Washington Tree Fruit Research Commission
Summer Technology Research Review
August 13, 2009
Campbell's Resort, Chelan

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	9:00	McFerson	**Introduction**	
			Continuing Reports	
1	9:10	Hoheisel	A database to aggregate research results and assess technologies	08-10
5	9:20	Peace	Developing flavor gene markers for the WA tree fruit industry ***final report***	07-09
15	9:30	Schupp	Mechanized blossom and green fruit thinning ***teleconference***	08-10
16	9:40	Taylor	Economic analysis of technology adoption by Washington apple growers ***teleconference***	09-10
21	9:50	Allard	Mobile linear asymmetric fruit transport system	09-10
28	10:00	Dhingra	Rosaceae micropropagation and tissue culture platform	09-11
34	10:10	Whiting	Investigating flower bud hardiness of tree fruit cultivars ***teleconference***	09-11
39	10:20	Koselka	Robotic scout for tree fruit ***teleconference***	
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46	10:30	Koselka	Automated picking hand ***teleconference***	08
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57		Jones	Expanding and stabilizing WSU-decision aid system	07-09
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CONTINUING PROJECT REPORT **YEAR**: 1
WTFRC Project Number: TR-07-707

Project Title: A database to aggregate research results and assess technologies

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Cooperators:
Kent Waliser, Sagemoore Farms, Ines Hanrahan, WTFRC, Tory Schmidt, WTFRC, Matt Whiting, Washington State University, Tom Auvil, WTFRC, Cameron Nursery, Paul Tvergyak

Total Project Request: **Year 1:** $9,078 **Year 2:** $1,000

WTFRC Collaborative expenses:

Item	**2008**	**2009**	
Stemilt RCA room rental			
Crew labor			
Shipping			
Supplies			
Travel			
Miscellaneous			
Consultation time[1]	2665		
Total	**2665**	**1000**	

Footnotes:
1. Approximately 100 hours to aggregate, explain, and transfer existing datasets from Tom, Tory and Ines.

Budget 1:

Organization: Washington State University

Telephone: 509-335-2867

Contract Administrator: Jennifer Jansen

Email: jjansen@wsu.edu

Item	**(2008)**	**(2009)**
Salaries		
Benefits		
Wages [1]	$4536	
Benefits (9.6%)	$435	
Equipment		
Supplies	$300	
Travel [2]	$2,307	$500
Miscellaneous		
Database development [3]	$1500	
Database refinement		$500
Total	$9,078	$1,000

Footnotes:

1. Salary for one full time summer person to assist with database entry and surveying.
2. Travel includes mileage and hotel to survey growers in the five fruit growing regions of Eastern Washington and a trip to Oregon.
3. Computer programming of the initial database will be contracted to specialists within WSU.

Objectives:

1. Develop a searchable database that will capture rootstock-variety combinations for apples and cherries, as well as varietal characteristics, management practices, and environmental factors.
2. Aggregate data from existing sources (i.e. projects with OSU, WSU, WTFRC, and nurseries) on rootstock/variety trials and replant practices.
3. Perform a targeted survey of grower and researcher trials that are both geographically and variety robust.
4. Publish to the web under the new tree fruit web portal.
5. Generate reports and analyses to assist collaborators in assessing replant practices and the effects of management practices on production of targeted fruit.
6. Assess the status of the database and identify gaps where incorporation of new variables would assist in development of targeted fruit production.

Significant Accomplishments for the Year:

Relevant rootstock and variety data has been organized and entered for WTFRC, WSU Cherry Breeding Program, OSU Cherry research and most of WSU Apple Breeding Program. Data from select growers is the only information left to aggregate and enter.

Programmers in Pullman, WA are completing the database. There have been a few errors discovered and they are working on that before formal beta testing. The Orchard Conditions Database includes a basic search option with just four criteria to select from—crop, rootstock and/or variety, county, size and/or yield. This data is displayed in a table (figure 1) with basic information.

Figure 1: Output of a "basic search"

Variety	Rootstock	County	Strain	Year	Harvest Date	Soluable Solids	TA	Firmtech (g/mm)
Bing	Mazzard	Yakima		2006		11.00	0.35	
Sweetheart	Mazzard	Chelan		2006		12.50	0.67	
Sweetheart	Gisela 6	Chelan		2006				
Bing		Douglas		2006				
Skeena	Mazzard	Okanogan		2006				
Rainier	Mazzard	Douglas		2006				

The Orchard Conditions Database also includes an advanced search that allows the user to select nearly any of the variables in the database (i.e. crop, rootstock/variety, location, yield and quality, management practices, temperature, and post harvest). The results of this search are exported directly to excel for easy sorting and comparison. Lastly, there is an administration page that allows select users to enter data manually online or upload an excel spreadsheet.

<u>Next Steps:</u>

- For each of the varieties and rootstocks, we will create a page with standard information and pictures if applicable. These pages will be created from the literature and with links from the home and results page.
- Collect and enter grower data.
- Beta test and make suggested modifications
- Release to public

- Meet with researchers to discuss ways to strengthen the information or data collected. Although some of this is being done now.

Methods:
Objective 1. In year one, we will collaborate with the WSU Extension Communications & Educational Support department to develop a searchable database with a user-friendly interface. The database will account for apple and cherry information on 1) variety and rootstock, 2) environmental conditions, 3) management practices and 4) fruit characteristics.

Objective 2. In year one, we will obtain existing datasets from horticultural trials including as many of the variables as outlined in objective 1. This database aims to capture information from multiple sources on numerous horticultural aspects. Therefore, populating the database with information will incorporate several methods. Initially, the database will be populated with existing data from multiple sources (i.e. WTFRC, WSU cherry and apple breeding programs, and Oregon State University).

Objective 3. In year two, we will perform a targeted survey from a minimum of 3-5 growers in each of the tree fruit growing regions of Washington (i.e. Okanogan, Lake Chelan, Wenatchee Valley, Columbia Basin and Yakima Valley). The goal of this survey is to capture a sample of the information available from the numerous on-farm trials that are not readily accessible to the producer community at large. These data will serve to supplement the existing research trial data.

Objectives 4 and 5. In year two, after the database has been populated, we will publish it to the web for immediate use by growers and researchers. We will also generate reports to collaborate with participants interested in examining the effects of replant practices and the effects of management practices on production of targeted fruit. This information can be inserted into AgProfit to determine profitability and feasibility of plantings and employed technologies.

Objective 6. In year two, we will organize two small workshops to demonstrate the database held in conjunction with the Washington Horticultural Association Annual Meeting in Wenatchee (2009) and the Cherry Institute in Yakima (2010). The purpose of these workshops will be to have producers assess the utility of the database for identifying benchmarks for targeted fruit production. As developed, we envision that the database will be useful for generating a snapshot of existing fruit production in multiple geographic locations and could be used as a starting point to assess individual production practices as they relate to production of targeted fruit.

FINAL PROJECT REPORT

Project Title: Developing flavor gene markers for the WA tree fruit industry

PI:	Cameron Peace	**Co-PI(2)**:	Jim Olmstead
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Co-PI(3):	Bruce Barritt / Kate Evans	**Co-PI(4)**:	Rod Drew
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Cooperators: Amy Iezzoni, Wayne Loescher, Randy Beaudry, Steve van Nocker (Dept Horticulture, Michigan State University), Dorrie Main, John Fellman, Amit Dhingra (Dept Horticulture & LA, WSU Pullman), Nnadozie Oraguzie (Dept Horticulture & LA, WSU Prosser), Yanmin Zhu (USDA-ARS, Wenatchee), Carolyn Ross (Dept Food Science & Human Nutrition, WSU Pullman), Eric van de Weg, Marco Bink (Plant Research International, Netherlands) , Eben Ogundiwin (UC Davis, California), David Chagne and Susan Gardiner (Plant & Food Research, New Zealand), Jim McFerson (WTFRC, Wenatchee), Fred Bliss (Davis, California)

Other Funding Sources

	As PIs	As co-PIs only
Total completed	$356,623	
Total current	$851,710	$77,616
Total to begin soon		$11,500,000

Completed

Agency Name: WTFRC Apple Review
Amount awarded: $158,422 in 2008
Notes: "Apple scion breeding". Barritt PI, Peace co-PI. Synergistic project and beneficiary of flavor gene advances for apple.

Agency Name: WTFRC NW Cherry Review
Amount awarded: $80,893 in 2008
Notes: "Breeding and genetics program for Pacific Northwest cherries". Olmstead PI. Synergistic project and beneficiary of flavor gene advances for sweet cherry.

Agency Name: WTFRC Apple Review
Amount awarded: $40,575 in 2007

Notes: "Adapting available genomics tools to enhance WA apple breeding". Peace. Synergistic project on marker-assisted breeding application for the WSU apple breeding program.

