FINAL REPORT
April 2011

Specialty Crops Block Grant Program,
Utah Department of Agriculture and Food

Cooperative Agreement No. 12-25-B-0848
Original Termination Date: March 31, 2010
Extension for Two Projects to March 31, 2011

As required by the Specialty Crop Block Grant Program, the Utah Department of Agriculture and Food (UDAF) is providing the "Final Report" for Cooperative Agreement No. 12-25-B-0848. Under the agreement, sixteen (16) projects were approved in 2009 with a termination date of 3-31-10. Fourteen of the projects were completed by the deadline and provided UDAF a "Final Report" included in last year's Annual Report. Two of the projects: Inspecting and Auditing Food Plants ($3,750); and, Locating, Documenting, and Collecting Clones of Native Utah Plants ($5,294); received extensions to 3/31/11 and provided Annual Reports last year.

The 'final reports' of the 14 projects were previously approved, but are again provided along with the 'final reports' of the two extended projects completed prior to 3/31/11, thus compiling the "Final Report" for Cooperative Agreement No. 12-25-B-0848. Project reports are provided in the following order (The two new 'final reports' are G. and O.):

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A Standard Form 269A, Financial Status Report, is provided along with the written report which is a summation of the financial performance of all projects. A breakdown of grant money along with recipient outlays and total outlays for each project is provided on page 68 of this report.

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A. Improving Orchard Irrigation

Outline of the issue, problem, interest, or need for the project: 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. In some cases, this has led to over-irrigation 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. 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 (Shephardson et al., 1970). 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, the process 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. 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). Damaged and weakened trees require additional chemical inputs for addressing secondary insect and disease problems. 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. There are two potential benefits of this approach. First, a crop can be produced with less water. Second, a well-timed and precise level of drought stress can result in a desirable growth response. RDI is now widely used in the commercial production of wine grapes, as well-timed drought stress reduces fruit water content, but results in increased concentration of flavor and color compounds, which results in a higher quality wine. RDI has also been tested in prunes, another stone fruit crop, with promising results. Since prunes are dried after harvest, RDI applied during stage III fruit development actually increases the quality of the harvested product. Since much of Utah's tart cherries are now dried after harvest, RDI may be a means of not only conserving water inputs, but actually increasing the quality of the harvested product.

Approach: Develop and implement tools and techniques for improving orchard irrigation management for Utah, by: (1) adapting the orchard weather station network for evapotranspiration estimates, (2) implementing the use of soil moisture monitoring techniques to guide irrigation decisions; and (3) investigating RDI as a water-saving strategy in tart cherry orchard management.

Specific approaches for 2009 included:

1. Upgrade weather stations for collecting ET data to be disseminated via the internet to growers.
2. Carry out a third season of RDI management and continue to evaluate effects on fruit quality and orchard health.
3. Collect feedback from participating orchards on orchard water use.
4. Report progress and results at the winter fruit meetings.

Goals Achieved:

Irrigation scheduling – Orchard weather stations: The orchard weather station network is now accessible online through the Utah Climate Center website (climate.usu.edu). Direct reporting of evapotranspiration (ET) model output is posted to this website daily. Some of these stations have been equipped with soil moisture sensors, but these sensors have had some reliability and calibration issues that have prevented this information from being reliable enough for disseminated to growers.

Irrigation scheduling – on-site data loggers: A series of four automated data loggers were deployed in commercial orchards in 2009 to assist growers in using soil moisture monitoring equipment. Four operations were included as cooperators. Three of the 4 cooperator operations had equipment in multiple orchards. The total number of orchards where the technologies were implemented is 8. Data loggers were installed in both apple and tart cherry orchards, with sensors placed at 30, 50 and 80 cm soil depths. Orchard locations were in West Payson (1), Payson (1) and in North and South Santaquin (2). Both Watermark and M.K Hansen brands of data loggers were used. Feedback was solicited from grower participants and the data loggers were showcased at the summer field day.

Regulated Deficit Irrigation: During 2009, a third year of regulated deficit irrigation (RDI) was carried out at the cooperators tart cherry orchard near Santaquin, Utah. Replicate 36-tree blocks were subjected to one of five irrigation levels from pit hardening to harvest. Data were collected from the central 10 trees in each block to compare tree stress (mid-day stem water potential), fruit size, fruit quality, commercial yield and packout. Unlike during the previous seasons, the orchard set an extremely large crop load which resulted in very different treatment effects compared to previous years.

During the 2009 irrigation research, we found some serious negative effects from deficit irrigation use. With an extremely heavy crop load contributing to the tree stress, irrigation treatments that were successful in previous years resulted in dramatic reductions in packout of harvested fruit, with the more sever treatments resulting in tree death. At this time, we need to refine our procedures before recommending this approach for broad commercial implementation. We are currently focusing on methods for better monitoring tree stress so that growers can confidently impose deficits without risking the loss of their crop and orchards. Therefore, written recommendations for distribution throughout Utah and the Intermountain West may not be ready in 2010.

Results, information, updates and new features have and will continue to be posted to the USU Extension and Utah Climate Control websites. Fact sheets generated for this project are also posted on the Extension website which can be accessed at http://extension.usu.edu/publications. The direct address is http://extension.usu.edu/htm/publications/by=category/category=186. The Utah Climate Center website is now equipped to provide near real-time updates of weather conditions, including updates on calculated water use. This can be accessed under "Orchard Weather Data" which is under the "Plant Management Tools" button. The main web address is http://climate.usu.edu. The direct link to the orchard weather network is: http://climate.usurf.usu.edu/stationstuff.php.

Time at the 2009 winter fruit meetings did not allow for an irrigation panel discussion. However, the project manager, Dr. Brent Black, polled participants and communicated their experiences both at the 2009 summer farm tour and at the January 2010 winter meeting.

Results, conclusions and lessons learned:

Irrigation scheduling – Orchard weather stations: Commercial fruit growers are becoming more and more accustomed to accessing the online data products from the orchard weather stations. In addition to ET data for irrigation, pest management models and real-time temperature data are increasingly being accessed.

Irrigation scheduling – on-site data loggers: The West Payson orchard where the data logger and Watermark sensors were located experienced a catastrophic outbreak of fire blight, a bacterial disease, and the entire orchard was removed mid-season. Consequently, the grower was not able to use the data logger system. Data from the Watermark brand data logger installed in the Payson orchard was only infrequently accessed and did not influence irrigation management decisions. One of the two Santaquin data loggers was placed in a research plot for comparison against other soil moisture monitoring equipment (capacitance probe) that the grower was already using for orchard irrigation decisions. The orchard manager at the second Payson site frequently accessed the M.K. Hansen data logger and successfully implemented the information in irrigation management decisions.

The M.K. Hansen brand data logger was deemed more user friendly, and the graphical display of water depletion curves proved to be more useful in making management decisions in the field.

Regulated Deficit Irrigation: In 2009, tart cherry orchards throughout northern Utah set extremely large crop loads, particularly compared to 2007 and 2008 when previous RDI treatments were carried out. Yields among irrigation treatment over the three years are shown in Figure 1 below. Data are shown in relation to the amount of water applied (percent of commercial irrigation practice).

Although total harvested yield wasn't significantly affected by irrigation treatment in any of the three years, packout was significantly affected. In 2007 and 2008, packout was approximately 75% and did not differ significantly among irrigation treatments (Figure 2). In 2009 however, packout ranged from 42 to 55% and was correlated with the amount of irrigation water supplied. In other words, the more severe the irrigation deficit, the lower the packout.

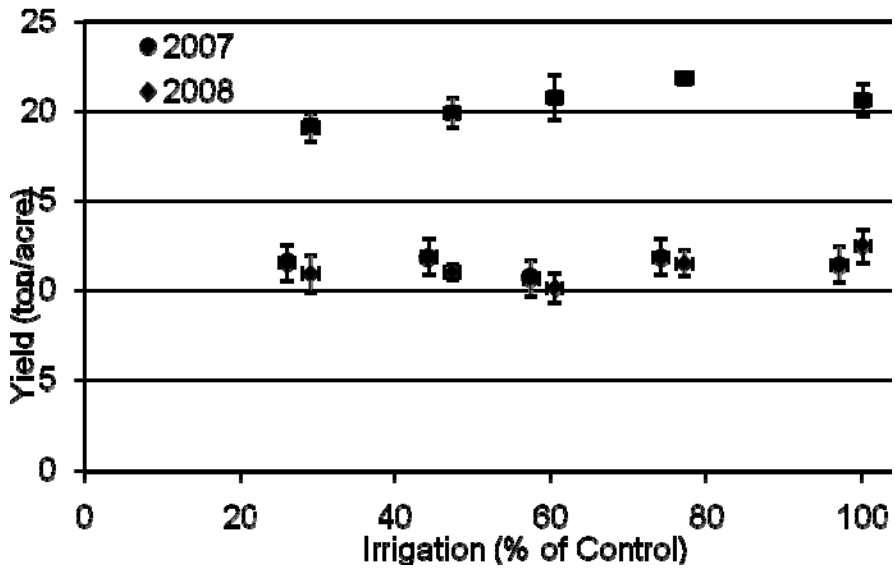

Figure 1. Effect of irrigation level from pit hardening to harvest on mechanically harvested yields over three seasons. The effect of irrigation level on total yields within a season was negligible (relatively flat line). However, yields were significantly different in 2009 compared to 2007 and 2008.

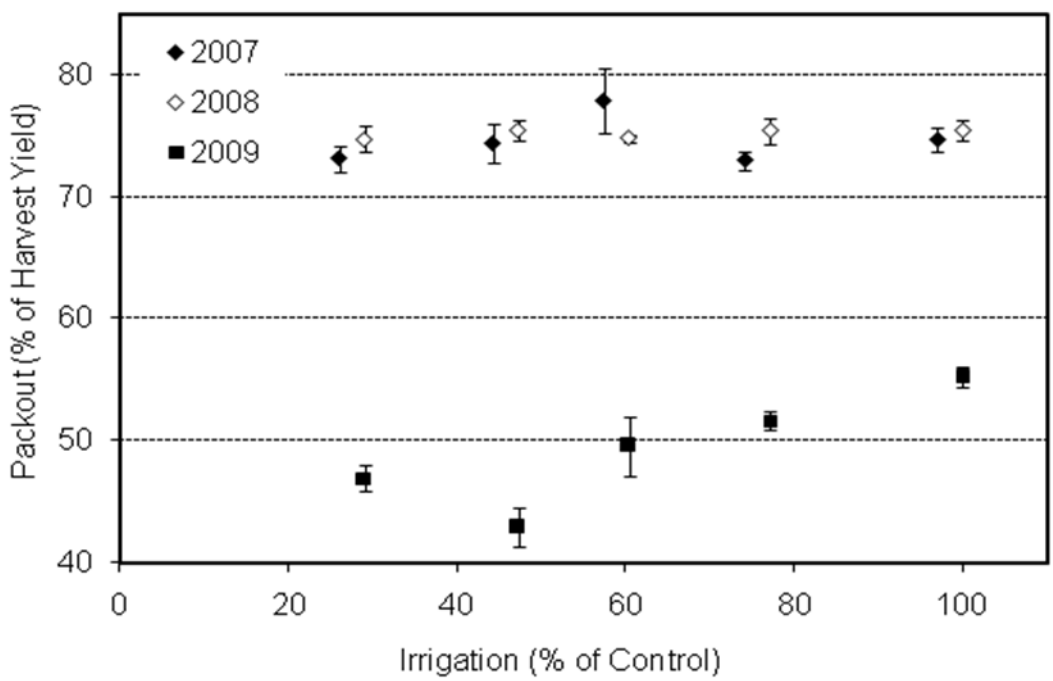

Figure 2. Effect of irrigation level on packout, as determined by measuring the quantity of fruit in the field tank, and the weight of pitted packed fruit.

The decrease in packout was primarily attributed to undersized fruit. During the packing process, fruit that is too small for proper pitting is eliminated by a sizing chain. The quantity of

undersized fruit in both 2007 and 2008 was between 1 and 3%. However, the amount of undersized fruit in 2009 ranged from 23% in the fully watered control to >35% in the most severe deficit treatments (data not shown).

Table 1. The effect of deficit irrigation on the dry matter content and soluble solids concentration (SSC) of samples of fruit flesh collected pre-harvest.

Treatment	Dry matter content (%)				SSC (%)			
	2007		2008		2007		2008	
C-100	14.4	B	13.8	B	14.1	B	13.3	B
RDI-77	14.3	B	13.8	B	14.0	B	13.4	B
RDI-60	14.6	AB	14.1	B	14.3	B	13.5	B
RDI-47	14.7	AB	14.1	AB	14.4	AB	13.7	AB
RDI-30	15.3	A	14.8	A	14.9	A	14.3	A
P-value	0.0074		0.0017		0.0009		0.0003	

Fruit quality

Results in both 2007 and 2008 indicated that deficit irrigation in a year where the crop load was light to moderate could improve the processing quality of the fruit. Table 1 shows the effect of deficit irrigation on fruit dry matter content (% dry matter) and on the soluble solids concentration (sugar content). Both of these increased with deficit irrigation. These results taken together with the lack of yield reduction in these two earlier seasons suggested that RDI could have some important benefits in improving fruit quality.

Tree stress

Mid-day stem water potential is a measurement used to determine the level of water stress in the tree. During the 2007 and 2008 seasons, the most severe RDI treatment resulted in midday stem water potential readings of approximately -1.3 MPa. However, with the added crop load stress in 2009, even the highest watered treatment exceeded this level of stress. Antunez-Barria (2006) reported that the midday stem water potential threshold for causing noticeable negative stress in sweet cherry was -1.5 MPa. Assuming a similar threshold for tart cherry, all of the irrigation treatments in 2009 except for the fully watered control, exceeded this deficit level prior to harvest.

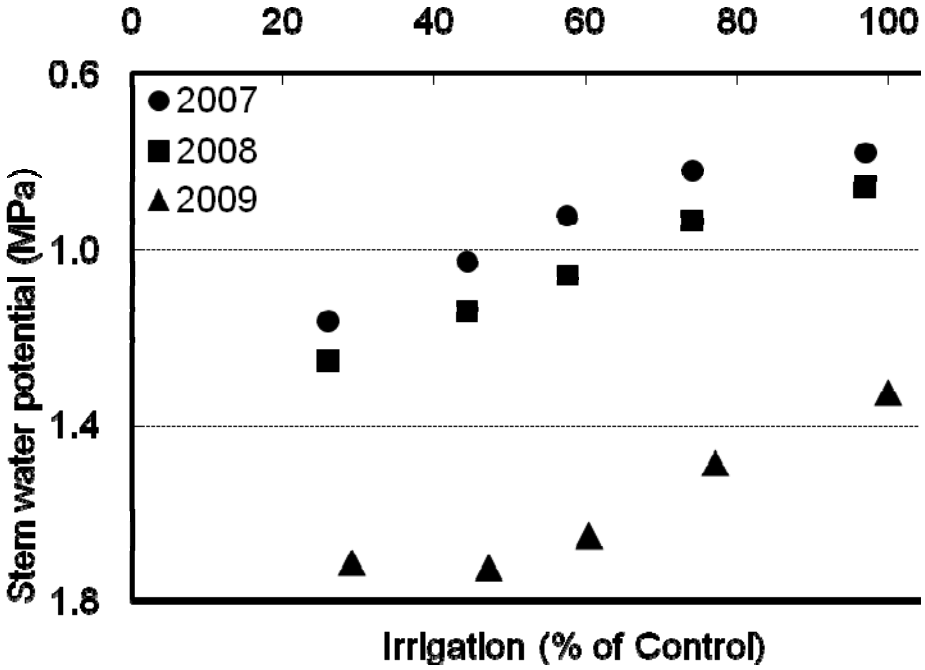

Figure 3. Midday stem water potential (tree stress) as a result of deficit irrigation treatments over three seasons. A stress threshold of -1.5 MPa was previously suggested for sweet cherry.

One of the objectives of imposing irrigation deficits in the period leading to harvest was to attempt to reduce trunk injury resulting from mechanical harvesting. In order to evaluate this, frequency and severity of new trunk injury was scored immediately after harvest. Figure 4 shows that severity of trunk injury was decreased with deficit irrigation in both 2007 and 2008. In 2009 however, treatment differences were not as dramatic. It is likely that the added stress on all treatments resulting from the large crop reduced cambium growth, and consequently decreased the likelihood of injury resulting from mechanical harvest.

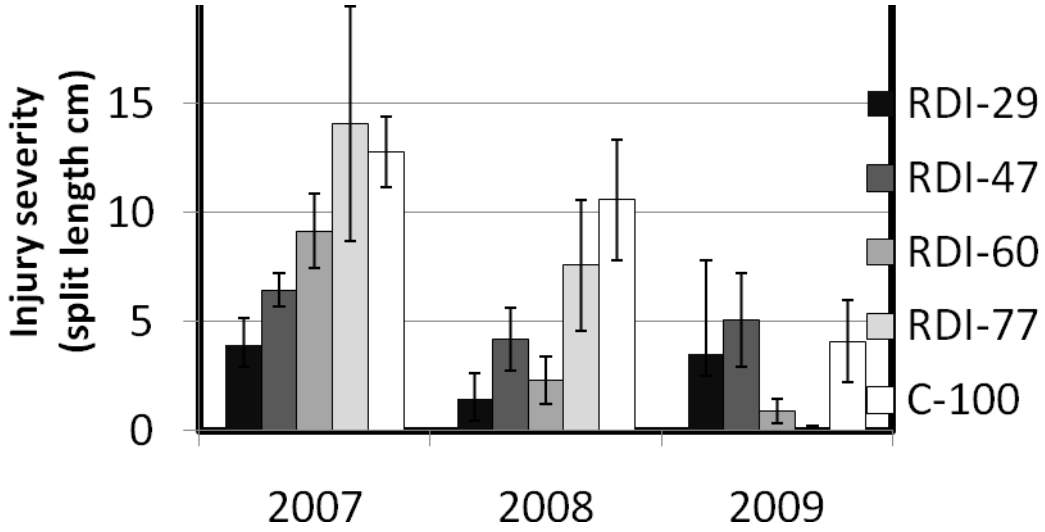

Figure 4. Effects of deficit irrigation on severity of trunk splits over three seasons. C-100 indicates fully irrigated control (Control - 100%). RDI indicates regulated deficit irrigation and the percent of control during the stage III fruit ripening period.

The most disturbing result of the 2009 season was the level of tree mortality. With the stress of the large 2009 crop load, tree mortality was widespread throughout the industry. In the irrigation trial, even the fully watered control plots experienced some mortality which increased with severity of water deficit (Figure 5). By comparison, none of the trees in any of the treatment plots died during the 2007 or 2008 experiments.

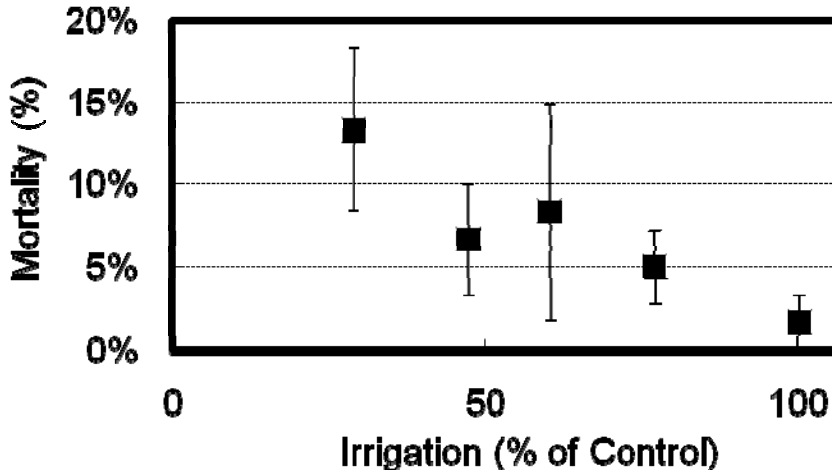

Figure 5. Effect of deficit irrigation on tree mortality in 2009.

The major conclusion from this three-year study is that RDI may be beneficial in years where the crop load is light to moderate. However, these same irrigation treatments applied in a heavy crop year will likely exceed tree stress thresholds resulting in tree mortality, and crop loss. In order for RDI to be implemented in a consistent and safe manner, orchard managers need methods to

easily and accurately monitor tree stress so that the positive effects of RDI can be realized, and the negative effects resulting from excessive stress can be avoided.

