin to produce fruit for evaluation and the eventual release of varieties for use in Utah and the Intermountain West, providing an attractive landscaping shrub for Utah homeowners that could produce an abundance of highly nutritious berries with limited agronomic inputs, including water. Additionally, the varieties should provide the opportunity to spawn commercial industries and farming enterprises in Utah and the Intermountain West. The majority of this type of evaluation and work will come in the future as the plants mature and begin to produce fruit.

Beneficiaries: The overall purpose of the project is to select and breed improved cultivars of Saskatoon's or serviceberries for use by commercial producers and for homeowners to use in edible landscapes. The shrub is native to vast areas in the Intermountain West. It was highly sought after and has been an important food item of Native Americans and early settlers in this region. It is also considered to be an important shrub for many classes of wildlife. The species can be found growing on semi-arid ranges receiving 10-12 or more inches of annual precipitation, including being found throughout the Quaking Aspen (*Populus tremuloides* L.) zone in Utah. It can be a large shrub attaining heights of up to 14 feet on some sites, while on other sites ecotypes can reach maturity at only a few feet. Serviceberries have significant genetic diversity and thus high potential for improvement through selection and breeding.

This article appeared in The Herald Journal, it included many more pictures, the whole copied article was too large to send. It also makes reference to an earlier, similar article in the Utah Forestry News, a publication of Utah State Cooperative extension. The following internet address should take you to the article without all the pictures. Please read to more fully understand our group and serviceberry project.

http://news.hjnews.com/allaccess/article_abde9416-1f86-11e2-b2df-0019bb2963f4.html

The Forestry Extension article can be viewed at:
http://forestry.usu.edu/files/uploads/UFN/Summer12.pdf

Please read through the article that was in The Hearal Journal (a newspaper that serves Northern Utah and is based in Logan, Utah) this past fall. It describes IPPFBE and I talk about the serviceberry project toward the end. I talk about commercial industries and edible landscapes. It also makes mention to a similar article that was in the Utah Forest News, a publication of Utah State University Cooperative Extension. There is also planting plans and data sampling at the end of the report.

IPPFBE has spent somewhere between $35,000 and $40,000 of our money on this serviceberry project, mostly labor, but also seed collection and greenhouse growing expenses. We are a 501.c.3 non-profit and depend on grants, donations, and royalties for our existence. The serviceberry project is to solely enhance and help the serviceberry industry in Utah as well as throughout the Intermountain West. It also offers the public edible landscapes as well as wildlife habitat. We are committed to this end.

Plant materials purchased for this project include: Containers for growing seed, potting soil, green house heat, and mycorhizae inoculants. Labor includes: Selecting and collecting seed, stratifying the seed, planting and growing seed, evaluation and data collection, and making presentations.

I was in Russia to visit with the folks at the Vavilov Institute in St. Petersburg about several ongoing projects. They provided me with some serviceberry seed, but none germinated. It also was some from Canada. So IPPFBE will not get any benefit until the project spawns commercial industries, edible landscapes and extra business for whole sale and retail nurseries. I have also included a sampling of our planting plans and data from two sites. There are no private or public companies in the United States working on serviceberries. The article talks about opportunities for the entire state as does the earlier publication. During our first field day, the head of Utah State University Extension attended along with 10 extension agents. The second field day was requested by Utah State University Extension, it included 20 extension agents from throughout the state of Utah. We made a presentation on the serviceberry project. Rose Long (Utah State University Extension) was also present, she wrote the article referred to. The extension agents are excited about this project and are committed to disseminate information to their respective counties throughout the State of Utah. I am also in the process of writing an article for Rangelands on our serviceberry project and the method we used to enhance germination.

There used to be a large cane berry, mostly raspberry production in Utah, it has succumbed largely to a little known blight. Serviceberries could provide an alternative crop for these growers. Through the newspaper article, the field days with extension agents, etc. The project had the potential to provide information to hundreds of thousands of people and potential producers in Utah and the Intermountain Western United States.

I am very optimistic about the future of our serviceberry project.

As I mentioned above, the commercial production of serviceberries is a fast growing industry in south-central Canada. Serviceberry orchards in some areas of Canada can yield over 8 tonnes per hectare. The current demand far exceeds supply, making serviceberries a highly profitable crop for producers.

IPPFBE would like to develop the diverse genetic material obtained and release varieties in the future that would spawn or enhance commercial industries and, additionally, provide an attractive landscaping shrub for Utah homeowners that could produce an abundance of highly nutritious berries with limited agronomic inputs, including water. The release of improved varieties of Saskatoon Serviceberry for use in Utah could potentially affect every homeowner in Utah who is interested in planting an attractive, drought tolerant edible landscape. It would provide a highly nutritious food source that is high in antioxidants and could be dried, frozen or canned for year-round use. It could also spawn commercial industries throughout the state that would sell fresh berries, jams, syrups, and dried fruit. It could help provide an alternative crop for producers of cane berries that are having production problems in Utah. In Saskatchewan alone, the Saskatoon berry industry is estimated to account for 50 million Canadian dollars in terms of economic activity.

As mentioned above, tree and shrub breeding projects take time, some more than others. They are long-term projects, but they have high potential to produce food and harvest atmospheric carbon as edible landscapes and commercial orchards, particularly in their rapid growth phase on land unsuitable for many annual crops. We did hold two field days with extension agents from around the state to show them our research farm in Thatcher, Utah. The serviceberry project was discussed along with all of our other plant breeding projects. The initial goal of getting a broad serviceberry germplasm base established in evaluation nurseries has been achieved, better than anyone imagined at the beginning of this project. However, the real benefit of this project will come as the plants mature and begin to produce fruit for evaluation and the eventual release of varieties for use in Utah and the Intermountain West, providing an attractive landscaping shrub for Utah homeowners that could produce an abundance of highly nutritious berries with limited agronomic

inputs, including water. Additionally, the varieties should provide the opportunity to spawn commercial industries and farming enterprises in Utah and the Intermountain West. The majority of this type of evaluation and work will come in the future as the plants mature and begin to produce fruit. The beneficiaries are the people of Utah who will plant much improved varieties of Serviceberries for both home use in edible landscapes and also those who will create enterprises based on productive varieties released from this germplasm base. Additionally the retail and wholesale nursery industry will benefit with increased demand for serviceberry varieties released from this germplasm. Utah State University and the Garfield county extension planting have the potential to create similar benefits there as well. The species should prosper there in terms of productivity and cold hardiness. IPPFBE did not benefit from this project financially and spent considerably more of our own money than the grant provided in order to achieve this goal and advance our mission. This will benefit all Utah homeowners who want to plant edible landscapes. Entrepreneurs and production agriculturalists who want to grow the fruit and develop markets for products such as pick-your own operations, fresh and frozen berries, jams, syrups and other unique products. It will provide the opportunity to replace cane berry production on areas that are blighted and offer a rotation crop. As I mentioned earlier, demand far exceeds supply in Canada. It will benefit all Utahans in terms of stabilizing soil, harvesting excess atmospheric carbon, filtering and cleaning precious water, harvesting deep micronutrients. It will also create increased sales for both retail and wholesale nurseries. The wildlife of Utah both big and small game will benefit from increased use in wildlife plantings and reclamation projects.

Lessons Learned and Future Project Plans: The only real delay was the poor germination of the initial seed sent from Dr. Bob Bors at the University of Saskatchewan who oversees the small fruit-breeding program there. However, It should even make the project better because I was able to personally go through their large nurseries and make selections based on fruit quality, taste, size, and shrub vigor after years of natural selection. If you are interested in a high germination percentage with serviceberries, clean promptly after harvest, keep moist and cold stratify at 35 degrees F for 4 months. Germination approached 100% for all collections. I am hopeful this discovery will increase the use of serviceberry for planting in wildlife habitat plantings. As the high cost of seed and disappointing wildland planting results have curtailed the use of this highly palatable shrub to all classes of wildlife. Highly productive adapted varieties could also reduce the seed price, stabilize the supply and increase the use by federal and state agencies for reclamation, fire rehabilitation and wildlife habitat plantings.

Providing money and time we plan to evaluate, rate and collect data of the various important agronomic attributes at the evaluation nurseries near Richmond, Thatcher, and Huntsville, Utah and Dayton, Idaho to maturity. The goal of this grant funding and project was the establishment of the large breeder-evaluation nurseries of the most promising Saskatoon serviceberry germplasm with a broad genetic base for future evaluation, selection, and breeding. The nurseries will be evaluated for establishment, disease, flowering, fruit set, fruit quality and size, overall productivity and plant vigor. The ultimate future goal is to select varieties to release of highly productive, tasty, nutritious and disease free varieties of Saskatoon/serviceberry, that are well adapted to Utah and the Intermountain Western United States. This initial effort and expenditure will provide the basis for the release of varieties to spawn commercial industries, edible landscapes and orchards on land unsuitable for production of annual crops.

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Follow-up Information: Sampling of the Planting & Data from two of our research sites:

Location	Row	Distance	#	Species	Genotype	Poll.	Source	Planted	Vigor & Est.
SHNN	2	5 Feet	7	AMAL	Par 90 B	OP	UOSCan.-GH	5-Jun-12	10
SHNN	2	40 Feet	7	AMAL	Campbell	OP	UOSCan.-GH	5-Jun-12	9
SHNN	2	75 Feet	7	AMAL	Hawes	OP	UOSCan.-GH	5-Jun-12	9
SHNN	2	110 Feet	7	AMAL	Innes/Borden	OP	UOSCan.-GH	5-Jun-12	8
SHNN	2	145 Feet	7	AMAL	Martin	OP	UOSCan.-GH	5-Jun-12	10
SHNN	2	180 Feet	7	AMAL	Holodniuk	OP	UOSCan.-GH	5-Jun-12	8
SHNN	2	215 Feet	7	AMAL	Smokey	OP	UOSCan.-GH	5-Jun-12	10
SHNN	2	250 Feet	7	AMAL	Northline	OP	UOSCan.-GH	5-Jun-12	10
SHNN	2	285 Feet	4	AMAL	Pearson	OP	UOSCan.-GH	5-Jun-12	10

SHNN	3	5 Feet	7	AMAL	Quaker	OP	UOSCan.-GH	5-Jun-12	9
SHNN	3	40 Feet	7	AMAL	Hawton	OP	UOSCan.-GH	5-Jun-12	9
SHNN	3	75 Feet	7	AMAL	Parkhill	OP	UOSCan.-GH	5-Jun-12	9
SHNN	3	110 Feet	7	AMAL	Thissen B	OP	UOSCan.-GH	5-Jun-12	10
SHNN	3	145 Feet	14	AMAL	Par 90 TRS	OP	UOSCan.-GH	5-Jun-12	10
SHNN	3	215 Feet	14	AMAL	Northline	OP	UOSCan.-GH	5-Jun-12	9
SHNN	3	285 Feet	4	AMAL	Success	OP	UOSCan.-GH	5-Jun-12	8
SHNN	4	5 Feet	7	AMAL	Smokey X Regent	OP	UOSCan.-GH	5-Jun-12	9
SHNN	4	40 Feet	7	AMAL	Gallaher NW	OP	UOSCan.-GH	5-Jun-12	9
SHNN	4	75 Feet	7	AMAL	Innes/Borden	OP	UOSCan.-GH	5-Jun-12	9
SHNN	4	110 Feet	7	AMAL	Pasteur	OP	UOSCan.-GH	5-Jun-12	9
SHNN	4	145 Feet	7	AMAL	Hawes 98	OP	UOSCan.-GH	5-Jun-12	9
SHNN	4	180 Feet	7	AMAL	Soron	OP	UOSCan.-GH	5-Jun-12	9
SHNN	4	215 Feet	7	AMAL	Reid # 1	OP	UOSCan.-GH	5-Jun-12	10
SHNN	4	250 Feet	11	AMAL	Honeywood	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	5 Feet	3	AMAL	Success	OP	UOSCan.-GH	5-Jun-12	9
SHNN	5	25 Feet	3	AMAL	Pearson	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	45 Feet	1	AMAL	Honeywood	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	50 Feet	2	AMAL	Honeywood	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	65 Feet	1	AMAL	Reid #3	OP	UOSCan.-GH	5-Jun-12	10

SHNN	5	70 Feet	1	AMAL	Reid #3	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	85 Feet	5	AMAL	Reid #3	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	110 Feet	7	AMAL	Par 90 TRS	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	145 Feet	7	AMAL	Parkhill B	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	180 Feet	7	AMAL	Northline B	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	215 Feet	6	AMAL	Parkhill	OP	UOSCan.-GH	5-Jun-12	10
SHNN	5	255 Feet	6	AMAL	Quaker	OP	UOSCan.-GH	5-Jun-12	9
DN	13	988 Feet	7	AMAL	Innes / Borden	OP	UOSCan.-GH	8-Jun-12	10
DN	13	1022 Feet	7	AMAL	Par 90 B	OP	UOSCan.-GH	8-Jun-12	10
DN	13	1058 Feet	7	AMAL	Success	OP	UOSCan.-GH	8-Jun-12	10
DN	13	1093 Feet	7	AMAL	Parkhill	OP	UOSCan.-GH	8-Jun-12	10
DN	13	1128 Feet	7	AMAL	Hawes 98	OP	UOSCan.-GH	8-Jun-12	9
DN	13	1164 Feet	7	AMAL	Success	OP	UOSCan.-GH	8-Jun-12	9
DN	13	1198 Feet	4	AMAL	Northline	OP	UOSCan.-GH	8-Jun-12	9
DN	14	735 Feet	7	AMAL	Innes/Borden	OP	UOSCan.-GH	6-Jun-12	9
DN	14	770 Feet	7	AMAL	Pasture	OP	UOSCan.-GH	6-Jun-12	9
DN	14	805 Feet	7	AMAL	Hawes 98	OP	UOSCan.-GH	6-Jun-12	9
DN	14	840 Feet	7	AMAL	Northline	OP	UOSCan.-GH	6-Jun-12	9
DN	14	875 Feet	5	AMAL	Hawton	OP	UOSCan.-GH	6-Jun-12	9
DN	14	905 Feet	7	AMAL	Success	OP	UOSCan.-GH	6-Jun-12	8

DN	14	940 Feet	7	AMAL	Northline	OP	UOSCan.-GH	6-Jun-12	10
DN	14	974 Feet	7	AMAL	Innes/Borden	OP	UOSCan.-GH	6-Jun-12	9
DN	14	1009 Feet	7	AMAL	Thiessen B	OP	UOSCan.-GH	6-Jun-12	10
DN	14	1044 Feet	7	AMAL	Par 90 TRS	OP	UOSCan.-GH	6-Jun-12	10
DN	14	1079 Feet	10	AMAL	Northline	OP	UOSCan.-GH	6-Jun-12	10
DN	15	817 Feet	7	AMAL	Pembina	OP	UOSCan.-GH	6-Jun-12	10
DN	15	852 Feet	7	AMAL	Smokey	OP	UOSCan.-GH	6-Jun-12	10
DN	15	887 Feet	7	AMAL	Quaker	OP	UOSCan.-GH	6-Jun-12	9
DN	15	922 Feet	7	AMAL	Success	OP	UOSCan.-GH	6-Jun-12	9
DN	15	957 Feet	7	AMAL	Holodniuk	OP	UOSCan.-GH	6-Jun-12	9
DN	15	992 Feet	7	AMAL	Parkhill	OP	UOSCan.-GH	6-Jun-12	9
DN	15	1027 Feet	7	AMAL	Senga	OP	UOSCan.-GH	6-Jun-12	9
DN	15	1062 Feet	7	AMAL	Dyck	OP	UOSCan.-GH	6-Jun-12	9
DN	15	1097 Feet	7	AMAL	Par 90 B	OP	UOSCan.-GH	6-Jun-12	10
DN	15	1137 Feet	7	AMAL	HoneyWood	OP	UOSCan.-GH	6-Jun-12	10
DN	15	1172 Feet	14	AMAL	Martin	OP	UOSCan.-GH	6-Jun-12	10
DN	15	1241 Feet	7	AMAL	Northline	OP	UOSCan.-GH	6-Jun-12	9
DN	15	1275 Feet	4	AMAL	Par 90 TRS	OP	UOSCan.-GH	6-Jun-12	10
DN	16	912 Feet	14	AMAL	Par 90 TRS	OP	UOSCan.-GH	6-Jun-12	10
DN	16	982 Feet	10	AMAL	Soron	OP	UOSCan.-GH	6-Jun-12	9

DN	16	1034 Feet	7	AMAL	Campbell	OP	UOSCan.-GH	6-Jun-12	9
DN	16	1066 Feet	14	AMAL	Reid #1	OP	UOSCan.-GH	6-Jun-12	10
DN	16	1137 Feet	7	AMAL	Hawton	OP	UOSCan.-GH	6-Jun-12	9
DN	16	1172 Feet	7	AMAL	Pearson II	OP	UOSCan.-GH	6-Jun-12	10
DN	16	1207 Feet	7	AMAL	Innes/Borden	OP	UOSCan.-GH	6-Jun-12	9
DN	16	1247 Feet	7	AMAL	Reid # 3	OP	UOSCan.-GH	6-Jun-12	9
DN	16	1276 Feet	4	AMAL	Hawton	OP	UOSCan.-GH	6-Jun-12	9

2010-7. Breeding Improved Frost-Resistant Apricots (*Prunus armeniaca* L.) For Increased Use and Profitability in Utah

Final Report

Project Summary: This project was proposed to select and breed improved cultivars of Apricots for use in commercial industries and for homeowners to use in edible landscapes. 2010 and 2011 provided a great example of the value of the IPPFBE apricot-breeding program. Most, if not all, of the commercial apricot crop in Northern Utah was lost due to spring frosts. The improved trees at the IPPFBE research farm near Thatcher, Utah, (of Central Asian origin) showed very little damage. About 80% of our trees had good fruit set and more than 10% of the IPPFBE apricot trees were rated as having excellent fruit set. We are prepared to set in motion the final testing, evaluation, and training efforts that will lead to the release of enhanced, superior apricot cultivars for Utah production. Typically, apricot producers get a good crop on average about two out of five year. Public support is critical to our research effort and will permit IPPFBE to maintain its status as a public non-profit corporation and continue our objective.

Project Approach: We have added numerous new material and crosses to our program. We have also collected and analyzed data on the various nurseries. We have selected 3 trees as future varieties for formal varietal release and further testing. We also hosted a field tour of the Northern Nut Growers Association's annual meeting along with several members of the North American Fruit Explorers group. Additionally Dr. Brent Black, Fruit Extension Specialist from Utah State University attended and invited all of the University Extension personnel. I would like to discuss further and expound on some of the aforementioned activities.

We were able to get delicious, cold hardy; white fleshed apricot scion wood from Turkmenistan. This was grafted onto superior root stock trees at our Thatcher location. One of the selections we are planning on releasing is referred to as the J-7-4 apricot. The seed originated from Uzbekistan and was planted in 1999. The tree has produced a good to excellent apricot crop every year since year 4

after planting the pit near Dayton, Idaho, which is our coldest research location. Several of those years temperatures during flowering and anthesis dipped into the low 20's F. Further, while I was making several crosses with pollen from the best germplasm from Rutgers University, I emasculated the balloon stage flowers on several branches of the J-7-4 tree for directed pollinations. We recorded an early morning temperature low in an adjacent field of 12 degrees F two feet above ground level. The tree produced a full crop even the emasculated/finger-pollinated flowers. Two years ago (2010) we had a killing frost in the single digits F. All apricot blooms were lost. About 3 weeks later we were astonished at a ¾ bloom on the J-7-4 tree, according to apricot breeders from the VIR institute, a somewhat rare trait in some Central Asian apricots is the initiation of a second or continuous bloom and apparently the J-7-4 tree has this genetic trait. Additionally, it has a sweet, edible, nutritious pit. The fruit is of average quality and flavor, perhaps somewhat better than the landrace often referred to as the Chinese or Mormon apricot that is often planted in Utah and the Intermountain Western United States.

Goals and Outcomes:

We have planted out all of the crosses from the J-7-4 tree pollinated with four outstanding trees from the Rutgers University breeding program. The pollen parents were selected for excellent fruit flavor, large fruit size, excellent overall fruit quality and storability as well as being later blooming. Our hope is to find one or more of these crosses that retains the cold hardiness, late blooming, the ability to initiate a second or continuous bloom of the J-7-4 apricot and produces large, delicious, fruit annually with a tasty, nutritious sweet pit. This continuous bloom is a rare trait in apricots and the director of the Vavilov Institute outside of Tashkent, Uzbekistan who works primarily with apricots showed us a tree that had ripe apricots in late September of 1998 and through an interpreter told us that this was the only tree in her collection with this continuous bloom character. This was the maternal parent of the J-7-4 tree.

We also made strategic apricot seed collections from Uzbekistan and Kyrgyzstan in 2011 and they were planted at our Thatcher research location during the spring of 2012.

After analyzing over 6 years of fruit production and quality data we have selected six other candidates for varietal release and further testing. They are consistently heavy producers of large flavorful fruit at the Thatcher location.

On July 19, 2011 we provided a tour for about 110 specialty crop stakeholders of our Thatcher, Utah apricot research to members of the Northern Nut Growers Association, the North American Fruit Explorers and extension personnel from Utah State University. It seemed everyone in attendance was impressed with our operation and particularly the fruit quality. They also seemed anxious for us to release varieties as soon as possible. During the summer of 2012 we also hosted numerous Extension Agents from throughout the state led by Mike Pace. We also hosted a group from the USU forestry extension and an article was written up on the entire project through forestry extension. Here is a link to the article (http://forestry.usu.edu/files/uploads/UFN/Summer12.pdf). Additionally an article about the Thatcher orchard was in the Tremonton Leader Newspaper. (http://www.tremontonleader.com/?s=Going+Nuts+in+Thatcher). Additionally an article was prepared for the Logan Herald Journal (http://news.hjnews.com/allaccess/article_abde9416-1f86-11e2-b2df-0019bb2963f4.html). Arthur Douglas from the Salt Lake USDA FSA office visited the Thatcher site with a group from the NRCS and the FSA during the summer of 2012.

We also will now have four additional apricot nurseries that will hopefully provide further improvement on the apricot and additional future varietal releases. Those include the J-7-4 crosses, the Turkmenistan material, new material from Rutgers University and the new collections from Uzbekistan and Kyrgyzstan.

Apricots are considered by many to be one of the most delicious and delectable tree fruits. Little known in the U.S.A. is that they can also provide a tasty, edible nut that is nutritious and health promoting. Sweet-pitted apricots have been produced and appreciated with a minimum amount of cultural care for millennia in the temperate regions of Central Asia and China. For centuries, apricots from Central Asia were unavailable in the U.S. Our recent introductions grown in Utah have shown great promise for improving frost resistance and fruit quality.

A number of promising developments have been observed in IPPFBE's apricot improvement and evaluation program near Thatcher, Utah. They include:

1. Identification of selections with improved cold tolerance during flowering. It is interesting to note that most, if not all, of the apricot trees near Willard and Perry, UT, lost their crops in 2010 due to spring frosts. Fewer than 5% of our collection from Rutgers and Central Asia showed any frost damage, about 80% had good fruit set and over 10% were rated as having excellent fruit set.
2. Identification of accessions with improved resistance to lime-induced iron chlorosis. This finding is important with the high pH soils in Utah.
3. A substantial increase in the length of the fruit ripening period from early to late fruit maturity, over standard cultivars grown in UT. Not only will this lengthen and expand the opportunity for marketing apricots, it will also increase the window of opportunity to avoid early spring frosts.
4. Improved and a high degree of variability in fruit color, flavor, sugar and acid content, and textures. By incorporating the germplasm from Rutgers University and Central Asia, the traditional apricot flavors are expanded to include flavor hints of peach, apple, and lemon. Some of the selections have much larger fruit than common varieties.
5. Identification of selections with improved tolerance to saline irrigation water.
6. Identification of selections producing sweet, nutritious edible pits (kernels). Apricot kernels can provide nutritious food for the public and expand marketing opportunities for growers.

Many of these characteristics exceed those of any current U.S. variety. IPPFBE has obtained a valuable collection of apricot germplasm from its working relationship with Rutgers University and from our germplasm collection efforts in Central Asia. The new varieties will provide enhanced fruit quality and flavor, a more consistent and dependable yearly crop, a diversity of ripening times to increase the period of apricot marketability, and better adaptation to high pH, salty soils and saline irrigation water.

Central Asia is considered to be a center of diversity for many important fruit and nut tree species, including wild and cultivated apricots. Despite the richness of genetic diversity found in Central Asian apricot populations and collections, very little germplasm material from this region has been utilized in western breeding programs. Since the breakup of the Soviet Union, Central Asian research institutes and plant material have become more available for reciprocal germplasm exchange and scientific collaborations, and western researchers have been able to access these extremely important genetic resources. In 1998, an apricot selection and breeding project was begun with the goal of developing trees having the specific traits necessary to be consistently productive in Utah. This

program was expanded and enhanced with open-pollinated seeds originating primarily from Uzbekistan and Kyrgyzstan. The program focused on traits such as frost tolerance, delayed flowering time, increased disease resistance, and increased fruit size and quality (sugar to acid ratio, texture, flavor, flesh color, etc.).

Breeding Improved Frost-Resistant Apricots (Prunus armeniaca L.) Sampling of the data collected through this project:

ID	Tree ID	Variety	Stage	Set	Stage	Set	Stage	Set	blooms	Stage	Set	frost damag
			4/13/09	4/13/09	2010	2010	4/23/11	4/23/11	5/17/11	4/2/12	4/2/12	4/11/12
3	TMS 06-07	Tilton			90%	2	bal	2		40%	3	7
4	TMS 06-08	Rival			90%	3	20%	3		50%	2.5	6
5	TMS 06-09	Perfection			90%	3	80%	3.5		90%	3	6
6	TMS 06-10	Harglow 8265			80%	4	1st	3		bal	2	8
7	TMS 07-04	NJA 123 HARDY	pk	1	90%	5	30%	2		80%	5	7
8	TMS 07-06	A53 X101	pk	1	90%	5	45%	3		80%	5	6
10	TMS 07-11	53 X NJA	tb	2	80%	4	20%	4		60%	5	5
12	TMS 07-14	J8 30 (TASTY)	sb	2	40%	5	10%	1		1st	5	8+
13	TMS 07-16	J8 30 (TASTY)	0	0	60%	5	40%	3		80%	5	5
14	TMS 07-18	JA 32	pk	2.5	90%	5	70%	4.5		90%	5	5-
16	TMS 08-01	NJA 104	lb	5	90%	3	90%	5		95%	4	7
17	TMS 08-04	NJA 104	lb	2	90%	5	80%	2		40%	4	8
18	TMS 08-06	H34-4	l st	4	80%	5	50%	3.5		20%	5	8
20	TMS 08-09	H34-37 (sweet)	tb	1	40%	5	pk+	5		lb	4	9

21	TMS 08-11	H34-37 (sweet)	sb	1	50%	5	10%	5		10%	4	8+
22	TMS 08-13	NJA 123	sb	1	20%	3	40%	4	2	30%	3	8
23	TMS 08-15	NJA 123	lb	1	90%	3	80%	2		50%	5	9
24	TMS 08-17	A53 X101	vsb	1	40%	4	bal	3		30%	3.5	8
25	TMS 08-19	A53 X101	tb	1	90%	5	60%	4.5		90%	5	7
26	TMS 09-01	NJA 97	pk	2.5	80%	5	5%	4		75%	4.5	7
27	TMS 09-03	NJA 97	pk	3.5	80%	5	30%	3.5		40%	5	7
30	TMS 09-08	41-184 (tasty)	pk	4	90%	5	85%	3.5		50%	5	6+
32	TMS 09-11	Goldstrike	pk	2	70%	5	30%	4		10%	3.5	9
33	TMS 09-14	NJA 104	lb	2.5	95%	5	90%	2.5		90%	5	7+
34	TMS 09-16	NJA 104	pk	3.5	80%	5	35%	5		80%	4	7+
35	TMS 09-18	NJA 123 (HARDY)	sb	2.5	70%	5	25%	3.5		50%	4.5	8
36	TMS 09-20	NJA 123 (HARDY)	lb	3.5	90%	5	65%	4		80%	4	6
37	TMS 10-06	NJA 208-32	pk	3	70%	5	80%	4		90%	5	7+
39	TMS 10-09	NJA Early Samarkand	sb	1	bal	5	20%	5		1st	4.5	8+
40	TMS 10-12	NJA Early Samarkand	lb	4	10%	5	35%	5		50%	3.5	7
41	TMS 10-15	NJA 97	sb	1	bal	4	5%	5		10%	4	9
42	TMS 10-17	JA 32	tb	2.5	80%	5	90%	3.5		90%	5	6
43	TMS 10-20	JA 32	l st	4	90%	5	75%	5		90%	5	5
45	TMS 11-03	H34-31 (sweet)	lb	4	10%	5	25%	4		10%	4	9
46	TMS 11-06	A53 X101	pk	4.5	90%	3	15%	3		70%	5	7
48	TMS 11-08	A53 X101	bal	3	90%	3	15%	3		80%	4	7+
50	TMS 11-11	NJA 101	bal	4	90%	4	40%	2.5		90%	5	5

51	TMS 11-13	NJA 123 (HARDY)	lb	4	1st	4	20%	5		60%	3	8
52	TMS 11-15	NJA 123 (HARDY)	pk	3	90%	2	60%	2.5		80%	3.5	6
53	TMS 11-17	J8-30	lb	2	bal	5	15%	5		20%	5	7+
55	TMS 12-01	NJA 105	l st	5	70%	1	60%	5	2	80%	2	7
56	TMS 12-03	NJA 105	lb	4	10%	4	pk	4		bal	4	9
59	TMS 12-07	1-82 NJA 53 X NJA	pk	4	90%	2	50%	5	3	50%	3.5	8
60	TMS 12-10	J8-30 (tasty)	pk	5	90%	3	70%	4.5		90%	5	4
63	TMS 12-15	NJA 105	l st	5	90%	5	60%	4		90%	4.5	4+
64	TMS 12-17	Early Samarkand	l st	2	bal	3	70%	4		60%	4	6
66	TMS 13-07	Tomcot	l st	4	80%	4	5%	4		30%	4	8
68	TMS 13-10	Goldstrike	lb	3	80%	5	60%	5		90%	5	7 early
69	TMS 13-12	Goldstrike	l st	4	90%	4	80%	4.5	1	90%	3.5	6
71	TMS 13-15	NJA 101	sb	1	20%	5	10%	5		40%	3	8
72	TMS 13-17	NJA 43	pk	2.5	80%	4	85%	5		80%	4	6
73	TMS 13-19	NJA 43	pk	3	60%	4	30%	4		80%	5	6+
74	TMS 14-02	NJA 54	pk	1	90%	5	30%	3		60%	5	7
76	TMS 14-05	J8-30 (tasty)	l st	2	90%	5	50%	1		90%	5	6
77	TMS 14-07	J8-30 (tasty)	l st	3	90%	5	65%	2.5		75%	5	8+
79	TMS 14-12	NJA 97	bal	3	60%	4	15%	4.5		50%	4	8
81	TMS 14-15	NJA 208-32	lb	3	90%	5	50%	2.5		85%	5	8
82	TMS 14-18	J8-30 (tasty)	pk	3.5	90%	5	85%	3		85%	5	7+
85	TMS 15-05	1-82 NJA 53 X NJA	lb	3	80%	5	60%	2		50%	5	5
87	TMS 15-07	1-82 NJA 53 X NJA	pk	3	70%	5	5%	3		40%	5	6
88	TMS 15-09	NJA 208-32	l st	4.5	90%	3	15%	5		50%	4	4

89	TMS 15-12	NJA 208-32	lb	3	20%	5	40%	5		10%	5	8
91	TMS 15-17	H34-31 (sweet)	0	0	1st	4	bal	4		bal	5	8+
92	TMS 16-01	NJA 54	pk	4	80%	5	lb	4	1	70%	5	7+
94	TMS 16-04	J1 139 X 153 NJE 42 X NJE	sb	1	bal	4	lb	4.5		lb	4	9 late
95	TMS 16-06	J1-139 X 53	pk	4	20%	4	bal	4		10%	4	7+
97	TMS 16-09	NJA 101	sb	2.5	50%	3	5%	2.5		70%	4	7
99	TMS 16-13	Goldstrike	l st	4.5	70%	4	45%	3.5	3	20%	4	8
100	TMS 16-15	JA 32	sb	1	50%	5	5%	4		10%	5	9
101	TMS 16-17	H34-37 (sweet)	2	3	10%	5	pk	3		10%	5	8
102	TMS 16-19	Tomcot	lb	3	80%	5	pk	3.5		20%	5	7
103	TMS 17-03	NJA 97	pk	2.5	90%	3	15%	2.5	1	70%	4	6
105	TMS 17-06	NJA 104 (yellow stake)	sb	1	80%	5	15%	4.5		80%	5	5
107	TMS 17-09	NJA Early Samarkand	pk	4	90%	5	35%	4		90%	5	5
108	TMS 17-11	? No marker	l st	4	90%	3	30%	5		80%	5	7
112	TMS 17-15	J7 #4	pk	2	90%	3	tb	4.5	5	pk	4	9 late
113	TMS 17-16	J7 #1	0	0			pk	3.5		bal	4	9 late
115	TMS 17-18	J7 #3	0	0	70%	1	-	0		bal	1	8 late
117	TMS 18-02	J7 #1	0	0	50%	2	lb	3.5	3	10%	3.5	9 late
118	TMS 18-03	J7 #2	0	0	0%	0	tb	1	1	1st	2.5	8 late
119	TMS 18-05	J7 #4	0	0	50%	2	bal	3	1	90%	3	7+ late
121	TMS 18-07	J7 #2	0	0	70%	2	lb	3	4	1st	4	9 xlate
122	TMS 18-08	J7 #3	lb	1	50%	2	lb	2.5	3	10%	4.5	8 late
124	TMS 18-11	J7 #2	lb	2	50%	4	lb	4	4	10%	4	8+ late
126	TMS 18-13	J7 #4	lb	2	50%	3	lb	3.5	3	bal	3	9 late
129	TMS 18-16	J7 #1	pk	1	30%	3	5%	4.5	2	60%	4	8 late
131	TMS 19-01	J7 #3	GRAFT		50%	2	lb	2		70%	5	7+
133	TMS 19-03	J7 #3	sb	1	80%	1	bal	3	3	80%	4	8
135	TMS 19-05	7 #4	pk	1	bal	1	lb	2.5	1	40%	2.5	8
136	TMS 19-06	J7 #4	pk	3	0	0	tb	2		1st	2	8
137	TMS 19-07	J7 #4	bal	3	50%	3	10%	4		80%	4	9

139	TMS 19-09	J7 #3	0	0	90%	5	30%	4.5		90%	5	7
140	TMS 19-10	J7 #3	0	0	50%	2	pk	2.5	4	40%	4	9 late
141	TMS 19-11	J7 #3	lb	1	90%	2	pk	2	2	50%	5	9
142	TMS 19-12	No tag (J7 #3?)	0	0	80%	3	10%	3		70%	4	7
143	TMS 19-13	J7 # 4	pk	3	80%	3	bal	3	1	20%	4	8
144	TMS 19-14	J7 # 4	lb	2	0%	0	lb	3.5	4	40%	3	9
145	TMS 19-15	J7 # 4	0	0	50%	3	pk	4.5		10%	5	8+
146	TMS 19-16	J7 #4	?	?	50%	3	bal	4.5	1	50%	5	8
147	TMS 19-17						25%	4.5	2	80%	4.5	8+
148	TMS 19-18						lb-	4	5	bal	4	9 late
149	UZBEK S						10%	4	0	80%	5	8
150	UZBEK N						30%	5	0	90%	5	8+

Beneficiaries and Future Project Plans: The finalization of the release including Plant Variety Protection for the three aforementioned promising apricot cultivars. Future improved releases of cold-hardy apricot cultivars/varieties for use in Utah and the Intermountain Western United States providing a more consistent and dependable crop for current and future apricot producers, whose crops now are frequently damaged by frost. The excellent fruit quality coming out of the Central Asia/ Rutgers germplasm would spawn increased commercial activities throughout the state including the sale of excellent-quality locally grown fresh fruits over a much extended season, as well as jams, syrups, and dried fruit providing a significant impact on the economy of Utah. New frost tolerant cultivars would also positively benefit homeowners in Utah interested in planting an attractive edible landscape while providing a highly nutritious food source that is health promoting and could be dried for year-round use. To meet the demands of the industry and homeowners, the Utah nursery industry will also benefit from the release of our improved cultivars. Currently good apricot production in Utah is 2-3 years out of 5 years, which hinders producers due to lack of crop dependability. Obviously, when we release our apricot varieties that are productive every year with exceptional fruit quality, it will revitalize the Utah commercial apricot industry, as well as other areas in the Intermountain West. It will also provide homeowners in Utah and around the Intermountain West with a productive, tasty apricot and a sweet edible pit to plant edible landscapes that produce delicious fruit every year. This would provide a significant benefit to stakeholders throughout this region to produce food and harvest carbon.