Agency Name: WTFRC NW Cherry Review
Amount awarded: $67,900 in 2008
Notes: "Adapting available genomics tools to enhance Pacific Northwest sweet cherry breeding". Peace, Olmstead. Synergistic project on marker-assisted breeding infrastructure for the WSU sweet cherry breeding program.

Agency Name: Prunus CGC
Amount awarded: $8,833 in 2008
Notes: "Characterization of principle flavor components in the *Cerasus* subgenus members of the *Prunus* Germplasm Collection". Olmstead PI. Synergistic project – phenotypic data collection.

<u>Current</u>

Agency Name: WTFRC Apple Review
Amount requested: $169,210 in 2009
Notes: "Apple Scion Breeding". Evans PI, Peace co-PI. Synergistic project and beneficiary of flavor gene advances for apple.

Agency Name: WTFRC Apple Review
Amount awarded: $87,500 in 2009
Notes: "Genetic marker assistance for the Washington apple breeding program". Peace PI and Olmstead co-PI. Synergistic project on marker-assisted breeding application for the WSU apple breeding program.

Agency Name: WTFRC NW Cherry Review
Amount awarded: $45,000 in 2009
Notes: "Establishing the Marker-Assisted Breeding Pipeline for sweet cherry". Peace PI and Olmstead co-PI. Synergistic project on marker-assisted breeding infrastructure for the WSU sweet cherry breeding program.

Agency Name: WTFRC Apple Review
Amount awarded: $77,616 in 2009
Notes: "Developing an online toolbox for tree fruit breeding". Peace, Olmstead, and Evans co-PIs (PI: D. Main). Synergistic project – bioinformatics support for WSU apple and sweet cherry breeding programs.

Agency Name: WTFRC Technology Review
Amount awarded: $50,000 in 2009
Notes: "ABI 3730 DNA Analyzer to augment tree fruit breeding and research" Peace PI. Matched with $50,000 from Washington Wheat Commission (separate award, PI: D. See) to obtain refurbished ABI 3730 DNA Analyzer for high-throughput genotyping of tree fruit and cereals, based in Pullman.

Agency Name: WSU Agricultural Research Center
Amount awarded: $100,000 in 2009
Notes: Additional support to Dr. Peace and the "Pacific Northwest Tree Fruit Genotyping Laboratory" for high-throughput DNA extraction and genotyping equipment, complementing the ABI 3730 and removing technical bottlenecks for routine tree fruit genotyping.

Agency Name: USDA-CSREES, National Research Initiative
Amount awarded: $400,000 in 2008-2010
Notes: "Functional gene markers for Rosaceae tree fruit texture". Peace PI. Synergistic project – fruit texture genetic control in apple with emphasis on ethylene.

To begin soon

Agency Name: National Science Foundation
Amount awarded: $2,000,000 for July 2009 – June 2013
Notes: "Genome Database for Rosaceae". Peace and Olmstead co-PIs (PI: D. Main). Synergistic project to develop broad bioinformatics support for Rosaceae crops.

Agency Name: USDA-CSREES Specialty Crops Research Initiative
Amount awarded: $2,000,000 for September 2009 – August 2013
Notes: "Tree Fruit GDR: Translating genomics to fruit tree agriculture". Peace and Evans co-PIs (PI: D. Main). Synergistic project for practical application of bioinformatics to tree fruit crops.

Agency Name: USDA-CSREES Specialty Crops Research Initiative
Amount awarded: $7,500,000 for September 2009 – August 2013
Notes: "RosBREED: Enabling marker-assisted breeding in Rosaceae". Peace and Evans co-PIs (PI: A. Iezzoni). Broad umbrella project on genetic marker development and application that effectively supersedes the current flavor gene project.

Total Project Funding: $27,035

Budget History:

Item	**Year 1:** Jul07-Jun08	**Year 2:** Jul08-Jun09	**Year 3:**
Salaries	4552		
Benefits	1548		
Wages	6895		
Benefits	2040		
Equipment			
Supplies	12000		
Travel			
Miscellaneous			
Total	**27,035**	0	

RECAP ORIGINAL OBJECTIVES

This project seeks to **develop a generic system that identifies genes controlling traits of importance to the Washington tree fruit industry**, and to **implement this system using the example of fruit flavor**. Understanding the key control points for traits of interest is very valuable for improving crop production. This knowledge can then be put to practical use, such as in marker-assisted breeding, controlled sport induction, or chemical genomics. The project uses the candidate gene approach and capitalizes on expanding genomics databases and a large international network of tree fruit genomics, genetics, and breeding researchers. Specific objectives are to 1) develop DNA tests of flavor useful for Washington tree fruit breeding programs, 2) establish a temperate-tropical fruit genomics channel through linkages between the Rosaceae and papaya genomes, and 3) identify tropical fruit flavor genes having potential value for the Washington tree fruit industry.

While originally planned for three years, after two years of significant progress in this and companion projects, advances international in genomics, and recent success in new federal grant funding, we believe that the next steps to achieving the project's major goal are best made within the new federal projects of "RosBREED: Enabling marker-assisted breeding in Rosaceae", "Genome Database for Rosaceae", and "Tree Fruit GDR: Translating genomics to fruit tree agriculture", and the current WTFRC-funded projects on genetic marker assistance for WSU's apple and sweet cherry breeding programs.

SIGNIFICANT FINDINGS

- Our multi-pronged approach to channel genomics knowledge of fruit flavor (particularly sweetness, acidity, and aroma) into the WSU tree fruit breeding programs has successfully established major components of a system for genetic marker identification, and has generated several DNA tests with promise for the Pacific Northwest apple and sweet cherry industries.

- A "Master List" of 100 candidate genes with potential contribution to the formation of sweetness, acidity, and volatile aroma compounds were assembled. These genes provide valuable focal points for mining the whole genome sequences of apple and peach when publicly released later in 2009.

- Gene expression analyses by Dr. Randy Beaudry at MSU for volatile aroma candidate genes identified three classes of genes of particular interest, incorporated into the Master List.

- Preliminary whole genome sequencing of sweet cherry by Dr. Amit Dhingra was functionally connected with marker development within this flavor gene project.

- A "Flavor Gene Map" was created for displaying the many genomic regions relevant to flavor, to guide genetic marker development.

- Genomic regions in sweet cherry correlated with sweetness, acidity, individual sugars, and malic acid were placed on the Flavor Gene Map with data from a companion project

- Several promising candidate genes that appear to underlie flavor QTLs (quantitative trait loci, which are genomic regions correlated with trait performance without the controlling gene necessarily known) were identified, and are undergoing a process of validation and utility testing within the apple and sweet cherry Marker-Assisted Breeding (MAB) Pipelines.

- This project has served as a focal point for supporting and collating flavor performance data on apple and sweet cherry germplasm. Insights into sugar profiles of cherry were made by comparing data sets from two companion projects. Novel sugar profiles and aroma profiles were identified in cherry and apple germplasm for exploitation in WSU breeding programs – particularly as we implement genetic markers for those traits.

- Phenotypic data on apple flavor attributes were obtained by Dr. Beaudry for 184 lines (42 species and two hybrid lines) from the Geneva *Malus* core collection. Measurements included internal ethylene concentration, SSC, “taste” (tart, astringent, sweet, nutty, floral, fruity, bland, acid, lemon, alcohol, spicy, anise, and other unusual notes), and volatile compounds (volatile esters, aldehydes, alcohols, and terpenoids).

- We were unsuccessful in 2007 and 2008 to receive Australian funding to support this project’s specific objectives of establishing and implementing a temperate-tropical fruit genomics channel. Planned activities on this area for the final years of the project were therefore not conducted.

- Major federal funding has been obtained for two bioinformatics projects and one MAB Pipeline project, to begin in September 2009. Proposed Rosaceae community-wide work of those projects overlaps with and supersedes the originally planned system of this present flavor gene project.

RESULTS & DISCUSSION

Flavor attributes are important to the WA tree fruit industry and are high priority targets in the WSU apple and sweet cherry breeding programs. We have chosen and are testing genes that are likely suspects influencing in fruit flavor for apple and sweet cherry. We are also collecting and collating flavor-related performance data for experimental, breeding, and collection germplasm. Finally, Pedigree-Based Analysis combines the genotypic and phenotypic data to describe the effect of specific gene variants and their distribution in germplasm. With this system, we are transforming as many genes as possible into genetic screening tools for breeding, via the marker-assisted breeding approach. With marker-assisted seedling selection, the infrastructure for which we are developing in other projects, we can improve the efficiency of breeding operations by reducing the proportion of seedlings planted in the field with poor genetic value. Economic analyses within concurrent projects are providing bottom line figures that indicate substantial cost savings by implementing even one genetic marker that tags an important trait.

<u>The Master List of flavor genes</u>

Candidate genes with potential to contribute to the formation of sweetness, acidity, and volatile aroma compounds were assembled based on literature and advice from collaborators. This “Master List” contains (more than) 100 distinct gene sequences representing 51 types of genes (provided as Appendix 1 in the First Year Continuing Report, August 2008, and available on request).