Long-term outcome measures: As a result of this work, growers continue to gain experience in using modern technology such as weather stations and soil monitoring equipment to improve their irrigation management decisions. Extension efforts will continue to educate orchard managers on these and emerging technologies for more efficient orchard irrigation.

The work on regulated deficit irrigation provided some information that could be used to develop strategies for managing irrigation during drought years, or when water resources become more expensive. Where water resources are not limiting, this approach appears to be excessively risky. In order for this approach to be used more safely, more information is needed on how growers might reliably assess tree stress in the field. For research purposes, we used a "pressure bomb" method for measuring stem water potential. Although this method might be suitable for the more technologically advanced growers, it remains time consuming and tedious and would not be suitable for wide-spread adoption in the industry. More work is needed to identify new methods for field evaluation of tree stress.

Additional Information: Much of the results of the RDI study are published in a M.S. thesis (Papenfuss, 2010). Additional results have been submitted for publication in the journal Acta Horticulturae (http://actahort.org/) and should be available in print in late 2010.

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B. Validation and Demonstration of Trap Thresholds for Codling Moth in Mating Disrupted Apple Orchards in Northern Utah

Outline of issue, problem, interest or need for the project: Codling moth, *Cydia pomonella*, is the most severe economic pest of apples in Utah and the western U.S. A number of Utah apple producers apply pheromone mating disruption (MD) to decrease codling moth populations and fruit injury which then may allow them to reduce the amount of insecticide inputs. Monitoring codling moth populations is essential to determine frequency and timing of supplemental insecticide treatments. Standard pheromone lures are not effective in MD orchards because the MD-pheromone masks the traps. Several "new" lures (DA and DA-Combo) are available that contain a chemical extracted from ripe pears to attract male and female codling moths. Trap thresholds for the new lures were developed based on studies conducted in Utah from 2006-2008 (Alston and Murray 2008). A validation study was conducted in 2009 to validate and adjust thresholds, and to provide Utah apple growers with experience in using the thresholds.

Approach: Two replicates of each DA and DA-Combo lures (Trece Inc., Adair, OK) were deployed in large Delta traps in each of 20 apple orchards (5-10 acres in size) using pheromone mating disruption for management of codling moth. Traps were deployed on April 21 or 28, within 1-2 weeks of first moth activity, or biofix. Traps were serviced weekly to count and collect moths and trap positions rotated to prevent bias of trap position on moth capture. Lures were replaced every 7 weeks (manufacturer specifications are every 8 weeks, but we wanted to ensure that all lures had high release rates throughout the study). Sticky trap liners were replaced when they became filled with moths, other insects, or debris (typically every 2-3 weeks). Codling moths were collected into vials with Histoclear to dissolve the adhesive. In the laboratory, moths were sorted by gender and female abdomens were dissected under the microscope (10-20× magnification) to count the number of sperm packets, or spermatophores (Trece 2005). Weekly trap capture of male, unmated female, and mated female moths were determined and provided to cooperating growers. Growers were advised when a threshold was reached or exceeded (DA lure: 1 moth for 1st generation/2 moths for 2nd and 3rd generations; DA-Combo lure: 10 moths for all generations), and to consider applying a supplemental insecticide spray if the application timing was appropriate.

The percentage of fruit with entries by codling moth larvae was determined by inspecting 200 fruit in each study orchard on June 23, July 16, August 11, and September 17. Fruit sampling dates corresponded to about 75% and post-100% egg hatch for each codling moth generation. The level of fruit injury on each sample date was compared to previous trap capture counts and used to assess if threshold predictions were accurate. The number of false negative predictions (lure threshold wasn't met, but fruit injury occurred) and false positive predictions (lure threshold was met, but the grower did not apply an insecticide treatment and no fruit injury occurred) was determined for each lure.

Goals Achieved: As a result of this study, accurate and user-friendly thresholds for monitoring codling moth in mating disrupted orchards have been delivered to Utah apple producers. Information has been published in a USU Extension fact sheet (Murray and Alston 2010), presented at the 2010 Utah State Horticulture Association (USHA) annual convention, and a survey of codling moth mating disruption practices conducted at the meeting.

There were 75 attendees at the USHA presentation, and 20 surveys were returned. Of the respondents who grew apples, 35% used mating disruption to manage codling moth in 2009. All of the respondents who used mating disruption monitored for the insect: 50% used both 10X and DA-Combo trap lures, 33% used only DA-Combo lures, and 17% used only 10X lures. The survey did not ask how many acres were monitored using the 10X or DA-Combo in 2009. These data will be collected for the 2010 season in a survey conducted at the January 2011 USHA convention.

At this time, data on the number of times the Codling Moth Mating Disruption fact sheet have been accessed on-line are not available; however, the fact sheet has been distributed and discussed with 30 fruit growers so far at on-farm grower meetings in the spring and summer of 2010.

Accurate treatment thresholds will encourage Utah apple producers to implement pheromone mating disruption because they will have confidence in their ability to effectively monitor codling moth populations and prevent fruit injury. This will lead to reduced use of insecticides, reduced negative environmental impacts, reduced pesticide residues on apples, and cost savings.

Results, conclusions and lessons learned: In addition to thresholds developed previously for total moth capture per trap, female-only thresholds were evaluated for the 20 orchards. Female thresholds of 0.5 moth for the first generation and 1 moth for the second and third generations provided the most accurate predictions for both DA and DA-Combo lures. We also assessed whether using mated female moths only would improve thresholds, but use of total female moth counts was better.

Threshold Tables

Tables 1-4 summarize the predictions of supplemental insecticide treatments and fruit injury based on trap capture thresholds for DA-Combo and DA lures. Thresholds were evaluated for total moth trap capture (males + females; Tables 1-2) and for trap capture of female moths only (Tables 3-4) for each lure type. Weekly trap capture counts are presented for each of the 20 orchards. Weeks are displayed in the left column of the tables and orchard number (1-20) across the top. Each table is divided into the first codling moth generation (May 6 to July 3) and the second and third generations combined (July 6 to September 15). The percentage of fruit injury in each orchard is presented in the bottom two rows of the table for each generation. Moth counts are presented as cumulative trap capture since the beginning of the designated generation or since the last insecticide spray (i.e., cumulative moth counts reset to zero after a spray). The superscript letter “T” indicates when counts met or exceeded the designated threshold and the letter “I” indicates when an insecticide cover spray was applied to the orchard. The arrows indicate repetition of the same cumulative counts in the succeeding weeks. False negative predictions (the lure threshold wasn’t met, but fruit injury was detected) are encircled by red lines and false positive predictions (the lure threshold was met or exceeded, but the orchard wasn’t treated with an insecticide and no fruit injury was detected) are encircled by blue lines.

Thresholds for Total Moth Capture

Total moth thresholds for each of the DA-Combo and DA lures resulted in three false negative predictions across the season for the 20 orchards, where fruit injury occurred despite trap catch

not reaching the lure threshold (red encircled counts; Tables 1 and 2). The false negative predictions occurred for the same three orchards at the same timing in the codling moth generations. The DA lure threshold for total moths resulted in nine false positive predictions (blue encircled counts; Table 2). The growers were not advised to spray based on these DA thresholds being met because of concerns for unnecessary treatments. There were no false positive predictions for the DA-Combo lure.

Thresholds for Female Moth Capture

Female thresholds for the DA-Combo lure resulted in only two false negative predictions as compared to three for the DA-Combo total moth threshold; however, four false positive predictions occurred (Table 3). The DA female threshold resulted in the poorest predictions of fruit injury and timing of supplementary insecticide sprays: four false negative and 10 false positive predictions.

A summary of false predictions made by both types of lures and separated for the codling moth generations across the 20 orchards is presented in Table 5.

Combining DA-Combo Total and Female Moth Thresholds

Implementing the criteria that both total and female moth thresholds must be met in order to indicate the need for a supplemental insecticide spray, then use of the DA-Combo lure resulted in only one false prediction. This false negative prediction was for Orchard 1 from late August to mid September (compare false predictions in Tables 1 and 3). In all other cases for the DA-Combo lure, there was no overlap in false prediction between total and female moth thresholds. For the DA lure, there were 11 false predictions using both total and female moth thresholds (compare false predictions in Tables 2 and 4).

Conclusions

The DA-Combo lure trap capture thresholds resulted in fewer false predictions of apple fruit injury or the need for a supplemental insecticide treatment than the DA lure thresholds. The combination of use of the DA-Combo total moth threshold of 10 with the female threshold (0.5 female for first generation and 1 female for second and third generations) resulted in only one false negative prediction for the full season across all 20 orchards. In the one inaccurate case (Orchard 1), fruit injury occurred late in the season even though total and female trap capture thresholds were not met. This orchard was treated with the insecticide Baythroid during the week of August 10. Some fruit injury occurred before the Baythroid application (3.0% fruit injury detected on August 11). The injury that was measured on September 17 may have carried over from injury earlier in the second generation or occurred after the Baythroid application. Injury following the application suggests that control was inadequate for reasons relating to the application itself, such as inadequate tree coverage, too low of product rate, or resistance of codling moth to the chemical.

The DA lure thresholds appear to be too low for effective use under northern Utah conditions as supported by the high numbers of false positive predictions. Use of such low thresholds would result in over-application of supplemental insecticide treatments. Increasing the DA lure thresholds would result in an increase in false negative predictions. False negative predictions are not desirable by growers because they allow for fruit damage and loss of profits.

These research results support the use of trap thresholds with the DA-Combo lure for monitoring codling moth populations in mating disrupted orchards in northern Utah. Determination of both

cumulative total and female moth trap capture counts enhanced the accuracy of the DA-Combo threshold. Revised DA-Combo lure thresholds are proposed:

Trap thresholds for cumulative codling moth capture per trap with the DA-Combo lure to prevent fruit injury. Both thresholds must be met to indicate the need for a supplemental insecticide treatment. Cumulative counts begin at zero for each generation and reset to zero following an insecticide application.

CM generation	Total moths	Female moths
1st	10	0.5
2nd/3rd	10	1

Long-term outcome measures:

Output Products

USU Extension Utah Pests fact sheet describing the utility of the DA-Combo lure for monitoring codling moth in mating disrupted orchards and present findings on trap thresholds has been published (Murray and Alston 2010). A research manuscript will be prepared during spring/summer of 2010 and submitted to a refereed entomological research journal. Codling moth monitoring and lure threshold information will be presented to Utah apple growers, personnel from Extension, UDAF, NRCS, and other interested parties at the Utah State Horticultural Association annual convention and at other educational meetings in 2010 and beyond.

Additional Information:

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Table 1. Cumulative total moth trap capture per trap (since beginning of generation or last insecticide spray)

DA-Combo lure threshold: all generations - 10 moths

1st generation moth flight (May 6 to July 3)

Orchard	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**1**
May 4	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0
May 11	3	1	1	0.5	0.5	1	↓	0.5	1	↓	1.5	↓	↓	1	1	1.5	2
May 18	14.5^{T}	20^{T}	3.5	4	18.5^{T}	11.5^{T}	0.5	8^{I}	14^{TI}	20^{TI}	38^{TI}	1.5	6	8.5	6	2.5	11
May 25	32.5^{TI}	26^{TI}	5^{I}	6^{I}	33^{TI}	20^{TI}	2^{I}	0.5	0.5	1.5	2	3.5^{I}	7.5^{I}	14.5^{TI}	9.5^{I}	5.5	21
Jun 1	0	1	0	0	1.5	0.5	0	1	1.5	2	4	0	0	0	0	7^{I}	33
Jun 8	↓	↓	↓	↓	↓	↓	↓	↓	2	2.5	↓	↓	1	1	↓	1	4
Jun 15	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	5	↓	↓	1.5	↓	↓	7
Jun 22	↓	↓	↓	↓	2.5	1	↓	↓	↓	↓	6	0.5	2.5	↓	↓	1.5	11
Jun 29	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
% inj Jun 23*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
% inj Jul 16*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1.*

2nd and 3rd generation moth flight (July 6 to September 15)

Jul 6	0	1.5	2.5	0	2	0.5	1.5	0	0.5	2.5	2	0	0	2	0	1.5	15
Jul 13	↓	↓	↓	↓	3	↓	↓	1.5^{I}	1.5	3	3.5^{I}	↓	↓	↓	↓	↓	16
Jul 20	0.5	↓	↓	↓	3.5	↓	↓	0	↓	↓	0	0.5	↓	↓	↓	2.5	21
Jul 27	3.5	↓	3	↓	6	1	↓	↓	2.5^{I}	4.5^{I}	1	↓	1	↓	0.5	3.5^{I}	25
Aug 3	7	4	4.5	1	10.5^{T}	2	2.5	2	4	5	7.5	↓	2.5	3	1	1	7
Aug 10	7^{I}	4.5^{I}	5	1^{I}	11^{T}	↓	5.5	↓	6	6	10.5^{T}	1.5	3	↓	2	1.5	11
Aug 17	0	1	6.5	0	16^{TI}	↓	↓	2.5^{I}	9	8	12.5^{TI}	↓	3.5	4.5	↓	↓	14
Aug 24	1	4	7	↓	2.5	2.5	6	0.5	10^{T}	9	6	↓	4	5.5	3.5	↓	18
Aug 31	1.5	5.5	8.5	0.5	3	↓	↓	↓	12^{T}	10^{T}	10^{T}	↓	↓	↓	4	2.5	24
Sep 7	↓	↓	↓	↓	3.5	3	↓	↓	↓	↓	11^{T}	↓	↓	↓	↓	↓	25
Sep 14	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
% inj Aug 11*	*3.0*	*0.5*	*0*	*0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*1.*
% inj Sep 17*	*2.0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*0*	*0.5*	*0.5*	*3.0*	*0*	*0*	*0*	*0*	*0*	*6.*

^{T} Trap threshold reached or exceeded.

^{I} Insecticide cover spray applied to orchard.

* Percentage fruit injury in the orchard was assessed on June 23, July 16, August 11, and September 17.

Red lines encircle false negative predictions and blue lines encircle false positive predictions.

Table 2. Cumulative total moth trap capture per trap (since beginning of generation or last insecticide spray)

DA lure threshold: **1st generation: 1 moth** **2nd and 3rd generations: 2 moths**

1st generation moth flight (May 6 to July 3)

Orchard	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**1**
May 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May 11	↓	↓	↓	↓	↓	↓	0.5	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
May 18	0.5	0.5	1^{T}	1.5^{T}	4^{T}	4^{T}	1^{T}	1^{TI}	3^{TI}	1^{TI}	1.5^{TI}	0.5	0.5	3^{T}	↓	↓	2
May 25	2^{TI}	2^{TI}	2.5^{TI}	1.5^{TI}	9^{TI}	4^{TI}	1.5^{TI}	0	0.5	0	0	1^{TI}	1.5^{TI}	3^{TI}	0^{I}	0.5	2.5
Jun 1	0	0	0	0	0	0	0	↓	0.5	1^{T}	0.5	0	0	0	↓	1^{TI}	4
Jun 8	↓	0.5	↓	↓	↓	↓	0.5	0.5	↓	1.5^{T}	↓	↓	↓	↓	↓	0.5	2
Jun 15	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.5	0.5	↓	↓	2.5
Jun 22	↓	↓	↓	↓	↓	↓	↓	1^{T}	↓	↓	↓	↓	↓	↓	↓	↓	4.5
Jun 29	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
% inj Jun 23*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
% inj Jul 16*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1.*

2nd and 3rd generation moth flight (July 6 to September 15)

Jul 6	0	0.5	0.5	0	0	0	0	0	0	0.5	0.5	0	1	0.5	0	1	3.5
Jul 13	↓	↓	↓	↓	1.5	↓	0.5	0.5^{I}	↓	↓	1.5^{I}	0.5	1.5	↓	↓	↓	5
Jul 20	↓	↓	↓	↓	↓	↓	↓	0	↓	↓	0.5	↓	↓	↓	0.5	↓	↓
Jul 27	↓	↓	↓	↓	3.5^{T}	↓	↓	0.5	0.5^{I}	0.5^{I}	2^{T}	↓	2^{T}	1	↓	1^{I}	5.5
Aug 3	↓	↓	↓	↓	↓	0.5	1	2^{T}	0	1.5	2.5^{T}	↓	↓	1.5	1	↓	2
Aug 10	0.5^{I}	0.5^{I}	↓	0^{I}	↓	↓	↓	↓	1.5	↓	3^{T}	1	↓	1.5	1.5	↓	2.5
Aug 17	0.5	0.5	2^{T}	↓	4.5^{TI}	↓	1.5	2.5^{TI}	↓	2^{T}	4^{TI}	1.5	2.5^{T}	2^{T}	2^{T}	↓	3
Aug 24	↓	1.5	↓	↓	0	↓	↓	↓	0	↓	0.5	2^{T}	↓	↓	2.5^{T}	↓	4
Aug 31	↓	↓	↓	↓	↓	↓	2^{T}	0.5	2^{T}	2.5^{T}	1	2.5^{T}	↓	2.5^{T}	3^{T}	0.5	6
Sep 7	↓	↓	↓	↓	↓	↓	↓	↓	2.5^{T}	↓	↓	↓	↓	↓	↓	↓	↓
Sep 14	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
% inj Aug 11*	*3.0*	*0.5*	*0*	*0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*1.*
% inj Sep 17*	*2.0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*0*	*0.5*	*0.5*	*3.0*	*0*	*0*	*0*	*0*	*0*	*6.*

^{T} Trap threshold reached or exceeded.

^{I} Insecticide cover spray applied to orchard.

* Percentage fruit injury in the orchard was assessed on June 23, July 16, August 11, and September 17.

Red lines encircle false negative predictions and blue lines encircle false postive predictions.

Table 3. Cumulative female moth trap capture per trap (since beginning of generation or last insecticide spray)

DA-Combo lure threshold: **1st generation: 0.5 female moth** **2nd and 3rd generations: 1 female moth**

1st generation moth flight (May 6 to July 3)

Orchard	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**1**
May 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May 11	↓	↓	↓	↓	↓	↓	↓	0	0	0	0	↓	0	↓	↓	↓	0	↓	
May 18	↓	0.5^{T}	↓	↓	↓	↓	↓	0^{I}	0^{I}	0.5^{TI}	0^{I}	↓	1^{T}	↓	↓	↓	0.5^{T}	↓	
May 25	0.5^{TI}	0.5^{TI}	0.5^{TI}	0^{I}	0.5^{TI}	0^{I}	0^{I}	0.5^{T}	↓	↓	↓	0^{I}	1^{TI}	0^{I}	0^{I}	↓	0.5^{T}	↓	↓
Jun 1	0	0	0	↓	0	↓	↓	↓	↓	↓	↓	↓	↓	0	↓	0^{I}	1.5^{TI}	0^{I}	0
Jun 8	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.5^{T}	↓	↓	0	↓	
Jun 15	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.5^{T}	↓	
Jun 22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.5^{T}	
Jun 29	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.5^{T}	↓
% inj Jun 23*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
% inj Jul 16*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1.5*	*1.0*	*0*

2nd and 3rd generation moth flight (July 6 to September 15)

Jul 6	0	0	0	0	0	0	1.5^{T}	0	0.5	0	1^{T}	0	0	0	0	0.5	2^{T}	0	0
Jul 13	↓	↓	↓	↓	0.5	↓	↓	0^{I}	↓	↓	1.5^{TI}	↓	↓	↓	↓	↓	2^{T}	0.5	
Jul 20	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.5	0.5	↓	↓	↓	↓	↓	3^{T}	0.5	
Jul 27	↓	↓	↓	↓	↓	0.5	↓	↓	0.5^{I}	0.5^{I}	↓	↓	↓	↓	↓	0.5^{I}	3.5^{TI}	1^{T}	
Aug 3	0.5	↓	↓	0.5	↓	1.5^{T}	2^{T}	↓	1^{T}	1^{T}	1^{T}	↓	0.5	↓	↓	0	1^{T}	↓	
Aug 10	1^{TI}	0^{I}	↓	0.5^{I}	↓	↓	3^{T}	↓	1.5^{T}	↓	1.5^{T}	1^{T}	↓	↓	↓	↓	1.5^{T}	↓	
Aug 17	0.5	0.5	↓	0	1^{TI}	↓	3^{T}	0.5^{I}	1.5^{T}	↓	1.5^{TI}	↓	↓	↓	↓	↓	↓	↓	
Aug 24	↓	1.5^{T}	↓	↓	0	↓	3.5^{T}	↓	2^{T}	↓	0	↓	↓	0.5	↓	↓	↓	↓	
Aug 31	↓	5.5^{T}	↓	↓	↓	↓	↓	↓	↓	↓	2.5^{T}	↓	↓	↓	↓	↓	2.5^{T}	↓	
Sep 7	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.5	↓	↓	↓	
Sep 14	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0.5	↓	↓	↓	↓
% inj Aug 11*	*3.0*	*0.5*	*0*	*0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*1.0*	*0.5*	*0*
% inj Sep 17*	*2.0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*0*	*0.5*	*0.5*	*3.0*	*0*	*0*	*0*	*0*	*0*	*6.5*	*0.5*	*0*

^{T} Trap threshold reached or exceeded.