Lessons Learned: The only limitation with improving underutilized perennial crops for use on marginal cropland, some rangelands, commercial Industries and edible landscapes is time and money.

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2010-8. Establishing a Grower-Operated Fire Blight Detection Lab

Final Report

PROJECT SUMMARY

Fire blight has become a severe disease for Utah apple growers over the last several years. Losses in some Utah County orchards reached up to 20% in 2008. The disease spreads quickly, especially in high density orchards and in susceptible varieties such as 'Fuji', 'Gala', or 'Honeycrisp', which are commonly grown due to high market demand. Utah growers are limited in treatment options due to the buildup of resistance to the most effective antibiotic (streptomycin). The alternative antibiotic option is less effective, and must be applied at a precise timing to be effective. As a result, growers need instant notification if their trees are harboring the bacterium (*Erwinia amylovora*) that causes fire blight.

This project used a molecular DNA test called LAMP (loop-mediated isothermal amplification) to detect fire blight bacteria in apple flower clusters. LAMP has been previously shown to detect the bacteria in a few hours using reagents and equipment that are relatively cheap and safe. We set up the first ever "grower lab" at an apple processing plant in Utah County, and compared results from the grower lab to the same test run at the Utah State University cooperator lab. Historically, this apple processing plant has served the growers by detecting fire blight bacteria via flower stigma imprints onto an expensive growth media called CCT. If present, bacteria are detected in 36-48 hours, a timeframe that is too late to implement effective control. When LAMP tests were positive in the grower lab, we notified growers to treat when weather conditions were optimal for infection.

PROJECT APPROACH

The project team, Marion Murray (IPM Extension Associate, USU), and Doug Rowley (Manager, Mountainland Apple Processing Plant) conducted the LAMP testing according to specifications developed by Dr. Ken Johnson and Todd Temple, at Oregon State University. Marion and Doug purchased lab equipment, materials, and reagents needed to operate a grower lab at Mountainland Apples processing plant.

The LAMP tests ran from the start of bloom (May 9) to petal fall (May 27). Six growers in Utah County participated by collecting 100 flowers from selected blocks every day through the testing period and delivering them to Mountainland apples. Doug Rowley processed the flower clusters to 6 wash water samples each day, which were then driven to USU in Logan that same morning. Both labs then used the same wash water to run LAMP tests every day for 17 days, and then the two labs compared results. We also sent material from the first week of blossom collection to the USU plant pathology lab run by Claudia Nischwitz (Plant Pathologist, USU) to implement the CCT testing so that we could have a third comparison.

Upon initial detection of the fire blight pathogen via the grower lab LAMP testing, we notified growers by email and alerted them to use the fire blight risk model, called Cougarblight, to determine whether a treatment was required in their orchard. We inspected orchards at the end of the summer and communicated with participating growers and found that most of the orchards had light infestation (less than 1 infection per tree), but one grower had a small block of infested trees, and had to remove 30 trees.

The LAMP results for detecting the presence or absence of bacteria in the grower lab matched the USU lab 82% of the time. The results of the grower lab matched the USU plant pathology lab CCT tests 70% of the time. This error rate is not good enough to guarantee fire blight bacteria test results to growers. Molecular work takes time to perfect, and the inconsistency could have been due to low concentrations of *Erwinia*, contamination, or human error.
The developers of the LAMP test confirmed that when low populations exist on the flowers, results can be inconsistent, perhaps because there is not a step in the LAMP procedure to concentrate the samples to increase cell numbers for template preparation. Spring temperatures in 2010 and 2011 were lower than normal and not conducive to bacterial growth during the first half of apple bloom.

LAMP, however, still appears to be a promising rapid detection test when conducted from a grower-sustained operation that is located in close proximity to apple growers. Results from LAMP testing, when compared to weather data and the Cougarblight fire blight forecast model, are useful to determine the need to spray with an antibiotic. We plan to continue to operate the LAMP testing for the 2012 growing season, and will charge growers $9/test, which will cover the cost of supplies. The Oregon State University lab has agreed to verify our LAMP results with their own testing. If we can get to a point of consistent results, this lab will be the first of its kind conducting this type of testing.

Results of this project will be shared with the apple growers at the winter 2012 annual Utah State Horticultural Association growers meeting. Because of the inconsistencies between the two labs, a paper was not written for the industry magazine, Good Fruit Grower, but after a season of self-sustaining operation in spring 2012, we plan to submit a paper in the summer of 2012.

GOALS AND OUTCOMES ACHIEVED

USDA REVIEW:

Please report on your progress towards your expected measurable outcomes in the approved state plan:

- Reduced/optimized antibiotic sprays. Did you see an approximate 25% reduction in sprays, thereby reducing farm worker exposure to agricultural antibiotics as a result of this project. Did you measure this by personal communication with participating growers to compare antibiotic sprays in 2011 with 2010 and 2009. If this is a long-term goal, please elaborate on when you expect to see this kind impact and how you will track it. (see Number 1, below)
- Reduced pressure on bacterial resistance to antibiotics. (see Number 1, below)
- LAMP technology could potentially impact the Utah public and workers in fruit orchards, by decreasing human exposure to agricultural antibiotics, a growing public concern. Fewer antibiotic applications are an immediate measureable impact. Was human exposure to agriculture antibiotics reduced? (see Number 1, below)
- Did LAMP technology keep production costs down, thus maintaining availability of affordable, healthy, high quality fruit to the public. Did you measure this by personal communication with participating growers to compare antibiotic sprays and production costs in 2011 with 2010 and 2009? (see Number 1, below)

1. *Reduced (optimized) antibiotic sprays*. LAMP technology will enable growers to apply antibiotic sprays only when bacteria are active. Growers who participated in this project **responded to a written email survey**, and the average reduction in their antibiotic sprays was 20% as compared to 2010, and 25% as compared to 2009, a savings of $50/acre per treatment. Growers who participated in the survey reported a savings, on average, of $10,000 per 200 acre block in 2011, and $20,000 per 200 acre block in 2010. This savings allowed growers to offer affordable fruit to local markets with little to no antibiotic residue.

   We expected a 25% reduction for both years, but weather conditions in the spring of 2010 resulted in a reduced need to spray anyway, so that sprays in 2011 were already greater, even without the LAMP results. Reduced antibiotic sprays leads to other benefits: **reduced** farm worker and **consumer exposure** to agricultural antibiotics, reduced production costs, and lowered risk of antibiotic resistance in bacterial populations in orchards. A survey of bacterial populations' resistance to streptomycin was conducted in a separate USU project, the first since 2007. Results were similar to the prior survey, which means that resistance has not increased.

2. *Multi-state collaboration*. Utah State University and Mountainland Apples are collaborators of the LAMP work being done by plant pathologists at Oregon State University. Our results have been used by their lab to help to improve the LAMP testing. Collaborating with a large university such as OSU gives USU visibility and access to expertise and resources beyond our capabilities.

3. *Creation of the only lab of its kind in the western U.S.* The Mountainland grower lab is the only lab of its kind in the western U.S., and with the addition of the service fee starting in 2012, it will be self-sustaining, providing quick and effective fire blight detection results, allowing for implementation of control measures only when necessary.

4. *Student training* – an undergraduate student in the Nischwitz plant pathology lab received training in preparation of CCT media, culturing plant tissue, and identifying Erwinia cultures as part of this project. As a result of her work, she now envisions pursuing a Masters Degree in plant pathology.

BENEFICIARIES

This project directly benefits apple growers in the Utah County region (approximately 1056 acres and 70 operations). Grower organizations in other states can benefit from the success of Utah's grower-operated lab and can utilize its services or learn about setting up their own lab. There are no data for the economic impact of fire blight in Utah, but a severe epidemic, if left unmanaged or mismanaged, could reduce yields by up to 50%, and if a high density planting is destroyed, could cost the grower a $5,000-10,000 loss per acre in a single season. LAMP testing results can help apple growers to be more profitable.

LESSONS LEARNED

1. The LAMP molecular detection of fire blight is a valuable tool for fruit growers, and providing a high speed detection service within driving distance of apple orchards is important, and will provide growers the peace of mind to know whether an antibiotic spray is necessary to prevent serious losses.

2. It is important to compare results of molecular testing with direct culturing of the bacteria onto specialized growth media. The comparisons we conducted showed that the Mountainland grower lab needs further refinement the LAMP protocol. Using the remaining primers and reagents, we will continue to work on the molecular techniques with test runs in winter 2012 to be ready for the spring 2012 season.

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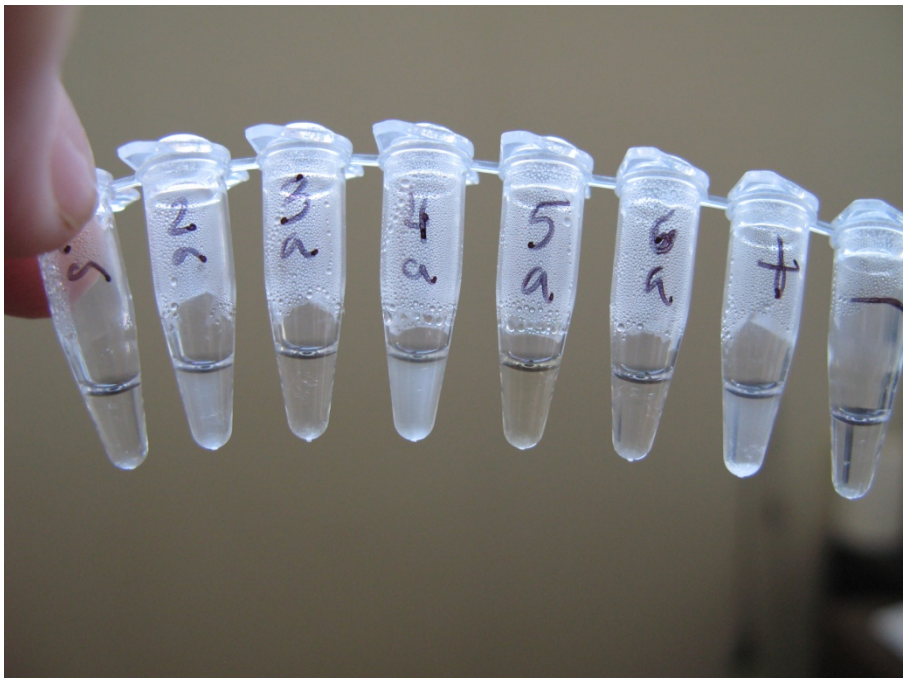
ADDITIONAL INFORMATION



In LAMP testing, sample tubes that are positive will have cloudy water while negative samples will have clear water. The sample numbers with cloudy water represent the detection of *Erwinia amylovora*, the bacterial pathogen that causes fire blight, from within healthy-looking flower clusters collected that same day. Using this test, results can be seen within 3-4 hours and growers can be better prepared to implement treatment based on the fire blight risk prediction model.

2010-9. Earwig Management in Peach Orchards

Final Report

Project Summary

The European earwig, *Forficula auricularia*, is a non-native insect pest of fruit and other crops. Earwigs are omnivorous (feed on plants and animals). The adults and young chew holes in buds, flowers, leaves and fruit, and are predators of soft-bodied insects. In peach, earwigs primarily damage fruit, and can cause significant yield loss through quality reduction and increased cullage. Earwigs are nocturnal in their feeding habits and climb into fruit trees to hide in protected sites. In a previous project funded by a Specialty Crop Block Grant we determined that corrugated cardboard rolls were an effective monitoring trap, and that sticky trunk bands and beating trays were ineffective monitoring tools for earwigs in peach orchards. We also found that overwintered earwig adults crawl into peach trees early in the season and spend significant time in the canopy based on captures in cardboard rolls placed on scaffold limbs. In the current project, we proposed to expand upon previous findings to develop a better understanding of earwig feeding habits, better document the extent of injury they cause to peach trees, evaluate their predation of soft-bodied insects, continue to evaluate effective monitoring tools, and continue to evaluate insecticide product efficacy and application timing.

Clockwise from upper left: cardboard roll trap tied to tree trunk, sleeve cage on peach shoot, earwig leaf-chewing injury, and fruit with earwig injury and adult male.

Project Approach

Objective 1. Earwig Trapping, Phenology, and Timing Control

Small rolls of corrugated cardboard (open face turned inward; flute size A; 9-10 in long 4-in wide strips; Wagner Packaging, Inc., Salt Lake City, UT) were held closed with small rubber bands and tied to the trunk or a main scaffolding limb of peach trees in one research orchard (Kaysville, Davis County) and three commercial orchards (Payson, Santaquin, and Genola, Utah County) in 2011. Traps were initially placed in mid-May, collected and replaced approximately weekly, and removed in mid-September. The experimental design was 12 replicates in each of the three commercial orchards and 6 replicates (two replicates in each of three blocks) in each of the insecticide treatments (see "Insecticide efficacy" methods below) in the research orchard. The number of each earwig life stage (adult male and female, and nymphs) per trap was counted.

At the Kaysville site, significantly more ($p \leq 0.05$) earwigs were caught in cardboard roll traps placed on tree trunks than on scaffold limbs (Fig. 1). Differences were greatest from mid-June to early August when trap capture was highest during the season. When trap capture was sorted by earwig life stage (overwintered adults, nymphs, and summer adults), trunk traps caught significantly more overwintered adults and nymphs than scaffold traps, but traps in both locations caught similar numbers of summer adults (Fig. 2). These same trends in trap capture were observed in the three commercial peach orchards (data not shown). Earwig phenology during the season based on capture in trunk traps showed only a small peak of overwintered adults in May, few early nymphs (instars 1 and 2) attracted to the traps throughout the season, a large peak of first generation late nymphs (instars 3 and 4) in late June to early July, a peak of first generation summer adu
early August, and a peak of second generation late instars and adults in early an
respectively (Fig. 3). Earwig phenology in the three commercial orchards was s
dampened peaks in one of the orchards most likely due to early summer insecti
not shown). These results suggest that overwintered adults and nymphs spend r
ground and trunk while summer adults spend similar amounts of time on the gr
canopy. These results also confirm that the European earwig is bivoltine (2 gen
northern Utah.

Clockwise from upper left: cardboard roll trap tied to tre
trunk, sleeve cage on peach sh
earwig leaf-chewing injury, an
fruit with earwig injury and a
male.

Fig. 1. Comparison of cardboard trap location in peach trees, Kaysville, 2011

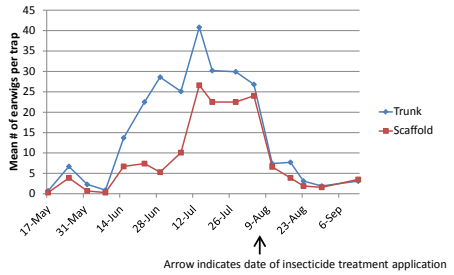


Fig. 2. Earwig life stage capture by trap location, Kaysville, 2011

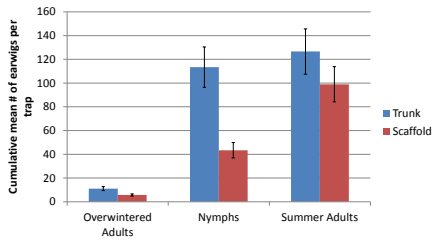
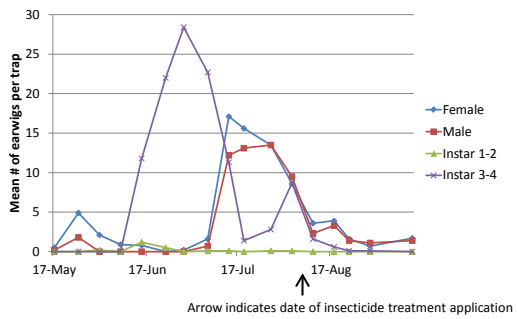


Fig. 3. Earwig life stage phenology, Kaysville, 2011 (trunk traps only)



Objective 2. Insecticide Efficacy for Earwigs

An insecticide efficacy trial was conducted in each 2011 and 2012 in a 1-acre peach orchard at the Kaysville research farm. The experimental design was a randomized complete block with three replicates. In 2011, there were six insecticide treatments: 1) untreated control, 2) carbaryl (Sevin XLR at 3 qt/acre), 3) spinosad (Success at 6 oz/acre), 4) spinosad (Entrust at 2 oz/acre) (organically certified formulation), 5) methoxyfenozide (Intrepid 2F at 12 oz/acre), and 6) lambda-cyhalothrin (Warrior at 2 oz/acre). In 2012, there were five insecticide treatments: 1) untreated control, 2) indoxacarb (Avaunt DG at 6 oa/acre), 3) carbaryl (Sevin 4F at 2.5 qt/acre), 4) spinosad (Success at 6 oz/acre), and 5) lambda-cyhalothrin (Warrior at 2 oz/acre). In 2011, the insecticides were applied once on August 10 with an orchard airblast sprayer at a volume of 100 gallons per acre. In 2012, plots were divided in half and one subplot received one application of the designated insecticide on August 2, and the second subplot received two applications of the designated insecticide on July 17 and August 2. In both years, earwig population densities in plots were monitored with cardboard traps as described above before and after insecticide applications. Fruit injury was assessed by visually inspecting 10 fruit per plot (1,800 fruit on each sample date) weekly beginning pre-treatment and for three weeks post-treatment. Injury from earwigs, cat-facing insects, and split-pits was measured.

In 2011, the insecticides Success and Entrust which both contain the active ingredient spinosad, significantly reduced earwig capture in trunk traps for more than two weeks after application (Fig 4). Sevin and Warrior reduced earwig counts one week after application, but then numbers were similar to the untreated plots by two and three weeks after application. Earwig counts in the Intrepid plots were never different from the untreated plots. All insecticides except Intrepid reduced fruit injury from earwig feeding as compared to the untreated (Tables 1 and 2). There were no effects on cat-

facing injury or split-pits which were relatively low (Table 2). Sevin and Success provided the longest-lasting protection of fruit, up to three weeks after applications (Table 1).

Fig. 4. Insecticide treatment effects on earwig densities, Kaysville, 2011 (trunk traps only)

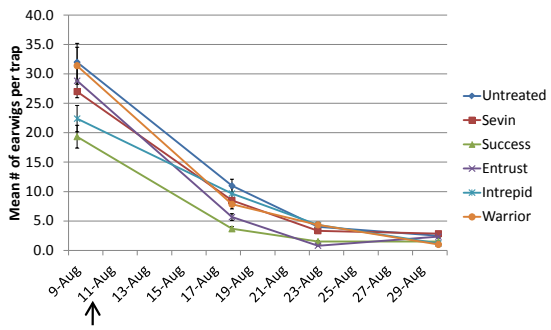


Table 1. Percentage of peach fruits with injury from earwigs, cat-facing, and split-pits following insecticide treatments applied on August 10, Kaysville, 2011.

Insecti-cide	Percentage of fruit with injury											
	Aug 9 (pre-trt)			Aug 16 (1 wk post-trt)			Aug 23 (2 wk post-trt)			Aug 30 (3 wk post-trt)		
	Ewg	Cat-f	Spl-pt	Ewg	Cat-f	Spl-pt	Ewg	Cat-f	Spl-pt	Ewg	Cat-f	Spl-pt
Untrt	16.7	0.0	6.7	30.0	3.3	16.7	46.7	3.3	6.7	33.3	6.7	13.3
Sevin	16.7	0.0	10.0	20.0	3.3	16.7	10.0	0.0	0.0	6.7	0.0	6.7
Success	16.7	0.0	30.0	13.3	0.0	16.7	6.7	0.0	0.0	0.0	0.0	3.3
Entrust	23.3	3.3	23.3	10.0	0.0	3.3	10.0	0.0	0.0	13.3	3.3	3.3
Intrepid	20.0	0.0	16.7	23.3	3.3	10.0	23.3	0.0	0.0	20.0	3.3	0.0
Warrior	16.7	0.0	6.7	13.3	3.3	16.7	23.3	0.0	0.0	10.0	0.0	0.0

Ewg=earwig, Cat-f=cat-facing, and Spl-pt=split-pit.

Table 2. Mean post-treatment fruit injury.

Insecticide treatment	% of fruit with injury post-trt		
	Earwig	Cat-facing	Split-pit
Untreated	36.7 a	4.4	12.2
Sevin	12.2 bc	1.1	7.8
Success	6.7 c	0.0	6.7
Entrust	11.1 bc	1.1	2.2
Intrepid	22.2 ab	2.2	10.0
Warrior	15.5 b	1.1	5.6
P>F	0.03	0.63	0.43

In 2012, Warrior was the most effective insecticide in reducing earwig densities. Success and Sevin were intermediate in their efficacy, and Avaunt was least effective (Fig. 5). Warrior was as effective

in reducing earwigs with just one application on August 2 as it was with two applications on July 17 and August 2. Success and Avaunt were more effective with two applications, while there was not any difference between one and two applications for Sevin. Peach fruit injury was least in the Warrior treatment, but also significantly less in Avaunt, Sevin, and Success than in the untreated control (Table 3). Cat-facing injury was greatest in the Avaunt treatment; greater even than in the untreated control. Split-pit injury was low and not different among treatments (Table 3).

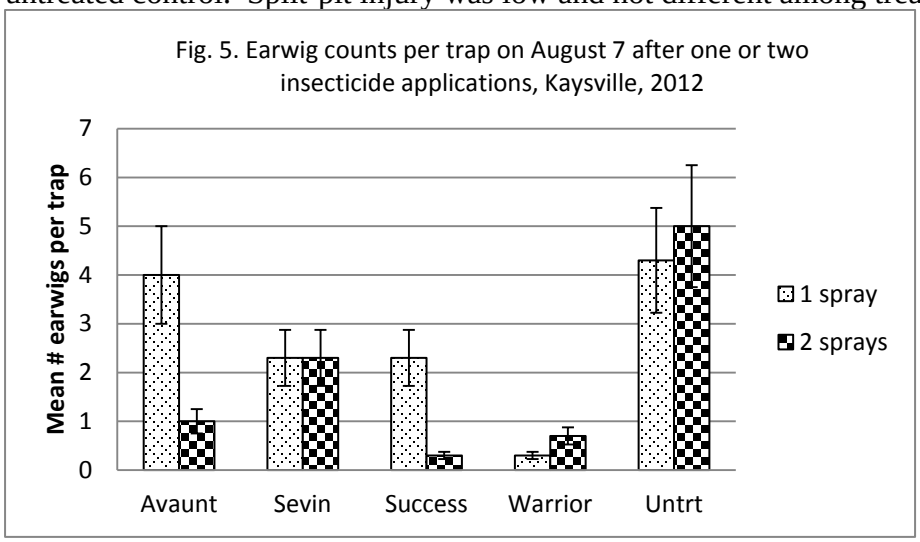


Table 3. Peach fruit injury on August 7, 2012, five days after the second insecticide application.

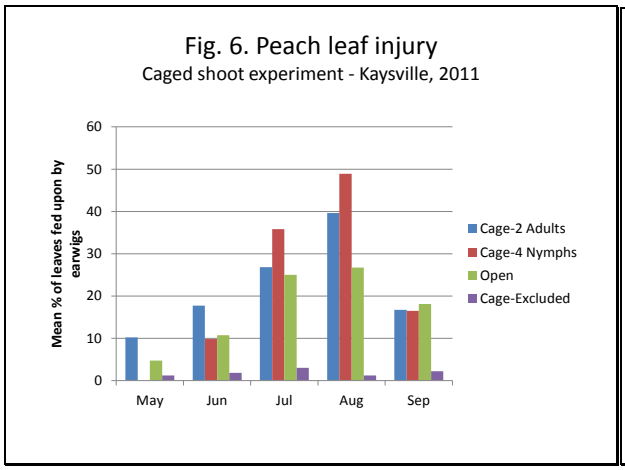
Insecticide	# sprays	# fruit out of 10 with injury			
		Earwig	Cat-Facing	Split Pits	Total
Avaunt	1	1.7 b	0.5 a	0	1.7 a
	2	2.0 b	1.0 a	0.3	3.3 a
Sevin	1	1.3 b	0 b	0	1.3 ab
	2	1.3 b	0 b	0.3	1.6 ab
Success	1	2.0 b	0.3 b	0.7	3.0 a
	2	2.0 b	0 b	0	2.0 a
Warrior	1	0.7 c	0 b	0	0.7 bc
	2	0.7 c	0 b	0	0.7 bc
Untreated		3.2 a	0 b	0.2	3.4 a
Insecticide *P* > F		***0.05***	***0.01***	*0.62*	***0.04***
# Sprays *P* > F		*0.65*	*0.18*	*0.65*	*0.59*

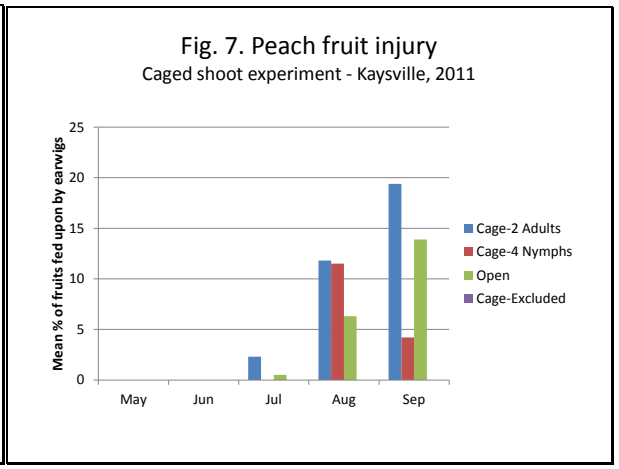
In summary for the two years, Warrior, Success, and Sevin were all effective in protecting peach fruit from earwig feeding injury. Warrior was as effective with one application applied approximately two weeks before full fruit maturity as when applied twice, at approximately four and two weeks before full fruit maturity. Avaunt and Intrepid were least effective against earwigs. Entrust is the organic formulation of spinosad, and was as effective as Success, the conventional formulation of spinosad. Entrust is an effective option for earwig control for organic peach producers, but spinosad products should be applied twice, approximately four and two weeks before harvest, for optimal efficacy and fruit protection.

Objective 3. Seasonal Peach Injury from Earwigs

When caged in no-choice tests on peach shoots, adults and nymphs fed on both leaves and fruits (Fig. 6 and 7). The majority of leaf-feeding occurred in July and August, on both earwig-caged and shoots

open to natural populations of earwigs (Fig. 5). Very little leaf-feeding and no fruit-feeding was observed on shoots from which earwigs had been excluded. A low level of leaf-feeding occurred in May before exclusion cages were applied and this injury carried through the trial. The first fruit injury by earwigs was observed in mid-July, but levels were low (Fig. 6). The majority of fruit-feeding occurred in August and September when fruit softened as they neared maturity. Fruit ripened in early to mid-September. Both adults and nymphs fed on fruits when caged on the shoots. Adult feeding was greatest in September, and few second-generation nymphs were active by this late in the season (Fig. 3).





Objective 4. Predation of Earwigs on Green Peach Aphid

Overwintered adult earwigs were caged on peach shoots infested by green peach aphid in 2011 and 2012. Green peach aphid densities were significantly decreased ($p \leq 0.05$) on shoots with 2 female, 2 male, and 1 each male and female earwigs as compared to shoots without earwigs. Differences occurred within one week after earwig adults were added to aphid-infested shoots, and continued for up to three weeks. There were no differences in whether earwig adults were pairs of all female, all male, or mixed genders.

Objective 5. Outreach

The following outreach outcomes were achieved: one Utah State University Extension fact sheet (http://extension.usu.edu/files/publications/factsheet/earwig-orn.pdf) , one *Utah Pests News* newsletter article (http://utahpests.usu.edu/files/uploads/UtahPests-Newsletter-summer11.pdf) , three tree fruit grower advisory articles that included information on earwig injury and timing of management (http://utahpests.usu.edu/IPM/htm/advisories/treefruit/) , and presentation of information on earwig monitoring and management at the 2011 and 2012 winter Utah State Horticultural Association conferences (http://www.utahhort.org/talks/talks.htm) , two in-season grower field meetings, two summer grower field days, and two Master Gardener (home gardener) classes.

Conclusions

Cardboard refuge traps placed on tree trunks were found to be an effective monitoring tool for earwigs. The traps provide a measure of relative density and life stage activity. Traps placed on trunks were more attractive than those placed on scaffold limbs, especially for overwintered adults

and summer generation nymphs. The European earwig is bivoltine (two generations per year) in northern Utah. It overwinters as an adult. The first generation of nymphs peaked in early July and adults in mid to late July. The second generation of nymphs peaked in late July to early August and adults in late August. Few early instar nymphs were caught in traps because they remain in ground nests which are guarded by the female parent.

Of the insecticides evaluated, Success and Entrust reduced earwig densities up to two weeks post-application as compared to untreated trees. Both of these reduced-risk insecticides contain the active ingredient spinosad which is produced by fermentation of a bacterium. The conventional insecticides carbaryl (Sevin) and lambda-cyhalothrin (Warrior) reduced earwig densities one week post-application, but then densities were similar to the untreated plots by the following weeks. Methoxyfenozide (Intrepid), a growth regulator that mimics the molting hormone of lepidopterous insects (caterpillars), and indoxacarb (Avaunt) with a unique mode of action, did not consistently lower earwig densities. All insecticides, except Intrepid, reduced fruit injury from earwigs as compared to untreated trees. Mean injury for the three week period following treatment was lowest in Success, Warrior, and next lowest in Entrust and Sevin plots.

Earwig adults and nymphs fed on peach leaves and fruits. Leaf-feeding occurred from May to September, but was greatest in July and August. The proportion of injured leaves declined in September. Because leaf injury carried forward to future shoot evaluations, these results suggest that little new leaf-feeding occurred in September when leaves are tougher and no longer actively growing. Second-generation adults caused the greatest injury to fruits in late August and September when fruits approach and reach maturation. Late-summer adults were also more active in tree canopies based on higher limb trap captures.

Overwintered adult earwigs, males and females, were effective predators on the soft-bodied green peach aphid. Predation was significant for up to three weeks after earwigs were added to caged peach shoots infested with the aphids. After three weeks, aphid densities naturally declined in cages with and without earwigs.

Grower Cooperators
Becky Ellsworth, Allred Orchards, Payson, UT
Curtis Rowley, Cherry Hill Farms, Santaquin, UT
Thor Lindstrom, Research Associate, Utah Agricultural Experiment Station, Kaysville, UT

Significant Contributions and Role of Project Partners
The project director, Diane Alston, oversaw all research objectives, including collection of data, analysis and summary of results, and was the primary author of publications and presenter of results to the tree fruit industry. Co-project investigator, Marion Murray, assisted with the pre- and post-project grower survey, reviewed the fact sheet and newsletter articles, and participated in outreach education. The three grower cooperators assisted with managing on-farm sites for the research studies, and applied insecticide treatments.

Goals and Outcomes Achieved
1. Greater awareness of earwig population densities in peach orchards through an efficient and effective trapping system. The cardboard roll traps are easy to deploy, maintain, and check for the presence of earwigs. The cardboard traps were demonstrated to peach growers at two field days, and

trapping results were disseminated at two educational conferences. In a pre-project survey in 2010, no peach growers indicated that they monitored for earwig populations. In a post-project grower survey conducted in 2012, 40% of peach growers responded that they monitored for earwigs.

2. *Decrease in injury to peach fruits resulting from optimal timing of effective insecticides for earwig control.* A similar percentage of growers from pre- and post-project surveys indicated that their peach orchards were damaged by earwigs (84 and 88%, respectively). When asked how much injury earwigs cause, in 2010, 69% of respondents reported 5-10% of crop injured and 15% reported < 5% of crop injured. In comparison, in 2012, 47% reported less than 5% injury while 40% reported 5-10% injury. These changes show a slight decline in the amount of crop injury caused by earwigs from the pre- to post-project survey. A total of 40% of survey respondents in 2012 said that they monitored earwig traps and fruit ripeness to help them optimally time insecticides for earwig control. This question wasn't asked in the pre-project survey; however, the increased use of earwig traps cited above and the reduction in crop injury are likely tied to the better timing of earwig control methods.