Gene expression analyses by Dr. Randy Beaudry at MSU for volatile aroma candidate genes identified three classes of genes of particular interest, incorporated into the Master List. Several putative genes of branched-chain aminotransferase (BCAT), pyruvate decarboxylase (PDC), and

2-isopropylmalate synthase (IPMS) were found to have expression patterns that increase concurrently with branched-chain ester production (details provided in the August 2008 report).

Sweet cherry ('Stella') whole genome sequence data obtained by Dr. Amit Dhingra at WSU were screened to identify cherry versions of Master List flavor genes for which no cherry DNA sequences were previously known. These cherry DNA sequences will facilitate the development of efficient flavor gene tests for cherry, because differences among genomes can cause some tests developed on apple and peach sequences to fail when attempted for cherry. Previously, only 1-2% of the DNA sequences for flavor genes in Rosaceae that we could obtain from public databases were from sweet cherry.

Master List flavor gene annotation (characterization) needs have provided a useful test case for the Genome Database for Rosaceae program's efforts in developing bioinformatics tools for tree fruit breeding – the focus of the current WTFRC-funded project "Developing an online toolbox for tree fruit breeding" and the upcoming SCRI-funded project "Tree Fruit GDR: Translating genomics to fruit tree agriculture" directed by Dr. Dorrie Main at WSU. To date, 37 of the Master List flavor genes have been identified in both apple and peach (list attached), the combined sequences have been assembled using different assembly programs, and the best consensus sequences have been annotated for coding region using the gene prediction program fgenesh and the protein domain program Interproscan. As part of the newly funded GDR and RosBREED (see below) programs we will align these sequences against the peach and apple whole genome sequences to generate more detailed and higher quality comparative annotations which will then be used to identify optimal primer sequences using PRIMER3, for use in screening on specific breeding germplasm.

"RosBREED" is a U.S. Rosaceae community-wide project that mobilizes international genomics, statistical, germplasm, breeding, and phenotyping resources to establish and implement a Marker-Assisted Breeding Pipeline for Rosaceae crops. More than a thousand fruit quality genes will be chosen for apple, peach, strawberry, and cherry, their sequences and variation thoroughly described, and their genomic locations pinpointed. Subsequently, fruit quality" genome scans" will be developed and screened on hundreds of cultivars, selections, and seedlings representing the crops and core participating breeding programs (which include WSU's apple and sweet cherry). Collation of existing performance data plus new standardized data collected for three additional seasons will be combined with genome scans with Pedigree-Based Analysis to identify and characterize fruit quality genetic variation. As the flavor genes on the Master List will be included in the genome scans, RosBREED's planned activities exceed those intended in the present flavor gene project. Thus it is most efficient to allow further flavor gene marker development to be conducted within RosBREED.

<u>The Flavor Gene Map</u>
Major flavor trait-influencing regions and flavor candidate genes in the *Malus* (apple) and *Prunus* (stone fruit) genomes were combined into a single visual database, the Flavor Gene Map. This Map currently has 53 flavor candidate genes and 57 QTLs for sweetness, acidity, volatile aroma, and astringency (Figure 1). These regions were determined by:

a) Surveying QTL literature on analyses in apple, peach, and cherry (Maliepaard et al. 1998; Wang et al. 2000; Etienne et al. 2002; Liebhard et al. 2003; Kenis et al. 2008; Dunemann et al. 2009). In recent scientific conferences, researchers at Plant & Food Research in New Zealand reported the location of a major locus (*2MBAc*) on chromosome 2 of apple controlling levels of the major volatiles contributing to typical apple aroma.

b) Obtaining unpublished data generously provided by colleagues involved in genetic mapping of flavor candidate genes. At UC Davis, Dr. Eben Ogundiwin has recently placed 12 flavor candidate genes on the *Prunus* genome within a study that is developing a "*Prunus* fruit quality gene map" (Ogundiwin, Peace, et al., manuscript submitted). At Plant & Food Research, Dr. David Chagne and students (Mukarram Mohammed and Aurélie Dimouro) mapped 13 flavor candidate genes from a list compiled by their flavor genomics specialists, Drs. Edwige Souleyre, Richard Newcomb, Robert Schaffer, and Ross Atkinson. That work was performed with the aim of identifying the gene controlling the *2MBAc* aroma locus, but thus far has not been successful. Nevertheless, the 13 candidate genes may be discovered to control other aroma loci, and so they are included on the Flavor Gene Map.

c) Considering also published gene locations of genes involved in the ethylene biosynthesis and perception pathway. Reports on transgenic apple fruit with the ACS and ACO genes knocked out (Dandekar et al. 2004; Schaffer et al. 2007) have shown that while sweetness and acidity development in fruit is apparently independent of ethylene, volatile aroma compounds – particularly volatile esters – are strongly affected by ethylene. The final enzymatic steps of volatile aroma compound synthesis are always affected by ethylene levels, and often the initial enzymatic step is also influenced (Schaffer et al. 2007). The genes for these volatile production enzymes are part of the Master List of flavor genes, while the ethylene genes are additional. Because low fruit ethylene production is a target for apple texture genetic improvement in the WSU apple breeding program, while low ethylene tends to result in lower aroma production, we seek flavor gene variants that enable pleasing aroma development in low ethylene genotypes.

d) Including cherry QTL data from the WTFRC-funded companion project "Adapting available genomics tools to enhance Pacific Northwest sweet cherry breeding" with Dr. Amy Iezzoni at MSU. Several QTLs were located for flavor components (SSC, absolute and relative sugar contents, total soluble solids, malic acid, and astringency) using the MSU experimental population of NYxEF (a cross between the wild cherry NY54 and heritage cultivar Emperor Francis).

Many cases were observed on the Flavor Gene Map where candidate genes for a flavor trait were at the same region as chromosomal regions influencing a flavor trait (i.e. QTLs) (Figure 1). As the map aligns kindred apple (*Malus*) chromosomes, and aligns ancestrally tied apple and cherry/peach (*Prunus*) chromosomes, QTLs for one crop were often in the same region as for other crops, and some of the gene-QTL co-locations were also across chromosomes, offering additional opportunities for gene function validation and utility assessment. Some of the opportunities are already being investigated further:

- At the bottom end of *Malus* chromosome 16 is located a major QTL for acidity, and a candidate gene for acidity showed up in the same place. This is also a region strongly influencing crispness and juiciness. Predictive tests for these traits based on the this chromosome 16 region are being developed within the apple MAB Pipeline (companion WTFRC-funded project "Genetic marker assistance for the Washington apple breeding program").
- The gene controlling the *2MBAc* locus on *Malus* chromosome 2 is not yet known, but we are tagging the region with nearby markers (with helpful genomic information provided by David Chagne at Plant & Food Research), and investigating its usefulness for predicting apple aroma presence/absence for parents and seedlings of the WSU apple breeding program.
- In an aligned region on Prunus chromosome 4 and Malus chromosomes 10 and 5 are major QTLs for sweetness, acidity, and volatiles, and candidate genes for volatiles. This region also holds major QTLs for texture. The synergistic NRI-funded project "Functional gene markers

for tree fruit texture in Rosaceae" is examining such linkages among traits in detail by measuring texture and flavor performance of a large apple germplasm set and studying several genes and markers in this region. That project will consider how selection for specific texture gene variants here would affect flavor attributes – ultimately to allow efficient selection for the best combination of both.

Other opportunities abound, thanks to the consolidation of otherwise widely dispersed data that the Flavor Gene Map provides. The Map will continue to be updated with locations of flavor genes and QTLs as they are discovered and reported. Arising opportunities for developing useful predictive DNA tests for flavor in Washington tree fruit will be exploited in the WTFRC-funded genetic marker assistance / MAB Pipeline implementation projects.