^{I} Insecticide cover spray applied to orchard.

* Percentage fruit injury in the orchard was assessed on June 23, July 16, August 11, and September 17.

Red lines encircle false negative predictions and blue lines encircle false positive predictions.

Table 4. Cumulative female moth trap capture per trap (since beginning of generation or last insecticide spray)

DA lure threshold: **1st generation: 0.5 female moth** **2nd and 3rd generations: 1 female moth**

1st generation moth flight (May 6 to July 3)

Orchard	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**1**
May 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May 11	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	
May 18	↓	↓	↓	↓	1^{T}	0.5^{T}	↓	0^{I}	0.5^{TI}	0^{I}	0^{I}	↓	0.5^{T}	↓	↓	↓	↓	0.5^{T}	
May 25	0.5^{TI}	0^{I}	0^{I}	0^{I}	4^{TI}	0.5^{TI}	0.5^{TI}	↓	0	0	0	0.5^{TI}	0.5^{TI}	0^{I}	0^{I}	↓	0.5^{T}	1.5^{T}	↓
Jun 1	0	↓	↓	↓	0	0	↓	↓	↓	0.5^{T}	0.5^{T}	0	0	↓	↓	0^{I}	0.5^{TI}	1.5^{TI}	0
Jun 8	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0	↓
Jun 15	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	1^{T}	↓	
Jun 22	↓	↓	↓	↓	↓	↓	↓	0.5^{T}	↓	↓	↓	↓	↓	↓	↓	↓	1.5^{T}	↓	
Jun 29	↓	↓	↓	↓	↓	↓	↓	0.5^{T}	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
% inj Jun 23*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
% inj Jul 16*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1.5*	*1.0*	*0*

2nd and 3rd generation moth flight (July 6 to September 15)

Jul 6	0	0	0	0	0	0	0	0	0	0	0.5	0	1^{T}	0.5	0	1^{T}	1^{T}	0	0
Jul 13	↓	↓	↓	↓	↓	↓	0.5	0.5^{I}	↓	↓	1^{TI}	0.5	1.5^{T}	↓	↓	↓	1.5^{T}	↓	1
Jul 20	↓	↓	↓	↓	↓	↓	↓	0	↓	↓	0	↓	↓	↓	↓	↓	↓	↓	↓
Jul 27	↓	↓	↓	↓	↓	↓	↓	↓	0^{I}	0^{I}	↓	↓	↓	↓	↓	1^{TI}	2^{TI}	0.5	↓
Aug 3	↓	↓	↓	↓	↓	0.5	1^{T}	0.5	0	1^{T}	↓	↓	↓	1^{T}	↓	0	0	↓	1.
Aug 10	0.5^{I}	0^{I}	↓	0^{I}	↓	↓	↓	↓	1^{T}	↓	1^{T}	1^{T}	↓	↓	0.5	↓	0.5	↓	↓
Aug 17	0	0.5	0.5	↓	0.5^{I}	↓	1.5^{T}	1^{TI}	↓	↓	1.5^{TI}	1.5^{T}	2^{T}	1.5^{T}	↓	↓	↓	↓	↓
Aug 24	↓	↓	↓	↓	0	↓	↓	0	↓	↓	0	↓	↓	1.5^{T}	1^{T}	↓	1^{T}	↓	↓
Aug 31	↓	↓	↓	↓	↓	↓	2^{T}	0.5	1.5^{T}	1.5^{T}	↓	↓	↓	2^{T}	1.5^{T}	0.5	1.5^{T}	1^{T}	2
Sep 7	↓	↓	↓	↓	↓	↓	↓	↓	2^{T}	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Sep 14	↓	↓	↓	↓	↓	↓	↓	↓	2^{T}	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
% inj Aug 11*	*3.0*	*0.5*	*0*	*0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*1.0*	*0.5*	*0*
% inj Sep 17*	*2.0*	*0.5*	*0*	*0*	*0*	*0*	*0*	*0*	*0.5*	*0.5*	*3.0*	*0*	*0*	*0*	*0*	*0*	*6.5*	*0.5*	*0*

^{T} Trap threshold reached or exceeded.

^{I} Insecticide cover spray applied to orchard.

* Percentage fruit injury in the orchard was assessed on June 23, July 16, August 11, and September 17.

Red lines encircle false negative predictions and blue lines encircle false positive predictions.

Table 5. Number of false predictions made by DA-Combo and DA lure thresholds during first and second/third codling moth generations in 20 apple orchards, Utah County, UT, during 2009.

	DA-Combo lure		DA lure	
	Total moths	**Female moths**	**Total moths**	**Female moths**
False negative prediction				
CM generation 1	1	0	1	1
CM generations 2 and 3	2	2	2	3
False positive prediction				
CM generation 1	0	1	2	3
CM generations 2 and 3	0	3	7	7
Total number of false predictions	3	6	12	14

C. Isothermal Loop-mediated Amplification (LAMP): a new technique of polymerase chain reaction to rapidly detect *Erwinia* amylovora, the bacterial pathogen causing fire blight in apples.

Outline of the issue, problem, interest, and need for this project:
Detection of *Erwinia amylovora* (*EA*), the causal agent of fire blight, in apples during bloom is essential to time effective applications of agricultural antibiotics to prevent infection at flowering. Previously, detection of EA relied upon on a diagnostic growth medium called CCT. CCT-medium enables growers to determine the presence of *EA* but only after culturing the bacteria for 36-48 hours. Isothermal loop-mediated amplification, or LAMP, is a new polymerase chain reaction (PCR) technology that shortens the time of detection of *EA* to approximately 6-hours and can be done on a kitchen counter with relatively cheap, and safe, reagents and equipment. The results can be visualized with the naked eye and technology is sensitive to very low concentrations of the bacteria on apple blossoms. Commercial apple growers could use this new technology to make fire blight management decisions in near real-time rather than being 36-48 hours behind the weather using the CCT-medium technology used presently.

Approach:
Prior to the implementation of the proposed research, the principal investigator and staff, at Utah State University (USU), received LAMP training from the Oregon State University (OSU) Plant Pathology Laboratory (Dr. Ken Johnson), where the new detection methodology was developed for fruit growers in Oregon. All costs of travel and training were paid for by the Plant Pathology project at Utah State University. Expertise was gained to conduct the appropriate tests and information was shared between OSU and USU. A collaborative project was established to implement LAMP testing. A proposal was to implement LAMP testing was submitted to the Utah Department of Agriculture and Food, which was subsequently funded. LAMP testing was implemented in Spring-2009.

Goals Achieved:

Samples were collected among participating apple growers. A total of 6-apple orchards were included in the experiment. Blossom samples were collected daily for a period of approximately two-weeks, driven to the plant pathology laboratory at Utah State University, and subsequently processed to detect the presence or report the absence of any EA on sampled blossoms. Jonathan, Gala, Ginger Gold, and Fuji apple varieties were utilized for the study. Samples consisted of 100-blossom clusters sampled at random throughout each orchard. Samples were collected in the early morning, placed in Ziploc plastic bags and couriered to the laboratory. Samples were washed, centrifuged, and bacterial cells suspended on membranes via filtration. DNA was isolated and loop-mediated primers specific for EA were used to detect the presence or absence of EA. Positive samples were typically cloudy or hazy if the reaction successfully detected the presence of the EA bacteria. Samples that were negative were typically clear. Positive and negative controls were included in each days samples. The figure below indicates the first sample date (2 May 2009) showing positive samples among orchards tested. On one occasion of sample testing, one grower participated in sample processing and visualization of the results. Final sample processing ending 12 May 2009.

Samples from left to right:

1. Grower 1 = Jonathans [sample is positive]
2. Grower 2 = Galas [sample is positive]
3. Grower 3 = Ginger Gold [sample is negative]
4. Grower 4 = Gala [sample is negative]
5. Grower 4 = Fuji [sample is negative]
6. Grower 4 = Jonathan [sample is positive]
7. Negative control treatment [no bacteria present, sample is negative]
8. Positive control treatment [EA bacteria spiked sample, sample is positive]

9. CCT-medium sample from stigma imprints of a EA positive orchard [sample is positive] , the final well on the right is empty (no sample present)

Samples were also run on a quantitative real-time polymerase chain reaction thermal cycler (real-time PCR) machine.

Results, conclusions and lessons learned:
The LAMP protocol to detect the presence or absence of EA in blossoms of orchards sampled in 2009 was successful. Growers used the data to initiate EA-management practices, relative to LAMP sampling outcomes, in near real-time, thus eliminating the delay to culture the bacteria on artificial medium. Growers were able to obtain results of sampling the same day blossoms were submitted to the laboratory for testing. Sample data were transmitted to growers by images sent via E-mail and phone conversations to provide results of LAMP testing. Real-time PCR results were at times corroborative but at other times inconclusive. In consultation with Oregon State University and Michigan State University, researchers at those institutions indicated that inhibitors of PCR reaction were much more likely to cause problems in the real-time PCR reactions but not in LAMP reactions. The reasons at present are not clear but LAMP detection of EA appears to be promising in the longer term. Data from LAMP testing can be compared to weather data and fire blight forecast models to verify and improve predictive models.

Long-term outcome measures:
More testing is needed to further determine the utility of LAMP detection of EA in apples at blossom related to management and forecasting management protocols. At present, the LAMP testing protocol seems to provide added flexibility in the management of fire blight in apple orchards.

Additional information:
The principal investigator continues to collaborate with Oregon State University's Dr. Ken Johnson. A publication is being developed to report the outcomes in a peer-reviewed journal. Dr. Kent Evans no longer works at Utah State University and is now working for the USDA-ARS cereal disease research unit in Pullman, WA conducting research on stripe rust of wheat and barley. He remains available to advise and comment on LAMP testing needs for growers in Utah.

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D. Weed Control in Apple, Peach and Tart Cherry Orchards

Outline of issue, problem, interest or need for the project:
Weed control in orchards is essential because:

1. Effective IPM control of pests such as mites, earwigs, 'cat-facing' insects and mice require that plant and weed residue be kept away from tree trunks, and that weeds not grow up into the tree canopy.
2. Thorough weed control in the tree row, allows growers to reduce total nitrogen applied by 30% to 50% because trees can efficiently utilize fertilizer banded in the weed-free "herbicide strip". This is extremely important because lower levels of nitrogen application will result in less potential for pollution of the groundwater as well as resulting in substantial savings in input costs.
3. Thorough weed control in the tree row allows more efficient irrigation because of reduced competition between the tree and weeds and allows more uniform distribution of irrigation water.
4. Weed growth in the tree rows, and particularly close to the tree trunk competes with the tree for water and nutrients and slows growth, and tends to depress the yield of fruit.

Many fruit growers in Utah have indicated interest in improving current methods, reducing costs and if possible to find a workable program that will allow season long weed control with a single application of herbicide or. Currently growers must apply herbicide 3 to 5 times per year which results in high material and application costs, as well as management challenges. The Utah Horticultural Research Committee has identified weed control as one of the research areas that needs emphasis.

Approach:
Under this grant, research plots were began in 2008 with funding by The USHA and the USDA's Specialty Crop Grant Program.

During March of 2008 research plots were established at several locations throughout the Genola, Goshen, Payson, and Santaquin areas of Southern Utah County. Some of these plots and treatments were continued into or through the 2009 growing season, and others were added or dropped for various reasons. The purpose of these plots and their locations were:

Genola & Goshen: Research plots to examine different approaches to weed control in young orchard plantings (1st and 2nd years after planting) were established, as well as sites to investigate methods of increasing the efficiency and effectiveness of herbicide application were planned and established.

Roundup & 2,4-D Resistance Plots: In 1st and 2nd year plantings of Peaches and Tart Cherries a series of small plots were established to investigate methods of increasing the effectiveness of commonly used herbicide treatment combinations. Several species, particularly; perennial morning glory, cheese weed (*malva neglecta*), iron weed, and koshia are increasingly hard to kill with low and moderate rates of Roundup (glyphosate) and amine formulations of 2,4-D (Weedar and Orchard Master). To gain acceptable levels of weed kill with these materials requires use of high concentrations (near label limits) of these herbicides and increased frequency of application, compared to the responses of these weed species 15 to 20 years ago.

Single Application Program Plots: Plots involving different herbicide materials at various rates and different dates of application were established in 2 commercial orchards, one in Santaquin Utah and one in Payson Utah. These plots were designed to evaluate various programs that held promise of requiring only one application each year.

Goals Achieved:

The goals of this research project were:

1. To improve weed control practices in orchards in the State of Utah we:
    a. To help improve weed control practices in orchards in the State of Utah various adjuvants (materials added to the spray mixture to increase efficacy of herbicide materials) were investigated to determine what the optimal adjuvant "package" was for glyphosate (Roundup) and 2,4-D (the most common herbicides used).
    b. Investigated various ways to manage what appears to be selected resistance in some of the most common, hard to control weeds found in Utah Orchards.

2. Define the lowest cost/lowest input programs. Cost analysis of the programs commonly used and those tested during the course of this research was preformed to determine what the lowest cost programs were.

3. Various "1 application per season" programs were tested by applying various herbicides and herbicide mixtures at different times throughout the season to determine the best time of application and rates of materials to be used which would allow for adequate weed control with only 1 application each season.

4. Some effort to explore weed management techniques that will enable growers to continue to intensify IPM, certified organic production, and sustainable orchard management systems was conducted.

Results, conclusions and lessons learned:

1. In the process of conducting these trials we found that the 4 most difficult species to control (perennial morning glory, cheese weed *[malva neglecta]*, kosha, and iron weed) tend to have leaf surface characteristics which resist thorough wetting. This partial or incomplete wetting occurs because of the wax, wax deposit forms and other surface characteristics interact with the surface tension of the spray solution to either prevent complete wetting of the surface, or to hold the material deposits on waxy layers, wax droplets or pubescence, above the plant surface.

    Either of these mechanisms limits the amount of uptake of the spray material by the leaves of the target species, resulting in incomplete and/or erratic kill of the plants. Because these weed species are increasingly more difficult to kill it appears that we have been selecting resistant strains or genotypes of these weeds over the last 15 to 20 years as we have relied on glyphosate and/or 2,4-D for most of our weed control.

2. For resistance management we found that by increasing the concentration of the commonly used wetting agents to 1 ½ pints per 100 gallons, and adding 50 pounds of 'sprayable' Ammonia Sulfate per 100 gallons of spray solution the degree of wetting and the efficacy of both glyphosate and 2,4-D was significantly increased. Also, we found that including one of several commercially available "penetration aids" such as Hook increased the efficacy of these materials.

A combination of the Ammonia Sulfate, slightly increased concentration of the wetting agents used, and use of a penetration aid, increased efficacy enough to allow use of moderate rates (4 pints of 43% glyphosate and 2 pints of Weedar or Orchard Master per sprayed acre) of these materials. We also found that where the initial application of these materials included Ammonia Sulfate, higher rates of wetting agents, and Hook, the control of weeds was thorough enough so that subsequent applications were effective at lower rates (3 pints of 43% glyphosate per sprayed acre) and 2,4-D was required only once per season.

During 2009 the above results were confirmed through treatment of additional small plots in a mature Tart Cherry block in Payson Utah, and larger test plots at Payson.

3. To test possible "single application programs" several alternative herbicide programs were applied to test plots and their season long efficacy was observed and recorded. Test plots of Goal, Chateau, Surflan, Matrix, Simizine, Karmex, Devernol, and generic formulations of the last 4 materials on this list were established in commercial orchards in Santaquin and Payson in 2008.

   It was found that when the highest label rates of Goal, Chateau, and Surflan were applied before bloom, in a mix which included glyphosate and the appropriate surfactants (discussed above), season long weed control could be obtained, <u>if</u> sufficient rainfall occurred within 7 days of the application to incorporate these materials into the soil. Because the rainfall is not dependable, the response of these programs is highly variable, and probably not commercially feasible at this time.

   In order to assure the necessary incorporation of the active materials in the above mentioned list we examined the response when these applications were delayed until just before the first orchard irrigation in late May or early June. When this was done we found the following results:

   a. Goal: When 6 pints of goal and 4 pints of glyphosate per acre were applied between 48 and 72 hours ahead of the first irrigation (2" of water applied by sprinkler), there was very good initial weed kill, and there was very little return weed growth through early October. Goal, however is not labeled for application at this timing so plots were limited in size, and this treatment can not be used commercially unless a label change is sought and obtained.

   b. Chateau: When 12 ounces of Chateau and 4 pints of glyphosate per acre were applied between 48 and 72 hours ahead of the first irrigation (2" of water applied by sprinkler), all the weeds were killed and the residual control was good to very good through late September, when some weeds germinated and survived. This would be a good program for growers, but the label for this material was withdrawn between the 2008 and 2009 growing seasons because of phytotoxicity when dust from treated areas was moved by orchard operations, wind, or traffic onto the foliage of the trees.

   c. Surflan: When 5 quarts of Surflan and 4 pints of glyphosate per acre were applied between 48 and 72 hours ahead of the first irrigation (2" of water applied by sprinkler), initial weed control was good and the residual lasted throughout the growing season and into the early portion of the following year. This is the best

candidate for a single application, season long herbicide treatment as the material is not extremely expensive, is very safe in terms of risk to the trees, and can be recommended for grower testing and use.

In sandy soils and on gravely areas there may be a 'follow-up' treatment of glyphosate required in August because this material tends to break down due to the high oxygen content of these particular soil types, interacting with photo degradation, and dilution as some of the material is moved, by irrigation, out of the surface into the slightly deeper areas where germination does not take place.

d. Matrix: When 4 ounces per sprayed acre of Matrix was added to 4 pints of glyphosate and the above discussed adjuvant package, the residual action of the Matrix extended the weed control period significantly. This material used in this manner will allow growers to obtain season long weed control with 2 applications of Matrix and glyphosate. The label on Matrix allows 2 applications of 4 ounces <u>if</u> the area sprayed with each application is less than 50% of the total area.

The downside to this program is that Matrix is relatively expensive and growers who have efficient herbicide application equipment can apply 2 applications of glyphosate, including materials, labor, and application costs for approximately the same dollar cost as a single application of a Matrix + glyphosate can be applied. Some growers may wish to use this program for management reasons, and to avoid the necessity of applying a weed spray application just before or during tart cherry harvest.

e. Simizine + Karmex: A mixture of these 2 'older' materials was included in these trials, and were considered, along with the untreated controls, as the standard against which other single application programs were judged. The number of blocks in Southern Utah County in which these materials can be safely used is relatively small because of the danger they present if areas in treated blocks are very sandy or gravely, in which case tree damage may result. With a few exceptions, those being only in blocks with uniform, medium to heavy textured soils can these materials be used. Other use of these materials is not recommended.

f. "Organic Programs": Some effort was made to examine alternative weed control strategies for organic production systems. The author has extensive experience with organic fruit production in Washington State and at Springdale Fruit Company in Springdale Utah. These operations have used various techniques such as "in row tillers" (Weedbadger etc.), the use of propane "flamers", and composted manures as a barrier to weed growth. These methods work fairly well, and the use of compost is currently the method relied on in the authors orchards. Though the area under the trees, are not weed free, the weed suppression is adequate under mature canopies because of the combined effects of the mulch and shade.

In this effort the author investigated the use of various seed oils such as Linseed and Sesame Seed oil in combination with mineral oil, lime sulfur, and micronized sulfur in small test plots on young trees at Payson Utah. Some of these combinations are effective against young weed seedlings, but the number of applications required would make them quite expensive. This area of effort was terminated when funding for similar work was obtained by researchers at USU.

Long-term outcome measures:
As the results of these research efforts were observed, an annual tour of the plots was conducted where growers from around the state were invited to come, observe the plots and discuss the techniques, materials, application methods and results. In addition, presentations of results were given at the annual meetings of the Utah State Horticultural Society in 2009 and 2010.

Many of the commercial growers, particularly in Southern Utah County have adopted some of the spray application methods defined by this research in management of resistance to glyphosate and 2,4-D, and also some of the longer lasting material combinations.