3. *Increase in use of reduced-risk insecticides for management of earwigs in peach orchards.* In the post-project survey, 73% of growers reported using broad-spectrum insecticides to control earwigs while only 18% used reduced-risk insecticides such as spinosad. Growers were not asked about which insecticides they used for earwigs in the 2010 survey, but only 62% indicated they used insecticides to manage earwigs. Thus, the proportion of peach growers using insecticides to manage earwigs appears to have increased over the course of this project, likely due to greater awareness of earwig injury and crop loss. A minority of peach growers currently use reduced-risk insecticides, but this will likely increase with continued educational outreach about the efficacy of spinosad for earwig population reduction.

Beneficiaries

The major beneficiaries are the growers and support industry for tree fruit production in the state. Project results have been disseminated to growers, Utah Department of Agriculture and Food inspectors, Natural Resource Conservation Service agronomists, Utah State University Extension agents, agricultural product suppliers, and others. In addition, the information has been disseminated to home gardeners via the USU Extension Master Gardener Program and Extension online websites. Face-to-face contacts for the project investigators in extending project information were at least 500 people. In addition, subscriptions to the Utah tree fruit IPM advisory is 4,163 and to the Utah Pests News is 3,144 people. New earwig monitoring and management information was disseminated to these advisory and newsletter subscribers in both 2011 and 2012.

Utah's peach production is valued at $5.7 million on 1,500 bearing acres. Peach price was $1,040 per ton for 5,500 tons of utilized product in 2010. In the pre-project survey, 62% of respondents reported applying an insecticide for earwig control. This translates to approximately 915 acres being treated for earwig control. Cost for just the insecticide including labor and equipment is estimated at approx. $50 per acre. If one application can be avoided due to better timing based on earwig population monitoring, approx. $46,000 can be saved by the industry. If the amount of harvestable peach product is increased by just 2% due to better earwig control (a conservative estimate based on the data that 68% of pre-project survey respondents reported earwig injury of 5-10%), then approx. $114,000 of greater profits could be realized (5,500 utilized tons × 0.02 ×$1,040 per ton) each year.

Lessons Learned
This project demonstrated the ease of use of an effective earwig monitoring tool. Growers were trained in its use. We documented an increase in earwig monitoring by peach growers up to 40% over the course of the project. We measured a decrease of nearly 30% in peach crop injury from the beginning to the end of the project that was likely a result of improved earwig monitoring and use of effective earwig management strategies. At the end of the project, 18% of growers reported using reduced-risk insecticides for earwig management as well as 20% of respondents who reported managing understory vegetation to decrease earwig habitat, and 7% who reported using trapping to decrease earwig populations and crop injury. This project can be credited with the increase in use of all of these reduced-risk earwig management strategies as a result of outreach education to the peach industry. The results from this project especially showcase the importance of demonstrating a convenient and effective insect pest monitoring tool to aid growers in adopting more effective pest management strategies. We documented an increase in use of reduced-risk insecticides with less risk for the health of farm workers and natural resources.

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Additional Information
Publications
Alston, D. G., and A. Tebeau. 2011. European earwig, *Forficula auricularia*. Utah State University Extension and Utah Plant Pest Diagnostic Laboratory ENT-145-11 (3 pp.), Logan, UT. (http://extension.usu.edu/files/publications/factsheet/earwig-tf.pdf)

Alston, D. and A. Tebeau. 2011. European earwig functional roles in peach orchards. Utah Pests News Vol. 5: 6-7, Summer, Utah State University Extension and Utah Plant Pest Diagnostic Laboratory, Logan, UT. (http://utahpests.usu.edu/files/uploads/UtahPests-Newsletter-summer11.pdf)

Murray, M. and H. Larsen (eds.). 2012. Utah-Colorado commercial tree fruit production guide (178 pp.). Utah State University Cooperative Extension Bulletin, Logan, UT. (http://intermountainfruit.org/) (Revised sections on earwig management based on project results)

Utah Department of Agriculture and Food Specialty Crop Block Grant
2010-10
Final Report
Project Title: Evaluation of Caneberry Varieties for Yield, Quality, and Susceptibility to Insect Caneborers in Northern Utah
Project Investigators: Diane Alston, Entomologist, Utah State University (USU)
Brent Black, Pomologist, USU
Collaborator: Thor Lindstrom, Research Associate, USU
Project Summary: Caneberries are a traditionally important agricultural industry in Utah. The fruits are high value with a short shelf life making them well-suited to local production and consumption. In the last decade, Utah's raspberry industry has been hard-hit by the outbreak of several virus diseases, one of which is spread by pollinators, causing changes in primary production

areas and suitability of varieties. New raspberry varieties have been recently developed that offer adaptability to a wider range of climates and virus resistance. The varieties were developed in the northwestern and eastern U.S., and few have been evaluated in the Intermountain West. In Utah, the raspberry horntail, *Hartigia cressonii* (Kirby), is the primary cane-boring insect pest. This project built upon two previous projects to evaluate the suitability of new raspberry varieties for production in Utah. Funding for the previous projects was secured from the Utah Specialty Crop Block Grant and Western Sustainable Research and Education programs. This project funded the installation of a new raspberry planting in 2011 at the USU horticulture research farm in Kaysville, UT. The new planting included eight summer- and eight fall-bearing varieties. We evaluated total yield, fruit size, production period, cane survival, and susceptibility to raspberry horntail. In addition, public taste tests of fall-bearing varieties was conducted in 2013. The raspberry variety site is used to educate producers and home gardeners about the suitability of new raspberry varieties for Utah.

Project Approach: Raspberry canes were planted in spring of 2011 (except a few were unavailable in 2011 and their planting was delayed until spring 2012). Plots were 24 ft long with an 11 ft buffer between plots, and replicated four times. Grass alleyways were planted in 2011, and a permanent drip and overhead irrigation system was installed in 2012. Berry yields were measured in 2012 (fall-bearing varieties only) and 2013. Cane infestation with raspberry horntail was measured weekly from mid-June through July in 2013. Taste testing of fall-bearing varieties was conducted at the Kaysville Farmers' Market on September 12, 2013. A total of 53 people participated. Each participant was given 10 pennies, instructed to taste each variety, and to vote for their favorites with their pennies.

The highest yielding fall-bearing varieties were Joan J, Polana, and Autumn Bliss (Table 1). In both 2012 and 2013, the first two years of productivity for the raspberry planting, these three varieties yielded the most berries. Brice and Autumn Treasure were delayed one year in planting, and so their first harvest was not until 2013, but yields were still lower than top-yielding varieties in their first year. The largest fruit size occurred in Joan J, Polana, Autumn Bliss, and Autumn Britten. First harvest dates for most varieties fell within the 220 to 235 JD range (August 7 to 22), but Autumn Treasure was notably later in its first year of production, 246 JD (September 2) in 2013.

Table 1. Yield, peak fruit size, and production season of fall-bearing raspberry varieties in 2012 and 2013.

Cultivar	Yield (kg/m)		Peak fruit size (g/fruit)		First harvest (Julian date)	
	2012	2013	2012	2103	2012	2013
Joan J	2.38±0.16	3.40±0.35	3.35±0.18	3.53±0.46	230±1.0	224±2.9
Polana	2.33±0.37	2.18±0.49	3.25±0.24	3.03±0.43	234±1.5	222±1.8
Autumn Bliss	1.73±0.18	1.82±0.44	2.98±0.05	3.05±0.41	230±0.5	220±0.5
Dinkum	1.14±0.25	1.22±0.25	2.83±0.15	2.65±0.19	234±1.5	232±1.5
Autumn Britten	1.10±0.13	1.0±0.23	3.28±0.15	3.03±0.30	235±1.2	232±0.5
Vintage	1.12±0.16	0.73±0.1	2.50±0.23	1.93±0.06	243±1.0	231±2.4
Brice*	---	0.72±0.10	---	3.35±0.51	---	228±5.1
Autumn Treasure*	---	0.06±0.02	---	2.48±0.11	---	246±2.0

*Planted in 2012, one year later than the other varieties.

In the taste panel, the preferred varieties were Autumn Bliss and Dinkum. Vintage, Autumn Britten, and Polana were the least preferred for their flavor.
For summer-bearing varieties, cold winters in 2011-12 and 2012-13 caused significant cane mortality in Octavia and Chemainus (Table 2). Prelude had moderate cane survival, but survival of Cascade Bounty and Nova were high, greater than 91%. Cane survival was correlated to berry yields. Highest berry yields were in Cascade Bounty and Nova, with much less in Prelude, Octavia, and Chemainus. Chemainus and Octavia had the largest fruit size, while fruit size for Cascade Bounty, Nova, and Prelude was smaller and similar. Interestingly, while Nova and Prelude are classified as summer-bearers, both varieties produced notable crops in fall of 2012 and 2013 (mean of 0.18 and 1.67 kg/m, respectively). Prelude produced significantly more berries in the fall than summer of 2013. The hot and long growing seasons experienced in both 2012 and 2013 may have caused the primocane-bearing effect in these two varieties. Mid-harvest date for most varieties ranged from 186 to 205 JD (July 4 to 23); however, Octavia was later at 219 JD (August 6). Prelude is known to be an early-bearer, and it was the earliest variety of the ones tested, but its summer yields were low in 2013 due to winter cane injury.

Table 2. Yield, peak fruit size, and production season of summer-bearing raspberry varieties in 2013.

Cultivar	Cane survival (%)	Yield (kg/m)	Peak fruit size (g/fruit)	Mid-harvest (Julian date)
Cascade Bounty	98.8±1.3	1.38±0.03	1.55±0.06	197±0.5
Nova	91.3±1.3	1.47±0.10	1.85±0.14	192±0.5
Prelude	88.8±2.4	0.54±0.09	1.58±0.17	186±1.2
Octavia	32.5±3.2	0.38±0.10	2.68±0.30	219±2.2
Chemainus	27.5±5.2	0.28±0.06	5.13±3.30	205±2.4

In 2013, raspberry horntail infestation peaked in late June for both fall- and summer-bearing varieties. Very few new infestations were found after July 10. The most susceptible fall-bearing varieties were Dinkum, Polana, Autumn Bliss, and Joan J. Dinkum was a mid-range yielding variety and cane growth was vigorous. Joan J, Polana, and Autumn Bliss were the highest yielding fall varieties and healthy and vigorous plants. It appears that the vigorous varieties were more attractive to raspberry horntail females for egg-laying sites. The fewest horntail larvae were found infesting Autumn Treasure, Vintage, and Brice. Autumn Treasure and Brice were planted one year later, in 2012, and so plants were smaller than for varieties planted in 2011. In general, lower infestation levels were observed in the varieties with fewer canes.

Table 3. Mean number of raspberry horntail larvae in eight varieties of fall-bearing raspberries per 24-ft plot from June 19 to July 29, 2013.

Cultivar	Mean no. larvae per plot

Dinkum		14.0
Polana	9.0	
Autumn Bliss	8.25	
Joan J	8.25	
Autumn Britten		3.75
Brice*	2.75	
Vintage		1.0
Autumn Treasure*	0.5	

*Planted in 2012, one year later than other varieties.

Cascade Bounty was the most susceptible summer-bearing variety to raspberry horntail infestation (Table 4). It was more attractive to horntail than all of the fall-bearing varieties. Nova and Prelude were also susceptible, while Octavia, Cascade Gold, and 1142-1 had the fewest larvae. The relationship of horntail infestation to variety vigor was the same as for fall-bearing varieties: the highest yielding and most vigorous canes had the most horntail. Octavia and Chemainus had low cane survival following cold winters, and there were fewer canes available for horntail to attack.

Table 4. Raspberry horntail infestation in seven summer-bearing varieties per 24-ft plot from June 19 to July 29, 2013.

Cultivar	Mean no. larvae per plot	
Cascade Bounty		22.75
Nova	13.5	
Prelude		8.25
Chemainus	6.0	
1142-1	2.0	
Cascade Gold	0.5	
Octavia		0.25

Goals and Outcomes Achieved: Caneberry producers were informed about raspberry variety trial results and raspberry horntail management at the annual Utah Berry Growers Association meetings on February 23, 2012 and February 27, 2013 (65 and 85 attendees, respectively). Producers, home gardeners, and outreach educators visited the research plots during USU research field day at the Kaysville farm on August 16, 2012 (65 attendees). The new varieties were promoted to consumers at the Kaysville Farmers' Market during 2012 and 2013 (average attendance to the market berry display was 75 people per week for four weeks each year = 600 contacts). Evaluation of grower needs and project impacts were surveyed at the Utah Berry Growers Association meetings in 2010 (pre-project) and 2012 (20 and 16 respondents, respectively). In the 2012 survey, 50% of respondents reported that caneberry acreage on their farm had increased in the last three years. Sixty-three percent of the respondents planted new berry acreage in 2011 and 25% planned to do so in 2012. In comparison, only 23% of respondents to the 2010 survey reported that they planted new berry acreage in 2009. The most popular raspberry varieties planted in 2011 were Polana and Polka, and growers planned to plant Autumn Bliss and Autumn Britten in 2012. In the 2010 survey, 56% were growing Caroline and 33% were growing Joan J. Polana, Polka, Autumn Bliss, and A. Britten are newer varieties with greater resistance to virus diseases. Growers have shifted to planting these new varieties, at least in part, due to information presented at the Utah Berry Growers Association meetings and USU field days. In 2012, 75% of respondents reported that their most problematic pest was the raspberry horntail. Spider mites and stink bugs were the other important pests. In 2010, there was less awareness about the severity of raspberry horntail, and the horntail, spider mites, and grasshoppers

were equally reported as the most problematic pest. In 2012, thirty-eight percent of respondents said they had increased their management intensity of raspberry horntail in the last three years as a result of training about its biology and management. One hundred percent of survey respondents said that they had increased their knowledge about pest management in the last three years, and 88% reported improvements in pest management on their farm. The increased interest in planting raspberry acreage, selection of new varieties, and improved pest management reflects that producers have learned from the information generated in this project and shared by project leaders with the Utah berry industry over the last three years.

Publications

Black, B., R. Heflebower, B. Hunter, S. Olsen, and D. Alston. 2013. Adaptability of primocane raspberry cultivars to a high-elevation arid climate. Journal of the American Pomological Society 67: 47-56.

Heflebower, R., B. Hunter, S. Olsen, B. Black, D. Alston, and T. Lindstrom. 2013. A comparison of fall-bearing cultivars for northern Utah. Utah State University Extension Horticulture/Fruit/2013-01PR (6 pp.), Logan, UT.
http://extension.usu.edu/files/publications/publication/Horticulture_Fruit_2013n-01pr.pdf

Alston, D., M. Murray, and C. Nischwitz. 2012. Utah home orchard pest management guide, HG137, 39 pp., Utah State University Extension and Utah Plant Pest Diagnostic Laboratory, Logan, UT.
http://extension.usu.edu/files/publications/factsheet/home-orchard-pest-mgmt-guide.pdf

Beneficiaries: Approximately 45 berry producers, 10 processors, 35 educators (e.g., Extension agents, Utah Department of Agriculture and Food inspectors), and 5 land management agency staff (e.g., Natural Resources Conservation Service) were the primary beneficiaries of this research project. Beneficiaries have become better informed about which raspberry varieties are best suited for production in Utah, including yield, time of production, cane susceptibility to winter injury, fruit quality (size and flavor), and susceptibility to the primary cane-boring pest, raspberry horntail. Growers and processors will make more informed decisions about variety selection, and educators will extend this information to additional stakeholders. The raspberry planting at the USU research farm will continue to provide data and serve as a research and educational venue for years to come.

Lessons Learned: New varieties of summer- and fall-bearing raspberries were found to be amenable for planting in northern Utah. Northern Utah has cold winters, hot summers, high elevation planting sites, and alkaline soils. Raspberry varieties are developed in locations with very different environments. Testing new varieties to help boost the viability of the Utah raspberry industry has been a major assistance to the industry. Producers confirmed that they are increasing plantings of raspberry, selecting new varieties to plant on their farms based on good growth characteristics and yield, and they are selecting varieties that are less susceptible to the major cane-boring pest, raspberry horntail.

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2010-11. High Density Orchard Systems for Improving the Competitiveness of Utah's Fruit Industry

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Final Report

Project summary: High density orchards provide a number of efficiencies, including: increased yields per acre, improved fruit quality, reduced labor costs, and earlier returns on investment. High density orchards also offer environmental benefits, as the use of fertilizers and crop protectants (fungicides, insecticides) can be more efficiently applied. Tart cherries are Utah's major fruit crop, but cannot be managed in high density orchards using existing technology. New production systems need to be developed to enable high density tart cherry production. Although high density systems have been developed for apples, these rely on dwarfing rootstocks that tend to be highly susceptible to the bacterial disease fire blight. Fire blight has become a prevalent problem in Utah's fruit growing regions, severely limiting the success of high density apple production systems. The primary objectives of this project are (1) to evaluate tart cherry production in an existing experimental high density orchard, and (2) establish new high density apple orchards to compare the performance of new fire blight-resistant apple rootstocks under Utah conditions
Experimental orchards were planted in 2010, and evaluated during the 2011 season. The tart cherry orchard focuses on both rootstocks and on specific management practices, while the apple plantings are specifically designed to compare rootstocks. Although these studies are planned to be continued for 10 to 12 years, results for this contract period are beginning to eliminate some rootstocks and management practices as being unsuitable for Utah's fruit growing regions.

Project approach:

Cherry: An experimental orchard of 'Montmorency' tart cherry was planted at the Kaysville Research Farm in Kaysville, Utah during the 2010 season. Experimental treatments include combinations of three tree training systems, four tree spacings, and four rootstocks. **Tree training systems** include a tall spindle consisting of one central leader with weak fruiting laterals that undergo renewal pruning to remain fruitful; a "parallel V" system where two permanent leaders will be established parallel to the row, each with weak fruiting laterals; and a "candelabra" system with four permanent leaders also established parallel to the row. The reasoning behind the multi-leader systems is to spread tree vigor out among leaders and better limit tree growth to the proper size. **In-row spacing** treatments include 4, 6, 8 and 10 feet. Previous research with apples, peaches and other tree crops has shown that close tree spacing also has a pronounced dwarfing affect on otherwise vigorous rootstocks. **Rootstocks** (listed from smallest to largest) include Gisela 3®, Gisela 5®, Gisela 6®, and the current industry standard Mahaleb. All of these rootstocks have previously shown adaptation to Utah climate and soils in a wide-spaced NC-140 planting.

The planting is arranged as an incomplete factorial split-split plot design, where the main plot treatments are tree spacing, the sub-plot treatments are rootstock, and the sub-sub plot treatments are training system. This design was used to reduce the likelihood of trees on larger rootstocks causing excessive border effects to neighboring plots. Likewise, the design is an incomplete factorial as not all rootstocks appear in each spacing and training system, and only the spindle system is used at the closest spacing. Gisela 5® is common to all treatments, whereas Mahaleb and Gisela 6® are included only in the wider plant spacings and Gisela 3® is included in the intermediate and close spacings. Each experimental plot is approximately 30 feet long, to allow for mechanical harvesting tests of individual treatment combinations.

Tree growth and initial survival was recorded in the fall of 2010, and again in the fall of 2011 (Table 1). Some tree mortality was seen in the multiple-leader treatments, which was likely more severe due to the heavy early pruning. These results suggest that standard nursery tree propagation practices are not well suited to this system. Additional nursery trees were ordered in 2011 for 2013 delivery, and these will be used in the second phase of this ongoing research. For trees from standard propagation practices, the single-leader spindle system seems to be working well.

Apple:

Two apple rootstock experimental blocks were planted in Spring 2010. Both plantings consisted of 31 different rootstocks, with each rootstock replicated and arranged in a randomized block design. One planting has Aztec Fuji as the scion cultivar and was planted in a tall spindle system at the Utah Agriculture Experiment Station Kaysville research farm in Kaysville, Utah. The second planting has Honeycrisp as the scion cultivar, and was established in a tall spindle training system on a commercial fruit farm (South Ridge Farms) in South Santaquin, Utah. Because some of the nursery trees showed exceptionally weak growth in the establishment year, all fruit was removed in the spring of 2011 to allow additional tree growth. Plants were evaluated at the end of the 2011 season for survival and tree growth (Table 2).

Goals and outcomes achieved:

The experimental orchards have now been established and will be a valuable research resource for the next 10 to 12 years. The plantings were showcased at the national NC-140 Tree Fruit Rootstock research meeting held in Utah on 4 November 2010. Early results were presented at the 2011 annual meeting of the Utah State Horticulture Association in February 2011, and will be featured at the 2012 Kaysville Fruit and Vegetable Field day in August. Three experienced tart cherry growers have been acting as an advisory committee in developing and refining training and pruning strategies for the tart cherry orchard.

Future plans - Plans for 2012 include ongoing maintenance of the planting, continued measurement of plant growth and initial fruit set. All trees will be cropped in 2012 to slow growth and vigor, and to evaluate precocity. USU is currently in negotiations to purchase over-the-row mechanical harvester to be used during the 2012 season to collect data on early cherry yields.

Beneficiaries: While it is too early to draw conclusions from any of these young planting, it is expected that the results will help to develop new strategies for growing tart cherries, and to identify regionally adapted apple and cherry rootstocks. These research orchards will benefit fruit producers in Utah by testing these technologies and providing demonstration areas where growers can observe recent developments. Because the Kaysville Farm Field Day is only held in even years, we were unable to feature this work during 2011. Our original projection was to reach 120 farmers representing 90% of the total tart cherry acreage. However, we fell short of this goal, only reaching an estimated 25 growers representing approximately 50% of the acreage. This grant was to establish a demonstration orchard that could be used for approximately the next decade. We plan to feature the planting at the 2012 field day and at future winter grower meetings, and are confident that we will reach the goal of 90% exposure during the course of this demonstration.

Lessons learned:

Cherry - For the tart cherry experiment, this type of production system has never been attempted. As a result, some of the early management decisions turned out to be mistakes. For example, trees used in the study were propagated according to normal commercial practices, which severely limited branching near the ground. In an effort to stimulate low branching, some heavy pruning cuts were

made. Many of the trees pruned in this way were either set back a year, or died. In the future, we will be looking at new propagation strategies, or other methods for inducing lateral branching.

Apple – The apple management system used here is better defined and is not the focus of this work. To this point, we have seen some dramatic differences in tree survival. One of the biggest culprits in tree death has been trees that break off at the graft union, due to wind. We have improved our trellis practices to reduce this breakage. However, there is a definite trend in rootstock susceptibility to this breakage. This is also important information, as the rootstocks prone to breakage are not going to be suitable in our environment, particularly in windier areas.

Status of Funds: All of the 2010-2011 funds for this project have been spent. Expense included seasonal labor ($1459), and irrigation and trellis supplies ($593). The remaining expenses were for replacement trees and travel.

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2010-12. Enhancing Tree Fruit Pest Management Outreach through Weather Stations and Online Tools

Partners:

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Final Report

Project Summary

This project, conducted through a collaboration with the Utah State Horticultural Association, the USU Extension IPM Program, and the Utah Climate Center, impacted almost all of Utah's 7,200 acres of specialty crop tree fruits and the associated grower-operators. Prior to this project, we determined that a demand existed from Utah's fruit growers for online access to various formats of weather data and for relevant, real-time pest management tools.

Weather data is essential to providing accurate plant protection. The USU IPM Program owns a collection of weather stations, all located within fruit orchards in northern Utah (known as "FGNet"). Prior to this project, FGNet was composed of 14 stations representing only 2,000 of the state's fruit

growing acreage. At times, the operability of some stations was unreliable and the data collected from the stations was not readily accessible by the commercial fruit growers. The IPM Program was constantly in a cycle of "catch up" with repairs, making them as needed, and was only able to provide weather data to growers on an as-needed basis. Having reliable, site-specific weather data would allow us to provide Utah fruit growers frost alerts, pest activity predictions, and access to real-time weather-related growing conditions.

Data from FGNet has been used by USU for research and to disseminate information. Site-specific weather data helps in presenting treatment recommendations for the weekly Tree Fruit Advisory, and assists over six University researchers in irrigation projects, plant chilling requirements, frost history, and more. In 2008, the Utah IPM program formed a partnership with the Utah Climate Center (UCC) to create Utah TRAPs (Timing Resource and Alert for Pests) located at climate.usu.edu/traps. (The website is explained in more detail under *Objective 4*, below.) Grower feedback of the TRAPs website revealed that its functionality and usability could be vastly improved.

All the proposed objectives of this two-year project were completed without any problems or delays:

1. *Add 3-5 weather stations to the FGNet weather station system in Utah.*
    a. We successfully added 4 new stations, serving up to an additional 2,000 acres.
2. *Upgrade the existing stations with antennas and new sensors, or calibrate existing sensors.*
    a. Sensors (temperature, wind speed, etc.) were calibrated on all stations, and some were replaced.
    b. High-gain antennas were added to stations whose connections repeatedly dropped, and 3 stations were linked to neighboring stations via radio transmitters to further improve reliability.
3. *Develop a text messaging system through the TRAPs website that provides timely, user-specified alerts.*
    a. A frost alert system was developed and used by 18 growers representing 3,400 acres in spring of 2011 and 2012.
4. *Expand the TRAPs website offerings.*
    a. A suite of new tools was added to the TRAPs website.

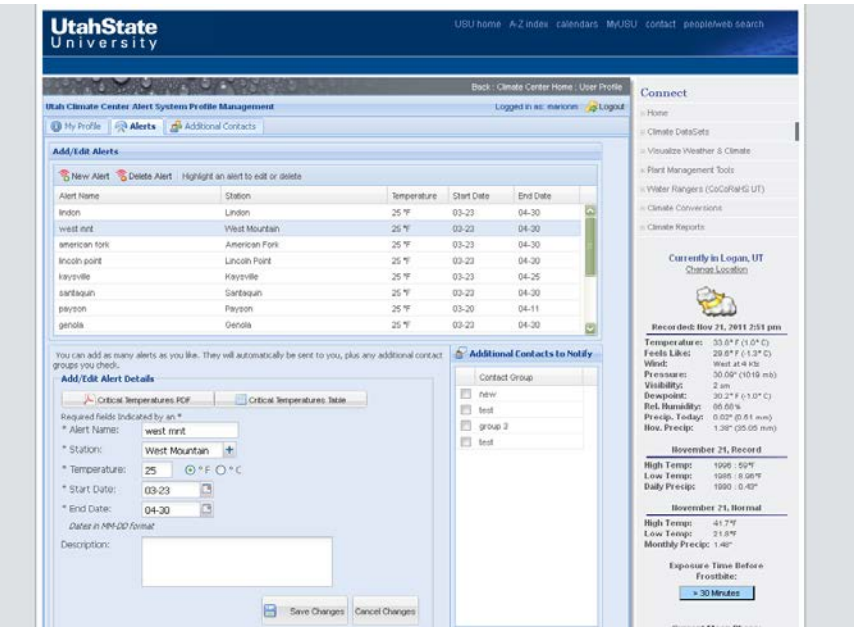
Project Approach

The project partners formed a stakeholder advisory committee of 3 fruit growers from the Utah State Horticultural Association (USHA) in January 2011 that would provide guidance in the direction of this project. The primary project applicants (Marion Murray-USU Extension, Jobie Carlisle-Utah Climate Center) met with the USHA advisory committee a total of six times. The advisory committee selected the locations of new weather stations and helped to coordinate their installation, helped to prioritize upgrades to existing stations, tested the new online tools and provided input and feedback on problems and changes.

Objectives 1 and 2: Add 3-5 weather stations to the FGNet weather station system in Utah, and upgrade the existing stations with antennas and new sensors, or calibrate existing sensors.
Murray and Carlisle purchased equipment for four new weather stations (three in 2011 and one in 2012), and located them in commercial orchards in River Heights, Lindon, Leeds, and Goshen, Utah.

Carlisle received volunteer assistance from the grower at each orchard during the station installations to help with digging the hole for the concrete pad and erecting the tower. Murray arranged telemetry accounts with Verizon, and Carlisle conducted the programming so that the data would link to the Utah Climate Center TRAPs website. In addition to adding the 4 stations, we also replaced all sensors and the datalogger for an existing station (located in a Santaquin, UT orchard) that was owned previously by a USU faculty member for research, and incorporated that station into the Climate Center database. Each new stations "covers" approximately 200-500 acres, and these additions have increased the area served by FGNet by up to 2,000 specialty crop acres.
Over the 2011 and early 2012 seasons, Carlisle installed high-gain antennas on all weather stations in FGNet, replaced sensors that were ineffective or outdated, and calibrated all the temperature and precipitation sensors. The addition of the new antennas has greatly enhanced communications between the central server at the Utah Climate Center and each station. Before the antenna installation, station communications sometimes went down for days at a time, which have not happened since. Reliable communications is always important, particularly in spring, when tree fruit growers are concerned about frost or need to know when to treat for a certain pest.

Objective 3: Develop a text messaging system through the TRAPs website that provides timely, user-specified alerts.
Two student programmers were hired by Carlisle and the Utah Climate Center in November 2010 to implement changes and additions to the TRAPs website and online weather data access. Murray and Carlisle met with the students approximately once every other week to discuss ongoing changes. From November 2010 – March 2011, the team worked hard complete the text messaging system for frost alerts so it could be used in spring 2011. The grower advisory committee and the project applicants tested the alert system in early March, and the programmers fixed the noted problems/issues. The system went live to users on March 20, 2011.



The frost alert system is available to specialty crop growers only, through an assigned login. The grower logs into the system, and has a profile that can be manipulated. The alert is set up by adding station locations and temperature parameters for which an alert is sent to email and/or phone (see image, right).

Twenty-six grower operations were provided login information, and 18 growers consistently utilized the system in 2011 and 2012. The student programmers were available to quickly fix any problems that arose so that the growers using the system did not lose any communications.

Objective 4: Expand the TRAPs website offerings

Utah TRAPs (Timing Resource and Alert for Pests, http://climate.usurf.usu.edu/traps.php) is a degree day calculator and pest management tool for specialty crop (fruit) growers in Utah, where growers can pick city locations (via search, clicking on a map, or from a drop-down menu), and fruit pest names and date ranges to receive information on pest and treatment status, based on accumulated degree days. Degree days are calculated from daily temperatures, and are used to predict insect emergence and life stages (phenology). Using degree days and insect phenology is an important component of integrated pest management, helping to reduce or fine-tune pesticide applications.

In June 2011, after completion of the text messaging system, Murray met with the fruit advisory committee to discuss suggested changes to the TRAPs website and to get feedback. Murray then met with the student programmers in late June to lay out a master plan of work to cover the following year. Programming work began in early July, and was strictly overseen by Murray via testing and biweekly student performance meetings.

Changes were initially loaded to a beta website for testing purposes from July 2011 – June 2012, when the new changes went live. The fruit advisory committee was asked to perform testing in late fall, late winter, and late spring to be sure that all changes were functional, yet simple enough for the average commercial fruit grower to understand. The following changes were implemented on http://climate.usurf.usu.edu/traps.php:

1. The TRAPs page design was reformatted to improve visual appeal.
2. A new GIS map interface was designed with search capabilities and geographic layers.
3. The 17 stations represented within FGNet, plus an additional 44 “co-op” weather station sites (UDOT, airports, etc.) are now available as red dots on the map, and in a drop-down selection menu.
4. The section of the page where growers input their parameters was redesigned to be easier to use, with step-by-step instructions.
5. Users on the TRAPs website can now select one additional pest to get treatment recommendations, to bring the total to 8 (obliquebanded leafroller-new, codling moth, peach twig borer, western cherry fruit fly, greater peachtree borer, San Jose scale, and fire blight)
6. The website speed was increased through a timely process of establishing a back end pre-calculation of degree days for each weather station and each pest.
7. The degree day results table was redesigned to be easier to read. The user can now scroll through the table to see up to 365 days of information (up from 10 days previously).
8. One of the most anticipated additions to the TRAPs website was to increase forecasting of data from 5 days to 4 weeks into the future, to help growers plan insecticide purchases and labor requirements accordingly. The first 7 days of forecast is based on triangulated data from NOAA that is site-specific (rather than what was being used, which was a forecast from the major Utah cities, which was not applicable to the more remote fruit

orchards). The last 21 days of forecasting is calculated from 30-year averages, generated for each location by Murray, and delivered to the programmers.

9. All data can now be exported to an Excel file.
10. Clicking on the browser's "back" button will keep the initial data loaded rather than refresh the page.
11. One of the most highly used pages is the web page showing up-to-the-minute weather data for a selected website ("Current Conditions"), and now users can access their favorite city location easily from the TRAPs website.
12. Growers are now able to generate a file of raw weather data by choosing fields and dates.

During 2012, and in particular during the growing season, Murray promoted the results of this project in a variety of ways. Extension agents received training at the USU Extension annual conference (March) on the use of TRAPs and the alerts, and how these tools can be incorporated into an IPM program. The information was also disseminated to growers via monthly field meetings, in the Tree Fruit IPM email advisory (3,500 subscribers), through a press release, and to growers at the annual winter meetings in Utah and Box Elder counties.

Goals and Outcomes Achieved

In early fall 2012 a link to an online, anonymous survey was emailed to growers to help measure outcomes for this project (18% response). The survey determined their use of TRAPs, the alert system, changes in pesticide use, economic changes, and fruit yields. The accomplishments and performance measures for this project include the following:

1. From March to May 2012, the TRAPs website was well-used, with an average of 32,000 hits and 9,120 pages views each month. Specialty crop growers who used **the TRAPs website reduced their pesticide use**, or switched from broad spectrum products to selective. One third (31%) learned not to spray during bloom, 45% reduced their use of broad spectrum products (organophosphates and pyrethroids), and 38% switched to softer materials. Almost all (99%) learned from the TRAPs website the importance of correctly timing pesticide applications to reduce inputs.

2. **The frost alert system saved growers thousands of dollars**. The cost of operating one wind machine for frost protection is $45/hour (fuel cost only), and machines may be run up to 100 hours/year. Frost machines cover 12-15 acres each, so the cost for a 50-acre farm could max out at $18,000 for the spring season. Growers who used the FGNet frost alerts and accessed online current weather conditions were able to more accurately time when to turn the machines on and off versus non-users who turned the machines on either too early, too late, or too long.

3. **Users of the TRAPs website and frost alert tool reported reduced costs and greater yields**. Responses from the survey showed that the use of these tools helped them to have healthier plants (68%), more marketable fruit (53%), and higher yields (48%), and almost a third of respondents reported reduced pest management costs.