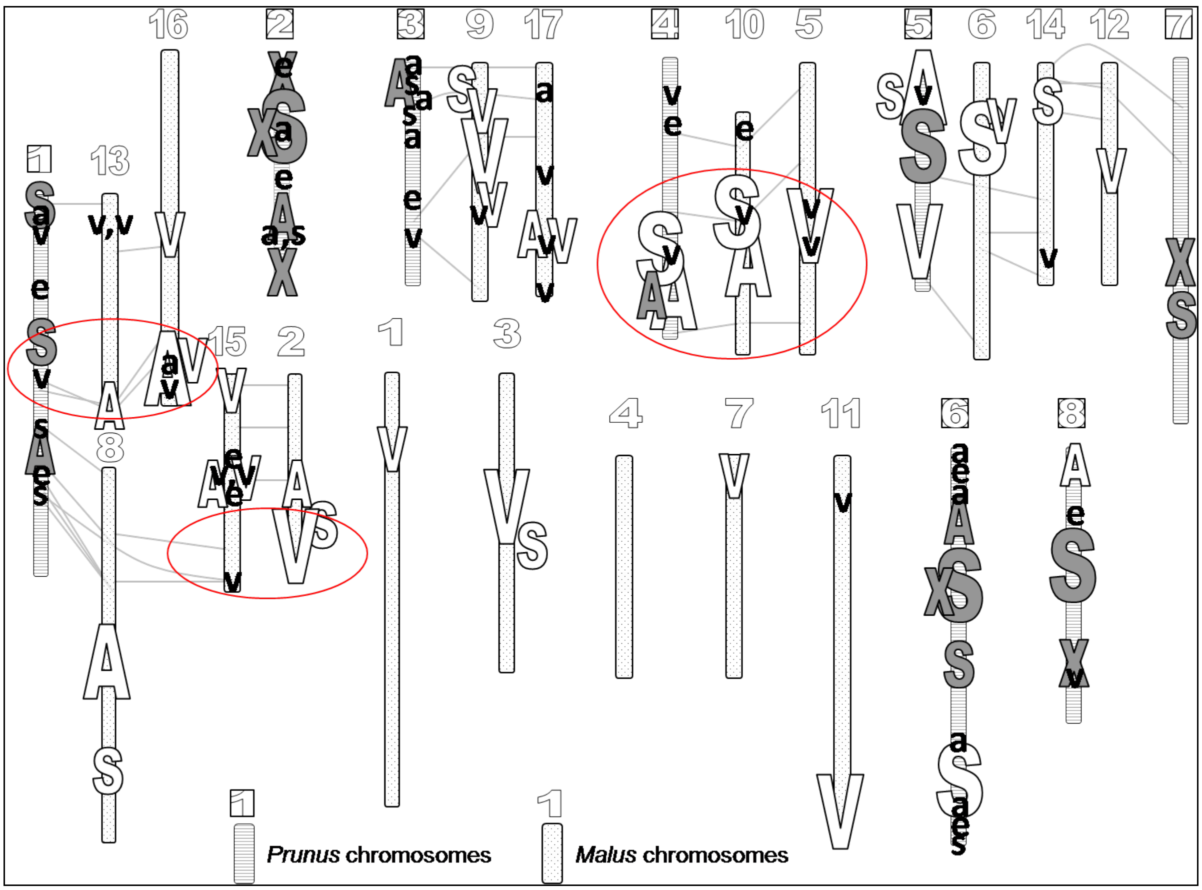

Figure 1: The **Flavor Gene Map** for apple and sweet cherry. S,s = sweetness, A,a = acidity, V,v = volatile aroma, x = astringency, e = ethylene. Chromosomal regions (QTLs – quantitative trait loci) influencing fruit flavor in the genomes of pome fruit (*Malus*) and stone fruit (*Prunus*) are indicated in block capital letters (larger letters = larger reported effect). Locations of candidate genes for flavor and ethylene synthesis/perception are shown in lower case letters. Horizontal lines show known connections between the related genomes. Three co-locations of candidate genes and QTLs targeted for further marker development are circled.

<u>Flavor Phenotyping</u>

This project has served as a focal point for supporting and collating flavor performance data on apple and sweet cherry germplasm. Two examples are described below.

Insights into sugar profiles of cherry were made by comparing data sets from two companion projects. The first data set was collected in collaboration with Dr. Dave Rudell at USDA-ARS Wenatchee, within the 2008 project "Characterization of principle flavor components in the *Cerasus* subgenus members of the *Prunus* Germplasm Collection". Approximately 80 accessions from the USDA cherry collection at Davis were measured for SSC, titratable acidity, and individual sugars and acids via gas chromatography-mass spectrometry (GC-MS). The second data set was for the MSU population of NYxEF, described in the previous section. Sugar and acid contents and proportions were compared between these two data sets, and revealed opportunities for introducing different and desirable sugar profiles into sweet cherry by (marker-assisted) breeding. These opportunities are being exploited in the breeding program. Astringency was also examined in the NYxEF population, and from the resulting data it appears that marker-assisted breeding can readily incorporate breeding against high astringency – which will improve the efficiency of using wild sources as parents.

Phenotypic data on apple flavor attributes were obtained by Dr. Beaudry for 184 lines (42 species and two hybrid lines) from the Geneva *Malus* core collection. Measurements included internal ethylene concentration, SSC, "taste" (tart, astringent, sweet, nutty, floral, fruity, bland, acid, lemon, alcohol, spicy, anise, and other unusual notes), and volatile compounds (volatile esters, aldehydes, alcohols, and terpenoids). As for cherry, this data provides opportunities for introducing unique flavor profiles, particularly for aroma, into breeding germplasm.

References:

Dandekar AM, Teo G, Defilippi BG, Uratsu SL, Passey AJ, Kader AA, Stow JR, Colgan RJ, James DJ (2004). Effect of down-regulation of ethylene biosynthesis on fruit flavor complex in apple fruit. Transgenic Research 13:373-384

Dunemann F , Ulrich D, Boudichevskaia A, Grafe C, Weber WE (2009). QTL mapping of aroma compounds analysed by headspace solid-phase microextraction gas chromatography in the apple progeny 'Discovery' x 'Prima'. Molecular Breeding 23:501-521

Etienne C, Rothan C, Moing A, Plomion C, Bodenes C, Svanella-Dumas L, Cosson P, Pronier V, Monet R, Dirlewanger E (2002). Candidate genes and QTLs for sugar and organic acid content in peach [Prunus persica (L.) Batsch]. Theoretical and Applied Genetics 105: 145-159

Kenis K, Keulemans J, Davey MW (2008). Identification and stability of QTLs for fruit quality traits in apple. Tree Genetics and Genomes 4:647-661

Liebhard R, Koller B, Gianfranceschi, L, Gessler C (2003). Creating a saturated reference map for the apple (Malus x domestica Borkh.) genome. Theoretical and Applied Genetics 106:1497-1508

Maliepaard C, Alston FH, van Arkel G, Brown LM, Chevreau E, Dunemann F, Evans KM, Gardiner S, Guilford P, van Heusden AW, Janse J, Laurens F, Lynn JR, Manganaris AG, den Nijs PM, Periam N, Rikkerink E, Roche P, Ryder C, Sansavini S, Schmidt H, Tartarini S, Verhaegh JJ, Vrielink-van Ginkel M, King GJ (1998). Aligning male and female linkage maps of apple (Malus pumila Mill.) using multi-allelic markers. Theoretical and Applied Genetics 97: 60-73

Schaffer RJ, Friel EN, Souleyre EJF, Bolitho K, Thodey K, Ledger S, Bowen JH, Ma J-H, Nain B, Cohen D, Gleave AP, Crowhurst RN, Janssen BJ, Yao JL, Newcomb RD (2007). A genomics approach reveals that aroma production in apple is controlled by ethylene predominantly at the final step in each biosynthetic pathway. Plant Physiology 144:1899-1912

Wang D, Karle R, Iezzoni AF (2000). QTL analysis of flower and fruit traits in sour cherry. Theoretical and Applied Genetics 100:535–544

EXECUTIVE SUMMARY

This project seeks to develop a generic system that identifies genes controlling traits of importance to the Washington tree fruit industry, and to implement this system using the example of fruit flavor.

Our multi-pronged approach to channel genomics knowledge of fruit flavor (particularly sweetness, acidity, and aroma) into the WSU tree fruit breeding programs has successfully established major components of a system for genetic marker identification, and has generated several DNA tests with promise for the Pacific Northwest apple and sweet cherry industries. Identifying genes with variants that influence important flavor components of apple and cherry will allow us to better understand the genetic value of parents and advanced selections of the WSU apple and sweet cherry breeding programs. The knowledge will also provide a means to genetically manage these traits for crop improvement.

- The project involved extensive collaboration with experts in the U.S. and other countries, particularly in collating resources and knowledge on flavor genetics.

- A “Master List” of 100 candidate genes with potential contribution to the formation of sweetness, acidity, and volatile aroma compounds were assembled. These genes provide valuable focal points for mining the whole genome sequences of apple and peach.

- A “Flavor Gene Map” was created for displaying genomic regions relevant to flavor, to guide genetic marker development.

- Several promising candidate genes that appear to underlie flavor QTLs (quantitative trait loci, which are genomic regions correlated with trait performance without the controlling gene necessarily known) were identified, and are undergoing a process of validation and utility testing within the apple and sweet cherry Marker-Assisted Breeding (MAB) Pipelines.

- Opportunities for introducing unique flavor profiles into Washington tree fruit breeding were identified and are being exploited.

- Major federal funding has been obtained for two bioinformatics projects and one MAB Pipeline project, to begin in September 2009. Proposed Rosaceae community-wide work of those projects overlaps with and supersedes the originally planned system of this present flavor gene project.

While originally planned for three years, after two years of significant progress in this and companion projects, advances international in genomics, and recent success in new federal grant funding, we believe that the next steps to achieving the project’s major goal are best made within the new federal projects of “RosBREED: Enabling marker-assisted breeding in Rosaceae”, “Genome Database for Rosaceae”, and “Tree Fruit GDR: Translating genomics to fruit tree agriculture”, and the current WTFRC-funded projects on genetic marker assistance for WSU’s apple and sweet cherry breeding programs.