Additional Information:
Dr. Seeley sends an email each week to a list of growers, extension agents, and other interested parties discussing the status of orchard operations and suggesting how growers can improve their growing practices at each stage of the season. These email messages, as appropriate, contain information gathered from these research efforts.

Summary: The most common approach to weed control in orchards in Utah is the use of glyphosate and glyphosate + 2,4-D mixtures. These programs can be and usually are quite effective but the grower must apply herbicide 3 to 5 times per season, and there are resistance selection, cost of application, and price considerations that must be taken into account. In early 2008 the price of glyphosate spiked, leaving growers who did not have a "stock" of this material in a bad situation, but the cost has since come back down to the point that these programs are still the low cost alternative after all things are considered.

This effort tested and defined several alternative programs, which are listed and discussed above, which growers are encouraged to test and evaluate under their circumstances so they can make their own decisions, and also so they may be prepared if the availability and/or price of glyphosate should become an issue in the future.

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E. Analysis of Codling Moth Mating Disruption Dispensers in a High-Elevation Northern Utah Apple Orchard.

Outline of issue, problem, interest or need for the project:
Codling moth is the primary pest of apples in Utah, and often requires large inputs of pesticides for control. Over the last several years, many large apple growers in Utah have adopted the use of mating disruption for control of codling moth. It is an excellent tool for organic and reduced-risk apple production. Mating disruption works by saturating the air with the same pheromone—codlemone—that

females emit to attract males for mating. Growers place emitters in an orchard at the manufacturer's labeled rate so that males cannot locate females, and mating is delayed or does not occur. The use of mating disruption over several years significantly reduces local codling moth populations and the need for insecticide applications.

The effectiveness of mating disruption depends upon the application rate, pheromone release rate and longevity of release (effectiveness) of emitters. Application rate is determined by the grower, but release rate and breakdown of hand-applied dispensers can be variable from site to site. Growers and pest consultants in northern Utah are concerned about mating disruption dispenser performance over the course of a season (approximately 140 days). It has been shown that dispenser release rate of pheromone increases with heat, however, the effects of increased UV exposure on dispenser breakdown has not been determined. The primary apple growing region in Utah occurs at 4500-5000 feet in elevation, higher than most orchard elevations in the Pacific Northwest, California, and eastern states. Only once has the codlemone release rate from mating dispensers been tested in Utah, and at that time, only one product was evaluated. Results showed that by the end of the season, the codlemone release rate in that product was less than the manufacturer's specifications. Determining effectiveness of mating disruption dispensers commonly used in Utah may alleviate growers concerns, and aid in the adoption of increased acreage using effective mating disruption products.

Approach:

The goal of this project was to provide an unbiased report of the pheromone content and release rate of commonly used mating disruption dispensers for the tree fruit industry in Utah. The information will be used to help growers to make prudent decisions for their pest management needs. It is important that growers have confidence in using mating disruption because this technology allows growers to reduce pesticide sprays, especially the organophosphate products such as Guthion, that are currently being phased out.

To test the dispensers, four different hand-applied brands were hung in a northern Utah apple orchard at 4800 ft. elevation throughout a period of 140 days (Table 1). At 14, 90, 120, and 140 days after deployment in the field, six dispensers were collected and sent to two different testing labs at Michigan State University. Dr. Larry Gut's lab tested for pheromone release rate (using the volatile trapping system) and Dr. Jim Miller's lab tested for residual pheromone in each dispenser. It was important to look at the results of both characteristics dispensers may contain residual pheromone, but it may not volatilize due to polymerization on the dispenser surface.

Table 1. Pheromone amounts, application rates, and cost/acre of codling moth mating disruption dispensers used in this study.

Dispenser	**(*E*,*E*)- 8,10-dodecadien-1-ol (codlemone)**	**Application Rate (minimum)**	**Product cost/acre**
Cidetrak CM	2.0% (120 mg)	400/acre	approx. $100
Isomate-C plus	53.0% (205 mg)	400/acre	$100
Isomate-CTT	53.0% (382 mg)	200/acre	$100
Checkmate CM-XL	17.5% (250 mg)	200/acre	$110

Some of the dispenser brands (Isomate and Checkmate) tested in this project also contain minor pheromone alcohols (dodecanol and tetradecanol), however, we report only on

codlemone ((*E*,*E*)- 8,10-dodecadien-1-ol) because research has shown that the secondary pheromone products do not contribute to a behavioral effect determining attraction and mating disruption in the field (Witzgall et al 2008) or the lab (McDonnough et al 1993).

Goals Achieved:

Results showed that all four dispenser types were still releasing codlemone, and all four had codlemone remaining within the membrane after 140 days in the field. Each dispenser type contained a high level of codlemone that dropped significantly in the first two weeks of deployment (Figure 2). After two weeks in the field, all of the dispensers started a gradual decline in the rate of release (Figure 3), with the two Isomate brands showing the steadiest release rate pattern. At the end of the study, the Isomate-C plus had 5% pheromone remaining, Isomate-CTT had 32% remaining, Checkmate had 8% remaining, and Cidetrak had 9% remaining.

Cidetrak: The codlemone release rate for Cidetrak was the lowest of the four brands tested over the entire 140 days. After 14 days, the release rate averaged 3.79 ug/hour, and after 140 days, the release rate averaged 0.28 ug/hr. The amount of codlemone within the dispensers was the lowest over the first 120 days, and the second lowest at the end of the study at 12.37 mg, twice as much as the Isomate-C plus.

Isomate-C plus : The average release rate for this dispenser over the first 14 days of field aging was 7.27 micrograms/hour (ug/hr). This rate remained fairly constant over the next 106 days. It was still releasing pheromone after 140 days in the field, but had dropped to an average rate of 2.51 ug/hr, the second highest of the four (behind Isomate-CTT). The Isomate-C plus dispensers started out with 147 mg codlemone, which gradually decreased to 6.53 mg by the end of the study.

Isomate-CTT: One would assume that because the CTT is a “double formulation” model of its counterpart (Isomate-C plus) that codlemone release rates would be twice as much. Evaluation of codlemone release prior to field deployment (day 0) showed that the Isomate-CTT did contain almost twice as much, and was releasing 2.5 times the amount of codlemone as Isomate-C plus. On day 14, the average release rate of Isomate-CTT had dropped to 13.89 ug/hr, still twice that of Isomate-C plus. After 90 days of field aging, the average codlemone release rate of CTT was almost the same as C+, at 6.34 ug/hr. This release rate, however, remained fairly constant through the next 50 days, and after 140 days in the field, the average release rate was the highest of the four tested, at 7.23 ug/hr, almost three times the average amount released by Isomate-C plus. Of the four products tested, Isomate-CTT had the highest amount of codlemone remaining in the dispensers at the end of the study, at 93 mg, 14 times the amount left in the Isomate-C plus, and almost four times the amount left in the Checkmate.

Checkmate: The average codlemone release rate of the Checkmate dispensers before deployment into the field (day 0) was the highest of the four, at 52.22 ug/hour. In 14 days, it had decreased by almost seven-fold to an average of 7.99 ug/hr, and after 140 days, the Checkmate dispensers were releasing an average of 0.52 ug codlemone/hr. Before deployment in the field, the average amount of codlemone in the Checkmate dispensers was the highest of the four tested, at 293 mg. After 90 days, it had decreased by half, and by 140 days, 24.85 mg remained.

A quantifiable amount of airborne codlemone required for successful mating disruption has not been determined. Individual codling moth females release approximately 0.005-0.007 ug pheromone/hour during calling (Bäckman 1997), and the two dispensers in this study with the lowest release rates after 140 days were releasing at least 41 times this amount. The level of pheromone necessary for successful disruption would depend upon a variety of variables including initial insect population. Utah growers are faced with high pest pressure due to small, disjointed farms and numerous backyard trees which would require the highest level of pheromone release as possible. The only way to determine whether the two products in this study with the lowest release rates (Checkmate and Cidetrak) are still effective at preventing injury would be to test them under field conditions to determine trap shutdown and prevention of fruit injury.

According to the National Weather Service, the summer of 2009 in Utah was cooler than average with a rainy and cool June and dry July and August. Extended periods of hot weather, such as was the case in the summer of 2007, may decrease effective lifetimes of dispensers. As such, we recommend to Utah commercial orchardists using mating disruption, whichever product they chose, to carefully monitor all treated blocks using pheromone traps and injury inspection, particularly toward the end of the season.

Figure 1. Average amount of codlemone content (mg) within four different brands of mating disruption dispensers tested over time in a Utah orchard.

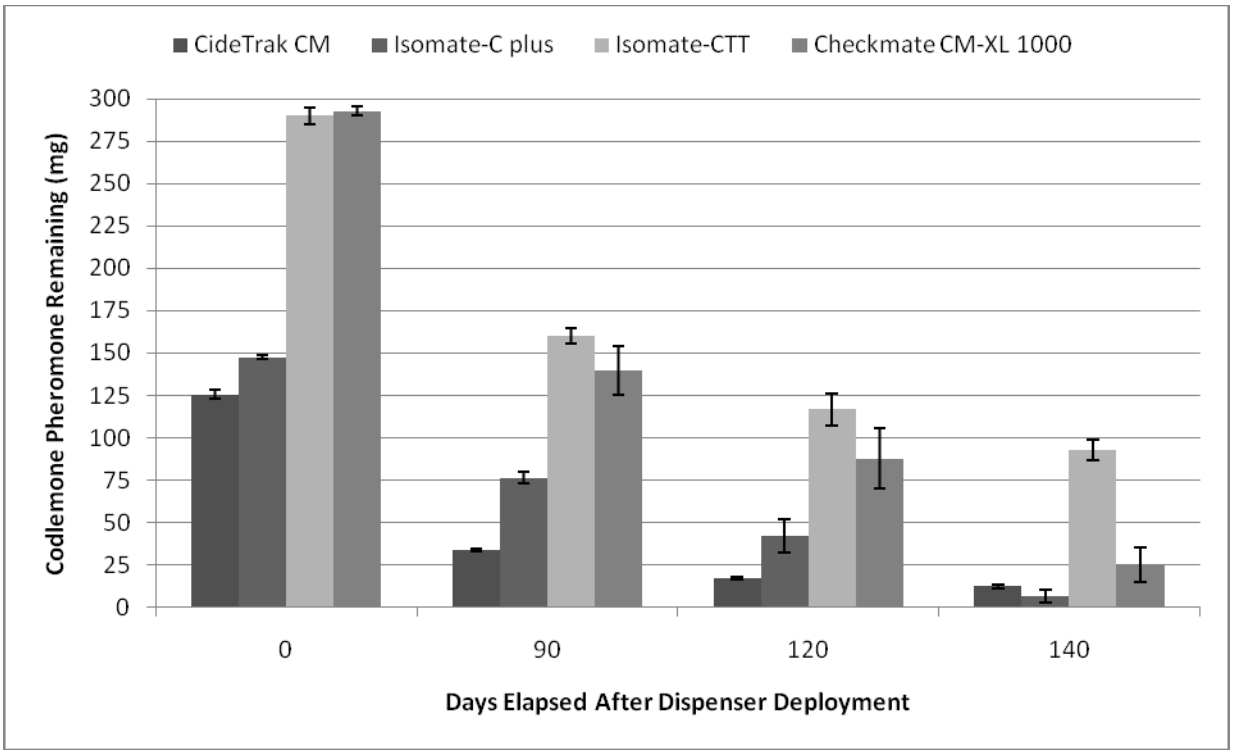
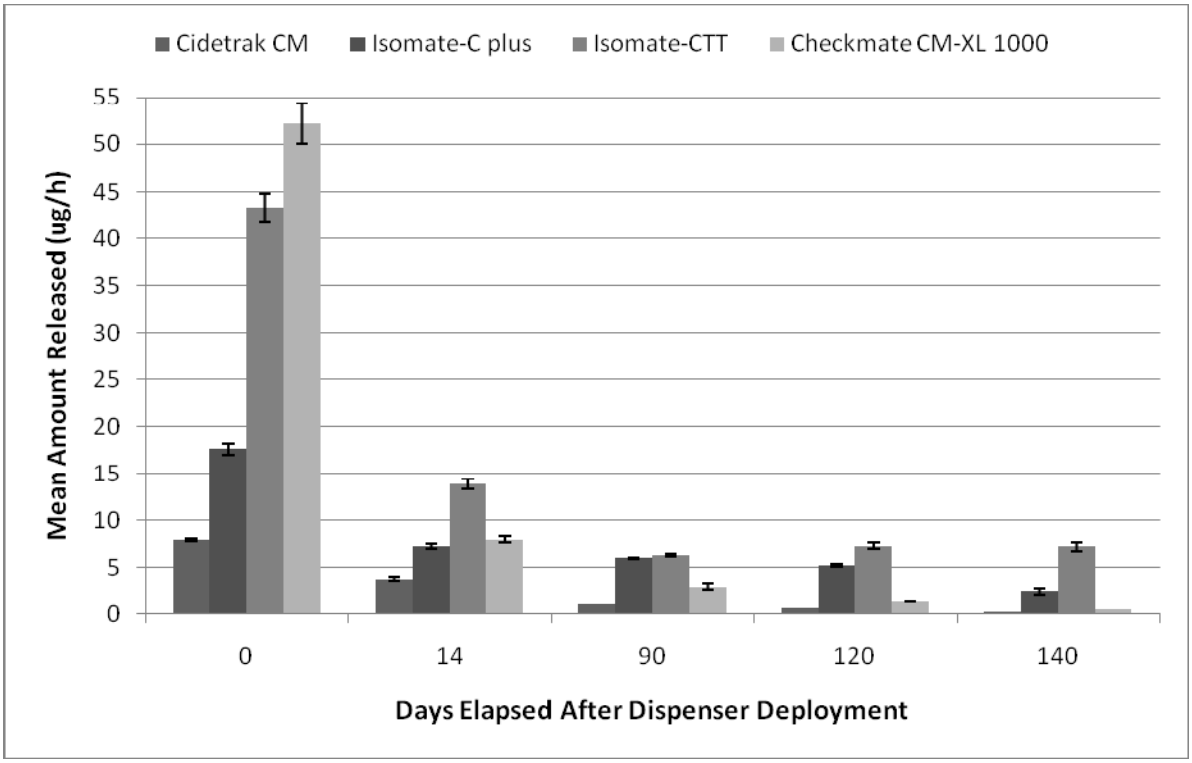


Figure 2. Average amount of codlemone released (micrograms/hour) by four different brands of mating disruption dispensers tested over time in a Utah orchard.



Results, conclusions and lessons learned:

Results of this project would have been more robust if we had the time and resources to test each product for effectiveness in the field. To do this, we would have applied the dispensers at the labeled rate, and measured codling moth trap catch and fruit injury for each treatment. But because USU does not have enough acreage on our experimental farm, and testing products on a grower farm is a risk for the grower, we were not able to conduct this part of the project. We did, however, use results of these types of studies from other states, and presented the information to Utah growers.

Long-term outcome measures:

1. *Increased adoption of mating disruption for codling moth.* The results of this study were presented in January 2010 to the participants at the annual Utah State Horticulture Association meeting, held in Provo, UT. Approximately 75 growers attended. The results of the study have given growers an unbiased review of the common brands available to them. After learning about the differences in the mating disruption products, approximately four growers commented to the authors that they were planning on changing brands because the results showed that the product they had been using was not an ideal product for Utah. This would result in potentially greater yield without any extra expense.

   In addition, we surveyed the Utah State Horticultural Association meeting audience members, and eight growers that have not been using mating disruption said that they plan to switch to this technology this coming season now that they know which product

will work best for their farm. This equates to a reduction in approximately 1-2 insecticide sprays the first year, and 2-3 sprays per year thereafter, per farm. After one to two years of mating disruption use on a given farm, the cost of this technology for growers is slightly less than a conventional spray program.

And finally, results of a tree fruit IPM survey conducted in winter 2010 are not available yet, but will allow us to see the level of adoption of mating disruption based on this study.

2. *Reduced codling moth populations over time*. Because of the expected increased adoption of mating disruption, and knowledge gained about how well these products work, we expect to see growers paying careful attention to codling moth populations in their orchards using precision monitoring. The trickiest period of management is near harvest, when the mating disruption pheromone concentration in the air is declining and codling moths are still laying eggs. Growers have learned to be diligent about suppressing codling moth with alternate means when necessary. They now have the knowledge of how long their mating disruption product is going to last (which is especially important in a hot, extended season), which will help to determine whether they will need to apply additional treatments at or near harvest, when control is critical to prevent wormy fruit.

   Growers that are familiar with how long their mating disruption product of choice lasts are able to more effectively manage this pest. As the number of growers that switch to using mating disruption increases, local codling moth populations should decrease. This benefits all growers in that ideally, the need for sprays on farms not using mating disruption may decrease. We plan to continue trapping for this insect pest throughout Utah apple orchards in 2010, and compare trap catch results with past years.

3. *Training opportunity for student employee*. The final outcome of this study was the successful training of one USU graduate student majoring in Natural Resources that assisted on this project. He received training from Extension specialists over the course of the season on codling moth biology and management, tree fruit operations, use of mating disruption for pesticide reduction and environmental benefits, monitoring techniques, experimental design, computer skills, and data analysis. The knowledge he learned is transferrable across other commodities and disciplines.

<u>Additional Information:</u>
This project targeted the large-farm apple growers in Utah (approximately 1500 acres). Results of this project were presented in poster format at the 2010 Western Orchard Pest and Disease Management Conference in Portland, OR, to an audience of approximately 150. It was also presented in oral format to over 75 growers in Utah at the annual Utah State Horticulture Association Convention in January 2010. We prepared a mating disruption fact sheet that was distributed to the growers and posted on the Utah IPM web site (utahpests.usu.edu/IPM). The slide presentation is also available there.

Growers using mating disruption are using just 1 to 3 supplemental cover sprays per season compared to 3 to 5 sprays for orchards under conventional management practices. The cost of mating disruption plus one supplemental spray is equivalent to a conventional program. Growers that switch to mating disruption will not only be applying fewer sprays, but will also save money in the long run. Mating disruption is applied once, and costs approximately $100/acre. Sprays range in price from $20/acre to $80/acre per treatment.

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

Outline of issue, problem, interest or need for project:
With rising costs of inputs, concerns over unintentional herbicide injury to trees and projected increased competition for scarce water resources, reduced input and organic 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.

Approach:
Five different combinations of organic and inorganic fertilizers and mulches have been established. These treatments will be compared for their effects on fertility, tree growth, weeds, and water use. Separate trials will evaluate new organic weed control products and novel cover crops for potential integration in orchards with arid climates and cold winters. This site will be used as a source of information and outreach to local fruit growers. Results from these experiments will provide new information to better advise growers on strategies for organic peach orchard establishment, and to optimize soil quality, while managing weeds, and optimizing water use in reduced input management strategies.

Goals Achieved:
We have been successful in meeting the second year's goals of this long-term project. We have not yet written or distributed any fact sheets on the organic and conventional orchard floor management project because 2009 is the first year of data collection on the project. One year of

data is insufficient in our opinion on which to base meaningful recommendations. Our goal is to write and distribute fact sheets after the second season of data collection, which is the 2010 year funded by the subsequent year Specialty Crop Grant. The final report for that project will contain findings and recommendations. When published, fact sheets will be posted to the USU Extension website, http://extension.usu.edu/htm/horticulture. A detail of our progress under each of our goals is presented below.

Goal A. *Manage weeds and optimize fertility for establishment of organic and reduced input peach production:*

Orchard Establishment: The new organic and reduced input peach orchard was established in April 2008. All treatments were reapplied in the spring of 2009 as planned: **1)** conventional herbicide + 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 **5)** compost + spray on paper mulch + organic herbicide.

Soil Nutrients, soil quality and tree growth: Soil nutrient data (nitrate, ammonium, P, K, Ca, Mg + trace elements, pH, electrical conductivity, and texture) were taken at 0-30cm from each plot in May 2009. In addition, soil nitrate and ammonium was measured at 0-30cm in June, July and August. Leaf nutrient data was collected in June and July and trunk diameter measured at the end of the growing season. Trees were supplied with 10g N per tree in the form of urea or steer manure compost in early June. Compost N rates were based on analysis of the product and assuming available N of 20% in the first season.