4. The addition of 4 new weather stations helps operations in an **additional 2,000** acres to monitor weather (frost, precipitation) and pest activity (through TRAPs website).

5. This project allowed for the **training and professional growth of two undergraduate students** in a premier web programming position to help specialty crop growers. The students were trained by senior programmers at the Utah Climate Center, located on the USU campus, and their performance reviewed by Murray. The students learned about agency/commodity partnerships, data acquisition, and online agricultural weather data tools. The student reviews were excellent. One student has a full time programming position with the Utah Climate Center, and the other will be perusing a M.S.

Beneficiaries
The commercial fruit industry in Utah is valued at $18 million, with over 365 operations covering 7,130 acres. All of the specialty crop growers in tree fruits benefit from this project, as they all can have access to the TRAPs website, and can request a login access to the frost alert system. The economic impact of the frost alert system and TRAPs has not been fully evaluated, but is estimated at a savings of approximately $90/acre (in reducing 2 pesticide sprays and optimizing wind machine use).

Lessons Learned

1. Grower support for this project was fantastic, from the work done by the advisory committee to the farm workers who helped dig holes for the weather station installations. Having an advisory committee comprised of the specialty crops that this project benefits is essential.

2. Although university students may be more difficult to manage, sometimes the amount of quality work they can do is staggering, given proper supervision, support, and encouragement.

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2010-13. Organic Seed Treatment

Final Report

PROJECT SUMMARY

Overall. A formulation composed of two natural product bacterial metabolites is a potential organic fungicide against crop pathogens. The research project involved development of production methods and assessing the new fungicide for efficacy as an organic vegetable seed treatment. The project addresses a major need in disease management strategies for organic farming in Utah and the Nation.

The Need. The organic farming industry is now the fastest growing segment of U.S. agriculture (Greene et al. 2009). With accelerated growth, however, come new and larger challenges. Among the most significant of these is disease management, predominantly fungal diseases which compromise output and quality. Fungicide seed treatment is a widely used strategy to reduce fungal diseases (Harman, 1991), and synthetic fungicides are profusely used in conventional farming for this purpose. Negative environmental and health impacts and uncertainties about the future availability of synthetic fungicides are prompting interest in organic farming including alternative organic strategies for seed treatments (Sooby et al., 2007). However, effective organic compatible seed treatment substances are nearly non-existent. This is an especially acute problem in the organic vegetable industry where there are frequent shortages of good quality organically produced seeds. A major thrust of applied research needs of the 2007 National Organic Research Agenda is to: "evaluate biological seed treatments and conditioners for fungus control (Sooby et al., 2007)." In the U.S.A., materials permitted for organic seed treatments include natural substances, naturally occurring microorganisms, plant extracts, and mined materials unless they appear as prohibited on the USDA's National List of Allowed and Prohibited Substances (USDA, 2007). However, effective organic vegetable seed treatment substances are scarce, and candidates from the USDA National List of Allowed and Prohibited Substances have not shown efficacy.

The Project Motivation. In year 2006, P.I. Takemoto and colleagues began testing mixtures of natural products: the cyclic lipodepsipeptide, syringomycin E (SRE) and rhamnolipids for antifungal activities. Rhamnolipids alone did not display inhibitory activities against true fungi or yeast, but SRE and a defined mixture of SRE and rhamnolipids (termed SYRA) showed potent fungicidal activities against all fungi, oomycetes, and yeasts tested. In the SYRA formulation rhamnolipids appear to enhance the fungicidal activities of SRE. SYRA's inhibitory activities against *F.*

***oxysporium*, *B. cinera*, *R. solani* and oomyctes species of *Pythium* and *Phytophora* are of particular interest for considering SYRA as a seed treatment. These organisms are often seed borne and the primary root rot pathogens of vegetable seedlings.** A limitation, however, was the availability of suitable amounts of organic-compatible SRE. SRE was produced conventionally using chemical solvents, and alternative production methods that are organic-compatible were needed. In contrast, large quantities of organic rhamnolipids are produced commercially using fermentative processes.

PROJECT APPROACH

To realize the application of SYRA as an organic seed treatment, the production of SRE using organic-compatible production processes required development. A production method was developed and shown to be scalable to gram quantities. Once development of such production processes was accomplished, organic SYRA was formulated and tested as an efficacious vegetable seed treatment in the laboratory and in the greenhouse. Cucumber seed treatment with the new organic SYRA formulation showed excellent suppression of *P. ultimum* in vitro in the laboratory and the corresponding fungal disease in the greenhouse.

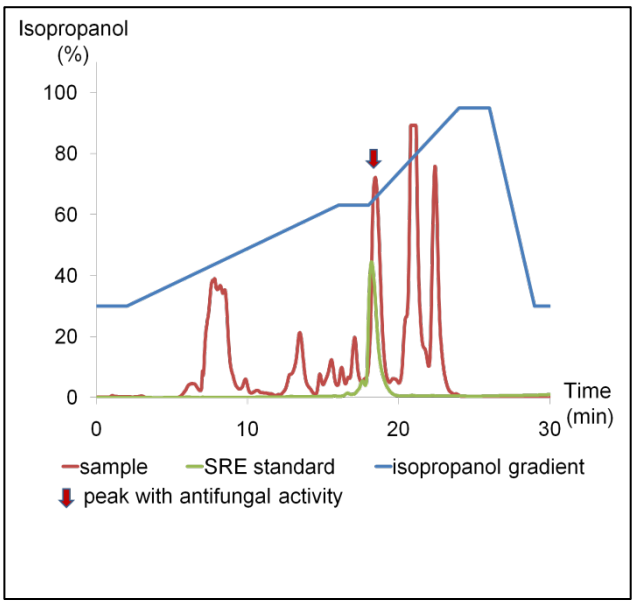
GOALS AND OUTCOMES ACHIEVED

The overall objective of this research was to produce organic-compatible SYRA and to examine its efficacy as an organic vegetable seed treatment substance. The specific objectives of the project were to: 1) develop production and purification procedures that yield organic compatible SRE), 2) test the in vitro fungicidal activities of organic SRE/rhamnolipid (SYRA) formulations, and 3) test organic SYRA as a vegetable seed treatment. As of November 2012, all objectives have been achieved.
The following is a summary of the outcomes achieved:

1) **SRE production and purification (Objective 1).** *Pseudomonas syringae* pv. *syringae* G10 was grown to produce SRE using a chemically defined medium (ISM) containing organic-compatible components. SRE yields of ~ 40 mg L^{-1} of culture were routinely achieved with fermentation in a New Brunswick Bioflo 310 fermenter using a 4L-capacity vessel. Maximum SRE production was judged by high performance liquid

chromatography (HPLC) and antifungal disk diffusion bioassays against the yeast *Rhodotorula pilimanae*. Methods for extracting and purifying SRE relying exclusively on isopropanol and water were developed. Isopropanol is an allowed synthetic substance for use in organic crop production. After culture extraction with isopropanol followed by solvent evaporation, the resulting aqueous extract was subjected to Amberlite XAD-2 column chromatography and HPLC both using isopropanol elution gradients. Purified SRE preparations from multiple chromatographic runs were pooled, antifungal activities quantitated, dried, and designated "organic SRE."

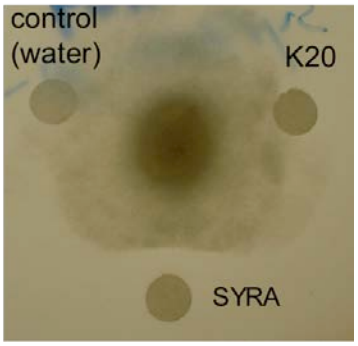
Sample data for Objective 1: Purification of purified organic SRE.



At the final HPLC purification step (left), the peak with Rf value of 18 min (red arrow) and showing activity with bioassay against *R. pilimanae* was collected. After lyophilization, about 50 mg SRE·L^{-1} of growth culture was obtained (below).

2) **Determination of fungicidal activities of organic SYRA (Objective 2)** Organic SYRA was prepared from organic SRE and rhamnolipids I and II (Zonix^{TM}, Jeneil Biosurfactant in a 1:3 (SRE : rhamnolipid, by weight) ratio. In vitro antifungal activities of organic SYRA were observed against several fungi including ***P. ultimum*** which is the most prevalent vegetable seed pathogens.

Sample data of Objective 2: Inhibitory activity of organic SYRA against *P. ultimum*



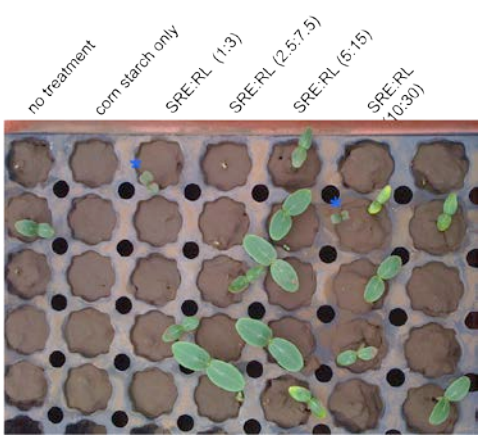
Disk diffusion assay showing fungicidal inhibition of a *P. ultimum* isolate (from cucumber) by SYRA. An agar plug of *P. ultimum* mycelia was deposited in the center of a potato dextrose agar plate and incubated for 1 day. Ten µL aliquots of SYRA (10 mgSRE /mL), water, and compound K20 (10 mg /mL) were each eposited on separate paper disc placed radially and at distance of ~1.5 cm from the plug. Mycelial growth was inhibited by SYRA. Aminoglycoside K20 (10 µL, 10 mg/ml) slightly inhibited mycelial growth. The water (control) showed no growth inhibitory effect.

Microbroth dilution antifungal assays showed that SYRA had fungal minimal inhibitory concentrations (MICs) against *P. ultimum* in liquid medium at SRE levels equivalent to 3.9 µg per mL.

3) Testing organic SYRA as a vegetable seed treatment (Objective 3)

Greenhouse studies were conducted on the suppressive effects of organic SYRA against *P. ultimum* during germination of organic cucumber seeds. **Cucumber seeds containing no fungicide were slurry seed treated with organic SYRA at various concentrations, sown in soil obtained from the USU Kaysville Farm (containing *P. ultimum*) and germination and seedling growth in the greenhouse were monitored**

Sample data of objective 3: Effect of organic SYRA on cucumber seed germination



Effects of pre-treating organic cucumber seeds with SYRA mixed with corn starch I the greenhouse. Seeds were suspended in the mixtures, air-dried, and stored at room temperature. Seeds (1 per well, 5 wells per treatment) were sown in non-sterilized soil collected from the USU Kaysville Farm site where project field trials are planned. Shown are results 12 days after sowing and greenhouse incubation. Blue asteriks (*) indicate weed seedlings. SYRA pretreatments increased germination rates. Untreated seeds were observed to be more susceptible to P. ultimum infection (data not shown.

Two outdoor field studies were conducted at the USU Kaysville Farm during Summer 2011. However, overall germination rates were variable and low (< 10%), and

significant rodent damage and climate related physical damage sustained by the seeds and seedlings were observed. Since standard commercial production of cucumbers and other cucurbits to the seedling stage are currently greenhouse operations, greenhouse studies (instead) were pursued further and also expanded to other vegetables. The cucumber germination trials with organic SYRA with larger numbers of data sets (100 to 200 per study) of test seeds and seedlings than previously used **continue to yield positive results similar to those shown above (Sample data of objective 3). Trials with tomato, eggplant, lettuce, and squash and with other fungi and oomycete species have been initiated and continue to this date. Also, greenhouse tests will be conducted with other fungi and oomycete species. The studies are conducted at the Utah State University greenhouse facilities. Based on our initial results, positive suppressive effects of organic SYRA formulations are expected in the expanded studies.**

4) How the findings are shared with organic growers and the scientific community

A) Co-P.I. Dr. Claudia Nischwitz is the Utah State University Plant Disease Extension Specialist for the State of Utah. In that capacity, she is continually in contact with crop producers within the state including the segment involved in organic farming. Through her crop growers are informed of current research activities at Utah State University including of progress and results of this project. As a result of these out-reach and service efforts, several commercial organic growers in Grand County, Utah, have expressed an interest in conducting field tests with the SYRA formulations and are currently seeking regulatory agency approvals to conduct such tests. It is not known by the P.I. how many organic growers have accessed the research results outside of the Extension activities described above (e.g. information accessed on the Internet, in published patents and meeting abstracts, from attendance at regional USU Extension workshops, etc.).

B) The results of this research have been reported to the public and the scientific community at the following scientific meetings:

- Kawasaki, Y., M. Grilley, and J.Y. Takemoto. 2011. Scalable production of syringomycin E as an organic compatible agrifungicide. 92nd AAAS Pacific Division

Annual Meeting Section: Agriculture and Horticultural Science, June 12-16, 2011, University of San Diego,

- Kawasaki, Y., M. Grilley, and J.Y. Takemoto. 2012. Syringomycin E: a Potential Organic-Compatible Agrifungicide, Oral Presentation, Annual Meeting, American Society for Microbiology Intermountain Division, Pocatello, Idaho, April 7, 2012

There were approximately 500 and 200 attendees at these two meetings, respectively. It is not known by the P.I. how many of the attendees were crop growers. In addition, the results are being prepared for presentation at the 2013 Annual Meeting of the American Phytopathology Society meetings to be held in August 2013 in Denver, CO and typically attended by several thousand plant pathology scientists.

C) A patent application by Utah State University has been submitted. The application is published as Takemoto, Jon Y., Michelle Grilley, Claudia Nischwitz, Yukie Kawasaki (Inventors). Organic Syringomycin Methods and Compositions. Patent CooperationTreaty Application, PCT/US12/41960, Docket No: P11065.02, U.S. Patent and Trademark Office, filed June 11, 2012

D) A manuscript describing this work for submission to a major science research journal is under preparation.

BENEFICIARIES

Organic SYRA has the potential to help overcome deficiencies in supplies and quality of organic vegetable seeds. This will **help the organic farming industry locally and internationally and contribute to the movement towards a more sustainable agriculture. With the current and parallel effort to produce SRE (a component of SYRA) at commercial scale, the prospects for success in producing, commercializing and using SYRA as an organic seed treatment are positive. The present findings also have the potential for expansion to a broader range of applications, i.e. wider in scope than merely SYRA and organic vegetable seeds. The SYRA formulation is not confined to the cyclic lipodepsipeptide SRE. More than a dozen plant bacterial antifungal cyclic lipodepsipeptides are known, and they appear to differ in their**

fungal target spectra. It is conceivable that an array of formulations based on different cyclic lipodepsipeptides**, each having preferential applications in organic disease management, may be developed.**

CONCLUSIONS

1) The antifungal cyclic lipodepsipeptide SRE was purified using organic compatible methods and reagents.

2) Organic SYRA that combines organic SRE and rhamnolipids is an effective organic vegetable seed treatment that suppresses fungal disease

RECOMMENDATIONS

Further research is needed to determine the feasibility of using SYRA in the field.

LESSONS LEARNED

Applications of SYRA in the field outside of greenhouse operations may be difficult.

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References:

Greene, C., C. Dimitri, B.-H. Lin, W. McBride, L. Oberholtzer, and T. Smnith. 2009. Emerging issues in the U.S. organic industry. *In* E. I. Bull. (ed.), vol. 55. Economic Research Service, Wash. DC.

Harman, G. E. 1991. Seed treatments for biological-control of plant disease. Crop Protect. **10:**166-171.

Sooby, J., J. Landeck, and M. Lipson. 2007. 2007 National Organic Research Agenda—Soils, Pests, Livestock, Genetics: Outcomes from the Scientific Congress on Organic Agricultural Research (SCOAR).

2010-14. Backyard/Small Acreage Research and Demonstration Garden

Final Report

PROJECT SUMMARY

Utah has a history of families growing gardens and the last several years Utah State University (USU) Extension has seen an increase in the request for information about gardening, fruit trees and small fruit production, especially from young urban based families. With more than 75 percent of the population living along the Wasatch Front (Utah, Salt Lake, Davis, Weber and Box Elder Counties), the need for a fruit tree and small fruit research and demonstration garden was critical to assist Extension agents in learning the basics of small fruit and fruit tree production and care.

USU Extension Agents designed, implemented and constructed a Backyard/Small Acreage Research & Demonstration Garden for fruit tree and small fruit production. The purpose of the garden is to provide educational opportunities for the public through viewing exhibits, attending classes and hands-on gardening experiences. The gardens will focus on the selection and cultivation of tree fruit and small fruit crops suited for the Wasatch Front.

Fruit trees have been planted to allow USU researchers to evaluate newer varieties of fruit trees by growing them in our Utah climate. This will assist USU Extension agents in recommending varieties to the general public for purchase. USU Extension agents along the Wasatch Front will be able to conduct classes and workshops demonstrating fruit tree pruning techniques, fruit tree grafting, fruit tree on different rootstocks, tree pruning systems and pest and disease control management. In the next 3 to 5 years, the fruit trees will be producing fruit that will allow home owners to taste the fruit prior to purchasing trees from local nurseries. The key is to identify varieties they will like and educate them how to properly take care of them.

One part of the orchard was planted with various types of dwarfing size rootstocks to demonstrate how the rootstock affects the size of the mature tree. The same variety of apple will be grown on dwarf, semi-dwarf and standard size trees to demonstrate to gardeners/orchardists what the size of tree they can expect when purchasing certain rootstock. Some of these trees included the new Geneva series that has shown great promise to being more resistant to fireblight.

The third part of the garden/demonstration site has been planted to displaying new small fruit varieties of grapes, raspberries and blackberries. Small fruit production is one of the most popular classes in the Master Gardener class series. Small fruit is also very popular at farmers markets and Community Supported Agriculture (CSA's) gardens as it can be successfully grown on small acreages by backyard gardeners.

The idea was that whether you are choosing two or three favorite fruit trees for a small urban backyard or have a larger orchard for the family and even farmers-market production, you will find up-to-date useful information on variety selection and care at the Backyard/Small Acreage Research & Demonstration Garden at the USUBC.

PROJECT APPROACH

In 2010, the committee met to decide on the fruit tree varieties for the apples, peaches, and miscellaneous fruit trees to be placed in the orchard. The trees were ordered late winter 2010 and early spring 2011 for spring delivery. Some of the heirloom trees we wanted to plant as part of the heirloom orchard were unavailable from nurseries so we ended up grafting our own trees in the spring of 2011. In grafting our own trees, we ordered scion wood and rootstock for this process. These trees were grafted in April 2011 and potted up during the summer months. Trees that were available from local nurseries and online were purchased.

The area was sprayed with glyphosate on two different occasions in the spring and summer of 2011 to control the weeds prior to working the ground (picture 1 prior to herbicide application). After the area was sprayed, the ground was worked and the irrigation system was installed (see pictures 2 and 3). The orchard floor was seeded to a grass mixture and allowed to become established prior to planting the trees (see pictures 4 and 5) the fall 2011.

The apple, peach and miscellaneous fruit trees were planted on October 14th. There are 22 varieties of heirloom apples and 18 varieties of currently on the market and new varieties of apples in the orchard (see the planting list on page 10 in the Additional Information section of the report). Eighteen varieties of peaches were planted in the orchard along with Asian pear, European pear, apricot, aprium, plumcot, pluot and Japanese European plums in the orchard. Seventy-five trees were planted in the orchard (picture 6).

Trees for demonstrating different pruning methods to homeowners and small orchard growers were planted and the training and pruning of these trees has begun. The apple trees for the rootstock demonstration trial were grafted onto the various rootstock in 2011. Grafts of all of the different rootstock were successful and the trees will be allowed to grow in pots and then placed in the orchard.

In 2012, the area for the grapes, raspberries, blackberries, and strawberries was the focus. Posts were set and wires attached for the training of grapes. A drip irrigation system was installed to irrigate the grapes with and to demonstrate a different irrigation system. A separate irrigation system was installed to irrigate the grass pathway with low angle nozzles to keep water off the grape leaves. This should discourage diseases and keep the grape plants as dry as possible throughout the growing season. Five grape juice varieties, 7 wine varieties and 30 table grape varieties were planted in the demonstration area (see page 11 in the Additional Information section of the report). They represent red, green, blue/black grapes with early, mid and late season ripening varieties. Several of them are new varieties not yet released from the University of Idaho's grape breeding program (see pictures 7-10).

Six summer and 6 fall bearing raspberries varieties in a variety of colors (yellow, purple, black, and red) were planted with an irrigation system involving drip tape an automatic battery operated timer (see pictures 11 & 12). Six different varieties of blackberries were also planted in the demonstration area this year and will demonstrate 3 different trellising methods for blackberries.

We have created 4 online extension publications for selecting and growing apples, strawberries, June and fall bearing raspberries in the home garden/orchard. These publications can be found at the following web address:
http://extension.usu.edu/htm/publications/by=category/category=186
An example of the publications can be found on page 12 in the additional information section of the report. We will continue to work on publications for selecting peach varieties, grapes, blackberries and miscellaneous small fruit for the home orchard as we get collect information from the demonstration orchard and vines in the coming years. The trees and vines are too young and not in production at this time.
The Utah State University Botanical Center with USU Extension offered Fruit Tree and Small Fruit Pruning and grafting classes in the spring of 2011 and 2012. The USU Extension offices along the Wasatch Front have offered also offered 9 sessions of Master Gardener classes in 2011 and 2012 (378 participants) where homeowners were instructed in Fruit Tree and Small Fruit Production for the backyard. In the fall of 2011, USU Extension in Davis County offered an Advanced Master Gardener class in Small Fruit Production to 37 individuals. In 2012, USU Extension had a Commercial Fruit Farm Field Day with 27 individuals attending, weekly farmers market (average attendance 600) from the July until the first part of October. Several tours from the farmers market were given through the demonstration orchard and a USU Extension Regional Staff Meeting with agents from along the Wasatch Front were able to tour the demonstration orchard and ask questions about it.

GOALS AND OUTCOMES ACHIEVED

1. The main goal of this grant was to establish an orchard of various kinds of fruit trees that USU Extension Agents along the Wasatch Front could become familiar with to assist the general public in selecting appropriate fruit tree varieties for their growing area. We planted an orchard with over 75 apple, peach, apricot, Asian pear, European pear, aprium, plumcot, pluot and Japanese and European plums trees that are irrigated with a micro irrigation system.
2. We planted a rootstock demonstration area to assist homeowners in selecting the correct size of tree for their orchard. This area will also help USU Extension Agents from around the state that are not familiar with fruit tree rootstocks to become associated with them.
3. We established an apple rootstock demonstration planting with some of the new Geneva apple rootstocks developed for resistance to fireblight.
4. Homeowners and small acreage owners can view small fruit production practices geared towards proper variety selection, plant row spacing and production techniques, different irrigation systems, mulchs and insect and disease control.
5. USU Extension Agents have a location that can be used as an outdoor classroom for teaching proper planting, pruning, and irrigation techniques on fruit trees and small fruits to residents along the Wasatch Front.
6. Online extension publications have been written and will continue to be written or updated on fruit tree variety selection, fruit tree pruning, dwarf rootstocks and small fruit production as a result of our work at the gardens.

BENEFICIARIES

The following groups benefitted by the completion of this project:

1. Utah State University Extension Agents along the Wasatch Front and the state of Utah.
2. Master Gardeners involved in the Master Gardener program.
3. Homeowners who enjoy tree fruit and small fruit production.
4. Commercial fruit growers who would like to grow some of the new fruit varieties that are coming onto the market and see them before the buy and plant them.
5. Small farms and CSA marketers who are looking at providing a niche fruit for a market.

LESSONS LEARNED

This type of project can be very rewarding watching it come from the planning phase, to spraying out the weeds, working the soil, installing different irrigation systems, installing trellis systems to planting the fruits trees and plants. All along the way, people have been excited to hear and see what we were doing with this weedy spot.

We probably should have written the grant for more money, acquired more land and expanded the project. It would have been great to have more varieties of trees, vines and plants to put into this garden. As it was, there was a large time commitment to get it to this stage but it was worth it. We are excited to see what the area looks like in 3 to 5 years when everything is in production.

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2010-15. Wasatch Community Gardens' Youth Gardening Program

Final Report

Project Summary

Low-income youth in Utah lack opportunities to discover and consume fresh, healthy fruits and vegetables. Most children eat far less than the daily recommended servings of fruit and vegetables, and childhood obesity is on the rise. Childhood obesity has been linked to other diseases, such as Type II diabetes, and has been linked to negative outcomes for children such as poor school performance, bad behavior, and health complications. These problems affect not only individual youth but also the entire community.

Wasatch Community Gardens addresses these issues through our Youth Gardening Program. Specialty Crop Block Grant (SCBGP) funding has supported this program previously. Funding in 2011 allowed us to continue the program, revise existing curriculum, create new curriculum, refine the program's goals and objectives, and improve our evaluation process. We were also able to complete a second year of a State standards-based school gardening curriculum, to be distributed for free to schools throughout Utah. With the additional funding we were awarded, we were able to publish and distribute high quality outreach materials, and reach a broader audience with the message of introducing youth to fresh fruits and vegetables.

By continuing our Youth Gardening Program year after year, we are able to develop ongoing relationships with partner agencies, work with the same groups and even some of the same kids for consecutive years, and continue to work with new youth each year.

Project Approach

Through our Youth Program, we served 1,353 youth in our gardens this year. Our goal was to give these youth access to healthy, local food; unique outdoor experiences; and organic gardening skills. SCBGP funding specifically supported the City Roots classes that are at the core of the Youth Gardening Program. This program is supported by long-term partnerships with over 25 agencies that serve low-income youth. Our partnerships with social service agencies and schools capitalize on our respective strengths as agencies, ultimately building capacity for each organization. Our partner agencies interact directly with families, recruit youth participants, and provide the necessary infrastructure, such as transportation to and from the garden. Wasatch Community Gardens complements this by maintaining dynamic and productive youth gardens as outdoor classrooms, and developing and running a unique garden-based education program that our partner agencies do not have the expertise or capacity to run.

City Roots classes are designed around a series of stated goals and objectives. First, we strive to provide opportunities to access to healthy, local food for the youth participants. Through our garden-based lessons, participants are empowered with the crucial life skills of preparing and eating healthy, nutritious food. Youth participants will ascertain the connection between healthy eating, the environment, and the food system. Participants will understand where food comes from and discover the benefits of eating nutritious foods.

City Roots classes also offer unique outdoor experiences to youth participants. Participants spend time outside in an urban, organic, community garden, fostering a connection to the natural world. Youth participants practice essential life skills of respect, teamwork, communication, leadership, creativity, and self-reflection.

Finally, City Roots classes teach basic organic gardening skills that can carry throughout a child's lifetime. By digging and planting in the soil, participants learn critical food growing skills, utilizing organic methods. Youth participants learn to identify parts of plants, as well as understand life cycles of plants, animals, and other natural cycles in a garden ecosystem. And through tasting the delicious fruits of their labor, participants experience the joys and challenges of growing fresh food in a four-season climate.
In 2011, our participants had ample of access to fresh food. 100% of our participants had opportunities to prepare fresh food during lessons and take home food they helped grow. Wasatch Community Gardens partnered with Utahns Against Hunger (UAH) to increase the amount of nutrition classes through which youth made connections between food and their health. After one lesson, 93%

of students asked were able to list at least one way whole grains benefit their bodies. In order to ensure that SCBGP funds were used to solely enhance the competitiveness of eligible specialty crops, an AmeriCorps member with UAH taught this lesson, not WCG staff. WCG's curriculum focuses on growing and eating fresh fruits and vegetables. Similarly, 90% of students could list at least of the important nutrients found in potatoes. Students tried foods they had never tried before or thought they did not like. One agency leader told us the youth would not touch sandwiches at a tea party the week before because they had radishes on them. As she was saying this, all the youth were eating mashed potatoes with radishes they had just harvested from the garden. One youth explained, "The ones at the garden taste different!"

During City Roots classes, our participants spent time fostering a connection to the natural world and practicing essential life skills like creativity, communication, and teamwork. The youth participated in several art projects, taking photographs of their favorite places in the garden and making seed packets. They had opportunities to experience being a part of a community of their peers, from working together to chop vegetables for a salad to helping one another push a wheelbarrow. They also had opportunities to hold, care for, and interact with the chickens living in our new Grateful Tomato Coop. Students learned about the lifecycles and benefits of garden bugs like red wiggler worms, ladybugs, and butterflies that are important to growing organic produce. After learning about monarch butterflies, 92% of participants asked could list their lifecycle stages. Youth had the chance to hold ladybugs and release them into the garden. Many of the youth who came to the garden were very afraid of bees. After learning all about honeybees, students became calmer around them and talked excitedly about how good they are for our gardens. One boy said, "I am not afraid of bees anymore! They're actually cool!"

Lastly, our youth had opportunities to grow some of their own food, while learning about organic gardening practices. During classes, they planted seeds, composted, and harvested fresh produce. A majority of participants demonstrated increased organic gardening knowledge and skills. For example, 85% of youth participants asked could list three cool season crops and three warm season crops, while 100% of youth asked could list what seeds need to sprout. Learning to grow their own food fostered in participants a genuine excitement about fresh fruits and vegetables. When some pea plants that the youth planted came up, the youth all remembered exactly where their peas were planted and were so excited to see them. Similarly, some youth dug up seed potatoes they had planted during class the week before because they were so anxious to see if anything had grown. They checked them every week after that.

Objectives and Outcomes Achieved

Objective: Ability to recognize and eat nutritious and healthy food. To measure this, we have set a target that 90% of participants identify and taste three new fruits or vegetables. Tasting and preparing produce is an integral component of the City Roots classes. In each lesson, participants explore the sensory attributes of a wide variety of edible plants, including fruits, vegetables, herbs, and flowers. Because participants are actively involved in growing and harvesting these plants, they feel ownership and excitement about the results of their efforts, and are both excited and willing to sample many unfamiliar foods. Being exposed to fruits and vegetables is the first, and sometimes the hardest, step in getting youth to make long-lasting, healthy nutritional choices. *2011 outcome: 100% of participants identified and tasted three new fruits or vegetables.*

Objective: Knowledge and ability to grow and eat seasonal fruits and vegetables. We have set a target that 90% of participants will gain a new gardening skill. Youth will engage in a series of

hands-on lessons based around the garden life cycle, from planting, watering, weeding, and harvesting, to composting and keeping harmful pests out of the garden. This outcome will empower the students with knowledge to grow their own organic fruits and vegetables as a low-cost means of eating healthy food. Additionally, the hands-on lessons will encourage a connection between students and the soil in which they plant, weed, and harvest. *2010 outcome: 100% of participants gained a new gardening skill.*

Objective: Achieving a more global understanding about where food comes from and how it reaches their tables. We strive for 100% of participants to take home a new fruit or vegetable to share with their families, to expand the reach of these new healthy behaviors into the home setting. Connecting a youth's experience in the garden to life outside the garden is an important component of the City Roots classes, encouraging healthy behaviors throughout a child's daily life. *2010 outcome: 95% of participants took home a new fruit or vegetable to share with their families.*

While these quantitative results help us measure the success of our Youth Gardening Program, quotes from the children who participate in City Roots classes also underscore that our garden-based education helps develop a generation of happy fruit and vegetable eaters. Here are some of the things we overheard in the gardens this year:

"This salsa is so good I can't believe we made it ourselves!"

"The best part of eating this food is that we made it ourselves and it comes from the garden so it is fresh."

"Gardening is my favorite class. We get to eat something every time we come!"

"I love digging around in the dirt! This is really fun!"

"When I grow up I want to do compost or be a carrot gardener. I will live in the greenhouse!"

"This is the best salad I have ever had!"

"I don't like it [the salad], I LOVE it!"
"This Bok Choy is so good! I am so glad that we get to go harvest in the hoop house!"

"This lettuce tastes like Cheetos!"

"Yum! Why are these carrots soooo much better than the ones from the store?"

Beneficiaries

Wasatch Community Gardens Youth Gardening Program served 1,353 primarily low-income youth, ages 3-18, in 2011. For the 525 participants in our City Roots weekly after-school garden-based classes for whom demographics were tracked, 70% came to us from households with "extremely low" incomes as defined by Federal guidelines and 12% were from households with "very low" incomes. Approximately 44 % of these participants were Hispanic or Latino.

Of the remaining 828 youth participants, 449 were youth who came to us through the juvenile justice system, agencies that serve disabled teens, and residential treatment centers for at-risk youth. These

agencies do not disclose demographic data about their clients. The other youth participated in gardening classes through field trips, service learning groups, our Junior Farmers program, and our new summer camps, City Sprouts. City Sprouts summer camps served 77 participants in its first year, 43% of whom received full scholarships.

Lessons Learned

While we are always learning and refining our Youth Gardening Program, two lessons in particular stood out this year.

The first lesson was that we could best utilize our resources by building on our strengths without overstretching our capacity. Two years ago we underwent a strategic planning process to determine the short-term direction Wasatch Community Gardens would take. As part of that process, which was based on a community needs assessment, we identified the need for a more formalized field trip program as part of the Youth Gardening Program, which we are currently developing. A field trip program gives our youth program staff a structured way to engage school groups in our youth gardens. These field trips introduce teachers and students to the excitement of garden-based learning. If a teacher is then interested in continuing this type of teaching and learning in a school garden on their campus, we are then able to provide the curriculum and training to make that school garden a success. Because we are limited in the number of children we can serve through City Roots after-school and summer classes, expanding our model of garden-based learning to schools throughout Utah helps us achieve our goals for the Youth Gardening Program in a more sustainable way.

The second lesson was a consistent theme of our programming that was really emphasized to our youth program staff this year. They were reminded time and again that cooking is truly the best way to make kids excited about eating fresh fruits and vegetables. While we have always incorporated cooking and tasting in our curriculum, this year we had the children prepare and eat more fresh food than ever before. From winter salads grown in the hoop house, to summer salsa, to a fall veggie dip based on kale and chard, the youth participants had the chance to cook and eat a huge variety of fresh fruits and vegetables. And more often than not they truly enjoyed their creations! While at this time most of our cooking is done using camp stoves or solar ovens, someday we would love to have a fully equipped teaching kitchen for the youth to learn in.

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Additional Information:
Please visit http://wasatchgardens.org/youth-programs for more details and photographs of children in our programs.