CONTINUING PROJECT REPORT **YEAR**: 2 of 3
WTFRC Project Number: TR-07-706

Project Title: Mechanized thinning for labor efficient tree fruit cropload management

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No report submitted.

CONTINUING PROJECT REPORT **YEAR**: 1 of 2
WTFRC Project Number: TR-09-904

Project Title: Economic analysis of technology adoption by Washington apple growers

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Cooperators: Tom Auvil – WTFRC
Karen Lewis - WSU Extension
Norman Suverly - WSU Extension

Total project funding request: **Year 1**: $23,368 **Year 2**: $24,075

Other funding sources

Agency Name: WSU-School of Economic Sciences, IMPACT Center
Amount requested/awarded: $10,000
Notes: Funds were granted to assist with the costs of conducting the technology survey
Other funding sources is for informational purposes only, for WTFRC to understand the scope of the project. These estimated costs are not presented as formal cost-sharing and therefore do not constitute a cost-share obligations on the part of Washington State University. Moreover, there is no requirement for WSU to document this other support of project as part of any cost-share or matching obligation.

WTFRC Collaborative expenses: None

Budget 1
Organization Name: WSU-SES **Contract Administrator: Ben Weller, ML. Bricker**
Telephone: (509) 335-5557, 335-7667 **Email address: wellerb@wsu.edu /mdesros@wsu.edu**

Item	2009 ($)	2010 ($)
Salaries	0	0
Benefits	0	0
Wages	15,557	16,179
Benefits	2,111	2,196
Equipment	0	0
Supplies	0	0
Travel	3,000	3,000
Survey	200	200
Extension Support	2,500	2,500
Total	**23,368**	24,075

The purpose of this research project is to determine the factors that impact technology adoption by Washington apple growers. The focus of the research will be on labor-augmenting technologies, specifically platforms. The motivation for this study was the observation that although automation and mechanization technologies are becoming more readily available to growers and positive impacts on profitability may be realized by implementing them, there is a lack of comprehensive understanding of the factors that may affect grower's decisions to invest in these technologies. Hence, the economic analysis aims to provide information that will be useful to Washington tree fruit growers as well as researchers who are focused on the future of the tree fruit industry. Moreover this study will give insights on Tree Fruit Research Commission priorities, by focusing specifically on profitability of technologies augmenting labor and improving worker safety.

Objectives

1. Evaluate the economic and managerial factors that contribute to a grower's decision to adopt automation and mechanization technologies.
2. Use the data collected during this project to support other educational programs and decisions aids focused on technology adoption.
3. Establish a program for continuously collecting production and management data from tree fruit growers.
4. Disseminate research results to tree fruit growers, packing houses representatives, researchers from other disciplines, and interested parties.

Significant Findings

No significant findings have been determined at this point in the project.

Methods/Activities

In support of objective 1, Taylor, Gallardo, Herb Hinman, and Karen Lewis conducted focus group interviews with three growers in Othello on June 16, 2009. The purpose of the interviews was to collect production cost and practice data for a representative Gala orchard. Currently, we are working to compile the information we gathered to generate a budget for establishment and production. The enterprise budget that will be generated from these data will serve two purposes: (1) It will allow us to do a partial budgeting analysis of the efficiencies and costs that will be realized from implementing platforms for certain orchard activities (e.g. pruning, thinning) in the technology adoption study. (2) It will be published as a WSU Extension Bulletin that, given certain assumptions on production practices, can be used as a benchmark for production costs by growers, lenders, and researchers.

Results and Discussion

The following specifications were assumed to determine the production costs for a new Gala block:

Gala Block Specifications

1	Architecture	2 dimensional system (planar canopy), randomly trained w/ 18" radius from tree center
2	In-row spacing	4 feet
3	Row spacing	10 feet
4	Root stock	Dwarf - 9 series
5	Block size	40 acres
6	Orchard Size	160 total acres & 140 productive acres (20 acres to roads, pond, loading area)
7	Trellis system	5-wire vertical system. Trellis is 11 ft high, with a 12 ft tree. Bottom wire at 18" from ground with 24" between each wire.
8	Irrigation system	Overhead cooling and drip (under tree) sprinklers, with two separate sub-main lines
9	Labor Technology	All hand and ladder (no platforms)

An initial draft of the Gala budget is attached below. We are still in the process of gathering data to complete the budget, as well as supporting analysis.

Draft Copy: Please do not distribute

(Cells marked with a * are missing information from growers and cells marked with ## are values to be calculated when all the data are gathered.)

Cost Per Acre of Establishing and Producing Gala Apples on 40 Acre Orchard Block

	Establishment Years				Full Production
	Year 1	Year 2	Year 3	Year 4	Years
Estimated Production (bins/acre)				25	50
Estimated Price ($/bin)	$	$	$	$ 200.00	$ 200.00
Total Returns				5,000.00	10,000.00
Variable Costs:					
Establishment					
Cleanup costs [1]	*				
Soil Preparation [2]	*				
Trees	7,079.00				
Planting (including labor)	545.00				
Paint	*				
Orchard Activities					
Pruning/Training (including labor)	*	*	*	544.50	544.50
Fertilizer	*	*	*	*	800.00
Pesticides for codling moths	*	*	*	*	*
Mating disruption for codling moths	*	*	*	*	*
Other chemicals	*	*	*	*	*
Beehives				*	*
General Farm Labor	500.00	500.00	500.00	500.00	500.00
Irrigation/Electric Charge	100.00	100.00	100.00	100.00	100.00
Harvest Activities					
Picking Labor				575.00	1,150.00
Other labor (checkers, tractor drivers)				125.00	250.00
Hauling Apples				150.00	300.00
Maintenance and Repairs					
Machinery Repair, Fuel & Lube	325.00	325.00	325.00	325.00	325.00
Irrigation & Pump Repair	*	*	*	*	*
Wind Machine Repair & Fuel				*	*
Alarm System Repair				*	*
Pond Maintenance				*	*
Other Variable Costs					
Overhead	##	##	##	##	##
Interest (7% of VC for 3/4 year)	##	##	##	##	##
Total Variable Costs	8,549.00	925.00	925.00	2,319.50	3,969.50

[1] Land clearing, including pulling of old trees (and trellis, if applicable), piling and burning, soil samples, ripping and disking (including labor costs).

[2] Soil/land preparation, including fumigation, layout and stake, fertilizer, rototiller, etc. (including labor costs)

Cost Per Acre of Establishing and Producing Gala Apples on 40 Acre Orchard Block

	Establishment Years				Full Production
	Year 1	Year 2	Year 3	Year 4	Years
	$	$	$	$	$
Fixed Costs:					
Establishment Costs (includes labor)					
Trellis System	1,473.00				
Irrigation System	2,165.00				
Mainline & Pump	500.00				
Wind Machine & Alarm System				1,750.00	
Pond				1,317.50	
Depreciation					
Trellis	73.65	73.65	73.65	73.65	73.65
Irrigation System	108.25	108.25	108.25	108.25	108.25
Mainline & Pump	25.00	25.00	25.00	25.00	25.00
Wind Machine & Alarm System				58.33	58.33
Pond				65.88	65.88
Machinery & Building Annual Replacement Cost	*	*	*	*	*
Interest					
Land	525.00	525.00	525.00	525.00	525.00
Machinery & Buildings	##	##	##	##	##
Establishment Costs		972.57	1,189.89	1,422.41	
Other Fixed Costs					
Land and Property Taxes	75.00	75.00	75.00	75.00	75.00
Insurance Cost (all farm)	*	*	*	*	*
Management Cost	400.00	400.00	400.00	400.00	400.00
Amortized Establishment Costs					2,996.37
Total Fixed Costs	5,344.90	2,179.47	2,396.79	5,821.02	4,327.48
TOTAL COSTS	13,893.90	3,104.47	3,321.79	8,140.52	8,296.98
ESTIMATED NET RETURNS	(13,893.90)	(3,104.47)	(3,321.79)	(3,140.52)	1,703.03
Accumulated Establishment Costs	13,893.90	16,998.37	20,320.16	28,460.68	

CONTINUING PROJECT REPORT **YEAR**: 1 OF 2 YEARS
WTFRC Project Number: TR-09-05

Project Title: Mobile linear asymmetric fruit transport systems

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Cooperators: Oxbo International Corporation, California Citrus Research Board, WTFRC, Familigia LLC, Washington State Growers Councils

Total Project Funding Request: **Year 1:** 200,000 **Year 2:** 500,000

Other funding sources

Agency Name: California Citrus Research Board & SCRI
Amt. requested/awarded: $1,000,000+ requested
Notes: Pending

WTFRC Collaborative expenses: None

Revised Budget: [1]
Organization Name: **Picker Technologies LLC**
Contract Administrator: **Vincent Bryan III**
Telephone: **206-275-0641** **Email address:** v3@pickertech.com

Item	2009	2010
Salaries	100,000	N/A
Benefits	28,000	N/A
Wages	30,000	N/A
Benefits	3,000	N/A
Supplies	14,000	N/A
Travel	25,000	N/A
Miscellaneous		N/A
Total	**200,000**	

Notes: Travel = In-field testing costs in WA and CA. Miscellaneous = 5% Contingency

OBJECTIVE 1

Develop and test one (1) pilot fully integrated mobile fruit transport harvest system that increase the economic efficiency of harvest and post harvest, 2.5 to 6 times over traditional methods.