Weed control: weed control was achieved in 2009 with either paper mulch or herbicide applications. We experimented with spray on paper mulch as opposed to laying sheet paper as in 2009. Weed densities were determined in the tree row and alley way. We conducted a second year of experiments evaluating mulch and herbicide combinations for most effective weed control in organic plots without hand weeding. Six alternative herbicides **1)** acetic acid 20% **2)** acetic acid 10% **3)** clove oil, **4)** lemon oil, **5)** scythe and **6)** glyphosate control were evaluated in combination with four mulches **1)** straw, **2)** paper, **3)** wood chip, **4)** bare ground control.

Goal B. *Optimize water use and soil quality through organic matter inputs, groundcover and mulches:*

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 to test the possibility of growing fertilizers within the orchard at two locations. Six combinations **1)** black medic, **2)** hairy vetch, **3)** alfalfa, **4)** clover alfalfa mix, **5)** orchard grass, and **6)** birds-foot trefoil were planted in a mature tart cherry orchard in the fall of 2009 at the Kaysville Research Station. An additional four treatments **1)** alfalfa, **2)** clover alfalfa mix, **3)** hairy vetch, and **4)** orchard grass were established under 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. Stand establishment was evaluated 30 days after planting and the number of undesirable plants per meter squared determined.

Results, conclusions and lessons learned:

Goal A. We are currently in the process of completing data analysis. Problems with the soil nitrogen analyzing equipment has slowed us down with the final soil data analysis but initial results from tree growth and weed count data clearly show that competition from weeds not lack of nutrients will be the main challenge when managing orchards in a reduced input or integrated fashion. Tree growth was greatest in response to compost + herbicide applications, exceeding though probably not significantly, conventional fertilizer + herbicide treatments. This is no doubt due to soil quality benefits associated with the use of compost. The spray on paper mulch was very successful in reducing the need for herbicide applications. It is likely that only one if any herbicide applications will be needed in these plots this year as a result. We are still in the process of analyzing the results of the alternative herbicide / mulch combination trial. Initial findings show that acetic acid and scythe both have potential as non-residual non-systemic contact herbicides relative to the glyphosate control. Both the clove oil and lemon oil were relatively ineffective on all weeds accept small annuals, however. Wood chip and paper mulches were the most effective mulch combinations. Straw could be effective if clean seed free straw could be obtained or a means of sterilizing it determined.

Goal B. Data analysis of the water savings associated with paper mulch are not complete, however, initial observations indicate water savings may be significant. Slightly, although probably not significantly, reduced tree growth was associated with use of the paper mulch, likely due to a slight tying up of nutrients as a result of the carbon added to the system. We intend to try to compensate for this with slightly increased fertilizer rates in the future.

Goal C. All six legume combinations seeded at the Kaysville Experiment Station and on farm at Tintic Valley Utah, were successfully established last summer and are growing well. The next phase of this project to take place in the summer of 2010 will be to determine biomass generated and subsequent contributions to orchard fertility, the ability of the different cover crops to stand up to wheel traffic and the water use efficiency.

Long-term outcome measures:

Establishing the orchard, and successfully collecting the first year of data 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.

Presentations: David Granatstein from Washington State University presented results from his research on reduced input and organic orchard floor management to the Utah Horticultural Association's annual meeting in February 2010. An introduction to the challenges of tree fruit production in Utah including an overview of this project was presented to members of the public as part of the Wallace Stegner Symposium at the University of Utah on March 12th 2010. A progress report of this research was presented to the members of the Utah Horticultural Association's grower research committee on April 8th 2010.

Field day: A field day will be held at the Kaysville experiment station on August 17 to highlight this project.

Additional information:
We have not submitted any publications from this project to date. This second year of the project represents the first year of actual data collection after orchard establishment and baseline data collection were completed. A second year of data will be collected over the coming season and results published in at least two initial publications. One on options for organic and reduced input weed control and one on the effect of mulches, soil quality and water use on tree growth. A fact sheet for extension purposes is also planned.

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G. Principles of Inspecting and Auditing Food Plants

Outline of issue, problem, interest or need for the project: Starting in the year 2011, Utah Fruit Growers will be required to participate in an annual Global Good Agricultural Practices (GAP) audit conducted by the USDA.

Payson Fruit Growers anticipated the need for GAP training and proposed holding a seminar to help Utah fruit growers and their employees understand, at the grower level, the importance of Global GAP Principles.

Approach: Payson Fruit Growers held the two-day Global Gap Training Workshop for Utah Fruit Growers with a focus on the following:

1. Global Good Agricultural Practices (Global-GAP)
2. A Pre-Audit Conducted by the Seminar Directors at 3 Local Farm Locations

Goals Achieved: Attendance at the seminar was high with over 90% of the Utah Tart Cherry growers, 60% of the Utah Apples growers and 70% of the Utah Peach growers in attendance.

The seminar schedule was as follows:

Day 1: Attendees were taught how to effectively apply Good Agricultural Practices (GAP)

Day 2: On-site GAP inspection of 3 local Fruit Farm operations

Results, conclusions and lessons learned: The attending fruit growers and their employees found the seminar to be informative and valuable. They also felt the on-site inspections would be helpful in establishing their individual GAP programs, as most are doing now.

Additional Information: Since the training seminar, Payson Fruit Growers has sponsored seven – two hour workshops based on the GAP principles taught at the seminar. This assistance is for any seminar attendee requesting help and is hands-on using the materials received at the seminar.

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H. Wasatch Community Gardens—Youth Gardening Program

Outline of the issue, problem, interest, or need for the project:
Childhood obesity may be today's most critical health issue, stranding a generation of youth without adequate opportunities to discover fresh, healthy food. This national epidemic strongly affects Utah with one in four children overweight and 10% classified as obese. Most alarmingly is the fact that 65% of youth who are currently overweight will remain so into adulthood.

In part because they lack access to healthy food, children from low-income families are more likely to be overweight and obese. The Youth Gardening Program specifically focuses on engaging low-income youth along the Wasatch Front in how to make healthier choices by discovering fresh fruits and vegetables and providing the students with the skills to be more active.

Approach:
The Youth Gardening Program at Wasatch Community Gardens educated participants about healthy habits through our weekly garden classes held in two of our youth gardens.
Through seasonally adapted sessions, students interactively explored the tastes of unfamiliar fruits and vegetables through cooking and tasting, gained knowledge of basic gardening skills, successfully grew and harvested their own produce, and understood the importance of organic gardening as a globally responsible practice. A total of 1,576 youth participated in the project during 2009.

Goals achieved:
Half of the Youth Gardening Program classes were held at the Grateful Tomato Garden in the Central City neighborhood and the other half at the Fairpark Garden on Salt Lake City's west side. Classes were taught year-round by a highly experienced youth educators. Throughout the seasons, youth prepared and tended almost 6,000 square feet of garden beds and harvest several thousand pounds of fresh produce to be eaten during class, shared with their families and donated to local food pantries.

In order to achieve the programs goals and objectives, Wasatch Community Gardens collaborated with roughly 30 social service agencies (i.e. Boys and Girls clubs, Youth City programs, the YWCA) to engage low-income youth in hands-on garden lessons. Original and innovative classes such as "Eat Your Colors" which focuses on nutrition, and "Three Sisters" which teaches the importance of garden planning, facilitated indispensable life experiences to provide the youth gardeners with education about and access to local healthy food.

Results, conclusions, and lessons learned:

Through the youths' participation in the Youth Gardening Program, the following measurable benefits were achieved at the end of each 6-10 week program session:

- 90% of participants could identify and taste three new fruits or vegetables. Tasting and preparing produce is an integral component of the Youth Gardening Program. In each lesson, participants explored the sensory attributes of a wide variety of edible plants, including fruits, vegetables, herbs, and flowers. Being exposed to fruits and vegetables is the first, and sometimes the hardest, step in getting youth to make long-lasting healthy nutritional choices.
- 90% of participants gained a new gardening skill. Youth engaged in a series of hands-on lessons based around the garden life cycle, from planting, watering, weeding, 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.
- 100% of participants took home a new fruit or vegetable to share with his/her families. Connecting a youth's experiences in the garden to life outside the garden is an important component of the Youth Gardening Program, encouraging healthy behaviors throughout a youth's daily life. Thus, youth bring fruits and vegetables they have grown back to their families expanding the reach of these new healthy behaviors into the home setting.

Long-term outcome measures:
In order to serve more youth, over the next two years we will partner with new youth agencies, in addition to the 30 current partners that currently bring youth to the garden. Some of these new partnerships will be founded on a field trip program to be established in 2011, built around an assortment of field trip modules that will take the youth to two of our youth gardens. In 2011 we will also continue to pilot a model school gardening program, to be replicable for schools throughout Salt Lake County by 2012. We have researched and developed a year-long weekly science-based school gardening curriculum for grades K-3 that is tied to the state curriculum and will work with a model school to refine the process of starting and maintaining school gardens in the future.

Additional information:
General information about the Youth Gardening Program can be found on our website at: http://wasatchgardens.org/about/programs/youth-gardening.

Contact:
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I. Utah Fruit and Vegetable Grower's Association

Outline of the issue, problem, interest or need for the project:
Commercial fruit and vegetable growers did not have and organization or association to facilitate networking and communication. Additionally, a growing number of backyard growers and gardeners have been looking for information, education and networking assistance.

Approach:
The Utah Fruit and Vegetable Association was formed to better connect commercial growers and gardening enthusiasts to one another, as well as to other community organizations and various distribution networks. Many smaller urban growers and gardeners don't always know where to go to access information from agencies and other growers.

Some of our major goals included establishing a 501 c3 non-profit organization; building a database of fruit and vegetable growers and gardeners; connecting the growers with agricultural service and educational organizations such as the Utah Department of Agriculture and Food and Extension; and also to provide internet-based and in-person forums and opportunities for growers to meet, network, pool resources, and learn from one another.

Goals achieved:
There were five main goals outlined in the work plan, all of which have been successfully completed.

a) **Create the Utah Fruit and Vegetable Growers Association**

We changed the name to the Utah Fruit and Vegetable Association prior to applying for a 501 c3 designation.

b) **Develop a database and potential membership list of Utah fruit and vegetable growers**

We reached out to several organizations such as Extension, local conservation districts, USDA Service Centers, Wasatch Community Gardens and local farmers markets to recruit members.

c) **Survey growers**

We asked our founding board members and many of our early registered members and Facebook fans about the types of issues they would like addressed in our online community and out annual in-person meeting.

d) **Create Website for education, networking and to allow growers to begin to market themselves**

An interactive Face Book style website was created and launched in May 2009. The site offers registered participants an opportunity to post questions, answers or other information

related to several fruit and vegetable growing topics. The site also features a general front page, contact information and helpful resources and publications anyone can access.

e) **Organize one in-person educational and networking forum**

The annual meeting was held on March 20, 2010 at the Columbus Center in South Salt Lake, Utah. One hundred people (including discussion leaders/presenters) registered for the Saturday afternoon event.

Results, conclusions and lessons learned:

- We recruited board members who represent both commercial growers and backyard gardeners.
- We now have more than 70 registered members on our website and more than 135 fans on our Facebook page.
- The annual meeting/Share Fair was attended by more than 75 gardeners and growers from throughout Utah. We had growers from at far north as Cache Valley and as far South as Washington County. While we had 100 registrants, a turn out of 75-80 on the first day of Spring was very satisfying. We collected more than 50 evaluation forms, all of which were either somewhat or very positive.

Additionally, one of the main benefits from the activities of UFAVA in this first year is that several growers and gardeners have connected. They are sharing information electronically and in person. In a few cases, experienced commercial growers are becoming mentors for younger growers who are just starting out as commercial growers, or farmers.

Long-term outcome measures:
One of the biggest long term goals of this organization is to have an impact on the amount of fruits and vegetables grown in Utah, both for sale and personal use. Along with encouraging and mentoring a handful of new commercial growers, UFAVA members helped start a local community farmers market last year (in South Salt Lake) and these same members are helping start a new market for 2010 in the Sugar House area of Salt Lake City. We plan to use our website and social networking pages to connect new and young growers and gardeners with more experienced mentors. We also plan to connect with Salt Lake County's Urban Farming Initiative program share information and connect with urban growers.

UFAVA's ongoing goal of increasing membership and networking opportunities among growers and gardeners has also been aided by periodic news coverage. The annual meeting received mentions in the Salt Lake Tribune, the Deseret Morning News and the Valley Journal newspapers. Most recently a local television news reporter sought out UFAVA representatives for comment when cold spring temperatures threatened fruit blossoms. We are striving to be a go-to organization when the news wants a comment about a fruit or vegetable growing issue or when individual growers or gardeners have growing questions.

Additional Information:
One of our main accomplishments for the year is the website: www.ufava.org. We are also proud of our Facebook presence, which can be accessed via the UFAVA web page.

Contact:

For additional information about the grant activities or budget, contact Kari Cutler. Karicutler@me.com. 801-468-0692.

J. Pioneer Craft House Gardening Education and Farmer's Market Program

Outline of issue, problem, interest, or need for the project: The Pioneer Craft House (PCH), located within the City of South Salt Lake, had a run down greenhouse on the premises, where gardening classes used to take place. The Craft House grounds also previously hosted a farmers market that only lasted one year. Additionally, the City of South Salt Lake, where the PCH is located, has a large minority and refugee populations, a high percentage of people living below the poverty line standard, and very low percentages of people who eat the recommended daily intake of fresh fruits and vegetables.

Approach: With all of those factors in mind, the Pioneer Craft House Specialty Crop grant was designed to refurbish the greenhouse, restart gardening education programs and restart the farmers market. The long term goal is to increase fresh food consumption of SSL residents.

We started in February 2009 planning the farmers market. The approach was to integrate gardening classes periodically into the weekly market activities to promote more home gardening within the City. The market itself also included a free Dutch oven dinner (donations were accepted) and weekly entertainment was provided.

The market planning committee estimated that the weekly average crowd was about 300-400 people. Some weeks drew much larger crowds.

Goals achieved: The market was advertised through banners and signed place around town; through articles in local newspapers including the Salt Lake Tribune, The Deseret News and the Valley Journals; and through television news advertising.

The project was very successful in increasing the number of times the South Salt Lake Farmers Market was held going from 4 times in 2007, none in 2008, to 15 weekly markets in 2009. The market averaged 3 to 4 produce vendors during the 2009 season, up from 1-2 during the 2007 season. Selection and variety was also far superior to previous years. During the height of harvest season there were a few weeks with six product vendors.

A total of 12 gardening and food classes were held during the season. The low attendance was 5, the high 26 with an average attendance of 12, or a total participation of 144. Most of the classes ended up being single evening courses. The project proposed pre-course and post-course testing.

However, testing was very informal and the results were not compiled or saved by the various instructors.

Results, conclusions, and lessons learned from the project: We learned a few valuable lessons about starting a farmers market. These are things we hope to improve on in future years, pending available funds:

1. We could have increased attendance and better served the most needy in the community if we had set aside funds to get set up to accept electronic benefits transfer payments from government issued SNAP cards.
2. We thought we had thoroughly checked to make certain there were no other Tuesday evening markets in the closest nearby towns. We only knew of one market in the metro area that night in a town about 20 miles away. We later found out the highly successful Downtown Salt Lake City Saturday Market was planning a spin-off produce only market for Tuesday evenings during the last half of our season. That market plus the beginning of public school classes around Labor Day reduced our attendance as the season went on.

The other portion of the project to refurbish the Greenhouse and re-establish a gardening curriculum at the Pioneer Craft House went very well. By the end of the grant period all of the repair and refurbishing work had been completed or contracted and all of the monies have been spent. Some of the work included:

- Re-wiring of the electrical system in the greenhouse.
- Replacing the heater.
- Replacing the watering system and repairing the water line.
- Replacing the work/planting benches.
- Replacing the greenhouse doors.
- Cleaning the greenhouse panels.

Long-term outcome measures: Informal gardening classes were offered last summer during the market. Additional offerings will now be scheduled. A group of refugees is also currently using some of the space behind one of the buildings as garden space. Next year they will use the greenhouse to start their plats. The refugee program is a part of the Salt Lake County Program to help refugees create financial opportunities for themselves.

Additional Information: The overall greenhouse/farmers market project has helped build a greater sense of community in South Salt Lake and has helped many local residents learn about the pleasures and health benefits of eating fresh fruits and vegetables.

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K. Extending Production Opportunities and Profitability on Small Farms with High Tunnels

Outline of issue, problem, interest, or need for the project: While Utah's climate and soils favor high yields, seasonal production windows are short and climatic conditions can impact early and late season productivity. High tunnels are a season-extension technology that provides low-cost ways for growers to extend the spring and fall production periods and provide local produce to markets when prices are high. 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; Pritts, 2003) 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, plant growth in our climate is limited more by day-night temperature fluctuations. These fluctuations reduce plant growth rates and late spring and early fall frosts dramatically limit the length of the field growing season. The high light intensity typical of spring and fall conditions in the west should provide opportunities for increased plant growth, but also may present new management challenges particularly if radiant cooling at night is great, or if fruits are prone to damage due to sunscald (Alexander and Clough, 1998; Darnell et. al., 2006). To overcome the effects of cold night temperatures secondary tunnels (fabric or plastic row covers) inside the high tunnels or through modest heat additions like soil and targeted air warming could be used to keep plants from stress. Shade cloths are also recommended during hot summer weather to reduce light loads and leaf temperature thus mitigating heat effects on productivity.

Developing high-tunnel production systems for the climatic regions of the Intermountain West will increase the returns that can be generated on small-parcel farms at the urban interface, and will also provide the ability to supply local produce to the region's rural population. This project assessed the crop production schemes in an attempt to maximize production and farm profitability for early tomato production. In a second set of work, cropping systems were evaluated for June-bearing strawberry. These cropping systems could provide growers early season market extensions to meet the growing demand for local produce in CSA's, farmer's markets and other market outlets (farm gate, restaurants, etc). Our goal is to use our production information to create economic cost of production and potential market returns and synthesize this information into production guides and fact sheets.

Approach:

1. Assess yield response of low energy inputs to improve early season tomato performance.
2. Assess yield response of alternative production strategies to improve early season strawberry performance.
3. Use information from research on tomato and strawberry to draft enterprise budgets and production guides for use throughout Utah.

Between 2005 and 2008 twelve (12) high tunnels of various designs were built on the Utah State University Greenville Research Farm in North Logan. The tunnels vary in size from 14 to 30 feet wide and 30 to 42 feet long (680-900 sq ft). We have two different designs; a less

expensive, PVC framed, low-sided, portable, field hoop houses (see Photo 1) used for vegetables and strawberries and the more expensive, steel framed, high-sided tunnel primarily used for growing raspberries and blackberries.

One area of concern has been how early season low temperatures can impact the growth and productivity of tomato and strawberry. One approach to dealing with low temperatures is to provide some supplemental heat to either the soil or the air around the plants when night temperatures fall to a critical value. We have already demonstrated that plastic row covers placed over plants inside the high tunnels can effectively alter air temperatures. This project assessed if low-cost targeted heating sources were suitable and economic for use in tomato production systems.

We evaluated three (3) heating approaches (Photo 1) to overcome the low temperature conditions that regularly occur early in the season. These systems include;

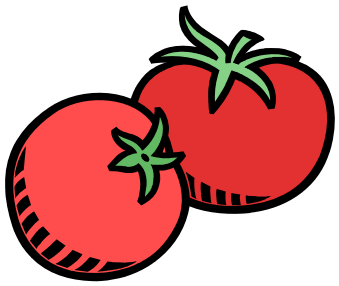
1) Thermostatically controlled heating cables buried in rows before planting tomatoes grown under low tunnels.
2) Thermostatically controlled soil heating cables plus 40 watt incandescent light bulbs place under low tunnels programmed to turn on at predetermined temperatures for tomato (~40F).
3) A control where no heat was provided but plants were grown under low tunnels.

For the strawberries trials, rooted plugs were transplanted on 5 dates the fall of 2008 (Jul 31, Aug 14, Aug 26, Sept 11, and Sept 25) for harvest in the spring of 2009. Planting dates were used to identify the optimal time for planting that maximized crown and flower development but minimized runner growth. In addition to planting dates, strawberries were grown in the conventional ground based system or in raised towers designed to utilize more of the tunnel growing area. Towers were made from PVC rain gutters positioned to face east-west or they had a southern exposure (Photo 2). To assess if the tunnels advanced earliness and productivity, an outside field site was planted similar to the ground based production system.