2010-16. Color, Anthocyanin Content, Antioxidant Activity and Seed Antioxidant Activity in Six Varieties of Utah Red Raspberries

Final Report

PROJECT SUMMARY PROJECT SUMMARY

Little research has been done on nutritional aspects of raspberries grown in Utah because there have been so few successful raspberry plots established in the hot dry climate found here. Developments in raspberry varieties, growing methods and fertigation have made raspberry growing in Utah more successful and a potential option for small farmers. The results of a research project funded by the USDA in 2009 indicated that Utah raspberries were significantly higher in overall antioxidant activity than comparable raspberries found in grocery stores. This motivated us to look deeper into the antioxidants activity found in Utah red raspberries.

The purpose of this project was to evaluate the differences in color, antioxidant content and seed antioxidant activity of six different varieties of red raspberries grown in Utah and compare the information we collected to existing data. Cornaby's established an experimental plot of raspberries in Salem, Utah with six varieties of raspberries grown in the same environment. This plot was set for replanting in Spring 2011, so it was vital that this project be completed at this time to maintain as much environmental control as possible. The project is timely, since antioxidant research is at the forefront of nutrition science and exploration of the different types of antioxidants found in foods are contributing to the food choices people make every day.

PROJECT APPROACH

Cornaby's Farm developed an experimental plot of six varieties of primocane raspberries with raised beds, underground fertigation, and a trellis system in 2007. Berry varieties included "Autumn Bliss", "Caroline", "Jaclyn", "Joan J", "Polana" and "Polka". Janet Stocks collected one pint of each variety from three different pickings during the 2010 season for analysis. Two additional varieties of California berries were purchased from the grocery store and analyzed as control data. This provided a random selection of each of eight varieties of berries and three sampling dates.

Analysis was conducted within 24 hours of picking the berries and included the measurement of total antioxidants (ORAC) and anthocyanin content (TAC), and three aspects of color for the different fractions of the six Utah raspberries and two commercial brands (see Table 1). Color testing was not performed on the seeds because it was not applicable to our research.

Dr. Troy Parker and his student, Shannon Synder, prepared the samples and performed measurements. Statistical analysis was completed by Dr. Dennis L. Eggett, including comparison of data with the results of the study that was funded by the Specialty Crops Grant in 2009.

A cursory glance of the data illustrates the drastic difference between the ORAC of the juice (18.4 ± 0.39 µmol TE/g), the pulp (24.45 ± 0.43), and the seeds (273.27 ± 11.15) when all Utah cultivars are combined, but there is very little anthocyanin content in the seed. The ORAC in the seed is likely from phenolic compounds that offer their own important contribution. Further research is indicated to determine the plausibility of isolating raspberry seeds from the waste stream of juice production and introducing the ground seeds into nutraceutical products for nutritional and monetary gain.

Table 1
Average ORAC, TAC, and color aspects of the juice, pulp and seeds of six varieties of Utah raspberries Across three pickings and two commercial varieties

JUICE					
Cultivar	ORAC µmol TE/g	TAC mg cyn-3-glu eq. /100 g	color		
			L*	chroma	Hue angle
Autumn	19.46323	20.50796	4.315556	12.37333	2.491111
Caroline	18.87486	23.11068	2.525	7.968333	2.576667
Jaclyn	20.4749	17.66915	3.158333	9.33	1.41
JoanJ	20.64434	23.53391	3.526667	9.893333	2
Polana	18.09383	20.19413	2.607778	7.74	1.354444
Polka	24.45105	20.14231	4.678333	14.06667	2.91
Commercial #1 Champ	15.03214	n/a	3.243333	9.816667	1.846667
Commercial #2 Naturipe	12.26557	n/a	4.006667	8.803333	1.12

PULP					
Cultivar	ORAC µmol TE/g	TAC mg cyn-3-glu eq. /100 g	color		
			L*	chroma	Hue angle
Autumn	25.53115	14.15135	15.38667	28.01333	11.74667
Caroline	26.17905	16.1888	19.08	35.77167	12.56167
Jaclyn	23.96364	11.68634	20.05167	32.45167	11.60167
JoanJ	26.9455	13.61559	16.71333	31.58667	14.27333
Polana	21.89383	14.67391	16.97	28.91333	13.56667
Polka	29.75203	13.45196	16.23	31.3	13.28333
Commercial #1 Champ	23.49666	n/a	19.66333	29.65	12.56
Commercial #2 Naturipe	18.09748	n/a	16.5	27.59333	11.12

SEEDS					
Cultivar	ORAC µmol TE/g	TAC mg cyn-3-glu eq. /100 g	color		
			L*	chroma	Hue angle
Autumn	293.8767	n/d			
Caroline	225.2256	n/d			
Jaclyn	236.9077	n/d			
JoanJ	303.9704	n/d			
Polana	2845.217	n/d			
Polka	298.0612	n/d			
Commercial #1 Champ	360.95573	n/d			
Commercial #2 Naturipe	342.99818	n/d			

ORAC: Oxygen Radical Absorbance Capacity, reported in µmol TE/g; TAC: Total anthocyanin content, reported in mg cyn-3-glu eq. /100 g.

Statistical interpretation of the data also showed that there is a significantly higher concentration of anthocyanins in Utah raspberry juice (20.86 ± 0.35 mg cyanidin-3-glucoside eq./100 g), compared to pulp (13.96 ± 0.35). This relationship raises the possibility of using red raspberry juice from Utah berries in commercial products to increase nutrition in beverages or other products. The anthocyanin content of juice and pulp were also significantly positively correlated with dark color (L*). In other words, the deeper red the raspberry color is, the higher it is in Total Anthocyanin Content and total antioxidant activity. This is significant for raspberry growers and consumers, since it marks the deeper colored Utah berries as an excellent food choice.

Other interesting correlations include the following:

1. There were significant antioxidant differences between the six varieties of raspberries within the juice and pulp, and these differences were similar to overall berry antioxidant capacity differences found in the 2009 study. Raspberry seeds do not contain anthocyanidins, so an evaluation of the juice and pulp was helpful in confirming the results of the earlier study.
2. Utah raspberry juice and pulp combined had a significantly higher antioxidant capacity than berry juice and pulp extracted from commercial berries.
3. ORAC and TAC both increased throughout the picking season (see Table 2). This could be the result of several factors, but the most likely is that more of the riper berries would be available for extraction into the sample. The different cultivars begin bearing at slightly different times. For example, the Polka cultivar begins bearing 3-4 weeks before the Caroline cultivar. By the middle of the season, all of the cultivars that were examined were at peak production.

Table 2
Selected ORAC, and TAC data by cultivar, picking and fraction.

Cultivar	Picking	Fraction	ORAC		TAC	
			Value	SE	Value	SE
All	1	juice and pulp	20.42	0.43	13.46	0.49
All	2	juice and pulp	23.68	0.57	17.57	0.49
All	3	juice and pulp	24.11	0.55	21.2	0.49
All	1	juice	18.48	0.55	17.19	0.7
All	2	juice	20.27	0.81	20.34	0.7
All	3	juice	21.2	0.75	25.05	0.7
All	1	pulp	22.37	0.66	9.72	0.7
All	2	pulp	27.08	0.81	14.81	0.7
All	3	pulp	27.03	0.81	17.36	0.7
All	1	seed	264	5.1	nd[b]	
All	2	seed	284.8	6.1	nd	
All	3	seed	273.6	6.1	nd	

ORAC: Oxygen Radical Absorbance Capacity, reported in µmol TE/g; TAC: Total anthocyanin content, reported in mg cyn-3-glu eq. /100 g.

GOALS AND OUTCOMES ACHIEVED

Our goal for this project was to confirm the nutritional superiority of Utah raspberries over all others. This goal was not achieved, but we took great steps toward verifying the nutritional strengths of raspberries in general, and Utah raspberries in particular. This information can be used to encourage farmers who may be interested in growing raspberries, as well as consumers who are looking for wise food choices.

Our second goal was to verify a direct correlation between color and antioxidant content. The most common brand of raspberries found in grocery stores are barely red, but the berries are beautifully formed, uniform in size and keep well. This type of berry is changing the consumers' definition of what a raspberry is supposed to look and taste like. Unfortunately, this kind of berry is the least sweet and has the lowest antioxidant capacity. The data obtained from this study provides ammunition for Utah farmers who are competing with produce that is shipped in and nutritionists who are guiding people toward healthy food choices.

Another goal was to break down the constituent parts of the raspberries and identify the source of the different antioxidants. I had always assumed that the juice would have the lowest antioxidant capacity, since it is primarily water, but I was surprised to see the strength that comes from the juice. I was also amazed at the intensity of antioxidants contained in the seeds. This data could drive the production of many food products made with Utah raspberries to increase nutrition.

Our final goal was to present the results of this project to participants at the International Food Technology Conference and prepare a paper for publication in an agricultural or nutrition journal. The presentation was completed on schedule and involved over 50 people. A summary of the results was also presented to a class on growing raspberries in the home garden at the Conservation Gardens in Orem. This was received by about 125 people. Our paper was accepted for online publication in *Plant Foods for Human Nutrition* in the November 7, 2012 edition.

BENEFICIARIES

This project will benefit scholars seeking to find ways to identify and increase specific oxidants, farmers looking for additional markets for their fruit, educated consumers who are looking for healthier food choices, and can also be applied to the supplement industry. This information, as well as the findings for the 2009 Specialty Crops grant we received have been shared with members of the Berry Growers' Association, Utah State Master Gardeners, Utah State Master Preservers, and participants in a raspberry class taught at the Conservation Garden in Orem, Utah. Updates will be shared with participants in an additional raspberry class at the Conservation Gardens in March. In all, over 500 people have benefited from the information gained during this research project.

LESSONS LEARNED

One of the biggest challenges we have found in all of the antioxidant research we have conducted is that there is no standard method established for extracting juice, pulp and seeds. The method we ultimately used resulted in conflicting data when we compared total antioxidant activity (ORAC) of the whole fruit with the sum of the antioxidants derived from the juice, pulp and seeds. This led us to conclude that significant antioxidant activity is found in the druplet walls themselves, a fraction that we could not capture with the method we used for extracting the seeds.

Another slight bump in the operation occurred when Dr. Parker accepted employment at another institution. He completed data collection and analysis and submitted the article for publication, but has had limited time to dedicate to completing the article for print publication or assisting with this report.

Although we had a few challenges to work with, we were able to obtain solid data and identify strong correlations that can be used to further research in this area. If appropriate academic support can be obtained, we would like to investigate better ways to extract the seeds and druplet walls from the waste stream and identify ways to dry, grind, and reintroduce it into fruit products to increase antioxidant activity and positively impact nutrition.

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Juice, Pulp and Seeds Fractionated from Dry Climate Primocane Raspberry Cultivars (Rubus idaeus) Have Significantly Different Antioxidant Capacity, Anthocyanin Content and Color

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Abstract Raspberries contain flavonoid antioxidants whose relative concentrations may vary between the juice, pulp, and seed fractions. Oxygen radical absorbance capacity (ORAC), total anthocyanin content, and berry color were determined for six cultivars of primocane raspberries grown in a dry climate (Utah, USA). Significant ORAC differences were found between juice (18.4±0.39 μmol TE/g), pulp (24.45±0.43), and seeds (273.27±11.15) with all Utah cultivars combined. A significantly higher concentration of anthocyanins was present in Utah raspberry juice (20.86±0.35 mg cyanidin-3-glucoside eq./100 g), compared to pulp (13.96±0.35). Anthocyanin content of juice and pulp were significantly positively correlated with dark color (L*). This is the first report of fractional differences in dry climate raspberries, and has implications for the juice and supplement industries.

Keywords Raspberry · Antioxidants · Anthocyanin · Color · ORAC

Abbreviations

AWA	70:29.5:0.5 acetone:water:acetic acid
ORAC	Oxygen radical absorbance capacity
TAC	Total anthocyanin content
SE	Standard error
nd	Not detected
cyn-3-glu eq.	Cyanidin-3-glucoside equivalents
TE	Trolox equivalents

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Introduction

Fruit and vegetable consumption has been associated with decreased mortality and lower incidence of cancer [1, 2] and cardiovascular disease [3]. The naturally occurring antioxidants found in fruits are primarily phenolic compounds, and are thought to decrease disease risk in part by preventing free radical damage [4]. Other mechanisms are also beginning to become better understood, including at the transcription factor, gene, and enzyme level, with direct effects on inflammatory processes [5, 6]. Berries in particular may also support healthy quality of life and healthy aging [7, 8].

Raspberries contain both high amounts of phenolic antioxidant compounds and a high antioxidant capacity [9]. Although many compounds found in raspberries could be responsible for their high antioxidant capacity [10], phenolic compounds, especially anthocyanins, are likely the major contributors [11].

Most recent raspberry studies [12–17] have limited application to dry climate irrigated raspberry farming due to cultivar and environmental differences. Previous work in our laboratory [18] has found that dry climate (Utah, USA) raspberries have a higher antioxidant capacity than the USDA average [19], and that the antioxidant capacity varies across the picking season. However, the distribution of antioxidant capacity of raspberries among the primary fractions of the raspberry (juice, pulp and seed), and how the picking time affects the antioxidant capacity of specific fractions has not been explored. As food products may contain only a portion of the whole berry (for example, seeds are often discarded, or

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in an OXO Good Grips food mill (Chambersburg, VA, USA only the juice is collected), it is important to understand the role each component plays in the total antioxidant capacity of a raspberry.

Moore [20] found that anthocyanin content and raspberry color correlate (L*, a* and b* were all significant); however, it is not known to what extent this applies to specific fractions of the raspberry. Because consumer perception of food quality is in large part based on color [21], further research of color and anthocyanins in raspberry fractions will better help producers understand the relationship be- tween anthocyanin content, color and cultivar.

Since raspberry seed walls are not appreciably penetrated during processing or consumption, the antioxidant proper- ties of raspberry seeds are not usually included in studies of raspberry fruit. However, raspberry and other seed oils are becoming an important ingredient in supplements. The ben- efit of the antioxidants which seeds contain remains poorly understood both in the context of the whole fruit and as a separately valuable commodity source of antioxidants. One study [22] conducted on a variety of berry seed oils showed that red raspberry seeds had high antioxidant potential; however, these measurements were not compared to other fractions of the berry and only the lipid soluble fraction was evaluated. Raspberry juice is available as a commodity, though during its production, the pulp portion is discarded. By exploring all three fractions in many different cultivars of raspberry, the relative antioxidant and anthocyanin value of each fraction can be determined. This informa- tion would be of particular value to juice and supplement manufacturers.

The objective of this study was to compare six cultivars of raspberries grown in a dry climate. It was hypothesized that there would be differences between individual cultivars, and that seeds would have the highest antioxidant capacity of the three fractions.

Materials and Methods

Materials AAPH (2,2′-azobis(2-amidino-propane)dihydro- chloride) was purchased from Wako Chemical (Richmond, VA). Common buffer ingredients, fluorescein, perchloric acid, Trolox, 12 M HCl and methanol were purchased from Fisher Scientific (Fair Lawn, NJ, USA).

Raspberry Collection Six cultivars of Rubus idaeus L. rasp- berries (‘Autumn Bliss’, ‘Caroline’, ‘Jaclyn’, ‘Joan J’, ‘Polana’ and ‘Polka’) grown on a test plot as part of a 20 acre farm in Salem, Utah, USA, were collected, on August 18, September 21, and September 29, 2010. Agricultural methods used on this farm were consistent between cultivars and included raised beds, underground fertigation, and a trellis system. Only ripe red raspberries easily removed from the stem were collected; no other post-harvest treatments were performed. Sufficient berries were collected from each cultivar to perform all analyses.

Sample Preparation Each cultivar (200 g) of fresh raspber- ries was macerated) using the fine disc (~1.5 mm pore size), and seedless puree was collected below the food mill in a pitcher. After maceration, the food mill and remain- ing macerated berries were weighed, taring to the food mill. Five samples of the puree were collected into 1.5 ml tubes and juice was separated from pulp by centrifugation (10,000× g for 30 s). Juice was transferred to a new set of 1.5 ml tubes. Juice and pulp were weighed, taring to the tubes, and averaged. Seeds and remaining macerated rasp- berry in the food mill were then separated by blending and rinsing (Waring commercial laboratory blender, Waring Products Inc., Torrington, CT). The blender was filled about 3/4 full with distilled water three times, accompanied by 30 s of blending on low speed, and water fractions contain- ing pulp without seed were discarded. At the conclusion of this procedure only pulp-free seeds remained at the bottom of the blender. Seeds were weighed wet after wicking off moisture with a paper towel, then dried in an Excalibur food dehydrator (Sacramento, CA, USA) for 1 h at 41 °C, re- weighed, and pulverized in a coffee grinder (Model E160B, Hamilton Beach/Proctor-Silex, Inc., Southern Pines, NC) for 2 min or until all seed walls were penetrated (visual inspection). Pulverized seeds were divided into aliquots and deposited in 1.5 ml tubes. All samples of juice, pulp, and seed were stored at −80 °C immediately after processing and analyzed within 30 days.

Colorimetry The color of the fractions from each of the six cultivars was measured immediately after collection using a Hunterlab Colorflex spectrophotometer (Hunter Associates Laboratory, Inc., Reston, VA, USA). Separated juice and pulp L*a*b* values were measured by adding 200 µl of juice (or an equivalent amount of pulp to match the surface area covered by the juice) to the bottom of a 3 oz. glass. L*a*b* values were then converted to L*C*h using Chroma

$$C = (a^2 + b^2)^{1/2} \quad \text{and hue angle} \quad h = \arctan(b/a)$$

Oxygen Radical Absorbance Capacity (ORAC) The ORAC assay was performed following the procedures of Freeman et al. [23] with some minor modifications. The plate layout was modified so that outside wells were not used, and the standard curve and samples were organized by column rather than by row. Samples and standards were loaded into wells of Corning Costar 96-well black side clear bottom plates (Fisher Scien- tific) via a Precision Micropipettor (BioTek Instruments, Inc., Winooski, VT, USA) followed by reading every minute for

120 min in a BioTek Synergy 2 fluorescence plate reader (BioTek Instruments, Inc.). ORAC values were expressed as Trolox equivalents per gram (TE/g) of raspberry.

Total Anthocyanin Content (TAC) TAC was determined by the combined and modified methods of Pirie and Mullins [24] and Mejia-Meza et al. [25] on a BioTek Synergy 2 plate reader using 96-well black side with clear bottom plates (Corning Inc., Corning, NY). HCl in aqueous metha- nol (50 % CH_3OH, 0.05 % 12 M HCl, 49.95 % dH_2O) was used as the extraction solvent. The extracts of juice, pulp and seed were measured at an absorbance of 530 nm in duplicate. Measured anthocyanin values were converted to mg cyanidin-3-glucoside equivalents per 100 g fresh weight using a molecular weight of 449.2 and a molar extinc- tion coefficient of 26900/M/cm [11] and a pathlength of 0.29 cm.

Statistics All samples were evaluated in duplicate or triplicate. Significant differences were determined using an analysis of variance and $p<0.05$ to determine significance (SAS statistical software, v 9.2, SAS Institute, Inc., Cary, NC). Post-hoc Tukey adjusted comparisons were used to determine significant pair-wise differences in a factorial design.

Results and Discussion

Colorimetry Anthocyanin content had significant negative correlation with the L* color value (a lower value indicates greater darkness) for both separated juice (p00.04) and separated pulp (p00.006), and a positive correlation with the hue angle for juice (p00.0002). L* was significantly positively correlated with chroma in the juice ($p<0.0001$) and chroma was negatively correlated with hue angle in the pulp (p00.03).

When analyzing the color of the various raspberry cultivars, pickings and fractions, there were few significant differences. Utah raspberries were significantly darker in the later season pickings. Some significant color differences were found in the juice fraction when combining all pickings (Table 1). The Polka cultivar had the highest chroma, and Caroline the highest hue angle.

ORAC While several antioxidant assays could have been selected, or more than one, and there are pros and cons to each [26], ORAC was selected for history of use, a refined protocol in our laboratory, and for its relevance to physiology [27]. While we could have selected more than one assay, all are equally limiting to physiological relevance. The goal of the use of an antioxidant assay in this study was to get a global measure of antioxidant capacity and to compare it to the other measures selected.

When all cultivars were combined, raspberry ORAC values significantly increased as the season progressed when juice and pulp data were combined (Table 1). A similar pattern was apparent when separating the cultivars by juice, pulp and seed (Table 1). The pulp had a significantly higher ORAC than the juice, though both had an upward pattern, suggesting that the differences in ORAC were not due to one fraction, but to changes in both juice and pulp.

Seed ORAC was significantly higher than juice and pulp, but seed antioxidant content did not change as the season progressed (Table 1). The seeds may be less affected by temperature or other environmental variables which change as the season progresses. The significantly higher seed ORAC values compared to pulp or juice correspond with data collected for other fruit seeds [28].

When separating Utah raspberry data by cultivar and fraction, no significant ORAC differences in the juice or pulp fractions between cultivars arose (data not shown). The Polka cultivar had the highest (nonsignificant) ORAC in the juice and Joan J in the pulp fraction. There were, however, significant differences between cultivars in the seed fractions (Table 1). Autumn Bliss, Joan J and Polka had significantly higher ORAC values than Caroline and Jaclyn cultivars. No correlation was found between juice or pulp and seed ORAC values.

Finally, data were analyzed by fraction, picking, and cultivar (data not shown). The Polka cultivar had a surprising increase in ORAC from the first picking to the third compared to the other cultivars. The Polka cultivar juice ORAC value was significantly lower than the other cultivars in the first picking, then juice and pulp were significantly higher than the others in the second and third pickings. Genetic variation may explain these differing responses to environmental signals. This hypothesis is in agreement with other work [29] that found significant differences between cultivars of raspberries, which the researchers attributed to phytonutrient:color ratio variations.

Combined ORAC Values Compared to the Whole Fruit ORAC values for juice and pulp were combined post hoc to represent the whole fruit and then values were compared to the data of Freeman et al. [18], which was collected from the same cultivars used in this study (Table 2). Because the method of Freeman et al. involved blending, which would have resulted in minimal disintegration of seed walls, seed values were not considered in this comparison. The resulting values found in this study were significantly and unexpectedly lower than whole raspberry ORAC values from the study of Freeman et al. The difference between these two studies indicates that more than half of the ORAC value of a raspberry is found in the drupelet walls (which were discarded in our method), but likely the main source of antioxidants in

Table 1 Selected color, ORAC, and TAC data by cultivar, picking and fraction

Cultivar	Picking	Fraction	Color								
			L*			Chroma			Hue angle		
			Value	SE		Value	SE		Value	SE	
Autumn Bliss	all	juice	4.32	0.34	bc	12.67	0.83	bc	11.49	1.2	a
Caroline	all	juice	2.53	0.42	a	8.38	1.0	a	17.77	1.5	bc
Jaclyn	all	juice	3.16	0.42	ab	9.45	1.0	ab	8.31	1.5	a
Joan J	all	juice	3.53	0.6	ac	10.1	1.4	ac	11.44	2.1	ab
Polana	all	juice	2.61	0.34	a	7.88	0.83	a	10.57	1.2	a
Polka	all	juice	4.68	0.42	bc	14.37	1.0	c	11.77	1.5	ac

Cultivar	Picking	Fraction	ORAC			TAC		
			Value	SE		Value	SE	
All	1	juice and pulp	20.42	0.43	a	13.46	0.49	a
All	2	juice and pulp	23.68	0.57	b	17.57	0.49	b
All	3	juice and pulp	24.11	0.55	b	21.2	0.49	c
All	1	juice	18.48	0.55	a	17.19	0.7	b
All	2	juice	20.27	0.81	ab	20.34	0.7	c
All	3	juice	21.2	0.75	ab	25.05	0.7	d
All	1	pulp	22.37	0.66	b	9.72	0.7	a
All	2	pulp	27.08	0.81	c	14.81	0.7	b
All	3	pulp	27.03	0.81	c	17.36	0.7	bc
All	1	seed	264.00	5.1	d	nd		
All	2	seed	284.80	6.1	d	nd		
All	3	seed	273.6	6.1	d	nd		
Autumn Bliss	all	seed	301.37	10.73	c	nd		
Caroline	all	seed	215.79	10.28	a	nd		
Jaclyn	all	seed	236.91	11.87	ab	nd		
Joan J	all	seed	302.25	10.28	c	nd		
Polana	all	seed	285.22	11.87	bc	nd		
Polka	all	seed	298.06	11.87	c	nd		

[a] ORAC, reported in μmol TE/g; TAC, reported in mg cyn-3-glu eq./100 g; color values have no units. Values not sharing a lowercase letter in a vertical group not separated by a line space are significantly different

nd not detected

Table 2 Comparison of raspberry component ORAC values with whole raspberries

Cultivar	Whole berry ORAC[a]	Juice ORAC	% Juice	Pulp ORAC	% Pulp	Juice + Pulp ORAC (calculated)	Drupelet walls (calculated)	% From drupelet walls
Autumn Bliss	47.9	19.5	37.2	24.3	21.6	12.5	35.4	74
Caroline	33.8	18.6	32.2	26.2	25.1	12.6	21.2	63
Jaclyn	43.7	20.5	24.9	24.0	33.8	13.2	30.5	70
Joan J	44.8	20.1	30.2	26.9	28.5	13.7	31.1	69
Polana	36.1	18.0	38.0	21.9	21.0	11.4	24.7	68
Polka	40.4	21.1	25.0	26.3	24.9	11.8	28.6	71

All values are reported in μmol TE/g

[a] Data in this column from [18]. Seed data is not included because seeds were not broken open in [18]

Freeman et al. Some variation may be attributed to a different harvest year; however, the controlled growing conditions, fertigation system and same cultivars would not likely account for a >50 % loss in antioxidant capacity. Thus, we conclude that drupelet walls are a significant source of antioxidant capacity in raspberries.

There is no defined method to determine where the pigmented pulp and juice ends and the drupelet wall begins, other than what we have defined herein. Also, there was no indication in the pulp collected that any drupelet walls became part of the pulp extract. No papers could be found specifically isolating and analyzing raspberry drupelet walls. However, skin of other fruits are known locations for high concentrations of antioxidant activity [28, 30]. It was expected that a large portion of the raspberry antioxidant capacity would be found in the pulp after milling the berries. Because the drupelet walls were discarded in the method used to obtain the seeds, the antioxidant activity cannot be directly confirmed as it was impossible to go back and redo experiments after the crop year had ended and collected samples were exhausted. Thus, we chose to compare to the previous year and make assumptions that would allow a comparison. Milling was performed without heat or hydrolysis, which prevented separation of antioxidants from drupelet walls. Others [31, 32] have found a significant increase in antioxidant yield with heat processing and enzyme treatment.

Total Anthocyanin Content Anthocyanin content was measured on juice, pulp, and seed fractions of each picking of the six cultivars of Utah raspberries. Total anthocyanin content increased as the season progressed when all cultivars, juice and pulp were combined (Table 1).

When separated into juice and pulp, the pattern was the same, with juice having a higher anthocyanin content than pulp (Table 1). When averaging all cultivars and pickings of the Utah-grown berries, juice had significantly higher anthocyanin content than pulp. Seeds contained almost no anthocyanins; the small values obtained likely arose from contaminants on the outer surface of the seeds. This confirms that the high antioxidant capacity of raspberry seeds is not due to anthocyanins [33].

To determine statistical differences in anthocyanin content at the most detailed level, all fractions, pickings and cultivars were compared (Table 3). Unlike in the ORAC data, there were many significant differences in TAC. Cultivar Joan J had the highest juice and pulp anthocyanin content after the first picking. Joan J retained the top anthocyanin content in juice after the second picking, but was second to Polka in pulp anthocyanin content. By the third picking, Caroline replaced Joan J and Polka for highest anthocyanin content in both juice and pulp. In contrast, Jaclyn had the lowest anthocyanin content across all pickings in both juice and pulp. Table 1 indicates significant increases across pickings with cultivars combined, and Table 3 shows that this change was consistent across all cultivars. Though, some cultivars increased in anthocyanin content irregularly as the season progressed, all cultivars combined showed an overall increase in both juice and pulp fractions. Anthocyanins are a major contributor to

Table 3 Total anthocyanin content (TAC) of dry climate-grown raspberries separated by fraction, picking and cultivar

Picking	1			2			3		
Cultivar	mg cyn-3-glu eq./100 g	SE		mg cyn-3-glu eq./100 g	SE		mg cyn-3-glu eq./100 g	SE	
Juice									
Autumn Bliss	16.3	0.48	b	21.3	0.55	bc	24.0	0.62	a
Caroline	17.3	0.48	bd	23.1	0.55	bd	29.0	0.62	b
Jaclyn	12.8	0.48	a	16.9	0.55	a	23.4	0.62	a
Joan J	20.4	0.48	c	23.5	0.55	cd	26.7	0.62	ab
Polana	19.6	0.48	cd	17.1	0.55	a	23.9	0.62	a
Polka	16.9	0.48	b	20.2	0.55	b	23.4	0.62	a
Pulp									
Autumn Bliss	9.36	0.22	c	15.92	0.56	ad	17.17	0.50	b
Caroline	9.47	0.22	bc	15.95	0.56	bcd	23.14	0.50	d
Jaclyn	8.11	0.22	a	12.76	0.56	a	14.19	0.50	a
Joan J	11.65	0.22	d	14.06	0.56	ac	15.14	0.50	ab
Polana	10.46	0.22	bcd	13.37	0.56	ab	20.19	0.50	c
Polka	9.26	0.22	abc	16.77	0.56	cd	14.32	0.50	a

Columns within each fraction (juice or pulp) not sharing the same lowercase letter are significantly different. Seed values were not included due to the lack of anthocyanin content

antioxidant capacity in raspberries [34], though not the only contributor [33]. Therefore, anthocyanin content is strongly indicative of changes that occurred in the raspberries across cultivars and pickings.

ORAC and TAC Correlation Anthocyanins are likely significant contributors to the overall antioxidant capacity of raspberry juice [34], though we did not find a significant correlation between ORAC and TAC in this study. Kalt et al. [35] calculated a correlation between ORAC and total anthocyanins for accumulated blueberries, strawberries and raspberries and reported an r00.90, though the raspberry data was scattered. Because ORAC measures overall antioxidant content, phenolic acids, flavonoids and other antioxidants may be in higher concentration than anthocyanins, thus minimizing the effect of anthocyanins on ORAC in this study. Similarly, these other antioxidant compounds may mask a correlation between antioxidant capacity and anthocyanin content. Anttonen and Karjalainen [12] found significant variation in anthocyanin and phenolic content of raspberries depending on the cultivar, in agreement with our results.

Limitation One limitation of the study was that the drupelet walls were discarded; therefore, we can only make the mathematical assumption that drupelet walls contain the majority of the ORAC value in the raspberries (see Table 2).

Summary To our knowledge, this is the first report determining the contribution of different fractions of dry climate primocane raspberries to antioxidant capacity, and specifically anthocyanins. We conclude that antioxidant capacity and total anthocyanin content increases across a picking season, suggesting that berries offer higher levels of potentially healthful compounds during the latter part of the season. Evidence also suggested that raspberries cultivated in a dry climate may contain more antioxidants than commercial cultivars grown elsewhere [19]. It is also concluded that antioxidant content was far greater in raspberry seeds than in pulp or juice, while the opposite effect was found for total anthocyanin content. Finally, there are significant differences between cultivars in antioxidant capacity and anthocyanin content. Many potentially healthful compounds in raspberries may be lost, depending on the fraction of the raspberry removed, during processing. The removal of seeds or pulp would have the greatest effect on its antioxidant capacity or anthocyanin content, respectively. These results have implications in juice and supplement markets where raspberry components might be utilized.