The goals and activities for the next 6 months are to:

I. Continue Endurance Testing of the 'Charlie' Prototype in Lynden until the end of 2009.
II. Improve durability through design and updates of the Core Technology and supporting systems' structure of the 'Charlie' Prototype during the remainder of Endurance Testing.
III. Build and Deploy 4 Pilot Harvesters for the 2009 Apple Harvest in WA for Customer Feedback and collection of efficiency data.

Schedule of activities:

I. Endurance Testing start May 1, 2009 end of 2009.
II. First Pilots in Orchard Aug 2009.
III. Peach Evaluation June 10, 2009.

No deviations at this time from original objectives or schedule.

SIGNIFICANT FINDINGS (First 6 Months)

- Transport Tube has been improved to effectively and gently deliver fruit through a 25 foot tube (length increased) and a 9 foot elevation.
- Flexibility of the tube and the laborers' picking portal very effective in Citrus Eval in the efficiency and mobility of the laborer during harvest.

METHODS

for VALUE PROPOSITION

This portion will test and validate labor efficiency gains, culling capture, and damage to fruit in the bin when compared to traditional hand harvest and transport methods. Field observation and testing in 2008 suggest an average picking speed of 30 apples per minute using traditional hand harvest methods. The fruit handling system has been designed to operate at up to 2 apples per second per picker, four times as fast. Culls are currently thrown on the ground or placed in the bin which is shipped to the packing house. Culls may constitute 2% - 25% of an orchard harvest, with an estimated half of the culls created from fruit damaged during harvest, and transport. Use scanning reports to identify percentage of crop culled in field, and test bins to assure fruit placed in bins is of a higher degree of " damage-free" prior to transport to packing house.

for SHOP TEST AND CITRUS FIELD TEST

B. Field test plan & functional eval:
   1) Field validation of all items from shop test plan
   2) Dynamic evaluation on all systems, product damage under dynamic operation, core technology performance
   3) Maximum operational angle verification of all systems. 7% grade
   4) Trellis fit, interference analysis
   5) Maneuverability
   6) Turning requirements
   7) Steering
   8) Braking/park brakes
   9) Operator interface
   10) Bin sequencing timing and performance evaluation
   11) Picker load balancing functionality

12) Machine productivity, Limitations to productivity
13) Machine transport: field and road, trailer loading
14) Horsepower usage, Fuel usage and capacity
15) All fluids: flow and cooling capacity checks
16) Electrical loading and capacity: 12V, 24V
17) Endurance test plan: Cumulative testing from California and Washington
18) Minimum machine hours prior to pilot build: 200 harvest hrs

for APPLE TEST TRACK

Take 80 Apples (Golden Delicious) in the range from 2.5 inches to 4 inches and progressively feed them into the Transport Tube at 2 Apples per second. The Functional areas will be evaluated to make sure that the transition of the Apple occurs efficiently and with minimal bruising. The Impact Recording Device (IRD) will then be passed through the Harvester to see if excessive impacts (which could result in bruising) are recorded or to divulge areas of concern.

A. Functional test plan
   1) OBJECTIVE for APPLE TEST TRACK
      a) Apples/IRD pass through Transport Tube
      b) Apples/IRD are decelerated in Vacuum Deceleration Box and pass successfully to Transition Conveyor
      c) Apples/IRD are efficiently transported onto Transition Conveyor
      d) Apples/IRD move from Transition Conveyor to Scanning Conveyor
      e) Apples/IRD are tumbled, scanned, and culled per the Sorting Algorithm
      f) Apples/IRD move from Scanning Conveyor to Dry Bin Filling Conveyor
      g) Apples/IRD are effectively delivered and filled into the Dry Bin

for BIN PATH

Using a plastic MacroBin and a wood bin, feed the bins into the carriage transport, taking note of cycle times and mechanical interaction. Measure openings and interference to verify fit for all sizes of bins

   1) OBJECTIVE for BIN PATH
      a) Bins are loaded onto entry ramp.
      b) Bins are automatically loaded into Cull position
      c) Cull Hopper works properly
      d) Bins are automatically and properly unloaded from Cull Bin position
      e) Bins are shuttled and automatically loaded into Dry Bin position
      f) Dry bin and Cull bin shuttling and filling work properly
      g) Bin unloading occurs effectively

for OPERATION and MECHANICAL CONTROL

This portion will evaluate and address areas of interaction for the stopping, starting, and possible malfunction of the interaction between the vacuum motors, water pumps, loading ramps, Transition Conveyor motor, hydraulic Scanning Conveyor motor, shuttling conveyor motors, scanning "tumbling" mechanism, culling mechanism, lift cylinders for Cull and Dry bins, mobility controls, all STOPS, Picking Platform mobility, and Engine Function.

   1. MECHANICAL ELEMENTS
      a) Propulsion system functional tests
      b) Engine package: operation, cooling, 12/24 v alternator functionality

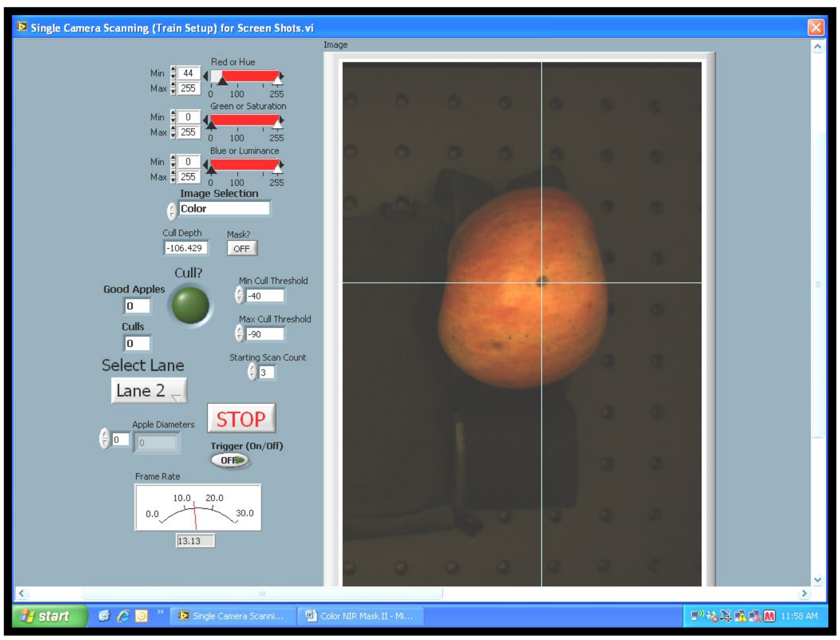
c) Hydraulic package: initial data acquisition
d) All actuated cylinder functionality
e) Mechanical integrity of the overall machine

RESULTS & DISCUSSION (first 6 months)

- The *picking* efficiency (Whitney et. al.) for Citrus pickers increased vy a factor of at least 2X with the harvester configuration designed for apple orchards (*economic* efficiency for Apples still needs to be determined after data is collected in the fall).
- Harvester movement 5.2% of time and platform movement 2.6% time; 24 X 24 and 20 X 20 Plantings a significant improvement over ladder/bin methods
- Full Bin to Empty Bin transition: 30 seconds
- Mechanical Issues addressed by the end of Citrus Test decreased 70%

<u>OBJECTIVE 2</u>

Develop and test an in-field cull sorter and bin storage system (to decrease storage costs and increase revenue opportunities for the grower).



The goals and activities for the next 6 months are to continue proof of mechanical components and reliability. Validate sensing ability to 'cull' apples with the mobile scanner technology (Apple Test Track and Fall Harvest 2009).

No deviations at this time from original objectives or schedule.

SIGNIFICANT FINDINGS

- Cull defects, Stem, and Calyx for Apples can be determined with current Scanning Algorithm. Need to continue to improve IO interface to enhance frame processing speed and software optimization (including complete de-bug)

- The size of each piece of fruit and a histogram can be successfully logged for each bin of apples.

METHODS

The scanning algorithm should identify 80% of the offending fruit with a 90% confidence level for culling. Packing Houses at best try to achieve 90% of cull identification within a more controlled environment. With graded apples being 10X more valuable than a cull, feedback suggests allowing a few culls into the graded bin would be a better situation than culling a higher quality grade of apple. The Fruit Handling System will allow for logging of different 'cull' defects and the ability to 'tweak' scan settings during harvest, per Grower preferences.