We monitored soil and air temperatures, tracked energy use, kept track of labor and input costs, monitor plant growth and measured the yield and quality of tomato and strawberries for these projects. Fruits were sold at the USU teaching greenhouses or the Logan Farmers Market to assess economic return. The yield and economic data was used to create the enterprise budget for the crop. Data collected was use to develop production schedules guides (see Appendix 1-3) that describe those feature needed to successfully grow high value crops in high tunnels. In addition to the heating, tomatoes were transplanted on three dates (March 17, March 30 and April 7, 2009) to ensure that plants were exposed to less than ideal environmental conditions thus assessing the benefits of supplemental heating treatments.

<u>Goals achieved:</u>

Tomatoes:



It was difficult to distinguish any temperature differences between the unheated control and those treatments that used soil heating cables or the combination of light bulbs and heating cable to regulate the temperature under low tunnels. Therefore the mean

temperature under the low tunnels was compared to the outside temperature for the March 1 to May 10 time period of 2009 (Figure 1). It is important to note that putting a low tunnel inside a high tunnel ensured that air temperatures around the plants stayed near or above the critical base temperature (10C or 50F) needed for tomatoes to grow. For this study, more than 288 plants were planted and there was a 99% survival for all treatments (data not shown).

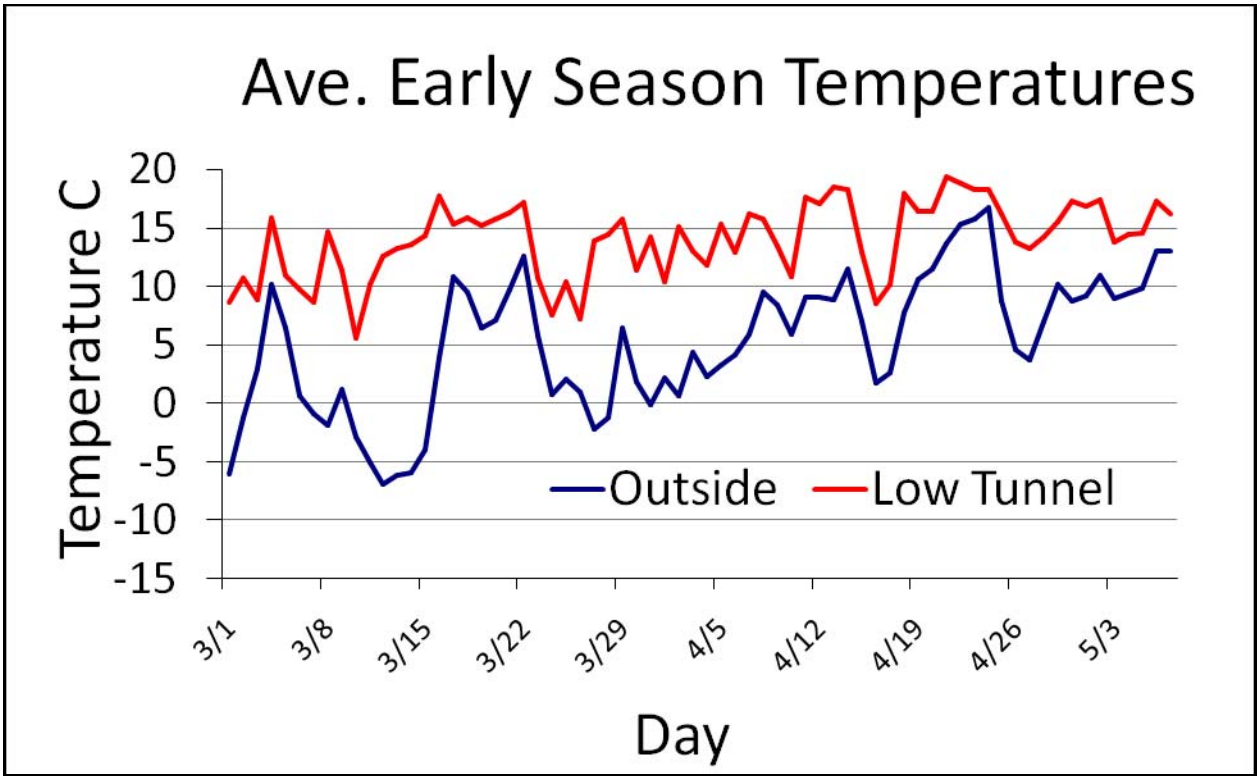


Figure 1. Early season temperatures in low tunnels compared to outside temperatures from March 1 to May 10, 2009.

Tomatoes grew normally and flowering commenced in mid-late May for the various planting dates. The first fruit harvest in all treatments began on July 7. Heating both the soil and air around tomato plants had a significant positive effect on early yield when compared to the unheated control (Table 1). Heating the soil alone had an intermediary effect on productivity. Early tomato yield constituted all ripe fruits harvested between July 7 and 24. While heating the soil and air improved early productivity, there was no significant difference between heating treatments on marketable or total yield in 2009 though there was a trend toward increased yield with more heating approaches.

The earliest planting date had a significant positive effect on early and marketable productivity when compared to the latest planting date in 2009 (Table 1). Even though the risk of cold weather is greater with early planting dates, there is a real positive effect to planting early and using some supplemental heat that improves earliness and generates greater marketable yield. In 2009, outdoor tomatoes were not available in the local marketplace until around the 10th of August. Thus the advantages of high tunnels were to provide product that could be marketed for

4-5 weeks before field grown tomatoes took away the competitive edge. In most years, most tunnel grown tomatoes were harvested in a 4-5 week period further reinforcing the advantage of using tunnels to increase early productivity and create new market opportunities.

Table 1. Effect of low input heating and planting date on early, marketable and total yield of tunnel grown tomatoes in 2009.

Heating Treatments	Yield (lb/plant)		
	Early#	Marketable	Total
Unheated	2.6	9.7	11.0
Cable Heat	3.1	9.9	11.9
Cable + Lights	4.2	10.8	12.6
Planting Dates	Early	Marketable	Total
March 17	4.4	10.8	12.6
March 30	4.0	10.6	12.1
April 7	1.5	8.8	10.8
ANOVA	p-values		
Heating	<0.001	0.235	0.285
Planting Date	<0.001	0.035	0.135
Heat*Planting	0.01	0.178	0.355

- early harvest included all fruits picked between July 7 and 24.

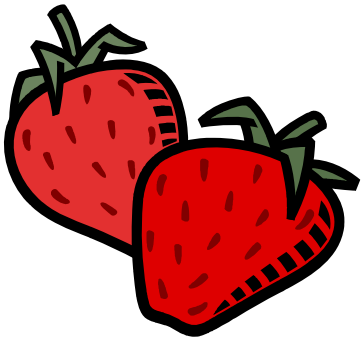
Partial Tomato Enterprise Budget.

Yield and input cost data were used to develop the partial Enterprise Budget based on the management system developed at the Utah State University high tunnel research facility (Table 2). Net income for a 14 x 96 foot low-cost PVC high tunnel is estimated to be $1,995. This includes total sales of approximately $3,600 less total expenses of $1,605. Total expenses include annual operating expenses, or the expenses associated with yearly production (supplies, labor, etc); as well as the annual depreciation costs of the high tunnel and irrigation system. The high tunnel and irrigation systems will be used over multiple years so an equal portion of their total cost (depreciation) was assigned to each year they are expected to remain in service (6 yrs lifespan). Sales data were collected from produce being sold at the Logan Farmers Market in 2009 and used for example purposes only. Higher or lower prices may be expected at other market venues (farm gate, wholesale, direct sales, etc). No comparison was made to field production of tomatoes where lower returns may be expected when a premium for earliness is not realized. In addition, commercially purchased steel-framed high tunnels generally cost significantly more than the USU designed PVC tunnels used for this project. Steel-framed tunnels are more permanent, larger in size, and can accommodate tractors and equipment that may reduce some labor costs.

Table 2: Spring Tomato Enterprise Budget (partial) for a 14 x 96 foot high tunnel.

	Units	Quantity	Unit price	Total
Sales				
Ripe Tomato Fruits	Pounds	1800	$2.00	$3,600.00
Supplies	Various			$325.00
Labor				
Site Preparation	Hours	8	$10.00	$80.00
Crop Management	Hours	55	$10.00	$550.00
Harvest/Post-harvest	Hours	30	$10.00	$300.00
Annual Operating (supplies and labor)				$1,255.00
Tunnel Depreciation				$275.00
Irrigation Depreciation				$75.00
Net Income				$1,995.00

Strawberries:



Planting date had a significant effect on runner and crown development in strawberries. To maximize yield, planting dates have to be early enough to allow good establishment and crown branching but not too early that the plant initiates and grows lots of runners. While later planting dates reduces runner development, it also reduces crown initiation and thus decreases flowering potential. In general, planting dates around the first of September had fewer runners and more crowns than earlier or later planting dates (data not shown). This resulted in better early and total fruit yields. Planting date had a significant quadratic early yield effect on strawberries for the in-ground and east-west towers but no effect on south facing towers in 2009 (Table 3). Predicted optimal fall planting date for the in-ground system was August 30 and for the east-west tower system was September 5. Early fruit yields were significantly lower when strawberries were grown in either the east-west or south facing towers when compared to the in-ground planting system. One of the main objectives of growing strawberries in high tunnels is to generate early yields which can be marketed at a premium. Tunnel grown strawberries in all planting systems began fruiting between May 7 and 14 while outdoor grown strawberries did not start fruiting until early June.

Table 3. Influence of fall 2008 planting date on early strawberry fruit yield for five different planting dates in four different systems in 2009. Early yields are from May 7 to June 8 which constitutes the period before outside production began.

Planting Date '08	Early Yield (grams/plant)			
	In-ground	East-West	South	Outdoor
Jul 31	218	49	131	-
Aug 14	250	139	138	-
Aug 28	329	131	147	-
Sep 11	295	138	154	-
Sep 25	228	91	164	-
ANOVA	P-value			
Date	0.042	0.009	0.910	-
linear	0.427	0.619	0.963	-
quadratic	0.006	0.002	0.377	-
Optimum	Aug 30	Sept 5	Aug 28	-

Table 4 provides the total strawberry fruit yield for the four different planting systems. Highest total yield was recorded in the high tunnel in-ground planting system for the August 28 2008 planting date. Yields were about twice as high in the in-ground system as compared to the east-west towers, south towers or outdoor field grown strawberry systems. Optimal fall planting dates ranged from late August to mid-September for the different systems.

Table 4. Influence of fall 2008 planting date on total strawberry fruit yield for five different planting dates in four different systems in 2009.

Planting Date '08	Total Yield (grams/plant)			
	In-ground	East-West	South	Outdoor
Jul 31	321	143	228	220
Aug 14	434	261	250	277
Aug 28	530	285	220	232
Sep 11	463	247	245	317
Sep 25	334	206	245	95
ANOVA	P-value			
Date	0.006	0.001	0.909	0.173
linear	0.693	0.751	0.591	0.074
quadratic	0.001	0.001	0.484	0.125
Optimum	Aug 29	Sept 3	-	-

A strawberry harvest (yield) time course to compare the four different growing systems is presented in Figure 2. This illustrates the weekly yield accumulation over time and provides some insight into developing extended fruit production to take advantage of possible crop shortages in the marketplace. Using a combination of high tunnels, different production

approaches and outdoor plantings, growers could have strawberries for the marketplace for up to nine weeks. This is considerably longer that the normal four week harvest window for outdoor June-bearing strawberries. Comparing systems based on per-plant production showed that the in-ground system had the highest early (329 g/plant) and a total (530 g/plant) yield. The south facing tower system had an early yield of 164 grams/plant and a total yield of 245 g/plant. The east/west tower system had the lowest early yield (131 g/plant) with an intermediate total yield of 285 g/plant. The outdoor field system yielded 317 g/plant.

However, due to the differences in design and tunnel space utilization with the east-west and south facing tower systems, plant density varied greatly. Total plant population was greatest in the east/west facing towers at 2 plants/ft^2 of tunnel floor area, compared to 1.5 and 0.7 plants/ft^2, respectively, for the south-facing towers and in-ground systems (in-tunnel and outdoor planted areas). Therefore the east/west towers maximized early yield per unit tunnel area (0.58 lb/ft^2) compared to 0.54 and 0.49 lb/ft^2 for the south facing towers and the in-ground tunnel system, respectively. The outdoor field system produced total yields of 0.37 lb/ft^2 which were the lowest performing system in this study. As can be seen from these results, high tunnels were very effective in increasing both early and total strawberry yields, and the east west facing vertical system maximized yields per tunnel area.

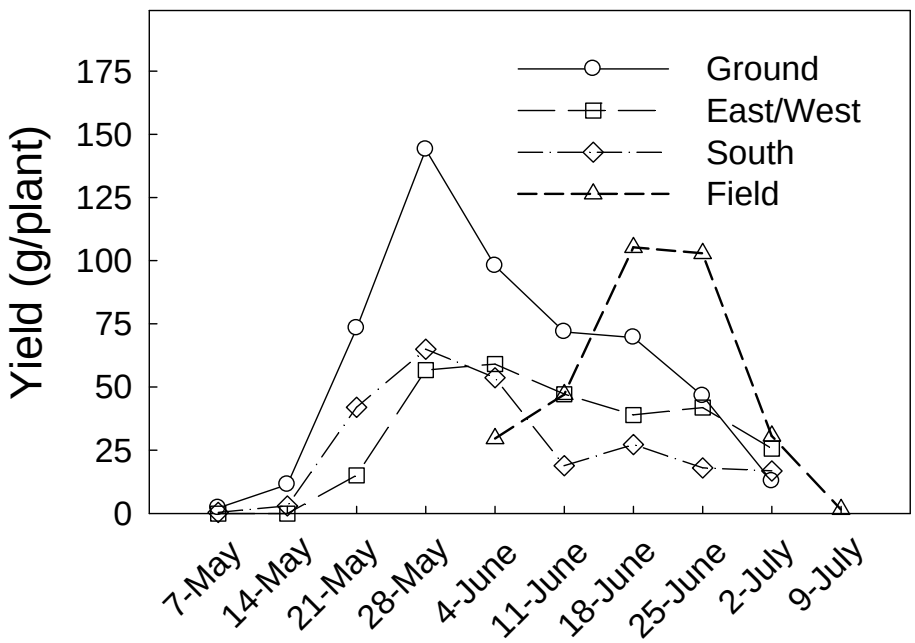


Figure 2. Strawberry fruit production time course for 2009 comparing four different production systems for the ideal planting dates in 2008. Planting dates for the different systems were 28 Aug, 28 Aug, 25 Sept, and 11 Sept for the in-ground, east/west-facing vertical, south-facing vertical, and field growing systems, respectively.

Partial Strawberry Enterprise Budget.

Data collected and used to develop the partial Enterprise Budgets for strawberry are based on the management system developed at the Utah State University high tunnel research facilities (Table 5). This system consists of fall planted strawberry plug plants, on raised beds that are covered

with plastic mulch. In this budget, supplies were purchased from local retailers and the amount of supplies used in establishing and maintaining the high tunnel strawberry planting were scaled up to accommodate a 14 by 96 foot high tunnel. Our limited experience suggests that a 50% markup over regular season prices is reasonable. We generally sold in-season strawberries for $3.00 for a 1 pound clamshell and early out-of-season strawberries for $4.50 per 1 pound clamshell both on the campus of Utah State University and at the Logan Farmers Market.

Net income for a 14 x 96 foot tunnel is estimated to be $1,655. This includes total sales of $4,380 less total expenses of $2,725. Total expenses include annual operating expenses, or the expenses associated with yearly production (supplies, labor, etc); as well as the annual depreciation costs of the high tunnel and irrigation system. The high tunnel and irrigation systems will be used over multiple years so an equal portion of their total cost (depreciation) was assigned to each year they are expected to remain in service (6 yrs lifespan). Sales data is used for example purposes only. Higher or lower prices may be expected at other market venues (farm gate, wholesale, direct sales, etc). No comparison is made to field production of strawberries where lower returns may be expected when a premium for earliness is not realized.

Table 5: Strawberry Enterprise Budget (partial) for a 14 x 96 foot high tunnel. Information presented based on the in-ground production system.

	Units	Quantity	Unit price	Total
Sales				
Early Strawberries	1-lb clamshells	840	$4.50	$3,780.00
In-season Strawberries	1-lb clamshells	200	$3.00	$600.00
Total Sales				$4,380.00
Supplies				$525.00
Labor			$10.00	
Site Preparation	Hours	35	$10.00	$350.00
Crop Management	Hours	60	$10.00	$600.00
Harvest/Post-harvest	Hours	90	$10.00	$900.00
Annual Operating (supplies and labor)				$2,375.00
Tunnel Depreciation				$275.00
Irrigation Depreciation				$75.00
Net Income				$1,655.00

<u>Results, conclusions, and lesson learned:</u> High tunnels can effectively be used in Utah as an early season extension technique for the production of both tomato and strawberries. Tomatoes grown in tunnels produced high early yields with significant production occurring up to 5 weeks before outdoor tomatoes. Therefore, fruits should be able to be sold at a premium in local markets. Tomatoes planted in mid- to late March generated higher early and total yields than

those planted later in April. The additional cost of heating either the soil or the soil and air around plants was not warranted for later plantings but did improve production when used with early planting dates. Additional work is being conducted on supplemental heating but at present we cannot recommend its use as the returns only just cover the cost of setup and operation.

Similar findings were noted with strawberries grown in high tunnels. Production was up to five weeks earlier in the high tunnel as compared to outdoor field production. High yields were achieved in the east/west-facing vertical system as valuable high tunnel space was utilized more efficiently thus increasing yield per unit area. However, the additional yield benefits were not sufficient to offset the additional costs of production for plants, building materials, and management costs associated with the use of towers. Additionally, fall planting date for the in-ground system and the east/west-facing vertical system was also optimized for northern Utah conditions. Our studies indicate that the optimal fall planting date for early yields is approximately within the range of late August to early September.

Long-term outcome measures:

Tomato Enterprise Budget:	Appendix 1	pages 11-12
High Tunnel Tomato Production:	Appendix 2	pages 13-21
Strawberry Plug Plant Production:	Appendix 3	pages 22-26

http://extension.usu.edu/files/publications/publication/Horticulture_HighTunnels

Additional information:

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Photo 1 (upper): Evaluation of mid-March planted tomatoes. Note lights for air warming and low tunnels to improve temperatures near the plants. Photo 2 (below): Evaluation of autumn planting dates and south facing towers for early strawberries in tunnels.

Appendix 1. Spring Tomato Enterprise Budget for a 14 x 96 foot low cost high tunnel.