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References

1. Dragsted LO, Strube M, Larsen JC (1993) Cancer-protective factors in fruits and vegetables: biochemical and biological background. Pharmacol Toxicol 72:116–135
2. Seeram NP (2008) Berry fruits for cancer prevention: current status and future prospects. J Agric Food Chem 56:630–635
3. Nunez-Cordoba JM, Martinez-Gonzalez MA (2011) Antioxidant vitamins and cardiovascular disease. Curr Top Med Chem 11:1861–1869
4. Battino M, Beekwilder J, Denoyes-Rothan B, Laimer M, McDougall GJ, Mezzetti B (2009) Bioactive compounds in berries relevant to human health. Nutr Rev 67:S145–S150
5. Seeram NP (2008) Berry fruits: compositional elements, biochemical activities, and the impact of their intake on human health, performance, and disease. J Agric Food Chem 56:627–629
6. Liu RH (2004) Potential synergy of phytochemicals in cancer prevention: mechanisms of action. J Nutr 134:3479S–3485S
7. Paredes-López O, Cervantes-Ceja ML, Vigna-Pérez M, Hernández-Pérez T (2010) Berries: Improving human health and healthy aging, and promoting quality life—a review. Plant Foods Hum Nutr 65:299–308
8. Szajdek A, Borowska EJ (2008) Bioactive compounds and health-promoting properties of berry fruits: a review. Plant Foods Hum Nutr 63:147–156
9. Rao AV, Snyder DM (2010) Raspberries and human health: a review. J Agric Food Chem 58:3871–3883
10. Pellegrini N, Serafini M, Colombi B, Del Rio D, Salvatore S, Bianchi M, Brighenti F (2003) Total antioxidant capacity of plant foods, beverages and oils consumed in Italy assessed by three different in vitro assays. J Nutr 133:2812–2819
11. Moyer RA, Hummer KE, Finn CE, Frei B, Wrolstad RE (2002) Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: Vaccinium, Rubus, and Ribes. J Agric Food Chem 50:519–525
12. Anttonen MJ, Karjalainen RO (2005) Environmental and genetic variation of phenolic compounds in red raspberry. J Food Comp Anal 18:759–769
13. De Ancos B, Gonzalez EM, Cano MP (2000) Ellagic acid, vitamin C, and total phenolic contents and radical scavenging capacity affected by freezing and frozen storage in raspberry fruit. J Agric Food Chem 48:4565–4570
14. González EM, de Ancos B, Cano MP (2003) Relation between bioactive compounds and free radical-scavenging capacity in berry fruits during frozen storage. J Sci Food Agric 83:722–726
15. Kähkönen MP, Hopia AI, Heinonen M (2001) Berry phenolics and their antioxidant activity. J Agric Food Chem 49:4076–4082
16. Liu M, Li XQ, Weber C, Lee CY, Brown J, Liu RH (2002) Antioxidant and antiproliferative activities of raspberries. J Agric Food Chem 50:2926–2930
17. Ozgen M, Wyzgoskiz FJ, Tulio AZ, Gazula A, Miller AR, Scheerens JC, Reese RN, Wright SR (2008) Antioxidant capacity and phenolic antioxidants of midwestern black raspberries grown for direct markets are influenced by production site. HortScience 43:2039–2047
18. Freeman BL, Stocks JC, Eggett DL, Parker TL (2011) Antioxidant and phenolic changes across one harvest season and two storage conditions in primocane raspberries (Rubus idaeus L.) grown in a hot, dry climate. HortScience 46:236–239
19. Haytowitz DB, Bhagwat S. Nutrient Data Laboratory, Agricultural Research Service, U.S. Department of Agriculture (2010) USDA Database for the Oxygen Radical Absorbance Capacity (ORAC) of Selected Foods, Release 2. http://www.ars.usda.gov/nutrientdata
20. Moore PP (1997) Estimation of anthocyanin concentration from color meter measurements of red raspberry fruit. Hortscience 32:135
21. Imram N (1999) The role of visual cues in consumer perception and acceptance of a food product. Nutr Food Sci 99:224–230

22. Parry JW, Cheng ZH, Moore J, Yu LL (2005) Fatty acid compo- sition and antioxidant properties of cold-pressed marionberry, boy-senberry, red raspberry, and blueberry seed oils. J Agric Food Chem 53:566–573
23. Freeman BL, Eggett DL, Parker TL (2010) Synergistic and antago- nistic interactions of phenolic compounds found in navel oranges. J Food Sci 75:C570–C576
24. Pirie A, Mullins MG (1976) Changes in anthocyanin and phenolics content of grapevine leaf and fruit tissues treated with sucrose, nitrate, and abscisic acid. Plant Physiol 58:468–472
25. Mejia-Meza EI, Yanez JA, Remsberg CM, Takemoto JK, Davies NM, Rasco B, Clary C (2010) Effect of dehydration on raspberries: polyphenol and anthocyanin retention, antiox- idant capacity, and antiadipogenic activity. J Food Sci 75:H5– H12
26. Niki E (2011) Antioxidant capacity: Which capacity and how to assess it? J Berry Res 1:169–176
27. Prior RL, Wu X, Schaich K (2005) Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. J Agric Food Chem 53:4290–4302
28. Sandhu AK, Gu LW (2010) Antioxidant capacity, phenolic con- tent, and profiling of phenolic compounds in the seeds, skin, and pulp of Vitis rotundifolia (muscadine grapes) as determined by HPLC-DAD-ESI-MS(n). J Agric Food Chem 58:4681–4692
29. Cekic C, Ozgen M (2010) Comparison of antioxidant capacity and phytochemical properties of wild and cultivated red raspberries (Rubus idaeus L.). J Food Comp Anal 23:540–544
30. Lata B (2007) Relationship between apple peel and the whole fruit antioxidant content: year and cultivar variation. J Agric Food Chem 55:663–671
31. Borowska EJ, Szajdek A, Czaplicki S (2009) Effect of heat and enzyme treatment on yield, phenolic content and antioxidant ca-pacity of juices from chokeberry mash. Ital J Food Sci 21:197–209
32. Woo KS, Hwang IG, Song DS, Lee YR, Lee J, Jeong HS (2008) Changes in antioxidant activity of Rehmannia radix libosch with heat treatment. Food Sci Biotechnol 17:1387–1390
33. Nutrient data laboratory, Agricultural Research Service, U.S. Department of Agriculture (2007) USDA Database for the Flavonoid Content of Selected Foods, Release 2.1. http://www.ars.usda.gov/nutrientdata
34. Wang H, Cao G, Prior RL (1997) Oxygen radical absorbing capacity of anthocyanins. J Agric Food Chem 45:304–309
35. Kalt W, Forney CF, Martin A, Prior RL (1999) Antioxidant capac-ity, vitamin C, phenolics, and anthocyanins after fresh storage of small fruits. J Agric Food Chem 47:4638–4644

2010-17. **Effect of Fungicides on Learning and Memory in the Blue Orchard Bee (*Osmia lignaria*)**

Final Report

PROJECT SUMMARY

Over the last several decades, the use of solitary bees as an alternative to honey bees (*Apis mellifera* L.) for pollination of commercial crops has increased, in part as a response to ongoing problems faced by commercial honey bee populations and pollinators in general (National Research Council, 2007). The blue orchard bee, *Osmia lignaria* Say (Hymenoptera: Megachilidae), with its strong preference for fruit tree flowers and its tendencies to fly in cooler weather and to cross-pollinate by frequently moving between trees, is a proficient pollinator with great potential for commercial orchards (Bosch and Kemp, 2001).

Powdery mildew is a widespread fungal problem, affecting a large variety of fruits and vegetables. Pollinator managers have previously noted that blue orchard bee nesting is disrupted and sometimes completely discontinued after applications of fungicides (Ladurner et al., 2005, 2008; S. Peterson, personal communication). Previous testing of fungicides commonly used in commercial orchards did not reveal delayed or acute toxicity in blue orchard bees (with the exception of Captan) (Ladurner et al., 2005) or abnormal nesting behaviors (Ladurner et al., 2008). Therefore, the cause of disrupted nesting in fungicide-sprayed orchards has not been discovered. We hypothesized that

fungicide consumption disrupts blue orchard bee nesting by causing confusion that results from learning inhibition and/or memory loss. Testing of this hypothesis in the laboratory was initiated in 2010 by Dr. Cory Stanley, in collaboration with Dr. Theresa Pitts-Singer of the USDA-ARS Bee Biology and Systematics Laboratory (BBSL). This project, completed by Dr. Stanley, continued that work, testing the effects of fungicides used to treat powdery mildew in Utah orchards on blue orchard bee learning and memory.

PROJECT APPROACH

The four fungicides tested were Rally® (active ingredient: myclobutanil), Rubigan® (active ingredient: fenarimol), Pristine® (active ingredients: pyraclostrobin and boscalid) and Procure® (active ingredient: Triflumizole). Conditioning and testing of fungicide-fed and control (not fed fungicides) blue orchard bees took place during Mar-May 2011 and Mar-May 2012.

The entire conditioning and testing schedule is summarized in Table 1. Fungicides were fed to bees throughout a four day conditioning period, in which bees were trained to associate one odor with a sucrose reward and a different odor with water. Both sucrose solution and water contained one of the four tested fungicides. Each fungicide was tested at a concentration equivalent to the highest rate recommended on the label for treating powdery mildew in apples (Table 2). The two odors used were phenylacetaldehyde (PAA) and geraniol. Both possible odor combinations were tested (i.e., PAA associated with sucrose and geraniol associated with water, as well as the converse). On day 5, bees were tested to determine if they learned which odor was associated with sucrose. A fifth group of bees, serving as controls, were subjected to the conditioning and testing protocol, but were never fed fungicides. Over the two years, a total of 895 bees were tested in the learning impairment phase of the project (Table 3).

Bees that correctly chose the sucrose-associated odor were held for two more days, during which they were fed sucrose solution, but not fed fungicide. On day 8 they were tested again to determine if their memories were affected by fungicide ingestion. A total of 292 bees were tested in the memory impairment phase of the project (Table 4).

Data from both years were combined for analysis using Fisher's exact tests. For the first test, which compared the ability of fungicide-fed bees to learn odors to bees that were not fed fungicide's learning ability, only females fed Rubigan were significantly different than control bees (Figure 1). Interestingly, Rubigan-fed females were more likely to choose the reward associated odor. The second test compared the ability of fungicide-fed bees and control bees that had previously chosen the reward associated odor to remember that odor for two days after conditioning was completed. For the second test, none of the fungicide-fed bees performed differently than control bees (Figure 2).

The results of these experiments do not support our hypothesis that fungicide consumption disrupts blue orchard bee nesting by causing confusion that results from learning inhibition and/or memory loss. These experiments provide no evidence that fungicide ingestion affects bees' learning or memory. The one exception is female blue orchard bees, whose learning seems inexplicably enhanced by Rubigan. However, this result should be interpreted with caution; there is no reason to believe that Rubigan has a positive effect on bees. This result warrants further investigation.

This study should alleviate some of the concerns of pollinator managers and growers that desire to use these fungicides to treat for powdery mildew and other fungal infections. However, it still remains to explain reports that blue orchard bees' nesting is disrupted following fungicide sprays. Often, fungicides are not sprayed alone; rather, they are sprayed in combination with an adjuvant. The effects of fungicide and adjuvant mixtures on blue orchard bees are not known and should be the subject of future research.

Table 1. Conditioning and testing schedule. Fungicides were fed to bees (except control bees) on days 1-4. No fungicides were fed to any bees on subsequent days.

Day 1	Sucrose solution-filled feeder scented with Odor 1
Day 2	Water-filled feeder scented with Odor 2
Day 3	Sucrose solution-filled feeder scented with Odor 1
Day 4	Water-filled feeder scented with Odor 2
Day 5	Learning impairment test
Day 6	Sucrose solution-filled feeder, no odor
Day 7	Water-filled feeder, no odor
Day 8	Memory impairment test

Table 2. Fungicide concentrations fed to bees correspond to the maximum rate indicated on the label for treatment of powdery mildew on apples.

Fungicide	Concentration
Rally	0.000180 g per 1.00 ml water
Rubigan	0.313 µl per 1.00 ml water
Procure	0.313 µl per 1.00 ml water
Pristine	0.000347 g per 1.00 ml water

Table 3. A total of 895 blue orchard bees were tested during the learning impairment phase of the project.

	Rally	Rubigan	Pristine	Procure	Control
females	101	94	65	72	132
males	87	85	60	73	126
Total	**188**	**179**	**125**	**145**	**258**

Table 4. A total of 292 blue orchard bees were tested in the memory impairment phase of the project.

	Rally	Rubigan	Pristine	Procure	Control
females	15	39	19	30	41
males	17	35	15	28	53
Total	**32**	**74**	**34**	**58**	**94**

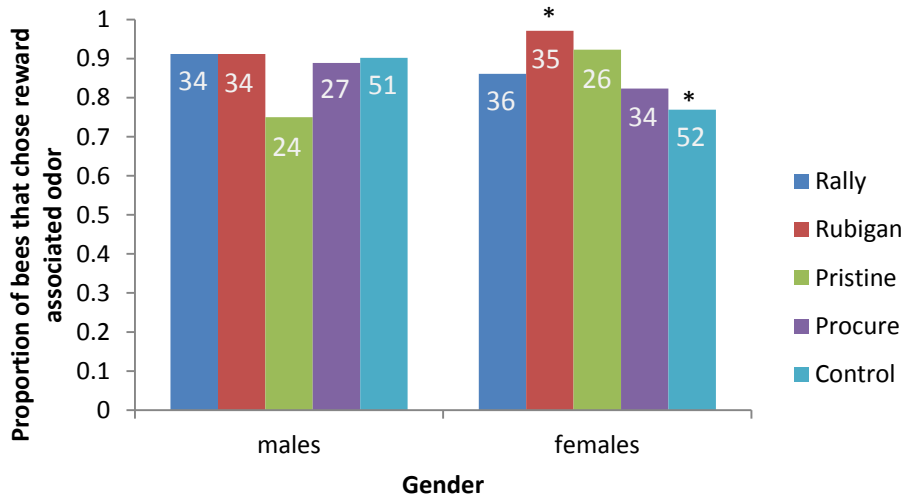

Figure 1. Proportions of bees that chose the reward associated odor in the learning (first) test. Numbers on bars indicate total number of bees in group that chose either odor. Groups marked with asterisks are significantly different at P = 0.01.

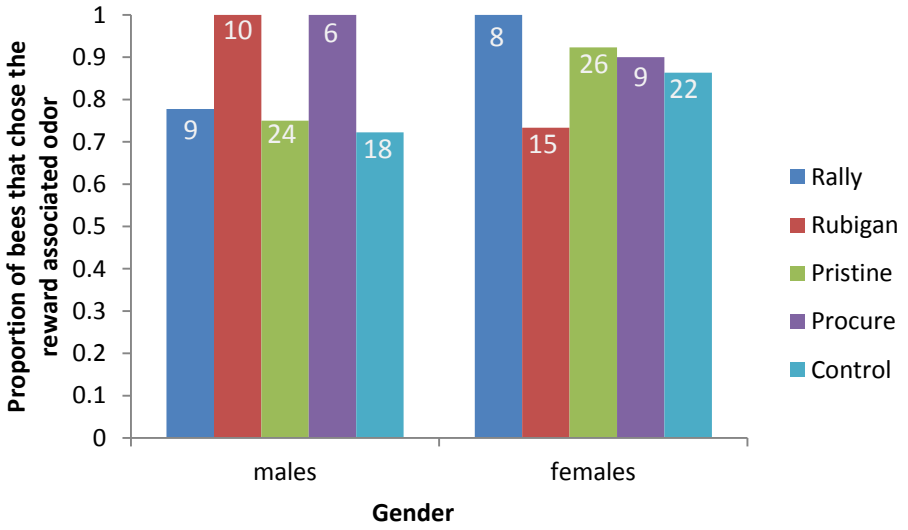

Figure 2. Proportions of bees that chose the reward associated odor in the memory (second) test. Numbers on bars indicate total number of bees in group that chose either odor. None of the fungicide-fed groups was significantly different from the control group at P = 0.05.

GOALS AND OUTCOMES ACHIEVED

Although growers are aware of the lethal effects of pesticides on pollinators, the sub-lethal effects of pesticides are often not considered. The results of this project have enhanced our understanding of these sub-lethal effects, and this understanding will be passed along to both growers and scientists. These results also provide groundwork for further experiments seeking to explain fungicides' alleged deterrence of blue orchard bee nesting, some of which are already in progress.

Project results will be presented at the annual Utah State Horticultural Association (USHA) meeting on January 30, 2013 and at the Northern Utah Fruit Growers meeting on February 5, 2013. Results were also be presented to about 25 scientists and stakeholders at the annual Orchard Bee Association meeting in Sacramento, CA on December 10-11, 2012. Preliminary results were presented to about 25 scientists and stakeholders at the annual Orchard Bee Association meeting in

December, 2011 in Modesto, CA and at the annual meeting of the Entomological Society of America (ESA) in Reno, NV in November, 2011, which was attended by over 2,700 people. Summaries of these experiments will be made available on the Utah Bees website (http://bees.usu.edu) and the Orchard Bee Association website. Preliminary results were included in the Spring 2012 edition of the quarterly Utah Pests newsletter, which is subscribed to by over 3,000 people and is accessed online by many more. Final results will be published in a future edition of the Utah Pests newsletter. In addition, manuscripts resulting from these projects will be submitted for publication in appropriate peer-reviewed scientific journals.

BENEFICIARIES

Powdery mildew is a widespread problem, affecting a large variety of fruits and vegetables. In Utah, more than $14 million is generated annually by over 300 operations that grow approximately 7,000 acres of tree fruits, many species of which are susceptible to powdery mildew. Many more backyard orchards exist that are often not accounted for in official estimates of orchard acreage in the state. The results of this project will be of interest to all pollinator managers and orchard managers that are concerned about the potential effects of fungicides on native pollinators and on honey bees. The results will be of particular interest to orchardists that are currently using, or are considering using, managed blue orchard bees to supplement or replace honey bees for pollination of tree fruits. These experiments allow orchardists to make better informed decisions concerning fungicide applications during the pre-bloom and bloom periods, as often occur when treatment of powdery mildew is necessary.

LESSONS LEARNED

This project modified methods previously used for conditioning solitary bees such that those methods can now be used to test sub-lethal effects of substances such as pesticides. This is particularly useful because methods that are traditionally used for similar tests in honey bees are not effective for solitary bees (Vorel and Pitts-Singer, 2012).

One difficulty encountered was bee mortality. For unknown reasons, bees often did not survive long enough to complete the entire conditioning protocol and both tests. This made it difficult to get bees to complete the memory test in large enough numbers for a robust statistical analysis. It may be necessary to explore ways of increasing bee longevity during the protocol so that these methods can be used to answer future questions about bee memory.

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ADDITIONAL INFORMATION

References

Bosch, J., and W. P. Kemp. 2001. *How to manage the blue orchard bee as an orchard pollinator*. Sustainable Agriculture Network, National Agricultural Library; Beltsville, MD, USA; 88 pp.

Ladurner, E., J. Bosch, W. P. Kemp, and S. Maini. 2005. Assessing delayed and acute toxicity of five formulated fungicides to *Osmia lignaria* Say and *Apis mellifera*. *Apidologie* 36: 449-460.

Ladurner, E., J. Bosch, W. P. Kemp, and S. Maini. 2008. Foraging and nesting behavior of *Osmia lignaria* (Hymenoptera: Megachilidae) in the presence of fungicides: cage studies. *Journal of Economic Entomology* 101: 647-653.

National Research Council of the National Academies. 2007. *Status of pollinators in North America.* National Academy Press; Washington, D.C., USA; 307 pp.

Vorel, C. A., and T. L. Pitts-Singer. 2010. The proboscis extension reflex not elicited in megachilid bees. J. Kansas. Ent. Soc. 83(1): 80-83.

18. Increasing Crop Pollination through Native Bee Nesting Habitats and Management Systems

Project Summary:

Commercial growers requiring entomophilous services generally desire greater or larger fruit set while simultaneously making an effort to reduce costs. Substantial managed honeybee losses (30–32% loss) recorded in 2006 were significant, which doubled and tripled the cost of crop pollination services. Losses from subsequent years remained about the same. Because of the expense, scientists and growers have fixated on alternative entomophilous pollinators.

Non-social, solitary bees can and are being used for orchard pollination, and the USDA's ARS scientists in Logan, Utah have proven Osmia *lignaria* (a "native" bee indigenous to the Pacific Northwest) is a superior pollinator than Apis *mellifera* in Cherries and possibly other crops. The species Osmia *lignaria* is found throughout Utah's valleys and mountains, and the species has predilections for important commercial fruits.

For those already familiar with the native bee industry, Osmia *lignaria* is among the more popular and manageable species, and bees from Utah and Idaho regions tend to be somewhat "larger and huskier," according to Glen Trostle, a USDA-ARS scientist. Larger *lignaria* females are known to fly farther than smaller females, thus increasing pollination at greater distances.

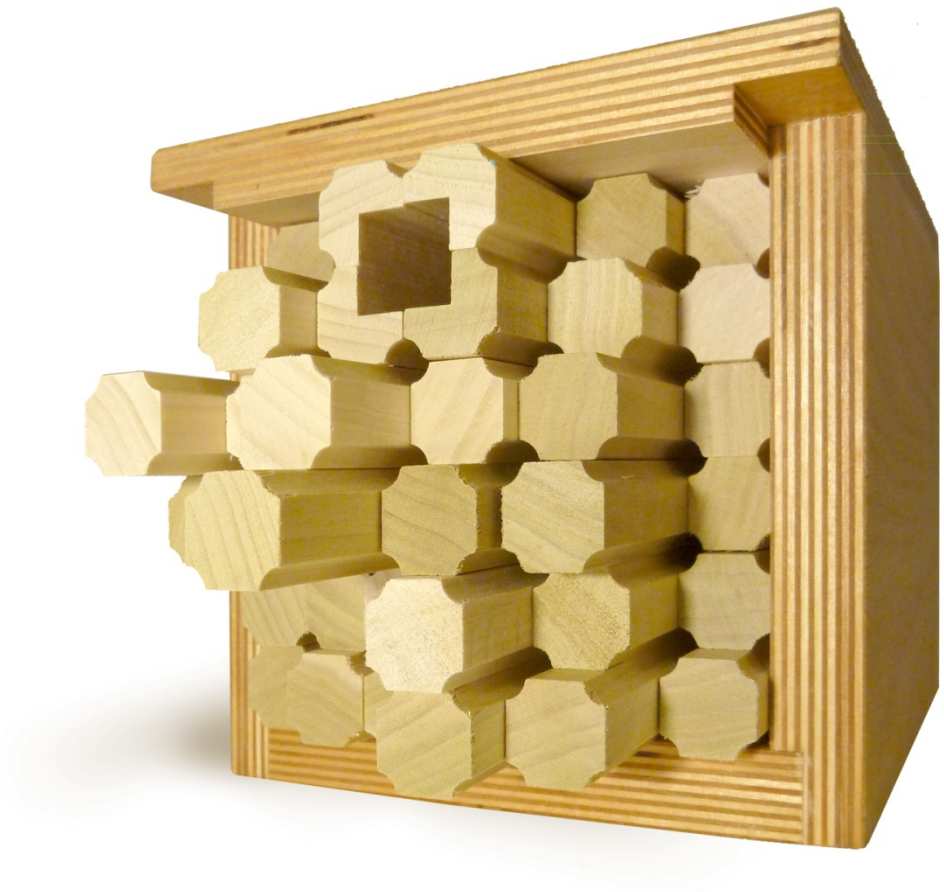
As the awareness of CCD (Colony Collapse Disorder), pollination expenses, grants related to pollination, and opportunities for grower sustainability increase, the market for native bee purchasing, ranching and necessary habitat is steadily growing.

In May of 2010, Kimball Clark applied with the Davis Applied Technology College and received a smaller-than-usual "Technology Commercialization Grant" (TCG) from USTAR (Utah Science Technology and Research). The TCG grant was dedicated primarily to the research & development of Clark's native bee nesting devices, whereby he was able to create a formidable "bee condo" design utility.

Clark converted his research into a business called NativeBees.com, and was awarded a singular Specialty Crop Block reimbursement grant that lasted from 2010 to 2012. Clark was then able to fabricate and assemble well over 100 bee condo habitats and distribute them—often with O. lignaria pupae—for entomophilous crop pollination throughout Utah and the United States. The

reimbursement funds also provided means for online distribution to growers, for pollination servicing and orchard research trips, and for public promotion of orchard bee pollination.

Clark's management systems are intended to reduce crop pollination expenses, encourage pollination sustainability, break the honeybee (Apis *mellifera*) addiction, and maximize crop output.



Project Approach:

Since January of 2011, well over 150 bee condos have been distributed to orchards, entomologists, bee supply resellers and residential growers. Condo installations include but are not limited to: Utah, California, Oregon, Washington, Idaho, Wyoming, Colorado, Nebraska, Vermont, Maryland, New York, and New Jersey. Roughly half of the bee condos included UT-origin O. *lignaria* or O. *lignaria* from the buyer's origin.

In 2011 and 2012, evaluations of the bees, habitat and fruit set were conducted.

Evaluations included:

a) Habitat location and preference
b) Foraging behavior
c) Nesting behavior
d) Predation
e) Stability of cavity nesting environment (bee condo)
f) Ease of cocoon harvest
g) Brief summaries of corresponding fruit set

Goals and outcomes achieved:

Habitat location and preference

It is well known in the industry that O. *lignaria* prefers certain tree blooming crops over ground blooming crops and the species is less distracted from undesirable forage than Apis *mellifera*. Abundant O. *lignaria* nesting results imply more pollen has been moved from blooming flowers, and thus more pollination has occurred within the surrounding area.

Many of the evaluations conducted under this grant in 2012 are best represented in the table below. It displays data in regard to the pollination efficiency of O. lignaria within specialty crop plantings. Generally speaking, when O. lignaria propagation results are strong—considering the specie's predilection for specialty crop fruits and their confined flight radius—it is assumed efficient pollination has occurred.

2012 Orchard Site	Location	Bee Origin	"Conceived"	Avg. % O. lignaria Return	Notes
Manning Orchard East	Fruit Heights, UT	UT-Kaysville	UT-Kaysville	0%	Condos vandalized
Manning Orchard Central	Fruit Heights, UT	UT-Kaysville	UT-Kaysville	30%	
Manning Orchard West	Fruit Heights, UT	ID	CA-Turlock	0%	
Robert Fetzer, 3.0	Draper, UT	UT-Kaysville	UT-Kaysville	369%	
Robert Fetzer, 2.0		UT-Draper, UT-Kaysville	UT-Draper, UT-Kaysville	109%	
Doug Lemon North	Willard, UT	ID	CA-Turlock	0%	
Doug Lemon Central	Willard, UT	ID	CA-Turlock	0%	
Doug Lemon South	Willard, UT	ID	CA-Turlock	0%	
Dean Storee East	Fruit Heights, UT	UT-Kaysville	UT-Kaysville	55%	
Dean Storee Central	Fruit Heights, UT	UT-Cache	UT-Cache	0%	
Dahle Farms	The Dalles, OR	OR-Clackamas	OR-Clackamas	?	Hasn't replied
Paramount Farms	Lost Hills, CA	UT-Cache	CA-Lost Hills	700%	Netted propagation enclosure; subsequent generations of UT-Cache origin bees, abundant mud
Munger Farms	Delano, CA	CA-? (mountains)	CA-? (mountains)	0%	
C&R Orchards	Livingston, CA	CA-San Luis Obispo	CA-San Luis Obispo	?	Hasn't replied
South Valley Farms	Wasco, CA	ID	CA-Turlock	0%	
				97%	

2012 Backyard Site	Location	Bee Origin	"Conceived"	Avg. % O. lignaria Return	Notes
Jake Olsen	Kaysville, UT	UT-Kaysville	UT-Kaysville	55%	
Steve Roberts	Kaysville, UT	UT-SLC	UT-SLC	1200%	Abundant mud
Dave Welch	Kaysville, UT	UT-Kaysville	UT-Kaysville	55%	2 add'l species
Max Hirschi	Kaysville, UT	UT-Kaysville	UT-Kaysville	200%	Wild population nearby
Paul Somer	Kaysville, UT	ID	CA-Turlock	0%	Observed high absconsion
Kimball Clark	Kaysville, UT	UT-Kaysville	UT-Kaysville	300%	Abundant mud, dense bee pop.
Dan the Mailman	Kaysville, UT	ID	CA-Turlock	55%	Rare ID-origin return
Mike Billman	Monmouth, OR	UT-Kaysville	UT-Kaysville	0%	
Richard Coles	West Jordan, UT	UT-Kaysville	UT-Kaysville	0%	
Doug Vincent	Sebastopol, CA	CA-San Jose	CA-San Jose	55%	
Thomas Baggs	Cleveland, UT	UT-Kaysville	UT-Cleveland	0%	
Kate Johnson	Salt Lake City, UT	UT-SLC	UT-SLC	600%	Trap Nested; didn't begin with bees
Charles Clark	Farmington, UT	UT-Kaysville	UT-Farmington	33%	
				196%	

According to the data collected, it appears that in 2012's season, "local" bee habitats (habitats which contained O. *lignaria* from the local environment) that were also positioned near abundant mud resources resulted in superior nesting.

It also appears that **local** bee habitats in older residential neighborhoods dramatically outperformed commercial orchard habitats. Some orchards contained import bees (ID-origin) and resulted in a net loss.

We theorize **local** bees did better in the residential environments because of:

a) the varying and abundant sprinkling schedules of adjacent properties—resulting in high, constant volumes of mud availability
b) the abundance of diverse and constant pollen from flowering trees/bushes/flowers throughout the bee's 6–8 week life span as a flying adult.
c) the diverse, large visual points of reference that direct bees to nesting sites
d) the lack of frequent chemicals used in orchard management that may afflict bees (pesticides, herbicides or fungicides).
e) other unknown factors

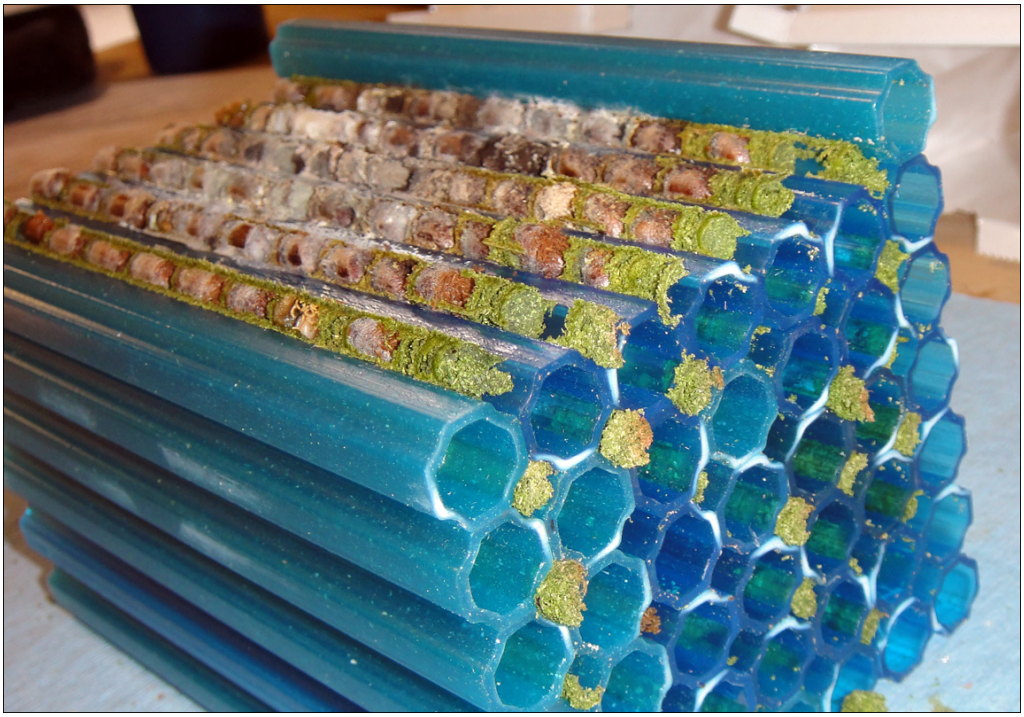
The failure of **imported** bees was likely due to:

a) improper storage and/or refrigeration of the cocoons
b) unknown factors prior to or during shipping
c) improper nesting habitat or cocoon release by the buyer
d) climatic or elevation differences that negatively affected the bees

e) the rare chance that imported bees happened to be used in orchards unsuitable for prosperous bee propagation
f) a mixture of some or all of the above

When mounting habitats, limit physical contact between the condo and horizontal, stationery objects. Placing habitats on (or touching) broad surfaces such as atop fence posts, rocks, pillars and/or tree stumps is discouraged. In these situations, ants, earwigs or other undesirable pests can easily discover and rob bee pollen from pollen-packed chambers.

A California grower reported mold (see image below) in some of Clark's unique bee condos (Orchardist version 3.5) where the habitat was mounted exactly horizontal or tipped slightly upward (toward the sky). Tipping the habitat's open front slightly downward (toward the ground) is recommended so any water that may enter the cavities or nesting area will run out of the bee condo housing instead of "cupping" rainwater or condensation. Recent research, however, suggests tipping condos upward during development to improve cocoon orientation can improve emergence rates.



Placing habitats in plain sight is helpful to bees, but often tempts destructive teenagers and curious workers. Labeling bee habitats with the ethic of reciprocity is recommended.

Bee condos painted in fluorescent blue outperformed fluorescent yellow, white, black, natural wood, wood sealed with linseed oil, wood sealed with beeswax and wood sealed with a mixture of beeswax and pollen.

Foraging behavior/preference

Although some O. *lignaria* imports had disastrous results in commercial orchard environments, both males and females were observed foraging within the first week of emergence. Very few, if any, were seen returning to their emergence area.

Whether imported or local, establishing a nest of O. *lignaria* the first year generally yielded poor propagation, whereas subsequent years substantially improved.

Apricot's early bloom may provide abundant food supply for warmer than normal springs that result in early Osmia emergence. In early 2012, O. *lignaria* was observed pollinating chokecherry prior to apple bloom. O. *lignaria* seems to prefer early apple bloom over late peach bloom, and full chokecherry bloom over full peach bloom.

A bizarre, late release of over 200 imported O. *lignaria* males and females revealed a preference for Bachelor's button over Borage, Rose of Sharon (Hibiscus syriacus), and a distant discovery and liking toward Japanese Knotweed catkins/flowers. Interestingly, the cut reeds from Japanese Knotweed are viable nesting habitats for O. *lignaria*. Mr. Clark has tested and used these reeds since 2008. Because these bees emerged so late in the year, they were visibly hungry. Upon emergence and after preparing for flight, O. *lignaria* would *immediately* fly atop the closest nearby flower and use its proboscis to suck up nectar. Some bees, once emerged from their cocoon, would instantly suck the juice from a crushed apple or a freshly-squeezed grape, if offered.

Nesting behavior
If a mud supply was provided near the nesting area, the quantity of mud "plugs" increased. Within seconds of soaking the ground with irrigation water, bees were observed hovering over and foraging in disturbed and shadowed muddy areas. Reflective pools or ditches with water to attracted bees more than areas where trees were watered using drip irrigation.

Predators & Pathogens

As known, increased populations of Osmia *lignaria* in a defined space simultaneously increases predators or pathogens in the same space. Common problems listed below—in descending order of prominence—were observed and documented in testing locations either during nesting, after nesting, or upon cocoon harvest.

Utah Locations
1. Carpet Beetle (Dermestid larvae)
2. Monodontomerus
3. Leucospis affinis
4. Earwigs
5. Ants
6. Mold

7. Chalkbrood (Among the most devastating)
8. Human interference

California Locations
1. Tricrania
2. Sapyga
3. Mold

If Mr. Clark's bee condos were not promptly removed prior to insect predatory emergence (generally in sync with the death or failed return of most O. *lignaria* females), the specific utility design did show some weakness in Utah and California locations compared to other "fully-sealed" cavities. Throughout each cavity on Clark's condos, four lateral gaps ran from front to back, which allowed intrusion from predators and pathogens. In many instances, although most gaps were pressed tightly together, tiny gaps were apparent due to variant sizing of the substrate being used. These gaps allowed predatory insects to insert their ovipositors (where applicable) and lay their offspring without much difficulty. When the design utility was tightly inserted into a wooden or aluminum box that acted as a protective housing, predation levels dropped dramatically.

To best avoid predators and pathogens, Mr. Clark recommends native bee nesting condos be removed or protected at the proper time. If not removed or protected, a high amount of invasion is likely to be discovered, whereby the cocoons must be harvested in the proper time frame, inspected, purged, and properly stored for an upcoming Spring release. The action of removal or protection thwarts attempts by parasites already in the cavities to ransack other chambers with larvae and pollen reserves. Removing (or protecting) a bee condo from the elements can rid an entire generation from parasites and maximize their numbers in the following generation, which in turn improves future pollination efforts.

Habitat Stability
As can be expected, the stability of the bee condo directly affects propagation numbers, which simultaneously affects pollination efficiency.

Clark's "Orchardist" bee condos were built specifically for commercial orchard use. They radically differed from traditional bee nesting methods (such as phragmite reeds, paper straws, drilled posts/logs or stackable trays) in that:

a) Bee cocoons could be quickly and easily harvested by growers, thus encouraging fruit growers or bee propagators to more easily achieve pollination sustainability
b) Bee condos must be used for decades in the outdoors, and to be of industrial strength. Because Osmia is likely to pollinate within a one-acre radius, several bee condos and bees would be required for commercial pollination efforts. Therefore, there the condos be abundantly placed, and economical.