RESULTS & DISCUSSION (first 6 months)

- During the Citrus Test, the fruit was sized for diameter with Scanning Technology but not defect culled because algorithms for citrus have not been developed/funded. Citrus Test required improvements to the Scan Ramp to quickly lay fruit down into the optimal scanning position.
- More rugged computer hardware was implemented from Citrus Test experience; 3 days of 100°F+ temperatures.

<u>OBJECTIVE 3</u>

Develop and test a 'dry bin' filler that minimizes damage to fruit while safely loading a bin in-field at a maximum of 8 apples per second.

The goals and activities for the next 6 months are to complete the Pilot Build for the Apple Orchard Harvest 2009 and implement improvements for continued endurance testing on the 'Charlie' Prototype.

No deviations at this time from original objectives or schedule.

SIGNIFICANT FINDINGS

- The in-sync transition of fruit from the Scanning Conveyor to the Dry Bin Filling Conveyor has been optimized.

METHODS

Outlined above.

RESULTS & DISCUSSION (first 6 months)

- Impact Recording Device yielded low level velocity-energy when compared to 'apple line'
- Bruise assessment of 80 Golden Yellow Delicious yielded 1 bruise incidence for Dry Bin Filler (missing foam padding was not protecting hard surfaces).
- Peaches yielded similar subjective (growers perspective) low level bruise assessment.

FOOTNOTES:

1. As originally forecast, project costs will exceed WTFRC grant. Picker Technologies has funded the difference to date. All 2009 grant funds have been used.

Picker Technologies, LLC
Project Billing Analysis
Actual Costs 3/1/2009 -5/28/2009

	System	Scan	Dry Bin	Total
Salaries	$ -	$ -	$ 895.96	**$ 895.96**
Benefits 1	$ 10,022.31	$ 1,860.77	$ 1,792.23	**$ 13,675.31**
Wages	$ 14,152.24	$ 2,000.00	$ -	**$ 16,152.24**
Benefits 2	$ 1,500.00	$ 1,000.00	$ 500.00	**$ 3,000.00**
Supplies	$ -	$ -	$ -	**$ -**
Travel	$ 20,773.32	$ 3,058.88	$ 1,167.80	**$ 25,000.00**
Total this billing	$ 46,447.87	$ 7,919.65	$ 4,355.99	**$ 58,723.51**

Salaries = gross salaries
Benefits 1 = co pd med/dent/life ins/ co pd payroll taxes
Wages = consultant fees
Benefits 2 = milestone incentive payments
Supplies = vendor payments
Travel = transportation, accomodations, meals, parts during travel

Previous billing	Total billing	Budget	Remaining to bill
$ 99,104.04	$ 100,000.00	$ 100,000.00	$0.00
$ 14,324.69	$ 28,000.00	$ 28,000.00	$0.00
$ 13,847.76	$ 30,000.00	$ 30,000.00	$0.00
$ -	$ 3,000.00	$ 3,000.00	$0.00
$ 14,000.00	$ 14,000.00	$ 14,000.00	$0.00
$ -	$ 25,000.00	$ 25,000.00	$0.00
$ 141,276.49	$ 200,000.00	$ 200,000.00	$0.00

CONTINUING PROJECT REPORT **YEAR**: 1
WTFRC Project Number:

Project Title: Rosaceae micropropagation and tissue culture platform

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Cooperators: Tom Auvil, WTFRC; Nnadozie Oraguzie, WSU; Gennaro Fazio, USDA-ARS; Herb Aldwinckle, Cornell, Geneva; Bill Howell, Northwest nursery improvement institute; Todd Einhorn, OSU

New cooperators: Tye Fleming and Todd Erickson

Total project funding request: **Year 1**: 30,000

Other funding sources

Agency Name: Helios Nursery
Amount requested/awarded: $15,000 / $15,000
Notes:

WTFRC Collaborative expenses: None

Budget 1
Organization Name: WSU **Contract Administrator: Betty Musick**
Telephone: 5093359505 **Email address: musickb@wsu.edu**

Item	**2009**		
Salaries	18,440		
Benefits	7,560		
Wages			
Benefits			
Equipment			
Supplies	2500		
Travel	1500		
Miscellaneous			
Total	**30,000**		

Note: The term "in vitro" repeatedly used in this project means "in tissue culture"; Magenta boxes are tissue culture vessels made of clear polypropylene material. It is a trademark and does not represent a magenta colored box.

JUSTIFICATION

Major goal of the project: This project addresses the ever-increasing time gap between development of new rootstock or scion genotypes by several breeding programs and their commercial utilization by the growers. This delay represents a financial burden both to the program that develops them and the fruit industry.

Rootstocks have revolutionized production of fruit in the PNW. However, problems remain with the existing rootstock genotypes that were adopted several decades ago especially in apple. New genotypes of rootstocks have been developed in different breeding programs but their commercial adoption has been delayed due to a simple yet vital factor of efficient multiplication. Liner bed multiplication is the traditional way of multiplying the rootstocks, however the new genotypes have been found to be hard to root and multiply. Multiplication of rootstocks in tissue culture is an alternative approach that has been implemented even for the older rootstocks with success.

The objectives of the proposal were:

1. Refine or formulate micropropagation protocols for Geneva rootstocks (apple), Pear rootstock OH x F and Polish Quince (Pear)
    - Objective 1A: Finalize the protocol for obtaining rooted rootstocks of G41 and develop similar protocols for G935 apple, OH x F and Pear Quince rootstocks.
    - Objective 1B: Third-party validation of the micropropagation protocols.
    - Objective 1C: Perform a cost-analysis of agar-based or temporary immersion system protocols to assess implementation of the methods in a commercial setting.
2. Define special light conditions for micropropagation of rootstocks and scions.
    - Objective 2A: Identify the most efficient light wavelength combinations for apple and pear rootstocks.
    - Objective 2B: Assess the cost-benefits of utilizing specialized growth chambers in micropropagation.
3. Transition the micropropagation research to the field – sustaining the Rosaceae micropropagation platform.

We obtained additional funding from Helios nursery and we have been able to carry out the work accordingly.

Revised Objectives

Objective 1: Rootstock production: Finalize the protocol for obtaining rooted rootstocks of G41

Objective 2: Rootstock acclimatization: Establish protocols for transfer of material from the lab to the green house

Objective 3: Standardize micropropagation of G-935 (apple), OHXF 87 (pear) and Gisela 6 (Cherry)

SIGNIGFICANT FINDINGS

Apple rootstock:
Geneva 41 rootstock propagation has moved all the way to the greenhouse tests. We have tested first batch of micropropagated plant material in mist beds achieving a survival rate of 65%. These plants were not rooted bud directly transferred to the greenhouse.

Rooting standardized:

We have also worked on resolving the rooting issue with G-41. In tissue culture plants, we can now obtain 100% rooting of explants.
Tissue culture media established for G-41 was tested on G-935 micropropagation. The G-935 genotype does not respond well to G-41 media. There is a need for new media formulations for G-935. We have made some initial progress on G-935 micropropagation in agar and are now working on temporary immersion system-based micropropagation.

Pear rootstock:
We have established OHXF 87 micropropagation system both in agar as well as in temporary immersion system. In addition, we have also obtained rooted pear rootstocks.

Cherry rootstock:
Over the past few months we have successfully established Gisela 6 rootstock in tissue culture with appropriate shoot growth. Next step will be to test temporary immersion system-based propagation. This work will initiate after enough explants are available from the agar-based micropropagation.

METHODS

Objective 1: Rootstock production: Finalize the protocol for obtaining rooted rootstocks of G41.
An in vitro liner consisting of 4 nodes is placed horizontally on the tissue culture media. After 6-8 weeks when each node develops into one or two individual shoots, the basal liner tissue is excised. Individual shoots are moved to rooting media placed in square transparent boxes called Magenta boxes. The normal light conditions are the conditions used in tissue culture room with 30 micro moles per m2 per sec with 16h day and 8 h dark periods. Under these conditions the rooting media used was supplemented with IBA and no sucrose.

Rooting has been obtained by using modified nutrient salts (MS media) and IBA. Prolific root formation is observed in 4 weeks.

Objective 2: Rootstock acclimatization: Establish protocols for transfer of material from the lab to the green house.
One of the major reasons for tissue culture derived plant mortality is sudden drop in relative humidity. To avoid humidity related mortality, the explants will be moved towards rooting while enclosed in Magenta boxes. In cooperation with Tye Fleming and Todd Erickson, multiplied rootstock shoots in tissue culture will be directly moved to mist beds and their performance will be monitored.

Objective 3: This objective utilizes standardize tissue culture protocols as for G-41.

RESULTS AND DISCUSSION

1. Geneva – 41 rootstock micropropagation pipeline is in place. We have established that each new genotype of apple rootstock requires special media formulation. This would explain lack of success in micropropagation in other labs.