Early Tomato Production			96' x 14' High Tunnel			
			units	quantity	sale price	total
Sales			lbs	1,800	$ 2.00	$ 3,600.00
			units	quantity	unit cost	Cost per tunnel
Supplies						
	Preplant and preperation costs					
		Soil Test	each	1	$ 14.00	$ 14.00
		fuel	gal	1	$ 2.50	$ 2.50
		Preplant fertilizers N-P-K	lbs	8	$ 1.00	$ 8.00
		Compost	tons	0.45	$ 50.00	$ 22.50
		plastic mulch	ft	290	$ 0.05	$ 14.50
		drip tape	ft	290	$ 0.05	$ 14.50
	Establishment					
		Transplants	each	200	$ 0.25	$ 50.00
		Plastic for low tunnels	ft	300	$ 0.20	$ 60.00
		Wood stakes	ea	100	$ 0.45	$ 45.00
		Baling twine	ft	2600	$ 0.01	$ 15.60
		46-0-0 Urea	lbs	1.5	$ 0.33	$ 0.50
	Tomato Harvest					
		Harvest boxes	each	20	$ 1.00	$ 20.00
		Market boxes	each	25	$ 2.40	$ 60.00
	Total Supplies					$ 267.10
Labor						
	Preplant and preperation costs					
		soil test	hours	0.5	$ 10.00	$ 5.00
		Apply preplant fertilizers	hours	0.75	$ 10.00	$ 7.50
		Tillage	hours	2	$ 10.00	$ 20.00
		cover with plastic mulch	hours	3.75	$ 10.00	$ 37.50
		install drip tape	hours	1	$ 10.00	$ 10.00
	Establishment					
		Planting labor	hours	2.5	$ 10.00	$ 25.00
		Install low tunnels	hours	3	$ 10.00	$ 30.00
		Stringing plants	hours	6	$ 10.00	$ 60.00
		Weeding	hours	6	$ 10.00	$ 60.00
		Plastic and shade cloth	hours	12	$ 10.00	$ 120.00
		Irrigation and temperature management	hours	26	$ 10.00	$ 260.00
	Tomato Harvest					
		Harvest and grading	hours	24	$ 10.00	$ 240.00
	Post Harvest					
		House clean out	hours	5	$ 10.00	$ 50.00
	Total Labor					$ 925.00
	Annual Operating Expenses (supplies and labor)					$ 1,192.10
	Annual Cost of High and Low Tunnels					$334.86
	Annual Cost of Irrigation System					$74.03
	Total Expenses					$ 1,600.98
	Net Income					$ 1,999.02

			units	quantity	unit cost	total
Tunnel Construction						
	High Tunnel					
		High Tunnel	each	1	$ 697.00	$ 697.00
		High Tunnel Construction Labor	hours	25	$ 10.00	$ 250.00
		6 mil Greenhouse film	24'x50' / 24'x	1	$ 200.00	$ 200.00
		Shade Cloth		1	$ 300.00	$ 300.00
	High Tunnel Subtotal					$ 1,447.00
	Low Tunnel					
		conduit arches	10' sections	30	$ 1.65	$ 49.50
		1/2" x 24" rebar	each	60	$ 1.66	$ 99.60
	Low Tunnel Subtotal					$ 149.10
	Total					$ 1,596.10
	Annual Cost of High and Low Tunnels					$334.86
Irrigation system						
		3/4" poly pipe	ft	14	$ 0.42	$ 5.88
		1" valve	each	1	$ 5.15	$ 5.15
		misc fittings	each	10	$ 1.00	$ 10.00
		drip hose adapter	each	6	$ 0.56	$ 3.36
		*injector	each	1	$ 265.00	$ 265.00
		* filter	each	1	$ 12.50	$ 12.50
		* pressure regulator	each	1	$ 11.00	$ 11.00
		*Instalation	hours	4	$ 10.00	$ 40.00
	Total					$ 352.89
	Annual Cost of Irrigation System					$74.03

L. Evaluating the Native Shrub "*Eriogonum Corymbosum*" as a Nursery Crop and for use in Low Water Use Utah Landscapes

Outline of issue, problem, interest or need for the project: Low water landscaping is a critical tool for water agencies and policy makers throughout Utah who are balancing limited water supplies against increasing demand from population growth. Low water landscaping is key to sustainable, long term water savings because it inherently changes behavior. Drought tolerant plants are essential to successful low water use landscaping. In particular, Utah native shrubs and wildflowers offer a tremendously valuable and diverse palette of attractive drought tolerant plants that are adapted to our arid climate.

The genus *Eriogonum* has many species native to Utah that are both attractive and drought-tolerant. *Eriogonum corymbosum* in particular is a shrubby species that is especially promising. It is found throughout southern Utah in dry habitats and, unlike almost all other native shrub and perennial wildflower species, it blooms the first year from seed. It also blooms during late summer-early autumn when little else is in flower, and is highly diverse genetically. The flowers

of *E. corymbosum* vary from white, to cream, yellow, pink and red. Its crown form also varies between very regular hemispheres to a more irregular open shape of different sizes, and its leaves vary in both size and color.

The diverse ornamental characteristics of *E. corymbosum* suggest the opportunity for a number of economically valuable cultivars. However, the genetic stability of this variation in ornamental traits is unknown. If these traits are not reproducible from seed, there is little prospect for cultivar development. Also, while *E. corymbosum* is found in dry habitats, how much drought it can tolerate in the landscape, while maintaining appearance and growth, is not known. Understanding the genetic stability of its ornamental traits and its drought tolerance is critical to the economic acceptance of *E. corymbosum* by the nursery industry and the plant-buying public.

Approach: The approach to developing Eriogonum corymbosum:

- Collecting *E. corymbosum* accessions that represent the range in variation in the visual characteristics of the species throughout the state of Utah.
- Plant the different accessions in a common garden and evaluate the range in characteristics under uniform conditions. Assess each accession for morphological characteristics including height, width, crown form, bloom start, flowering duration, flower color that relate to landscape value. We will also evaluate botanical characteristics, in particular male sterility. Male sterility is important if an accession has obligate outcrossing as it determines how stable any given trait may be in successive generations. In order to assess outcrossing, several flowering stalks from plant in each accession are bagged to eliminate outcrossing, and the morphology of the offspring is compared back to the parents.
- Two selected accessions that represent the range in morphological characteristics are planted in a field experiment. In addition, a non drought tolerant conventional landscape species (redstem dogwood, *Cornus sericea*) is also planted, and all species are irrigated at different frequencies over the growing season, every three days, every three days, or no irrigation. Impact of drought will be measured in terms of internal water potential, stomatal conductance (photosynthesis), above ground growth, and plant mortality.

Goals Achieved: How goals of project were achieved in 2009-10.

- Fifteen accessions, five plants per accession, representing a range of *E. corymbosum* habitats collected in 2005 and 2006 were planted in 2007 in a common garden and data collection began in 2008 and continued through 2009. Morphological data was collected on all surviving accessions. Several flowers on each surviving accession were bagged to exclude all pollinators.
- Collection of water relations data started in 2008 with midday stomatal conductance measurements and predawn leaf water potential on a weekly basis, and continued through 2009.

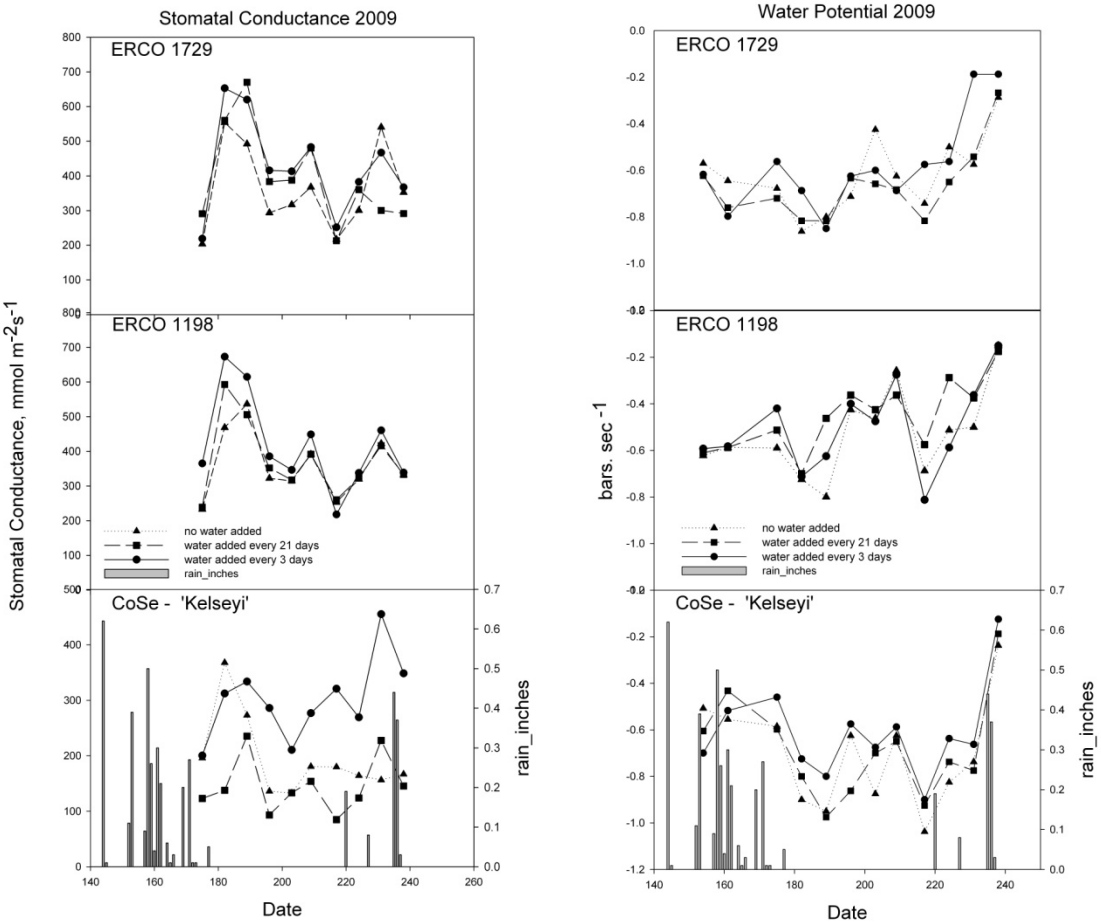
Results, conclusions, and lessons learned:

- We continued to collect seed samples from natural habitats from selected populations that had high field mortality.

- In the table below, those accessions in bold, red text are the tentative candidates for development into cultivars.

ErCo Accession	Sub Species	Flower color	Initial bloom	Bloom duration, days	Fade color	Form	Crown tightness	Size	Male Sterility
Flat top Butte	**corymbosum**	**white**	**20-Aug**	**37**	**dark rust**	**hemisph.**	**tight**	**med**	**Yes**
Goblin valley	unknown	cream	25-Sep	22	light rust	hemisph.	medium	med	Yes
Wire Mesa	matthewsiae	white	16-Sep	38	light rust	hemisph.	loose	large	No
Henryville Yellow	**gultinosum**	**yellow**	**23-Aug**	**54**	**brown**	**open**	**medium**	**med**	**No**
Long Canyon	velutinum	white	1-Sep	34	med rust	hemisph.	medium	large	No
East of Zion	corymbosum	white	16-Sep	24	light rust	hemisph.	medium	large	Yes
Rockville	matthewsiae	white	16-Sep	24	light rust	hemisph.	loose	large	Yes
Goblin Valley	unknown	pale yellw	15-Sep	32	light rust	hemisph.	medium	med	Yes
San Rafael Swell 1	corymbosum	white	28-Aug	36	dark rust	hemisph.	medium	med	Yes
San Rafael Swell 2	**unknown**	**white**	**28-Aug**	**36**	**dark rust**	**hemisph.**	**extra tight**	**small**	**Yes**
Springville 1 plant	matthewsiae	white	7-Sep	26	light rust	hemisph.	loose	large	No
Springville	matthewsiae	white	25-Sep	22	light rust	hemisph.	loose	large	No
Mt Carmal	corymbosum	white	15-Sep	22	light rust	open	medium	large	Yes
Tropic single plant	corymbosum	white	22-Aug	34	med rust	open	medium	med	Yes
Tropic	corymbosum	white	22-Aug	41	med rust	open	medium	med	Yes
Cannonville Yellw	gultinosum	yellow	23-Aug	55	brown	open	medium	med	No
Hell's Backbone	unknown	white	5-Sep	48	dark rust	hemisph.	tight	small	No
Long Canyon	velutinum	white	24-Aug	40	dark rust	hemisph.	medium	large	Yes
Moab	orbiculatum	white	15-Sep	30	light rust	hemisph.	medium	large	Yes
Shivwits	aureum	pale yellw	26-Sep	28	light rust	hemisph.	medium	med	No
Buckhorn Wash	corymbosum	white	18-Aug	46	med rust	hemisph.	tight	med	Yes
Wire Mesa	**matthewsiae**	**white**	**16-Sep**	**32**	**light rust**	**hemisph.**	**loose**	**large**	**No**

- These data are currently being analyzed through principal component analysis by the graduate student working on the project, Graham Hunter, and will be completed late summer when the student defends his thesis. These data are similar to that reported last year, pointing to the same accessions that have the most promise aesthetically. The key issue the graduate student is working on is the genetic stability of these accessions. Since we have observed in this study that ErCo is an obligate outcrossing species, maintaining the genetic integrity of a cultivar is crucial to success in the nursery trade, but we have not yet positively identified the best approach to maintaining this integrity.
- In 2009, we measured stomatal conductance on two of the *ErCo* accessions, a high elevation site at Long Canyon (1729 m) and a low elevation site Wire Mesa (1198), as well as the control species, Cornus sericea 'Kelseyi' (dogwood). Stomatal conductance is the opening and closing of the pores on the leaf that lets water out and carbon dioxide in (photosynthesis), and thus approximates photosynthesis quite well. These results that regardless of irrigation frequency, the *ErCo* showed no signs of water stress. 2009 had a long and very wet spring such that the growing season was shorter than normal. Lack of water stress is a positive sign showing in a common garden setting that ErCo is a very drought tolerant shrub that can anchor a low water landscape. Another interesting development was that the low elevation accession (Wire Mesa) showed signs of fungal leaf spot, while the high elevation accession (Long Canyon) did not. Also encouraging is that for the second year in a row no plants showed signs of root disease even with very frequent irrigation of every three days.



Long-term outcome measures:

- The first year results of the study from 2008 were presented at the ASHS conference in St. Louis, MO, in July 2009. The poster was well received by the nursery industry, and we received several inquiries as to the availability of the species for commercial production. An abstract of the poster was published in HortScience volume 44, page 1159, a publication of the American Society for Horticulture Science.
- An article that summarizes the merit of E. corymbosum as a landscape plant is drafted for submission to American nurseryman. This article will focus the wide diversity of types within the species, and its drought tolerances. This article will be condensed for submission to the INPA newsletter.
- We will be presenting information on E. corymbosum June 23, 2010 in an all day workshop and field day focusing on the use of native plants as pollinators. This will include a presentation by Roger Kjelgren in the morning on six native plants favored by native bees, a tour of native plant landscapes that include E. coymbosum, then a tour of our field plots of our field plots that will include both the irrigation study and the accession plot.

Additional information: A paper is drafted on the water relations data that will be submitted to the journal of HortScience, and a second paper will be drafted on the principal component

analysis of the accession. However, we are waiting on publishing anything on the E. corymbosum until the end of the summer growing season 2010. Mortality in the irrigation block and accession block measured in spring 2010 is a cause for concern. Spring 2009 was very wet, and summer 2009 was quite cool. So far in 2010 we have had a wet, cool spring, and summer so far has also been quite cool. Our concerns are that E. corymbosum can be negatively affected by the somewhat heavier loan soil where the irrigation and accession blocks are located. A heavier soil, even without irrigation, may limit survivability, and use in the landscape if E. corymbosum roots are susceptible to root rot during wet weather. We may need to recommend that it only be planted on well drained soil.

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M. High Desert Growers' Farmers' Market

Outline of issue, problem, interest, or need for project: The High Desert Growers were looking to expand their market into Emery County. It was hoped that this would encourage potential small vendors to participate in that market location and increase the number of people who would take advantage of fresh, local produce. It was determined that a market located in Castle Dale would be far enough away from Price to reduce competition with the Price market, yet close enough for some of the vendors from Carbon County to participate in the market. The goal was to increase the customer base and the number of vendors participating in the market.

Approach:

- Signage was purchased and a location for the market was established.
- The required licenses were purchased.
- Newspaper advertising was purchased in the Sun Advocate and the Emery County Progress. These are the only local newspapers covering the market area. Advertisements were run nine times in the Sun Advocate and seven times in the Emery County Progress.
- There are five local radio stations—KUSA, KASL, KARB, KOAL, KRPX. The greater number of ads were run on stations that have a listenership of young mothers and middle-aged women. Fifteen second advertisements were run on all five stations (KUSA – 48 times, KASL – 40, KARB – 50, KOAL – 27, KRPX – 55).
- Fliers were posted at six of the post offices in Emery County.

Goals achieved: The response was disappointing. Seven vendors from the Price market attended the Castle Dale market and no new vendors from Emery County joined the market. While the location parking was good the market was not very visible from the street. Local participation and sales at the Castle Dale market were low. Sales at the Price market were detrimentally affected by the Castle Dale market activities. There were 24 vendors who participated in the Price market throughout the season. The overall goal of exceeding $18,000 was not met. A best

estimate is $15,000 for sales between the two markets. This is an increase over the previous year. We believe current patrons are close to their spending limit. In order to get the market to grow we will need to develop a broader demographic base.

Results, conclusions, and lessons learned: While those customers who attended the market appreciated its presence, the vendors were discouraged. We have concluded that one more year to get the market established with a few changes may make it more feasible. The season will be shortened; the location will be moved to be more visible to traffic. Advertising will need to be re-evaluated. The vendors decided to try one more year before giving up on a market in Castle Dale.

Long-term outcome measures: We are currently in the evaluation and adjustment phase of trying to start this market.

Additional information: No publications or websites were produced.

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N. Utah Botanical Center Farmers' Market

Outline of the issue, problem, interest or need for the project: The Utah Botanical Center (UBC) farmers' market is being developed to share results from Utah Agricultural Experiment Station (UAES) research plots, promote buying local produce, and provide education on food production, preparation, and storage. The UBC includes a sustainable demonstration house and garden which is adjacent to the site of the market. An important need of the market is more publicity and promotion.
Approach: The project increased advertising for the market by installing nine banner posts along the street adjacent to the market. Large 2' x 4' banners were hung on the posts during the market season. Another 5'x20' banner was placed along Kaysville City Main Street to direct traffic to the market. A direct mail flyer was sent to 20,000 homes surrounding the market. Canopies and kitchen equipment were purchased to improve teaching of the food demonstrations. Expanded Food and Nutrition aides and Food Sense aides taught classes on easy to fix meals featuring local produce.

Goals achieved: The banner posts were a huge hit. They added a festive atmosphere to the market and generated a lot of attention from people driving by. Several people brought their direct mail flyer to the market and an associated plant sale. The banners, direct mail, and other advertising helped increase attendance at the market by 58% for the three weeks after the major advertising campaign. A total of 5,476 people attended the market over the season.

Results, conclusions, and lessons learned: The banners were probably the most successful component of the advertising campaign. The direct mail piece seemed less effective but will probably still be tried again next year. The food demonstrations and apple tasting program were

very popular with people visiting the market. The number of vendors at the market increase from 45 to 51 vendors—an increase of 13%. The organic broccoli and raspberries from the UAES plots were very popular with shoppers. The market is approved to accept Horizon (food stamp) cards and sales for 2009 were $281. This is an increase of 36% over last year.

Long-term outcome measures: The banner posts and Main Street banner will be used for many years to come to advertise the market. The canopies and kitchen equipment will also be useful for several years in the future. The overall advertising campaign has increased awareness of the market and also helped to let people know that the market is here to stay.

Additional information: The market is advertised on the website: utahbotanicalcenter.org. Each year, a color bookmark is prepared about the market and is distributed widely in the community.

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O. Locating, Documenting, and Collecting Clones of Native Utah Plants with Superior Potential in the Landscape Industry

Outline of issue, problem, interest or need for the project: Landscape water conservation is becoming an increasingly important to Utah's growing population. Interest in conservation is creating a potential niche market for locally produced clones of drought tolerant native trees and shrubs. There is ample anecdotal evidence to suggest that many exceptional plants already exist in the wild, but specimens must be located before they can be evaluated for use in the landscaping industry. The purpose of this project was to document the locations of such plants and begin the process of collecting them for nursery production and landscape use.

Approach: Unique clones of woody plants with potential for use in landscaping were located by several means including:

- Contacting federal and state agencies and land managers throughout the state and region who are familiar with native plant materials
- Contacting groups such as the Utah Native Plant Society, the Great Basin Native Plant Selection and Increase Project, the Western Region International Plant Propagators, and the Intermountain Native Plant Growers Association
- Presentation of project results and goals at meetings such as the 16th Annual Wildland Shrub Meeting held at Utah State University
- Contacting individuals from other universities in the region
- Physically exploring areas in search of such plants
- Contacting plantsmen in the region with individual knowledge of such plants

Goals Achieved: The goals of the project were achieved as outlined in the approach. Individuals were contacted and information on many plants was provided. In some cases tours were given

showing where plants were located. Additional plants were found simply through being sensitive to the need during travel throughout the state. Once found, each plant was documented by taking digital images and GPS coordinates. Where possible, samples were also collected with the goal of vegetatively propagating the plants. We were also able to employ students to help complete the project.

Results, conclusions and lessons learned: During the term of the project we have located and documented 78 specimens of various woody plants with landscaping potential (see Appendix A). These plants have been photographed, their location documented by GPS, and an assessment of their value made. While not all of these are worthy of introduction as new industry selections (approximately 60% merit continued study), we nevertheless conclude there are many outstanding plant materials growing wild with great potential for use in the industry. To date, another 41 plants or populations have been proposed, but remain to be documented (see Appendix B).