The exterior (or “housing”) of the bee condos used in orchards were built primarily of sealed or wood or aluminum.

Although wood is inexpensive and mimics a bee's natural environs, it was unfit for commercial and residential applications—even when coated with paint, beeswax, linseed oil, or a mixture of these topical applications. Rainwater, irrigation and UV rays were blamed for the warping and cracking, resulting in a flawed bee condo design wherein the structural dimensions were offset and negated the

loose-cell cocoon-harvesting function. Wood therefore, proved to disrupt the condo's ability to work as desired.

Aluminum, when placed in the commercial and residential environments, did not warp or immediately break down when exposed to UV rays. Most aluminum can stand up to 20 full years of exterior usage.

There has been talk from growers and scientists that Osmia might not opt to live within a metal nesting environment.

Clark has proved this untrue. In fact, when an all-aluminum cavity was offered amidst surrounding available wood cavities, each with the same dimensions, Osmia *lignaria* was observed nesting in the aluminum cavity. Its nesting offspring survived the subsequent seasons and emerged the following spring. The cocoons collected within the aluminum cavities lacked the usual white exterior silk threads that bind them to wood chamber walls, resulting in a cocoon that was much easier to remove. More research about Osmia's ability to properly reproduce in an aluminum cavity is recommended. Aluminum's structural integrity supersedes that of other substrates tested in the outdoors and parts can be mass-produced. Aluminum is a viable candidate for Mr. Clark’s industrial-strength patent-pending bee condo.

Ease of cocoon harvest

One of the most frequent questions is why O. *lignaria* cocoons must be harvested from their nesting cavities.

Manmade nesting environments known as "loose cell" habitats are devices where cocoons can be accessed. As mentioned previously, harvesting and protecting cocoons throughout the summer, fall and winter can substantially reduce mortality rates, resulting in more pollinators and less predators for the upcoming spring. Other benefits to cocoon harvesting are quantifying growth, quantifying bee sex (female cocoons are much larger and can be easily sorted), cocoon reselling, and the even dispersion of bees per acre (according to the gender ratios required).

It is generally known in the industry that about 9 out of 10 emerging females return to their original nest for future nesting. Obviously, loose-cell harvesting disrupts the natal environment, and a "loose" release of cocoons is likely to increase the rate of absconding females and subsequently decrease controlled pollination efforts. Particular care must be taken when bees emerge from manmade release environments, and temperate and structural release environments that mimic the original nesting environment can increase the likelihood of a female to return to its birthplace for future nesting.

Clark’s patent-pending bee condos have been built with the “loose cell” concept, in that cocoons can be accessed and harvested from the device more easily. Each cavity can be split 3 ways or more, whereby the contents can be emptied in mass (resulting in a harvest of 200 cocoons at once). Other methods require more tedious labor for cocoon access.

In honeybee pollination, hives are spread throughout orchards on pallets. In monocultural growing operations with thousands of acres, pallets are spread in incremental distances for thorough pollination. Even placement throughout orchards of this size can yield a more even pollination. Mason bees must also be spread throughout the orchard, but on a smaller and more defined scale.

Whereas honeybees generally forage between 0 and 3 miles from their hive, mason bees (in an acceptable habitat) forage and nest within a 1-acre radius, assuming there is sufficient forage. The distance each bee is willing to travel has heavy implications.

If a monoculture desires to supplement or use mason bees to their fullest extent within their growing operation, bee condos (nesting environments) must be evenly spread throughout each acre. Monocultures have thousands of acres, and therefore thousands of bees and condos are required. The only way to acquire and spread bees evenly throughout the growing operation is to harvest, purge, quantify and organize them for next year's emergence and pollination efforts.

Like honeybees, mason bee condo placement and collection need only occur twice per year.

Depending on the features, durability, and location of the bee condo, it may be able to withstand the elements for subsequent years and there is a possibility its placement in the orchard need only occur once. Bee collection, however, would need to occur once per year until sustainable numbers are reached. In geographic locations where the climate is suitable to the life cycle of the particular species being used, there is a likelihood that bee cocoon harvest, purging, quantification and organizing can occur on site.

Growers are already in their orchards pruning, spraying, treating, grafting, thinning, harvesting, disking the ground, sewing cover crop, etc. Adding tasks related to pollinator care is possible but experience shows that small growers generally detest adding more work to their load and large-scale growers are initially contracting others to conduct native bee servicing than deploy their own in-house resources. In situations where large-scale growing organizations have enough interest in native bee pollination, the responsibility is likely to fall on the shoulders of the bee inspection teams or those who coordinate pollination contracts (which may or may not be employees).

Due to the rising costs of honeybee pollination coupled with the offering of related grants from state and federal governments, there is a slow but steady curiosity by large-scale growers to undertake native bee research and/or pollination.

Corresponding fruit set

A detailed analysis of fruit set according to each native bee nesting location is difficult to quantify, and for a variety of reasons.

Analyzing the effects of entomophilous services requires several years of prolonged research that takes into account elements such as climate, wind, human intervention, tree variety, common orchard management practices (chemical spraying, pruning, grafting, watering schedules, etc.), and of course, fruit output (size, weight, color, seed/taste quality). Furthermore, these factors must be applied to settings without insect pollinators, settings with solely Apis *mellifera*, and in settings with solely Osmia *lignaria*, and in settings with all insect pollinators.

Such data can be quantified—and has been—but was not gathered in great detail for this particular grant. In addition, the required number of O. *lignaria* females to carry out such a study is great. Rather than focus on any one area, Clark spread his available pollinators across the State in various orchards and throughout other Western states, thus depleting the amounts needed for a defined,

relevant study of this topic. Although it is highly important, it is likely to require several years, excess detail, and a defined and confined space for such a research.

There are two or three important studies related to the effects of entomophilous services (particularly in the case of Apis mellifera vs. Osmia *lignaria*, etc) in cherry and almond orchards that have been presented to Mr. Clark as a member of the Orchard Bee Association. Neal Williams (UC Davis) presented some interesting data in regard to Almond pollination. Mr. Clark sent an email to Mr. Williams requesting a copy of his presentation, but Williams has not replied. Mr. Clark still has an audio recording of the presentation as well as several notes on the matter. Neal Williams has said his publication is near completion and will be public, soon.

Related studies made by Derek Artz of the USDA-ARS lab can be found through the Orchard Bee Association's website, http://www.orchardbee.org

It is safe to say that growers know their orchards well enough to observe a good year of fruit set vs. a poor year of fruit set. Growers will agree that when bees are not in their orchards during bloom time, production suffers (especially in the case of almonds). Crop output per defined acreage is often not measured in any great detail in small, private orchards—but it is likely to be measured in more detail when dealing with large commercial orchards.

Beneficiaries

Commercial Growers:

Chris Healey, Scott Manning (Sweet Cherries & Peaches, Fruit Heights, UT)
Robert Fetzer (Experimental Apple Orchard, Draper, UT)
Doug Lemon (Sweet Cherries & Peaches, Willard, UT)
Dean Storee (Sweet Cherries, Kaysville, UT)
Dahle Farms (Organic Sweet Cherries, The Dalles, OR)
Paramount Farms (Almonds, Lost Hills, CA)
Munger Farms (Almonds & Blueberries, Dalles OR)
C&R Orchards (Almonds, Livingston, CA)
South Valley Farms (Almonds, Wasco, CA)

Non-commercial growers (or otherwise not specified)

35 individuals provided land toward research or requested Mr. Clark's services for pollination during the grant period. 25 of these individuals were based within Utah, the majority being residential customers throughout the Wasatch Front. Follow-ups have bee requested from most, and about half have reported. Some have had great success with their bee populations, whereas others have not.

Apis *mellifera* providers used in this study:

Dale Orvedahl (Kaysville, UT)
Dave Barton (Kaysville, UT), minimal
Andrea Adair (Riverton, UT)
Mountain View Honey, LLC

USDA-ARS Scientists (Logan), USU Extension Agents, and NRCS employees that have provided scientific, informative or commercial assistance:

Derek Artz
James H. Cane
Rosalind James
Theresa Pitts-Singer
Glen Trostle
Cory Vorel
Danny McBride

Utah companies/corporations that assisted with condo parts/fabrication:

Ace Hardware (Kaysville, UT)
Air-O Fasteners (Kaysville, UT)
Easy-To-Use Products (Farr West, UT)
Ellis Planing Mill (Ogden, UT)
Fastenal (Layton, UT)
Intermountain Wood Products (SLC, UT)
Jones Bee Company (SLC, UT)
Kimball Clark Design (Kaysville, UT)
Lowe's
MacBeath Hardwood (SLC, UT)
McDonald's Fine Woodworking (Layton, UT)
Metals USA (SLC, UT)
Mountain West Mason Bees (Riverton, UT)
NativeBees.com (Kaysville, UT)
Professional Plastics/ SPI Semicon (Ogden, UT)
Regional Supply (SLC, UT)
S3 Signs (SLC, UT)
TandyLeather (Riverdale, UT)
The Home Depot
Underfoot Floors (SLC, UT)
Utah Patio Products(SLC, UT)
Wheelright Lumber (Ogden, UT)

Utah Independent Contractors, some of which were retired/temporarily unemployed:

Andrew Clark (Layton, UT)
Charles Clark (Farmington, UT)
Erin Clark (Kaysville, UT)
Sarah Clark (SLC, UT)
Spencer Clark (Kaysville, UT)
Stuart Clark (Clearfield, UT)
Boyd Mitchell (SLC, UT)
Joseph Norberg (Kaysville, UT)
Matthew Thompson (Kaysville, UT)
Paul Sommer (Kaysville, UT)
Holt and Lindy Tucker (Farmington, UT)

Utah Volunteers

Jeremy Christensen of Streamline Plastics (Farr West, UT)
Randy and Cathy Tucker (Farmington, UT)

Sally Clark (Farmington, UT)
Salt Lake Community College Students (SLC, UT)
Weber State University Botany Dept. (currently in progress)

Organizations where NativeBees.com participated or volunteered

CSBA (California State Beekeeper's Association)
USHA (Utah State Horticultural Association)
OBA (Orchard Bee Association)

It is important to note that with the coaxing of scientists from USDA-ARS lab, myself and other Utah attendees, the OBA plans to hold a 3-day international event late in 2013 at a Utah location.

Organicology (Portland, OR)
Ogden Nature Center
Wasatch Beekeepers Association
Utah County Beekeepers Association
AM570 KNRS' "Joy in the Garden"

RESULTS from Commercial Growers:

Chris Healey, Scott Manning (Sweet Cherries & Peaches, Fruit Heights, UT)
3 Orchardist 3.0 condos, each placed with 12 f, 20 m
9 small wooden nesting blocks each placed with 3 f, 5 m
Cocoon return: 2 plugs (average of 4 f, 8m) among 35 cavities
30% female return

Robert Fetzer (Experimental Apple Orchard, Draper, UT)
1 Orchardist version 3.0 condo, placed with 13 f, 20 m
Cocoon return: 24 plugs (average of 48 f, 96 m) among 35 cavities
369% female return

1 Orchardist version 2.0 condo, placed with 22 f, 30 m
Cocoon return: 12 plugs (average of 24 f, 48 m) among 24 cavities
109% female return

Doug Lemon (Sweet Cherries & Peaches, Willard, UT)
3 Orchardist version 3.0 condos, each placed with 13 f, 20 m
Cocoon return: 0 plugs among 35 cavities
0% female return

1 Orchardist version 2.0 condo, placed with 22 f, 30 m
Cocoon return: 1 plug (average of 2f, 4m) among 24 cavities
9% female return

9 small wooden nesting blocks, each placed with 3 f, 5 m
Cocoon return: 0 plugs among 9 cavities
0% female return

Dean Storee (Sweet Cherries, Kaysville, UT)
2 Orchardist version 2.0 condos, each placed with 22 f, 30 m

Cocoon return: 6 plugs (average of 12f, 24m) among 35 available cavities
55% female return

6 small wooden nesting blocks, each placed with 3 f, 5 m
Cocoon return: 0 plugs among 9 cavities
0**% female return**

Dahle Farms (Organic Sweet Cherries, The Dalles, OR)
No feedback received

Paramount Farms (Almonds, Lost Hills, CA)
5 Orchardist version 3.0 condos each placed empty
Cocoon return: 35 plugs (avg. of 70f, 140m) among 35 cavities on each
Insufficient detailed counts of cocoons were not available due to wood expansion, numbers forthcoming
700% female return from a farmed, netted enclosure

Munger Farms (Almonds & Blueberries, Delano, CA)
3 Orchardist (O. ribifloris) version 3.5 condos each placed empty within a hooped blueberry growing operation
Cocoon return: 0 plugs among 35 cavities
0% female return

17 Orchardist (O. ribifloris) version 3.5 condos each placed empty in two trap-nesting locations. Of the condos placed, 8 contained

nesting.
Cocoon return among inhabited condos: 285 f, 370 m among 252 available cavities
285% female return* in a trap-nesting environment.
*Females discovered were a mixture of O. *lignaria* and O. ribifloris.

C&R Orchards (Almonds, Livingston, CA)

1 Orchardist version 3.0 condo placed with an *unknown* bee amount
2 Orchardist version 3.5 condos placed with an *unknown* bee amount
Nesting has occurred but no detailed feedback has been received

C&R Orchards (Almonds, Turlock, CA)

1 Orchardist version 3.0 condo placed with an *unknown* bee amount
Cocoon return: 1 plugs (average of 2f, 4m) among 35 available cavities
Female return unknown due to unknown primary establishment

1 Orchardist version 3.5 condo (experimental plastic #1) placed with an *unknown* bee amount
Cocoon return: 6 plugs (average of 12f, 24m) among *15* available cavities
Female return unknown due to unknown primary establishment

1 Orchardist version 3.5 condo (experimental plastic#2) placed with an *unknown* bee amount
Cocoon return: 4 plugs (average of 8f, 16m) among *15* available Cavities

Female return unknown due to unknown primary establishment

South Valley Farms (Almonds, Wasco, CA)
1 Orchardist version 3.0 condo placed with at least 20 f, 30m
Cocoon return: 0 cocoons among 35 cavities
0% female return

Lessons learned

a) **Establishing a nest from transplant or "imported" bees can be problematic** as there are *many* known and unknown variables that negatively affect the bees.

Problematic variables include, but are not limited to: improper previous nesting environments/techniques, shipping problems, temperature variations, the crossing of genetic variations that disrupt offspring mortality rates, the introduction of invasive species, behavioral unknowns due to climatic differences, etc.

The Orchard Bee Association www.orchardbee.org , of which I am a member and the acting Secretary, is in the process of creating *detailed* industry standards to prevent, limit and monitor the above problems. These standards will be released to the public, shortly. Furthermore, our website www.nativebees.com enables the buying and selling of local bees to local buyers.

b) **Nest establishment in the first year is likely to yield poor propagation**, whereas subsequent years the propagation is likely to improve.

c) **More flying females are likely to abscond from the targeted pollination area when released by the uninformed or the inexperienced**. Beginners are more likely to establish nests and maximize numbers from "fixed cell" bees (opposite of loose cell). Alternatively, beginners are less likely to establish nests and maximize numbers from “loose cell” bees.

Advanced O. *lignaria* keepers, with the proper knowledge and equipment, are more likely to establish superior nesting with “loose cell” bees. Unless propagators are aware of common emergence practices, there will be a greater amount of absconding females—which ultimately limits successful pollination. A free publication from the Sustainable Agriculture Network discloses proper bee release, and can be found at http://www.nativebees.com/downloads/blue-orchard-bee.pdf

Bees placed in the Storey, Manning and Lemon (not the fruit) orchards faired poorly. The factors contributing to this poor establishment are unknown. Although there were mud resources near some nesting locations and not near others, the fact there was a near zero return was perplexing. Many of the bees released in these particular locations originated near Preston, ID but developed on Almond pollen from California’s almond orchards. It is possible this particular order of adult cocooned bees could have already deceased.

d) **Environments with a low supply of discoverable mud and water negatively affect propagation.**

e) **Water/mud proximity increases O. *lignaria* propagation**—the closer to the nest habitat, the better.

f) **Environments with low pollen diversity are likely to negatively affect propagation results**, whereas environments with high pollen diversity are likely to positively affect propagation results.

g) **Although wood is an inexpensive and natural nesting material, it nonetheless rots, expands and cracks in the outdoors** (UV rays, humidity and precipitation). Its dimensional integrity is therefore compromised which will ultimately affect bee nesting. Furthermore, wood nests absorb molds that are difficult to remove. Cleaning mold from wood also causes an unwanted amount of liquid that penetrates wood pores.

The inconsistency of weathering wood also disables the particular utility designed by Mr. Clark for cocoon release, and therefore called for another substrate with greater dimensional integrity such as plastic or metal.

When a series of dried, unsealed wood sticks were tightly inserted into a sealed outer wood or aluminum housing and exposed to the elements, the interior wood expanded so much it either:

1. Burst the outer wood housing (no matter how strongly it was built), allowing the compromised nest and pollen area to be ransacked by predators or weather. In some cases, sticks fell to the ground making the nesting condo uninhabitable.
2. Expanded so tightly within the container the wooden sticks were immoveable disallowing a proper “loose cell release.” In almost all cases, the sticks *could not be removed* unless completely dried out in the oven at high temperatures (which can kill nesting adults, disrupt diapause and confuse emergence times).

h) PVC *may* be a more acceptable substrate in a trapping situation than in a managed situation. When an established population of O. *lignaria* is given the option to nest in PVC (polyvinyl chloride), bees were more likely to nest in reeds, paper straws and wood blocks. When trapping, however, CA-origin O. *lignaria* and CA-origin O. *ribifloris* DID NOT show the same behavior, as PVC was inhabited just as much as reeds and wood blocks.

i) **Bees showed greater interest in wood nests sealed in fluorescent blue spray paint** over wood nests sealed with fluorescent yellow spray paint, beeswax, linseed oil, linseed oil+beeswax, or a mixture of crushed pollen and beeswax. It was disclosed in the December 2012 Orchard Bee Association meeting that fluorescent green was also a promising color.

j) **Beeswax served little purpose**. Bees are able to see ultraviolet colors invisible to the human eye. It is one of the reasons they are attracted to flowers, which often display ultraviolet coloring. Because beeswax glows under an ultraviolet light, has some pollen residue, and also acts as a sealant agent, it was assumed to be the perfect wood sealant and act as a "homing beacon" for O. *lignaria*. This proved untrue, and O. *lignaria* had difficulty grasping onto the waxed surface. Furthermore, beeswax melted in the sun (even with an agent that increased its melting point), making the surface somewhat tacky to any sun-basking O. *lignaria*.

k) Although O. *lignaria* amplifies the almond crop, California's Almond orchards within the San Joaquin Valley are not suitable to perpetually sustain UT-origin O. *lignaria*. Efforts to sustain them are underway, but require tremendous financial investments that may or may not suit growers. It was said by an almond grower in a recent OBA meeting, "The bees will encounter a terminal cross upon arrival."

Four different almond growers—each who had spent significant man hours and resources to increase their numbers—claimed the return of O. *lignaria* females in their respective orchards was somewhere

between 35% and 250%, averaging a return of about 140%. A single grower who used O. ribifloris said the return of his females was 0%.

Due to the relatively limited supply of O. *lignaria* from the industry, the OBA decided to focus on generating enough O. *lignaria* outside difficult regions to enable future shipments to CA almond orchards. This way, volume can increase without disrupting foundational supplies of farmed populations.

Kimball Clark, 801.458.0282
info@nativebees.com or www.NativeBees.com

data you could pitch:
- solar panel results?
- wardell and trostle results
- seed purchased and used in Livingston, CA

2010-19. Developing Reduced Input Conventional Orchard Floor Management Options for Soil Quality, Weeds, and Efficient Water Use

Final Report

Personnel: Jennifer Reeve, Brent Black, Corey Ransom Diane Alston and Claudia Nischwitz.

Project summary

With rising costs of inputs, concerns over unintentional herbicide injury to trees and projected increased competition for scarce water resources, reduced input management strategies that decrease

costs and remain practical to manage are of growing interest to fruit growers. Use of cover crops is the logical solution to reducing nitrogen inputs, protecting the soil, and managing weeds. Managing cover crops in orchards can be particularly challenging, however, in arid climates where groundcover competes with trees for water. The goal of this project is to document the benefits and or tradeoffs of reducing/substituting inputs in peach production in Utah as a means of improving resource use efficiency and improving net income to growers. This report outlines the findings and conclusions from the 2011 growing season which represents the fourth year of this long-term project.

The project approach, significant results, accomplishments and recommendations

Five different combinations of organic and inorganic fertilizers and mulches have been established and the second crop of fruit harvested. These treatments were compared for their effects on fertility, tree growth and yield, weeds, and water use. We held a grower advisory meeting on June 14th 2011. We presented our latest findings from the paper and gathered input and advice on the progress of the project so far. The growers were very satisfied with the look of the trees and how the project was proceeding. Results from this project were also presented at the Utah State Horticultural Association's (USHA) winter meeting on February 1st 2011. Approximately 80 growers and industry representatives attended. A second grower advisory meeting on the project was held prior to the USHA winter meeting at which support and appreciation for how the project was expressed.

In August 2010 we held a successful field at the Kaysville Experiment station to showcase the project. Approximately 80 tree fruit growers and industry personnel attended. A survey of field day participants was conducted to assess interest, questions and attitudes surrounding organic and reduced input conventional tree fruit production. A field tour of grower farms showcasing research and innovative management practices was also held in August 2011. Two fact sheets have been published to date as a result of this work and have been distributed at the USHA winter meetings and are also freely available online at the USU Extension and Horticulture websites (see section 7). Two peer reviewed research articles have also been published that make these findings available to the wider scientific community (see section 7 for references). A chapter in the Utah-Colorado Commercial Tree Fruit Production Guide on orchard floor management that incorporates findings from this project is also currently in review. At least two additional fact sheets are currently in preparation and a project website will be going live in the next few weeks and the research site will continue to be used as a source of information and outreach to local fruit growers.

Results from in-row fertility treatments on trunk cross sectional area show that use of compost and organic fertilizer resulted in tree growth equal to NPK. Available soil nutrients and soil quality was enhanced with use of compost when compared to NPK treatments. Weed control between the compost and NPK treatments was similar. Paper mulch decreased early season weeds compared to the herbicide treatments; however by the end of the season mulch alone was insufficient in controlling weeds. There was no difference in end of season weed control between the mulch + herbicide combination and the non-mulch treatments. Early reductions in tree growth as a result of using paper mulch had disappeared by year four as were early differences in leaf N. Tree leaf N was slightly higher in NPK than compost treatments in 2011, however all treatments were within sufficiency range. Leaf P was consistently higher in compost than NPK treatments. There were no differences in leaf K. The herbicide compost treatment had significantly more fruit per tree (28 vs. 22) than the other treatments and significantly greater fruit weight (Kg / tree) than the paper NPK treatment. All treatments had greater fruit weight and size compared to the compost paper mulch

treatment. These results indicate that weed pressure not lack of fertility is responsible for yield depression in organic non tilled systems using mulch.

Soil nitrate and ammonium was significantly lower in the compost treatments, however, this did not translate into a reduction in tree growth or yield in the absence of weeds as described above, so this represents a reduction in leaching potential to the environment. There were no differences in soil nitrate an ammonium as a result of paper mulch. Unlike in 2009 and 2010 there were no differences in soil organic nitrogen between treatments in 2011. Soil carbon was significantly improved in compost and paper mulch treatments in all years, however. Microbial indicators of soil quality were also significantly improved by the use of compost and mulch, however, there was no effect of soil quality or mulch on water use. This was surprising; with time we expect improved soil quality and use of mulch to improve water infiltration, and water holding capacity leading to reduced water use in those treatments.

Novel alleyway cover crops continued to be monitored at Kaysville and Tintic to determine the amount of on farm fertility that could be generated within the orchard. At the Tintic site (a young orchard planted in 2008) vetch, alfalfa, and the alfalfa-strawberry clover-white clover mix continued to produce more biomass and suppress more weeds than grass in 2011 (92 vs. 71 % suppression). Assuming 75% of an orchard is planted to cover crops, (the remaining 25% in vegetation free tree rows) seasonal above ground alfalfa biomass contributed 267 lb N / acre, hairy vetch 234, the legume mixture 220 and grass 56 lb N / acre. The benefit to using hairy vetch is that the majority of the biomass is produced early in the season which may be most in line with tree nitrogen demand. Hairy vetch was the most weedy (77 % suppression) of all the legume treatments however, and may require periodic reseeding if self-seeding does not prove sufficient. There is also a corresponding increase in water use by the legumes relative to biomass produced compared with grass.

The biomass produced at the mature tart cherry orchard in Kaysville was much reduced in its third year of production compared and the Tintic site due to the heavy shade environment. Alfalfa produced the most biomass followed by the alfalfa-strawberry clover-white clover mix. Hairy vetch and trefoil produced comparable amounts of biomass and only slightly more than grass. The black medic treatment produced the least biomass and was almost entirely dominated by weeds. This was disappointing in light of the fact that black medic is a significant natural component of orchard alleyways at the Kaysville location. In 2011 grass and alfalfa suppressed weeds equally well (89 and 86% suppression), the legume mixture moderately well (72% suppression) while trefoil, hairy vetch and medic did not persist and contained the most weeds (5-30% suppression). Alfalfa contributed 98lb N per acre and alfalfa-strawberry clover-white clover mix 75 lb / acre of nitrogen in above ground biomass that was deposited in the tree row as mulch. Down from the 179-194 lb N contributed in 2010 and significantly less than the less shady Tintic site. These results demonstrate that legumes have the potential to produce the nitrogen needed by a young tart cherry orchard with some contribution in mature tart cherry trees, however, most legumes do not persist very long in the heavy shade environment.

So far no significant differences in arthropod dynamics among treatments has been observed suggesting that none of the treatments are either increasing or decreasing arthropod pests or beneficials over the conventional control.

Goals and outcomes achieved

We have been successful in meeting the fourth year's goals (1st year of phase 2) of this long-term project. Details of our progress under each of our goals is presented below.

Goal A. *Optimize fertility and evaluate pest dynamics*

Orchard Establishment: The new organic and reduced input peach orchard was established in April 2008. All treatments were reapplied in the spring of 2009, 2010 and 2011 as planned: **1)** conventional herbicide + conventional fertilizer (NPK) as a check, **2)** conventional herbicide + NPK to be converted to organic after tree establishment, **3)** compost + conventional herbicide, **4)** NPK + spray on paper mulch + reduced herbicide, and **5)** compost + spray on paper mulch + organic herbicide.

Tree growth and yield, and leaf and soil nutrients: Soil nutrient data (nitrate, ammonium, P, K, Ca, Mg + trace elements, pH, electrical conductivity, and texture) were taken at 0-30 cm from each plot in May 2011. In addition, soil nitrate and ammonium was measured at 0-30 cm in June, July and August. Leaf nutrient data was collected in June and July and trunk diameter, and shoot elongation measured at the end of the growing season. Trees were supplied with 60 g N per tree in the form of 16-16-16 NPK or 4 kg steer manure compost applied in mid-March. To avoid excess accumulation of P and K in the compost treatments compost rates were based on equivalent P application of conventional fertilizer. Additional N was applied in the form of urea or Nature Safe 12-0-0 in June for a total of 114g N per tree.

Weed dynamics: Weed control was achieved in 2011 with either spray on paper mulch + acetic acid or herbicide applications. Weed densities were determined in the tree row and alley way.

Peach Yield: Yield was determined in terms of number of fruit, fruit size and weight. Damage due to insect and disease was recorded and marketable yield calculated.

Arthropod ground cover dynamics: Sweep net and pitfall samples of arthropods were collected approximately monthly from May to September in the alleyways of plots. Arthropods were sorted into nine major functional groups (pest herbivores, non-pest herbivores, detritivores). A total of 375 samples were collected on ten dates in 2011. Initially, entire samples were analyzed but due to time constraints, samples were aliquoted into smaller subsamples. Data are rarefied (100 iterations) to standardize subsamples. Over 100,000 arthropods have been sorted into 111 taxonomical groups, three 'broad' and nine 'specific' functional groups. Pitfall traps and tree-trunk adhesive traps were deployed biweekly to monitor arthropods with a bias toward the tree-row treatment.

Field Bindweed control: Isolation of *Phomopsis convolvulus* from bindweed in Utah orchards was unsuccessful. Most bindweed was infected with powdery mildew which does not affect its growth. The bindweed was also frequently colonized by spider mites. The presence of both powdery mildew and spider mites may have affected the colonization of bindweed in the field by *P. convolvulus* and thus we were unable to isolate it."

Goal B. *Optimize water use and soil quality:*

Water use: Soil moisture was recorded on a weekly basis starting in June and using capacitance probes installed in the soil.

Soil quality: Soil quality (soil organic matter, pH, electrical conductivity, enzyme activity) measurements were taken at a depth of 0-10cm in June.

Goal C. *Farm generated fertility:*

Different legume combinations were selected in 2009 to test the possibility of growing fertilizers within the orchard at two locations. Each treatment at the Kaysville and Tintic locations was evaluated for cover crop and weed biomass three times during the 2011 growing season before mowing. The six treatments were as follows: **1)** black medic, **2)** hairy vetch, **3)** alfalfa, **4)** clover alfalfa mix, **5)** orchard grass, and **6)** birds-foot trefoil in a mature tart cherry orchard at the Kaysville Research Station. An additional four treatments **1)** alfalfa, **2)** clover alfalfa mix, **3)** hairy vetch, and **4)**

orchard grass are located in a 2 year old cherry orchard in Tintic Valley, Utah. The treatments were assigned to 6 replicate plots measuring 12 x 15ft, in a randomized complete block design.

Beneficiaries

Students: Two undergraduate students were trained in research methods and data collection as a result of this project.

Grower advisory meeting: We held a grower advisory meeting on June 14th 2011. We presented our latest findings from the paper and gathered input and advice on the progress of the project so far. The growers were very satisfied with the look of the trees and how the project was proceeding.

Winter meeting: Results from this project were also presented at the Utah State Horticultural Association's winter meeting on February 1st 2011. Approximately 80 growers and industry representatives attended. A second grower advisory meeting on the project was held prior to this winter meeting.

Fact sheets: Two fact sheets have been published to date as a result of this work and two peer reviewed research articles. See below under additional details.

Lessons Learned

Successfully collecting the fourth year of data from this orchard has positioned us to be successful towards meeting out long-terms goals of testing and developing organic and reduced-input management strategies for tree fruit production in arid climates with cold winters, and in developing an outreach program for the projects. This year represented the first year of our production phase. We learned that compost can provide sufficient nutrients for growing a good crop of peaches provided weed control is good. The potential for loss of yield in organic production is therefor a result of inadequate weed control not lack of nutrients. Compost also improves soil quality and nutrient availability in high pH soils. The cost of compost is greater than NPK, however. Further research is needed to quantify the benefits of compost to the system as a whole in order to calculate a true cost benefit ratio. Mulches provide good early season weed control but provide insufficient weed control later in the season without additional use of herbicides.

There were benefits of mulch in terms of improved soil quality and reduction in the number of herbicide sprays needed to achieve good weed control. So far we have not seen significant reductions in water use as a result of using mulch, however. This is surprising and indicates it might take several years before expected water savings are realized. The cost of mulch and lack of water savings may prove prohibitive unless a premium can be obtained for the fruit such as in certified organic production.

Legumes establish well in both young and mature orchards and some species hold the potential to produce most if not all the nitrogen needed. This saving in terms of fertilizer inputs is balanced by increased irrigation water inputs. Legumes did not persist in the dense shade of the mature tart cherry orchard although persistence in younger orchards has been very good. This suggests that legumes might be best used in the establishment phase of an orchard. We will continue to monitor the performance of these systems in the second and third year of the production phase to determine best management practices for reduced input approaches to orchard management.

Contact person for the project.

For additional details and questions regarding the project please contact:
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Additional information available (e.g. publications and websites).

Rowley, M.A., B.L. Black, C.V. Ransom, J.R. Reeve, and J.E. Creech. 2011. Alternative alleyways for tart cherry orchards. *Journal of the American Pomological Society* **65**:208-217.

Rowley, M.A., C.V. Ransom, J.R. Reeve, and B.L. Black. 2011. Mulch and organic herbicide combinations for in-row orchard weed suppression. *International Journal of Fruit Science*.11:316-331.

Alston, D. and A. Tebeau. 2011. European earwig (*Forficula auricularia*). Utah State University Extension and Utah Plant Pest Diagnostic Laboratory Fact Sheet ENT-145-11 (3 pp.), Logan, UT. http://extension.usu.edu/files/publications/factsheet/earwig-tf.pdf.

Black, B.L. and Rowley, M. Orchard Floor Management. 2011. Utah State University Extension. http://extension.usu.edu/files/publications/publication/Horticulture_Fruit_2012-01pr.pdf

Roper, T., M. Rowley, M. Murray and B. Black. Orchard Floor Management. In: The Utah-Colorado Commercial Tree Fruit Production Guide. Eds. M. Murray and H. Larson. Utah State University Extension and the Western Colorado Research Center, Colorado State University. (in review).

20. Evaluation of Puffer Mating Disruption to Manage Codling Moth

Specialty Crop Block Grant FINAL Report

Project Title: Evaluation of Puffer Mating Disruption to Manage Codling Moth **(awarded 2011)**

Partners:

Marion Murray, Utah State University Extension
Diane Alston, Entomologist, USU Extension
Utah State Horticultural Association

Project Summary

This project tested the efficacy of a money-saving mating disruption product to manage codling moth in apple orchards in Utah. The product is called Checkmate Puffer CM (Suterra Corp., Bend, OR), and it works by emitting a puff of codling moth pheromone (at 1 puffer/acre) into the orchard air every 15 minutes. The air becomes saturated with female pheromone, preventing males from finding females for mating, and hence, reducing injury to the fruit.

All of the proposed objectives of this two-year project were completed without any problems or delays:

1. *Demonstrate a cost-effective, labor saving, efficient method of delivering pheromone in a mating disruption program.*
    a. We established two demonstration orchards and presented results.
2. *Determine if puffer technology works in commercial orchards in Utah.*
    a. We found that puffer technology works best on large orchards (35+ acres) with low codling moth population.

The primary insect pest for commercial growers of apple and pear trees in Utah is codling moth. The adult lays eggs on the fruit, and the larvae bore into the flesh. Without any control, orchards in Utah can have 70% - 90% damage to fruit. Many specialty crop orchards that have 10 or more acres in Utah use a technology called mating disruption as an effective, low-chemical use tool to manage this pest. The most widely used method of mating disruption is to hand-apply small dispensers to trees, at a rate of 200-400 per acre. Each dispenser emits a small amount of pheromone that mimics the female codling moth, preventing males from mating with females.

Hanging dispensers by hand is a labor-intensive process, averaging about $50/acre. During an era of reduced labor availability, increased costs, and relatively lower returns, Utah operations are looking for new options to save on labor and other costs. The application rate of the puffer is one per acre, with a labor cost of about $10/acre. For a 40-acre orchard, material costs of the two options are the same, but the orchard using Puffers will spend $1,600 less.

Puffer technology is used successfully in specialty orchards in California, Oregon, and Washington, and by a few in Idaho. From this project, we learned that in Utah, Puffers do last throughout the entire growing season, and they are most effective on orchards 35 or more acres in size where the codling moth population is low.

Project Approach

Objective 1: Demonstrate a cost-effective, labor saving, efficient method of delivering pheromone in a mating disruption program.

The project applicants (Murray, Alston) received permission from two fruit operations in which to conduct this demonstration and study. Larger-sized orchards were selected based on the manufacturer's recommendation. The first site, located in Payson, was a 35-acre apple orchard, and the second site, located in West Mountain, was a 40-acre apple orchard. For each site where Puffers were used, we also included a nearby 10-acre apple orchard using the hand-applied mating disruption dispensers for comparison.

The Checkmate Puffer CM units were donated by Suterra, the manufacturer. We deployed the puffers before bloom, on April 15, 2011 and again on April 9, 2012, throughout the two orchard blocks at a rate of one per acre, based on an aerial map provided by Suterra. Using factors such as wind direction and prior insect trapping records, puffers were strategically placed high in the tree or

on posts to minimize codling moth fruit injury. The Puffer product is comprised of a cabinet that encloses a puffer aerosol can. For this project, the cabinet was programmed to release pheromone sprays at 15-minute intervals, starting at 6 pm and stopping at 6 am. The hand-applied dispensers were hung by the operation at the same time as the puffers.

To introduce the puffer technology to specialty crop growers, Murray and Alston demonstrated how Puffers work and how they are installed to commercial growers in Utah County at a tree fruit field day in 2011 and 2012 at one of the Puffer test orchards. Murray also discussed the use of Puffers at the Utah Horticultural Association Annual Convention in winter 2012 and winter 2013. The information was also included in an article in the USU Tree Fruit Advisory newsletter as well as in the Intermountain Tree Fruit Production Guide. At all events and in all publications, we also noted the financial advantage of using Puffers where codling moth populations are low.

Objective 2. Determine if puffer technology works in commercial orchards in Utah.
In each treatment block, we hung insect traps to help determine effectiveness of the Puffer mating disruption. (The more moths the traps catch, the lower the effectiveness of the mating disruption.) We hung 20 traps in each Puffer block and 6 traps in each hand-applied block, using a pheromone lure designed for use in mating disruption orchards (CM-DA Combo (Trécé)). We also hung 20 additional traps in each Puffer block using lures designed for non-mating disruption orchards. Any moths caught in these types of traps could mean a failure of the Puffers (no moths were caught in these traps in either orchard in both years).

All traps were checked every week by Murray and a hired student, and the lures were changed as suggested by the manufacturer. When checking the traps, the moths were removed and stored in alcohol, and the student assistant later determined the gender of the moths using a microscope.
For both seasons, we measured codling moth damage to the crop in each test orchard at the end of codling moth generations one and two (typically early July and mid-August, respectively). Approximately 1,000 apple fruits were visually inspected in each orchard treatment for larval entries. Fruit with suspect larval entries were cut open to verify the cause. The percentage of fruit with larval entries (new or old) was then determined as an average of both generations.

Average weekly trap catch results for 2011 and 2012 are shown in Tables 1 and 2 below. In the Payson orchard, where the codling moth population was low, the trap catches in the Puffer block were no different from the trap catches in the hand-applied mating disruption block. Figure 1 shows a graph of the weekly trap catch in the Payson orchard. The West Mountain orchard was a site with a high population of codling moth, and there were more moths caught in the traps in the Puffer block than in the hand-applied block. In that orchard, neither the Puffers nor the hand-applied mating disruption was effective, and farm, even though it received supplemental insecticides for codling moth, had unacceptable injury for both treatments.

Table 1. Average weekly codling moth counts for all traps in the puffer block and hand-applied comparison block at the Payson and West Mountain orchards in 2011.

	Payson Orchard		West Mountain Orchard	
Date	**Puffers**	**Hand-applied**	**Puffers**	**Hand-applied**
05/16/11	0.0	0.0	0.3	0.1
05/23/11	0.0	0.0	0.4	0.2
05/31/11	0.0	0.0	0.3	0.1
06/06/11	1.4	0.8	6.9	6.3
06/13/11	0.1	0.2	7.3	2.5
06/20/11	0.4	0.3	9.5	2.6
06/28/11	0.0	0.0	13.2	2.3
07/06/11	1.5	0.0	11.9	2.9
07/11/11	0.0	0.0	7.2	0.8
07/18/11	0.0	0.0	10.2	4.5
07/28/11	0.1	0.5	0.9	0.2
08/02/11	0.1	0.0	0.3	0.2
08/18/11	0.6	0.0	7.4	3.6
08/25/11	0.2	0.0	5.8	5.7
09/10/11	0.1	0.0	4.4	2.8
10/22/11	0.0	0.0	0.2	0.2
TOTAL	4.5	1.8	86.4	108.9

Table 2. Mean codling moth trap catch per week for all traps in the puffer block and hand-applied comparison block at the Payson and West Mountain orchards in 2012.

	Payson Orchard		West Mountain Orchard	
Date	**Puffers**	**Hand-applied**	**Puffers**	**Hand-applied**
5/02/12	0.2	0.0	0.4	2.0
5/16/12	2.2	0.7	13.8	17.5
5/22/12	0.3	0.5	12.2	29.3
6/06/12	0.2	0.0	31.4	42.5
6/20/12	0.1	0.0	15.1	27.0
6/27/12	0.2	0.3	6.0	23.0
7/11/12	0.2	0.3	3.0	8.8
8/02/12	0.8	0.5	5.9	8.0
8/22/12	0.6	0.3	4.0	18.8
9/11/12	0.1	0.2	1.6	4.0
9/28/12	0.0	0.0	0.1	0.67
TOTAL	4.75	2.83	93.2	181.6

Figure 1. Average weekly codling moth trap catch for all traps in the puffer block and hand-applied comparison block at the Payson orchard in 2011 and 2012.

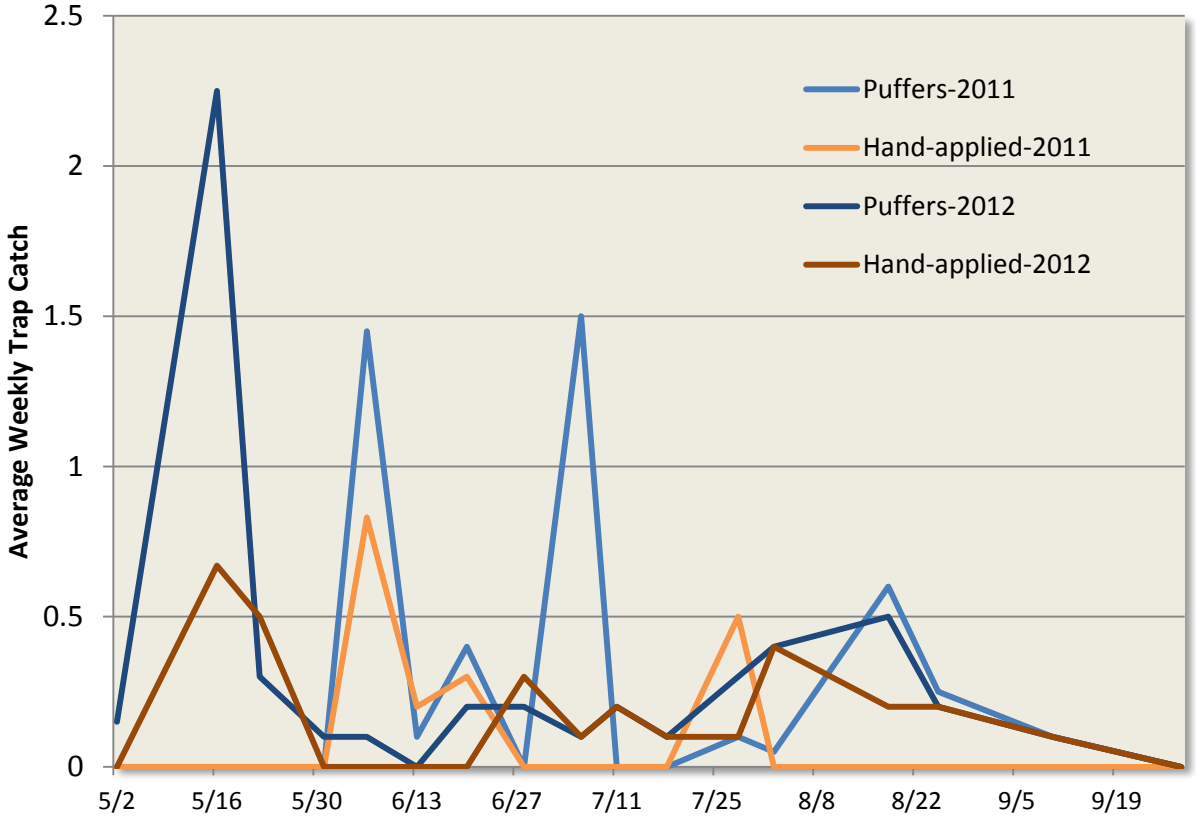
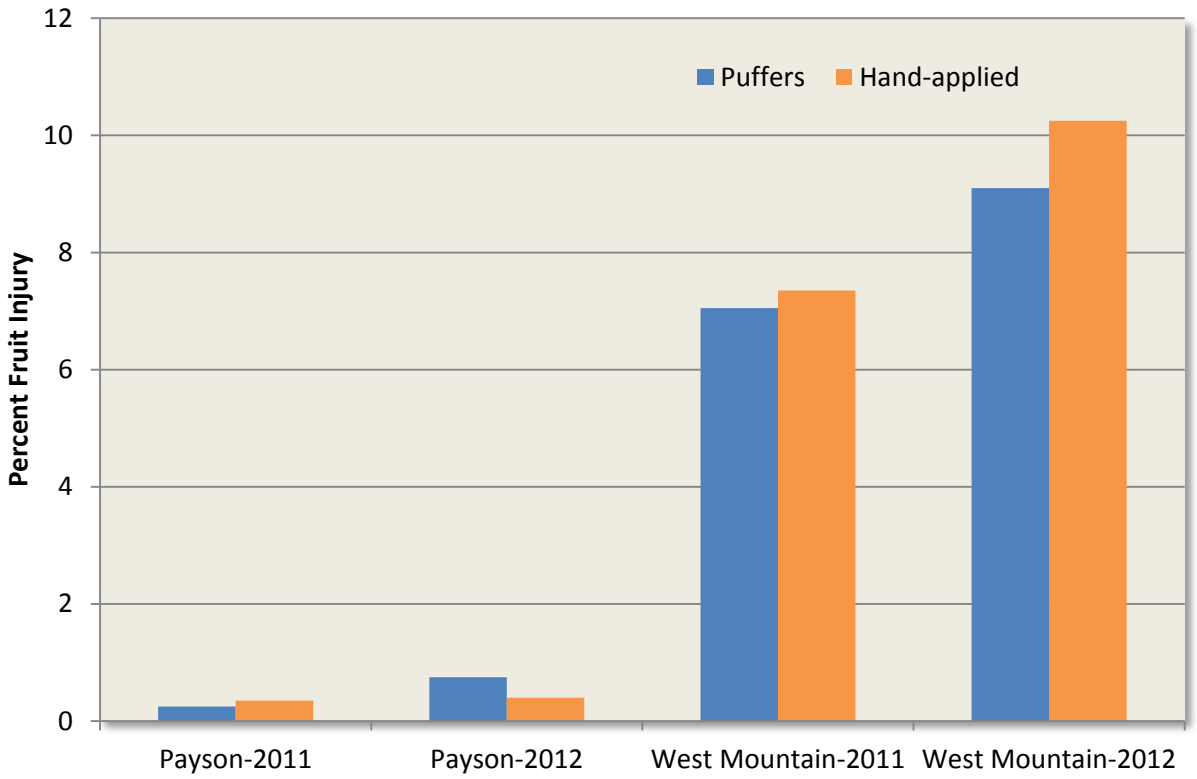


Figure 2 below shows the differences in fruit injury between the two treatment types for each orchard in each year. In general, injury in both the Payson orchard (where codling moth populations were low) and the West Mountain orchard (where populations were higher) was similar between the Puffer and hand-applied mating disruption treatments. In the West Mountain orchard, however, the amount of injury that occurred under both treatments showed that mating disruption in general does not work under very high populations.

Figure 2. Percent injury (out of 1,000 fruits assessed) caused by codling moth on apples in each orchard and each treatment type in 2011 and 2012.



To ensure the operation of the puffer units, Murray tested 20% of the units twice during each growing season. Murray checked the Puffer batteries and weighed the aerosol canisters to determine if their contents were dropping evenly among the Puffers. No defects or anomalies were found.

To provide a visual map of the puffer locations and overall trap catches, we recorded each puffer and trap location using a Trimble GPS. The student assistant then used ArcMap to produce the maps shown under "Additional Information." The maps show the concentration of the codling moth populations on each farm in relation to the puffer units.

Goals and Outcomes Achieved

We were able to see changes in grower behavior in codling moth pest management as a result of this project. The final results of this study were presented at the 2013 Utah State Horticulture Association meeting, held in Provo, UT. Attendance was 76 growers. We surveyed the audience at that time to determine which growers were considering using Puffers for the 2013 season, and knowledge gained. The following outcomes (# 1 and 2) were found on farms that adopted the use of Puffers, particularly since Puffers were found to work on blocks 35 acres in size or more with a low codling moth population.

1. **Increased adoption of mating disruption for codling moth, thus reducing pesticide inputs.** In Utah, codling moth control requires the greatest amount of pesticide inputs on apples and pears, costing growers thousands of dollars yearly, and contributing to pesticide

exposure of farmworkers and natural resources. Farms that use mating disruption apply 75% fewer pesticide sprays than conventional farms. Before this project, approximately 70% of the apple growing acreage in Utah that qualifies (i.e., greater than 10 acres in size) was under codling moth mating disruption, using hand-applied dispensers (approximately 1,100 acres). After this project, we found from the survey results and personal communication with growers that close to 80% of the qualifying apple acreage is now using mating disruption (a mix of hand-applied and Puffers), and that at least 600 acres had switched to using Puffers.

We will continue to measure codling moth damage, total trap catches, and the number of pesticide sprays in subsequent years to demonstrate reduction of total insecticide use and the shift to mating disruption in Utah.

2. **Increased cost savings for apple and pear growers using Puffers.** Results of the survey showed that growers that switched from using hand-applied mating disruption to Puffers for estimated a savings of $32/acre. For one 400-acre operation, this amounted to a savings of $12,800 in 2012. At least 600 acres switched to using Puffers, and several growers commented on the survey that they are considering switching to Puffers in the future.

   The survey also showed that use of Puffers allowed laborers to spend time on other important activities such as pruning and thinning. Mating disruption supplies need to be hung in the orchard by bloom, at a time when many activities are happening and workers are busy with other orchard projects. This project showed that a crew of two takes a full day to hang hand-applied dispensers on 35 acres, whereas those same two take just 1-2 hours to hang Puffers.

3. **Training opportunity for student employee.** One USU undergraduate student was hired from the biology department to help with this project over the 2-year period. He received training in insect identification, monitoring and trapping techniques, and a control strategy (mating disruption) that is an emerging option for larger organic and conventional growers. He also learned valuable computer skills including ArcGIS. The student will graduate in December 2013 with a degree in Horticulture.

Beneficiaries

This project serves apple and pear growers in the state who have orchard blocks of 35 acres or more in size and low codling moth population (approximately 10 large operations covering 1,200 acres). The primary goal is cost savings, where growers that use Puffers save up to $40/acre in labor costs over traditional mating disruption. At a time when farm labor is difficult to find and tightening budgets, this small amount could net huge savings for small specialty crop farms. Data from this study could apply to apple orchards in Colorado and Idaho that are similar in elevation and climate to Utah's.

Lessons Learned

1. We are fortunate that we could test this treatment option on actual grower farms. We worked closely with the farm operations throughout the process, by sending trapping and injury data

throughout the season. The owner of the farm that had high levels of injury during the Puffer treatment project reported that the injury level was actually similar to what he has seen in past years. We consulted with him on any supplemental codling moth treatments and he was not dissatisfied with the results.

2. We learned from the field day activities that specialty crop growers appreciate seeing a demonstration of any new treatment option. There was much interest in the use of Puffers, but growers had never considered it an option for Utah farms because of the uncertainty of how they effective they are, how they are applied, and their operation and maintenance.

Additional Information

Diagram of codling moth population density at the West Mountain farm in 2011 (left) and 2012 (right). The large black border is the puffer field, and the blue border is the hand-applied comparison field. The black squares represent the Puffer units.

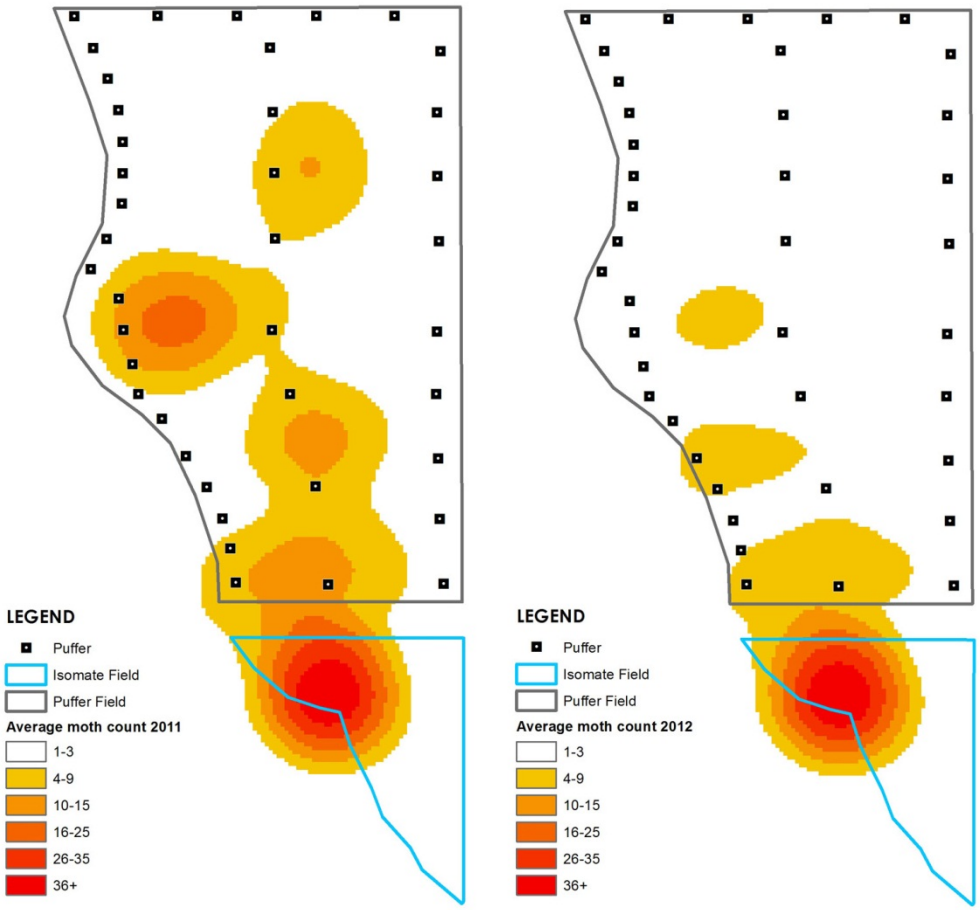
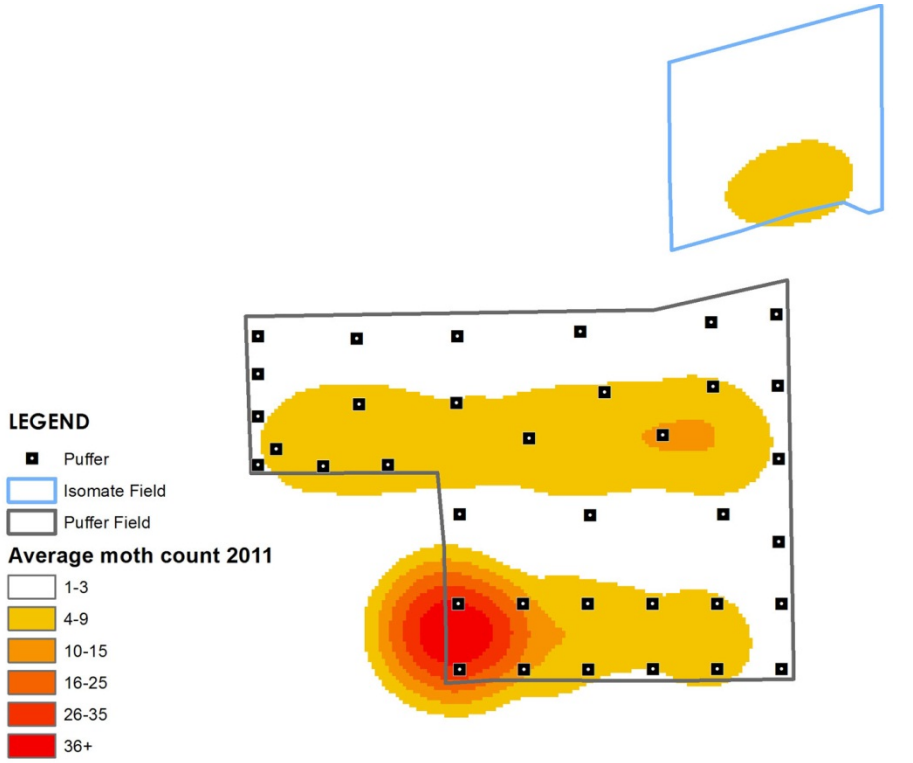
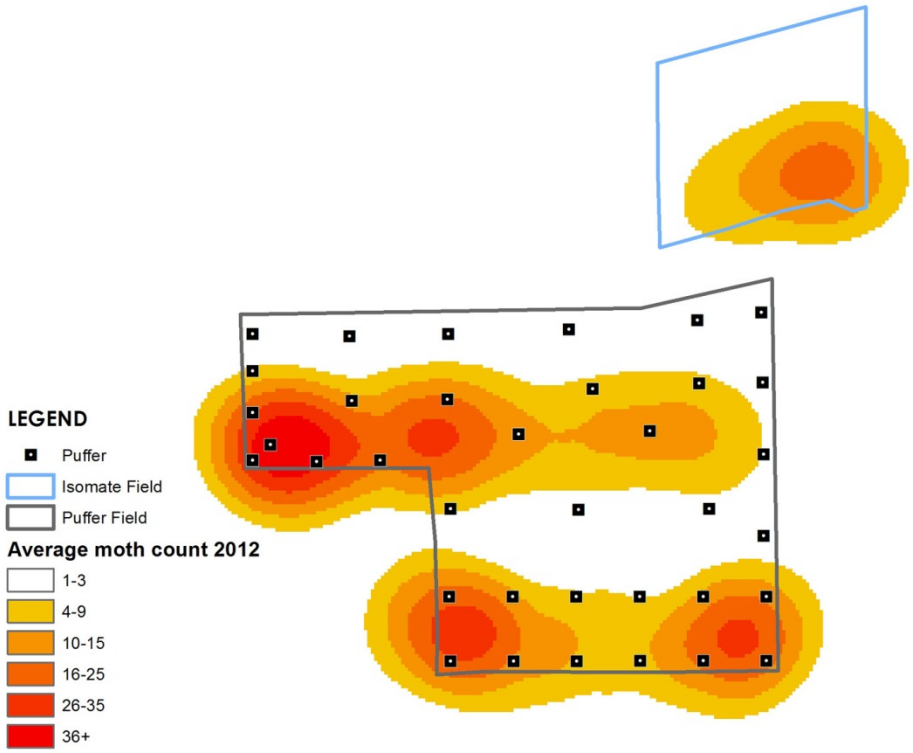


Diagram of codling moth population density at the Payson farm in 2011 (top) and 2012 (bottom). The large black border is the puffer field, and the blue border is the hand-applied comparison field. The black squares represent the Puffer units.





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2010-21. Determining Incidence of Three Diseases in Utah Stone Fruit Orchards

Marion Murray, Utah State University, and Partner: Utah State Horticultural Association

Final Report

Project Summary

We initiated this project due to an increase in tip dieback symptoms in peach orchards in Utah starting in 2009. Speculation as to the cause led some growers to apply fungicides that may have been unnecessarily applied, or may have been applied at the wrong timing. To understand the problem, the first ever formal survey of stone fruit diseases was conducted in Utah.

This project surveyed Utah stone fruit orchards for three specific diseases: brown rot (*Monilinia fructicola*), bacterial canker (*Pseudomonas syringae*), and cytospora canker (several *Cytospora* sp.). Brown rot has never been found in Utah, but is a problem on peaches in some parts of the West including California and parts of Colorado, resulting in yield losses due to diseased flowers and fruit and tip dieback. *Pseudomonas* is a bacterial disease that is often found on sweet cherry but rarely on peach. Cytospora is a common pathogen of peach. Both *Pseudomonas* and cytospora cause stem cankers and require proper pruning, plant health maintenance, and prevention of wounds, rather than chemicals to manage.

On the ten farms surveyed, coryneum blight was the most common pathogen found (although we were not directly surveying for it). Coryneum does cause tip dieback. Cytospora was the next most common pathogen, followed by *Pseudomonas*. *Monilinia* (brown rot) was not found on any samples collected in this survey, and we concluded that the tip dieback growers were seeing was caused by winter freeze injury, coryneum blight, or cytospora. Results of this project will help to build the capacity of Utah Plant Pest Diagnostic Laboratory in diagnosing plant diseases accurately and provide control recommendations, and will enable growers to more profitably implement stone fruit disease IPM programs.

Project Approach

The lead investigator (Marion Murray, USU) received training from Colorado State University in spring 2010 in identification techniques for stone fruit pathogens, including preparation of specialized media, fungal identification, and incubation techniques. Marion then trained a student assistant in

2011 to help work on the project. Marion and the student assistant both collected plant material and isolated fungi. Marion did the diagnoses and the GPS plotting and GIS mapping.

Orchard blocks sampled in this survey

Orchard Name	Location	Size (Acres)	Crop	Predominant Pest
Box Elder Orchard 1	Perry	4	peach	cytospora canker
Box Elder Orchard 2	Perry	6	sweet cherry	bacterial caner
Box Elder Orchard 3	Perry	15	peach	cytospora canker
Box Elder Orchard 4	Perry	12	peach	cytospora canker
Box Elder Orchard 5	Perry	3	sweet cherry	bacterial caner
Utah County Orchard 1	Payson	30	peach	cytospora canker
Utah County Orchard 2	Genola	15	sweet cherry	bacterial caner
Utah County Orchard 3	Santaquin	32	peach	cytospora canker
Utah County Orchard 4	Santaquin	12	peach	cytospora canker
Utah County Orchard 5	West Mountain	35	sweet cherry	bacterial caner

In 2011 we surveyed 10 stone fruit orchard blocks on 3 different dates in May, June, and August. At each survey date, we checked 10 trees by walking a random zigzag pattern and examining every tenth tree. We observed trees for symptoms (oozing twigs, dieback, blighted flowers, rotted fruit). Where they occurred, we collected tissue from that tree. During the May sampling date, we also collected healthy-looking flowers because the pathogen, *Monilinia*, causes latent infections in flowers, and symptoms do not show up on fruit until harvest. We plotted each symptomatic tree using a Trimble GPS.

Examples of symptomatic tissue collected

bacterial canker (*Pseudomonas*)

cytospora canker

secondary root rot introduced by insect

bacterial canker damage to fruit

The symptomatic plant tissue that was brought back to the lab was then identified to cause. We cultured fungi or bacteria from the samples using incubation to induce sporulation (cytospora), plating plant tissue onto potato-dextrose nutrient agar (cytospora, *Monilinia*, coryneum blight), or crushing plant tissue in water and streaking a droplet across specialized nutrient media for growing bacteria (*Pseudomonas*). When necessary, we wet-mounted spores for identification and examined them under a microscope.

Of the 100 asymptomatic flowers that were collected and cultured, none were positive for *Monilinia*. Most did not grow anything on the agar, and a few grew saprophytic fungi (non-pathogenic) that would be found anywhere in nature.

We collected a total of 248 plant samples with symptoms. Most samples were dead or dying twigs with visible gumming, while the rest consisted of leaves and fruit. Cytospora was identified most often, on 63 samples, and bacterial canker was identified on 34 samples. Although we were not looking for coryneum blight (shothole), this disease was found on 92 trees (based on visual observation). The remaining 151 samples were all diagnosed as caused by abiotic factors (primarily temperature extremes) or mechanical injury. Most of those cultures did not grow any fungi, while the remaining grew saprophytic (non-disease-causing) fungi, such as *Pennicillum*, *Alternaria*, or *Cladosporium*.

In spring 2010, we trained county agriculture Extension agents to identify brown rot, cytospora, and bacterial canker. In 2011, we received four brown rot suspected fruit samples (*Monilinia*): one from Box Elder County, one from Salt Lake County, and two from Utah County. All were negative for *Monilinia*, and were determined to be a secondary rot introduced by stink bug or other insect feeding, and from split pits.

Although the disease, brown rot, was not found, we did see that the disease, bacterial canker, is more widespread than originally thought. The main reason for this is due to the cool, rainy springs northern Utah has experienced for the last 3 years. Incidence of this disease would certainly increase

if we had not identified its widespread presence and notified growers. Through outreach efforts, growers can initiate management of this disease, as recommended by USU, to prevent further spread.

This report has been posted onto the IPM website at: https://utahpests.usu.edu/ipm/htm/fruits/tree-fruit-report, along with the bulleting showing brown rot symptoms that was distributed to growers at field meetings and to Extension agents. Marion included a short article on brown rot in the Tree Fruit IPM Advisory in spring 2011, and will include a more in-depth report of this project in a spring 2012 edition. The advisories are emailed to a subscription of 3600 fruit growers in Utah. Marion will present results of the survey to growers at the 2012 Utah State Horticultural Association, attended by approximately 80 growers.

Goals and Outcomes Achieved

USDA REVIEW

You mention that growers are applying less fungicide. How many growers are now applying less fungicide? See text in red below.

1. The Utah Plant Pest Diagnostic Lab, located on the USU campus, is now aware of the diseases that commonly occur on Utah stone fruit trees. Cultures collected from this survey were donated to the Utah Plant Pest Diagnostic lab, where they may be used to help the lab improve response time to clients submitting stone fruit disease samples.

2. Results of this project will be used by Marion Murray and the USU Extension plant pathologist to develop integrated pest management strategies for stone fruit diseases through the production of fact sheets and information output in the weekly Tree Fruit IPM Advisories. Marion will also incorporate results of this project into the 2012 Utah-Colorado Tree Fruit Management Guide.

3. Knowing which diseases are established in stone fruit orchards will allow Extension agents and specialists the ability to provide early warnings of potential disease outbreaks so that appropriate control measures may be accurately advised.

4. A long term outcome is that we expect to see improvements in profitability for Utah stone fruit growers due to improved ability to properly identify these disease symptoms. There have already been improvements in 2011. In a pre-survey for this project, 40 operations reported that they had sprayed on average, two treatments for brown rot in spring of 2009 and 2010. An oral interview with a selection of 20 of those growers in fall 2011 revealed that all 20 had stopped those fungicide treatments as a result of this project, saving upwards of $34/acre for one treatment. Pesticide applications should only be made when exact confirmation of a particular disease is made. It is important that growers are aware that diseases managed with cultural controls, such as cytospora and bacterial canker, should be pruned out to prevent spread and losses.

5. Maps showing prevalence of cytospora and bacterial canker will be used by Extension faculty and county agriculture agents at Utah State University as well as by the Utah State Horticultural Association. Growers and others will know where the disease was occurring in 2011 and could use the information for prevention of spread, for establishing new orchards, and for removing old orchards. The maps also show soil types, which can affect tree health, which in turn affects tree susceptibility to disease. For example, peach trees growing on the Pleasant Vale gravelly loam soil (see map, Utah County Orchard 4) that do not receive enough irrigation, will be stressed, and more susceptible to cytospora canker.

6. This project provided a training opportunity for a USU student employee majoring in biology. The student (3rd year level) learned about disease identification, monitoring and sampling techniques, sterile culturing and incubation techniques, photography, and management strategies. The experience he gained working on this project will help him in his senior level classes, as well as in finding a job in his area of interest, which is sustainable landscaping.

Beneficiaries

All commercial operations growing stone fruits in Utah will benefit from this project. Approximately 200 operations grow stone fruits in Utah on 5,181 acres. Utah is second nationally in tart cherry production, comprising 47% of all Utah grown tree fruits, and 61% of Utah stone fruits (3,150 acres). Peach is the second most commonly planted stone fruit, comprising 1,278 acres (26% of the total stone fruit acreage). Residential backyard growers will also benefit as this group contributes significantly to pesticide applications, and having a greater understanding of fruit tree pests (through the weekly Tree Fruit IPM Advisories and Master Gardener outreach activities) will help them to fine-tune applications.

Lessons Learned

3. Weather patterns affect plants and pathogens, and frost causes dieback in stone fruit more often than previously thought. Weather the past three springs was cold and moist, ideal conditions for spread of cytospora, bacterial canker, and coryneum blight, but not for brown rot. Weather conditions change from year to year so we will continue our search for unusual symptoms and other pathogens in our daily research and monitoring activities in Utah orchards.

4. Due to Utah's overall drier climate, symptoms may appear differently than what is recorded in the literature, or may affect only certain plant parts. It is important to collect plant specimens for culturing fungi that may not represent the typical symptoms for that target pathogen.

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