Plants with exceptional merit include the following:

- Six selections of bigtooth maple (based on color and form)
- A more northern selection of greenleaf manzanita
- Three selections of little-leaf mountain mahogany (dwarf, columnar, and rounded)
- A genetic dwarf of curl-leaf mountain mahogany
- A dwarf selection of rabbitbrush
- A Utah juniper with a unique contorted form and resistance to deer
- A creeping Oregon grape with unique glossy leaves
- A mountain lover with a tight, rounded form adapted to full sun
- A prostrate form of bitterbrush
- A prostrate form of purple sage (Clokeyi)
- A cascading form of roundleaf buffaloberry

We have learned that it is often challenging to obtain information on individual plants from people. The difficulties apparently lie in reluctance to share information that might have a personal economic value, hesitancy to judge a plant as worthy of being singled out for public use, a general misunderstanding of the purpose of the project, and an inability of public land managers to see the benefit of native plants as unique clones rather than genetically diverse populations. One solution to this challenge is to meet with individuals one-on-one, rather than trying to solicit information via mail or other forms of communication. In summary, while we have found some outstanding plants, we still believe there are more to be documented.

Long-term outcome measures: The ultimate goal of this project is to increase nursery production of native plants in Utah and reduce landscape water use as a result of those plants. While these are long term goals, progress has been made in the following ways:

- For the first time we have actual documentation of specific plant locations through GPS. This is a significant improvement over the anecdotal references of the past and creates a database that can be preserved and increased over time.

- Concurrent with this project, progress has also been made in developing vegetative propagation techniques for some of the more challenging plants through support from the UDAF Specialty Crop Block Grant Program.

- Production techniques amenable to Utah growers are also being developed

Additional Information: The results of this project are also available at the following sources:

Rupp, L.A. and M.R. Richards. 2011. Selection and Vegetative Propagation of Exceptional Native Woody Plant Clones. Report of the Intermountain Native Plants Cooperative. *In press.*

Richards, M.R. 2010. Selecting and Propagating Clones of Bigtooth Maple (*Acer grandidentatum* Nutt.). Thesis. Utah State University.

Rupp, L.A., W.A. Varga, and D.A. Anderson. 2010. Selection and Vegetative Propagation of Native Woody Plants for Water-Wise Landscaping. 16th Wildland Shrub Symposium, Utah State University/USDA-ARS-FRRL, Logan, Utah.

Cook, S. and L.A. Rupp. 2010. DROUGHT: A Database of Irrigation Requirements for WoodyPlants of Northern Utah. In Press.

Rupp, L.A. 2009. The effect of etiolation on rooting of Acer grandidentatum cuttings. Report of the Intermountain Native Plants Cooperative. pp. 16-17. http://www.uwyo.edu/wera1013support/docs/Report_of_the_Native_Plants_Cooperative_2009_final.pdf

Reed, M. and L.A. Rupp. 2009. The Effect of Etiolation on Rooting of *Acer grandidentatum*Cuttings. Combined Proceedings of the International Plant Propagators' Society. 59:353-355.

Rupp, L.A., M. Reed, W.Varga, V.P. Rasmussen, and C. Neale. 2008. Collecting *Acer grandidentatum* clones in northern Utah: An overview. Combined Proceedings of the International Plant Propagators' Society. 58:379-380.

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Appendix A. Plants located and/or collected

No.	*Genus*	*Species*	Authority	Location	Utah Counties or State
1	*Acer*	*glabrum*	Hale	Nevada	Nevada
2	*Acer*	*glabrum*	Rupp	N39.31462 W111.46635	Sanpete
3	*Acer*	*glabrum*	Rupp	N39.32422 W111.49178	Sanpete
4	*Acer*	*glabrum*	Warner	Monroe Canyon	Sevier
5	*Acer*	*grandidentatum*	Barker	Price Canyon	Carbon
6	*Acer*	*grandidentatum*	Laub	N41.52057 W111.94316	Box Elder
7	*Acer*	*grandidentatum*	Morris	Mt Pisgah Road	Cache
8	*Acer*	*grandidentatum*	Morris	Mt Pisgah Road	Cache
9	*Acer*	*grandidentatum*	Morris	Mt Pisgah Road	Cache
10	*Acer*	*grandidentatum*	Morris	N41.55787 W111.94540	Cache
11	*Acer*	*grandidentatum*	Morris	N41.56098 W111.94039	Cache
12	*Acer*	*grandidentatum*	Morris	N41.56179 W111.94002	Cache
13	*Acer*	*grandidentatum*	Reed	N41.50232 W111.95759	Cache
14	*Acer*	*grandidentatum*	Reed	N41.50242 W111.95759	Cache
15	*Acer*	*grandidentatum*	Reed	N41.50426 W111.95171	Cache
16	*Acer*	*grandidentatum*	Reed	N41.54828 W111.90807	Cache
17	*Acer*	*grandidentatum*	Reed	N41.55753 W111.90730	Cache
18	*Acer*	*grandidentatum*	Reed	N41.55967 W111.90307	Cache
19	*Acer*	*grandidentatum*	Reed	N41.56209 W111.91826	Cache
20	*Acer*	*grandidentatum*	Reed	N41.73905 W112.03588	Cache
21	*Acer*	*grandidentatum*	Reid	N37.79931 W112.81428	Iron
22	*Acer*	*grandidentatum*	Reid	N37.79989 W112.81364	Iron
23	*Acer*	*grandidentatum*	Rupp	N41.80454 W111.77279	Cache
24	*Acer*	*grandidentatum*	Rupp	N41.81461 W111.76855	Cache
25	*Acer*	*grandidentatum*	Rupp	N41.87493 W111.75004	Cache
26	*Acer*	*grandidentatum*	Rupp	N41.87506 W111.75001	Cache
27	*Amelanchier*	spp.	Love	Aberdeen, Idaho	Idaho
28	*Amelanchier*	spp.	Rupp	N41.92616 W111.47190	Rich
29	*Amelanchier*	*utahensis*	Bowns	N37.31049 W113.43415	Iron
30	*Amelanchier*	*utahensis*	Bowns	N37.67298 W113.03702	Iron
31	*Arctostaphylos*	*patula*	Rupp	N37.33332 W112.60096	Kane
32	*Arctostaphylos*	*patula*	Rupp	N37.40867 W112.55108	Garfield
33	*Arctostaphylos*	*patula*	Stevens	N39.34128 W111.53114	Sanpete
34	*Arctostaphylos*	*pungens*	Bowns	N37.28880 W113.30294	Washington
35	*Arctostaphylos*	*pungens*	Bowns	N37.29247 W113.30294	Washington
36	*Betula*	*occidentalis*	Rupp	N38.58033 W112.29328	Sevier
37	*Ceanothus*	*greggii*	Bowns	N37.28886 W113.30319	Washington
38	*Ceanothus*	*martinii*	Monsen	N39.33921 W111.51306	Sanpete
39	*Ceanothus*	*velutinus*	Rupp	N41.55825 W111.90514	Cache
40	*Ceanothus*	*velutinus*	Rupp	N41.92679 W111.47044	Rich

41	*Cercocarpus*	*intricatus*	Kjelgren	Logan, Utah	Cache
42	*Cercocarpus*	*intricatus*	Monsen	N38.51792 W113.54180	Beaver
43	*Cercocarpus*	*intricatus*	Rupp	N36.30189 W115.62288	Nevada
44	*Cercocarpus*	*intricatus*	Rupp	N36.30191 W115.62283	Nevada
45	*Cercocarpus*	*intricatus*	Stevens	N39.34091 W111.53160	Sanpete
46	*Cercocarpus*	*ledifolius (broom)*	Wildrick	N41.92770 W111.47055	Rich
47	*Cornus*	*sericea*	Rupp	N41.60602 W111.59439	Cache
48	*Ericameria*	*nauseosa ssp. nauseosa var.*	Stevens	N39.71696 W111.74880	Juab
49	*Ericameria*	spp.	Anderson	Raft River Mountain	Box Elder
50	*Ericameria*	spp.	Rupp	N38.58777 W113.78912	Millard
51	*Fraxinus*	*anomala*	Rupp	N39.14499 W110.71947	Emery
52	*Juniperus*	*osteosperma*	Rupp	N37.18091 W112.63829	Kane
53	*Juniperus*	*osteosperma*	Stevens	N39.12282 W111.96644	Sanpete
54	*Juniperus*	*scopulorum*	Rupp	N39.40526 W111.11291	Emery
55	*Juniperus*	*scopulorum*	Rupp	N39.41262 W111.11446	Emery
56	*Juniperus*	*scopulorum*	Stevens	N39.33824 W111.52394	Sanpete
57	*Juniperus*	*scopulorum*	Stevens	N39.34387 W111.52587	Sanpete
58	*Juniperus*	x *osteosperma*	Stevens	N39.34225 W111.55862	Sanpete
59	*Mahonia*	*fremontii*	Rupp	USU Campus	Cache
60	*Mahonia*	*fremontii*	Warner	N38.63457 W112.21033	Sevier
61	*Mahonia*	*repens*	Cope	Wellsville Canyon	Cache
62	*Mahonia*	*repens*	Cope	Wellsville Canyon	Cache
63	*Mahonia*	*repens*	Cope	Wellsville Canyon	Cache
64	*Mahonia*	*repens*	Rupp	N39.33122 W111.50755	Sanpete
65	*Paxistima*	*myrsinites*	Rupp	N43.49164 W110.91314	Wyoming
66	*Philadelphus*	*microphyllus*	Rupp	N39.14521 W110.71918	Emery
67	*Pinus*	*edulis*	Stevens	N39.12831 W112.01973	Sanpete
68	*Pinus*	*edulis*	Stevens	N39.12832 W112.01931	Sanpete
69	*Populus*	*tremuloides*	Reid	N37.65572 W112.66964	Iron
70	*Purshia*	*tridentata*	Rupp	N38.56154 W112.58338	Millard
71	*Quercus*	*gambelii*	Rupp	~N39.01739 W112.09053	Millard
72	*Quercus*	*gambelii*	Rupp	N38.56186 W112.57671	Beaver
73	*Quercus*	*gambelii*	Stevens	N39.12246 W111.96793	Sanpete
74	*Quercus*	*pauciloba*	Bowns	N37.57782 W113.13230	Iron
75	*Rhus*	*aromatica simplicifolia*	Bowns	N37.24034 W113.50282	Washington
76	*Rhus*	*glabra cismontana*	Stevens	N39.79592 W111.82127	Juab
77	*Salvia*	*dorii 'Clokeyi'*	Anderson	N36.29639 W115.62822	Nevada
78	*Shepherdia*	*rotundifolia*	Rupp	N37.13065 W113.09161	Washington

Appendix B. Potential plants yet to be located

No.	***Genus***	***Species***	**Authority**	**Location**	**Utah Counties or State**
1	*Amelanchier*	*alnifolia*	Monsen	North of Cedar	Iron
2	*Amelanchier*	*utahensis*	Monsen	Browse	Washington

P. Determining Effectiveness of Currant Borer Mating Disruption in Utah

Outline of the issue, problem, interest or need for the project: This study looked at the effectiveness of mating disruption on a five-acre block of black currants in northern Utah over a period of one season. Mating disruption is a fairly new technology that uses high loads of pheromone to prevent mating, and hence, prevent egg-laying. Over several years, mating disruption has been successful in reducing damage and local populations of a variety of pests (codling moth, oriental fruit moth, greater peachtree borer, etc.).

Production of black and red currants in the U.S. is limited due to a variety of factors. Infestation by the clearwing moth, currant borer (*Synanthedon tipuliformis*) is one of them. The currant borer is the most widespread of all the clearwing moth species. It causes stunted plants, weak canes, shoot dieback, uneven bud break, and fruit yield reduction by up to 50%. A five-acre site in northern Utah (Paradise, Cache County) is one of the few currant-producing sites in this state. It is heavily infested with currant borer, and if left untreated, could result in losses up to $250,000.

There are very few insecticides available to currant growers for control of currant borer. Growers in Washington historically used fenpropathin (Danitol), and elsewhere, carbaryl or malathion, on flying adults. The problem is that peak adult moth activity can occur in conjunction with harvest, so chemical treatment is not always an option. Using mating disruption to control this pest not only reduces pesticide use, but has been shown to be very effective in Washington, Connecticut, Italy, New Zealand, Tasmania, and other locations.

Although this study targets one large operation and several small operations, Utah has an ideal climate for growing currants, and improved control options for currant borer could pave the way to increased production. Currants (red and black in particular) are hardy, high value crops that serve both the fresh and processed markets. Interest in growing currants has swelled among US small fruit growers due to the health benefits of the fruit, their ease of growth, and the potential for income. Growers in Utah cannot compete with European growers, but can do very well with small plots geared to either the fresh market or value-added products such as syrup, jams, jellies, juice, or wine.

Approach: The test site was a heavily infested, five-acre black currant block located in Paradise, UT. An isolated 1-acre black and red currant block owned by the same grower was used as the untreated control, located approximately ½ mile away, and is the only other currant production site in the area.

Goals achieved: We applied twist-tie currant borer mating disruption dispensers onto stems at a rate of 200 per acre in the interior, and 400 per acre in a 20-foot perimeter area. No dispensers were hung in the control block. No pesticides were sprayed.

We cut 100 canes from the treated block and 40 canes from the untreated block both in spring and fall. For each cane, we recorded:

- cane injury on a scale of 1-4 (1=healthy and no obvious borer injury, 2=1-25% leaves injured or missing, 3=26-50% leaves injured or missing, 4=>50% of leaves injured or missing, or cane is dead)
- number of larvae and/or tunnels
- larval predators/parasites

We determined adult moth population by using yellow pheromone traps in the treated and control blocks. We hung three traps in the treated block and two in the control, and counted the moths each week. Ideally, the traps in the mating disruption block would have zero moths.

Results, conclusions, and lessons learned: Results were not as we had hoped. The infestation in the treated field actually doubled from spring to fall, while the infestation in the untreated field tripled (Table 1). We had hoped to see a significant decline in infestation in the treated field. There was no difference in percent of infestation in the treated field between the perimeter and interior canes at post-treatment sampling.

Table 1. Percentage of canes infested with currant borer larvae or pupae in the treated and untreated fields, pre- and post-treatment.

	Treated field	**Control field**
Pre-treatment	20%	12%
Post-treatment	44%	37%
% increase in infestation:	45%	32%

In contrast to increasing currant borer densities in canes from pre- to post-treatment, the average rating canes in both the treated and control field declined from spring to fall (Table 2). This could be explained by variation in subjective judgment by the staff who was rating the canes. In spring, the buds were still expanding and there was very little foliage so it was difficult to tell if buds were alive or dead.

Table 2. Average characteristics of cut canes from the mating disrupted field (treated) and control field, in spring (before treatment) and fall (post treatment).

Field and treatment time	Cane Injury Rating[1]	Gallery Length[2]	# Exit holes
Treated-spring	2.54	17.95	1.93
Treated-fall	1.79	12.26	2.51
Control-spring	2.36	19.76	2.41
Control-fall	1.77	13.68	2.24

[1] cane injury on a scale of 1-4 (1=healthy and no obvious borer injury, 2=1-25% leaves injured or missing, 3=26-50% leaves injured or missing, 4=>50% of leaves injured or missing, or cane is dead)
[2] gallery length: length of cane where boring had occurred

When looking at trap catch, we did see that the mating disruption was working because the number of moths caught in the pheromone traps was lower than the control block. At first, all traps in the treated block caught zero moths compared to high numbers (70+) in the traps in the control block. About 2-3 weeks later, the number of moths in the treated traps started increasing from a low of 7-9 moths/trap (compared to 80+ in the control traps) to a high of 26 moths (compared to 85+ moths in the control traps). These results suggest that the mating disruption dispensers were not effective in completely shutting down trap catch across the season. Possible reasons include too low of a pheromone concentration in the field to prevent moths from finding traps, too high of a moth population across the entire region, or wind moving the mating disruption pheromone "scent" off site.

Most currant borer larvae overwintered and pupated in the middle of the cane, or near the top. A few overwintered at the base of the cane. Parasites were not identified, but included wasps and fungi. Four currant borer larvae were found parasitized/killed within the canes in spring (12%), and nine were found parasitized/killed in fall (9%).

We have received a second year of funding for this project from the Specialty Crop Block Program. At least two years of data are necessary for credible results. Because of the unexpected findings in the 2009 experiment, we plan to make several changes to the methods for the 2010 experiment to improve mating disruption efficacy and determine what might be happening. We consulted with two other investigators who are currently or have in the past researched mating disruption on currant borer: Dr. Lorraine Los, Connecticut, and Dr. David James, Washington. Their research has shown excellent results with mating disruption in their respective states. They suggested several possibilities.

1. Wind may have been our biggest problem. According to Dr. James, there is evidence that moths can fly or be blown up to 0.5-1.5 miles away. The control field is about 0.5 mile away, and upwind from the treated field. To address this, we plan to apply dispensers a perimeter around the currant borer field of an extra 40 feet, and at a higher rate (600 per acre rate rather than 400 per acre rate).

2. Dr. Los commented that raspberries may be serving as a secondary, asymptomatic host. The infested currant field in this study is surrounded by raspberry fields on two sides, and it is possible that they are flying in from neighboring fields. To determine if raspberries are a secondary host, we will cut approximately 100 additional canes from adjacent raspberry fields and dissect them for currant borer larvae. We will also hang pheromone traps in neighboring fields to count emerging moths. If confirmed, this will be important and new information for Utah.

3. Dr. James commented that when he conducted this same experiment in similar-sized Washington currant fields, initial borer infestation was similar to what we found in Utah. Results there showed a decline in infestation after just one season. But when wind and possible immigration from raspberry fields is factored in, the initial pest population in the Utah field may have been too high for mating disruption to be successful without supplemental treatment. Currant borer mating disruption is new; therefore, there is not enough data to know what a "high population" is when using this technology. Recommendations for codling moth mating disruption, which has been used in the U.S. for over 2 decades, is to apply supplemental treatments the first two seasons when trap catch without mating disruption is over 20 moths per trap/week. For the 2010 experiment, we will apply a supplemental insecticide treatment of pyrethrin+piperonyl butoxide to half the field receiving the mating disruption treatment, and to half the control field.

We will present results of this project after the second year of data is collected to the Utah Berry Growers Association annual meeting in winter 2011 as well as to the Western Orchard Pest and Disease Management Conference in Portland, OR in January 2011. We will also prepare a fact sheet and provide results in a weekly IPM pest advisory to the berry growers in the state.

<u>Long-term outcome measures:</u>

1. *Registration of currant borer mating disruption for Utah currant growers.* The two years of data from this project will be combined with data from Connecticut, Washington, and British Columbia and sent to the distributor of the mating

disruption product for registration. Lorraine Los, entomologist in Connecticut, has received an IR-4 grant to expedite the registration process.

2. *Increased profitability for Utah currant growers and a reduction in environmental effects from the reduced use of insecticides to manage the key currant pest, currant borer*. If mating disruption is made commercially available, growers will not be hesitant to grow currants knowing this control technology is readily available. Pesticide use for currant borer will be significantly reduced.

Additional Information: References

1. James, D. 2002 Confusing (and Controlling) Currant Borers. Agrichemical and Environmental News. No. 192.
2. James, D. 2003. Secret Life of the Currant Stem Girdler: Another Opportunity to Use Sex Pheromones in Red Currants? Agrichemical and Environmental News, 201, January. http://aenews.wsu.edu/Jan03AENews/Jan03AENews.htm#CSG
3. Personal communication, David James, Entomologist, Washington State University.
4. Cranshaw, W.S., and D.A. Leatherman. 2006. Shade Tree Borers. Colorado State University Extension Fact Sheet No. 5.530.
5. Personal communication, Lorraine Los, Fruit IPM Coordinator, University of Connecticut.

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Summary of Financial Performance of all Projects:

Project Title	Grant Amount	Recipient Outlay	Total Outlay
A. Improving Orchard Irrigation	$ 6,000	$ 12,000	$ 18,000
B. Codling Moth Trap Threshold	4,730	1,800	6,530
C. LAMP—Fire Blight Detection	4,082	5,600	9,682
D. Weed Control in Orchards	4,000	2,750	6,750
E. Codling Moth Dispensers	6,532	2,125	8,657
F. Organic & Reduced Input Orchards	7,000	2,000	9,000
G. Inspecting & Auditing Food Plants	3,750	3,452	7,202
H. Youth Gardening Project	10,000	58,702	68,705
I. Fruit & Vegetable Growers Assn	8,252	400	8,652

J. Pioneer Craft House	6,100	664	6,764
K. Small Farm Tunnels	10,485	--	10,485
L. Native Shrub	7,701	--	7,701
M. High Desert Farmer's Market	2,000	716	2,716
N. UCB Farmer's Market	6,000	6,000	12,000
O. Native Plant Clones	5,294	--	5,294
P. Currant Borer Mating Disruption	4,855	--	4,855
UDAF Administrative Expenses	8,906	4,908	13,814
Totals	$105,687	$101,120	$206,807