Table 1 summarizes the results as provided by our cooperators at Helios Nursery.

Table 1:

Variety	Plant Date	Treatment	Total Plants	Current Survival	Callused	Rooted
G-41	4/8/2009	1	5	0		
	4/8/2009	2	5	0		
	4/8/2009	3	5	2		just rooting: 5
	4/8/2009	4	1	0		
	4/8/2009	5	4	4		4
	4/8/2009	6	2	0		
	4/8/2009	7	5	4	4	
	4/8/2009	8	6	0		
	4/8/2009	9	6	5	6	
	4/8/2009	10	5	1		
	4/8/2009	11	5	1		
	4/8/2009	12	9	0		
	4/8/2009	13	2	0		
	4/8/2009	14	2	1		
	4/8/2009	15	5	3		
	4/8/2009	16	3	1		
	4/8/2009	17	3	1		
	4/8/2009	18	5	2		
	4/8/2009	19	5	5		best plants: 5
	4/8/2009	20	3	2		
	4/8/2009	21	5	0		
	4/8/2009	22	4	0		
	4/8/2009	23	4	0		
	4/8/2009	24	4	0		
	4/8/2009	25	6	6	6	
			Total: 101 plants	65		

Figure 1: Rooted G-41 in rockwool placed in liquid rooting media.

2. Geneva – 935 rootstock. As mentioned above, G-935 needs its own media formulation. A derivative media of G-41 seems promising and is being tested in the lab currently.

3. Pear and Cherry rootstock. Published media formulations have been sub-optimal for pear and cherry rootstock micropropagation. We have formulated species-specific media to propagated pear and cherry rootstocks.

Figure 2 shows a micropropagated OHXF 87 explant.

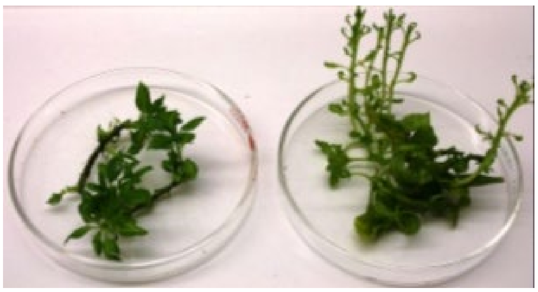

Figure 2: Micropropagated OHXF87 rootstock. Left plate- In agar and Right plate – In temporary immersion system

Timeline:

Objective 1: The unrooted plants were moved to Todd Erickson's green house for acclimatization. Now we will transfer the rockwool-rooted explants to the greenhouse as they get established. We expect this to be done in August 2009.

Objective 2: The acclimatization of tissue culture multiplied rootstocks continues.

Objective 3: Preliminary testing of media for G-935 seems promising and we expect to accomplish micropropagation of G-935 rootstocks by October 2009. Weather permitting the micropropagated pear and cherry explants will be transferred to greenhouse by October 2009.

We expect to establish rooting and acclimatization of G-41 rootstocks by September 2009 barring any unforeseen hurdles.

Milestones:
There are three milestones we want to accomplish with this project in this year.
1. Establish a streamlined protocol for G-41 multiplication and rooting in tissue culture. It seems we have accomplished this objective.
2. Develop a streamlined protocol for transitioning tissue culture derived G-41 into green house. This milestone is being targeted with both unrooted and rooted plant material.
3. We would like to have the micropropagation of OHXF 87 and Gisela rootstocks finalized by December 2009.

Role of Cooperators:

Previous Cooperators: These cooperators were listed for the original project. However, in the currently revised framework we will only work with Tom Auvil and Gennaro Fazio.
Tom Auvil, WTFRC – Coordinate tissue culture activities with the nursery industry and enable acclimatization of tissue culture derived plant material.
Nnadozie Oraguzie, WSU – Identify scions and rootstocks that should be multiplied in vitro to support the breeding program activities.
Gennaro Fazio, USDA-ARS – Implementation of standardized protocol to commercial nurseries.
Herb Aldwinckle, Cornell, Geneva – Validation of protocols established in our laboratory.
Bill Howell, Northwest nursery improvement institute – Supporting the research activities based on micropropagation and utilizing in vitro multiplied rootstocks in orchards.
Todd Einhorn, OSU – Micropropagation of Quince rootstocks.

New cooperators: Tye Fleming and Todd Erickson

Tye Fleming and Todd Erickson will utilize in vitro multiplied G-41 rootstocks and help in greenhouse based rooting and acclimatization. The cooperation has already been initiated.

CAHNRS Undergraduate Research funding:

There are two undergraduate students working on this project under supervision of Amit Dhingra and Scott Schaeffer. Salma Tariq and Maureen McFerson are heading the G-41 and G-935 projects respectively. The project was selected for CAHNRS Undergraduate Research Fellowship and will specifically support establishment of rooting under RBG light spectra. The results were presented at the annual CAHNRS awards banquet on April 4th 2009. The results of this project were presented at the annual Sunrise Orchard Field day.

CONTINUING PROJECT REPORT **YEAR**: 1
WTFRC Project Number: TR-09-903

Project Title: Investigating flower bud hardiness of new tree fruit cultivars

PI: Matthew Whiting
Organization: WSU-Prosser
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State/Zip: WA 99350

Cooperators: David Ophardt, Markus Keller, Lynn Mills

Total project funding request: **Year 1**: 35,000

Other funding Sources: None

WTFRC Collaborative expenses: None

Budget 1
Organization Name: WSU **Contract Administrator: ML. Bricker**
Telephone: 509-335-7667 **Email address: mdesros@wsu.edu**

Item	**2009**		
Salaries	$12,479		
Benefits	$10,358		
Wages			
Benefits			
Equipment	$12,163		
Supplies			
Travel			
Miscellaneous			
Total	**$35,000**		

Footnotes: salaries include an Associate in Research (@ 42% FTE plus benefits at 83%) responsible for region-wide program coordination, bud collection, data collection and analyses, development of extension material, and equipment maintenance and oversight. Equipment includes a Tenney T2 temperature test chamber with installed humidity control, datalogger, thermoelectric modules and a computer.

OBJECTIVES:

The objectives of this research project directly address the second highest rated research priority of the cherry industry[1], bud hardiness.

1. Establish new fruit bud hardiness standards by phenotyping several genotypes throughout the dormant season and anthesis

2. Partner with DAS to disseminate bud hardiness data to industry as rapidly and conveniently as possible

3. Develop preliminary data and framework for pursuing federally-competitive funding for further research & outreach

SIGNIFICANT FINDINGS:

- differential thermal analysis (DTA) is an effective method for determining dormant cherry and apple bud hardiness
- cherry and apple cultivars exhibit significant variability in hardiness
- DTA is not effective when buds lose hardiness in mid-March
- we can double the capacity for DTA in the freezer from 35 plates to 70 plates
- there is tremendous variability (≈ 20 F) in hardiness among buds on a tree/limb/spur
- Delicious and Golden Delicious were advanced in flowering compared to Gala and Fuji
- Bing, Chelan, and Sweetheart were similar in flowering and advanced compared to Benton
- Overall, Sweetheart was the least hardy cultivar and Benton was the most hardy
- Fuji was overall the least hardy cultivar and Gala was the most hardy
- Hardiness is gained and lost during bloom, depending upon temperature

METHODS:

Objective 1. We propose to assess floral bud hardiness of tree fruit cultivars throughout the dormant season (roughly between November and March) as well as throughout budbreak, to full bloom. Emphasis will be given to sweet cherry and apple. Bud samples will be collected from orchards with weather stations so that temperature variations among sites may be accounted for and to facilitate future modeling efforts. For sweet cherry, samples will be collected from the WSU-Roza farm.

<u>IAREC, PROSSER (2009)</u>
Fully dormant samples will be analyzed for hardiness by differential thermal analysis using programmable freezers (as described in Mills et al., 2006, attached). The freezer will be programmed to hold tissue at 4 C for 1 hr, drop to -40 C in 11 hr, and return to 4 C in 10 hrs. The system will record voltage output at 15 s intervals and the exotherms will be identified manually from a plot of voltage vs. time. Data will be summarized as LTE_{10}, LTE_{50}, and LTE_{90} (i.e., the temperature at which approximately 10%, 50%, and 90% of the buds were killed, respectively). As buds break endodormancy and progress through the stages of flowering, exotherm analysis will not be feasible

[1] Cherry Industry Priority Setting Session, Prosser, WA, 19 August, 2008

and bud damage will need to be assessed by dissection and visual inspection for tissue death after 1 hour at room temperature. Most assessments of hardiness at flowering will study pistil damage at 0.5 C increments with temperature changing at 4 C per hour. Additionally, we will evaluate the role of the rate of temperature decline and dew point on bud hardiness. At each sampling, high quality digital images representative of various stages of sampling will be collected for use as visual cues for extension materials and new bud hardiness charts. We propose to build immediately a system similar to that utilized by the viticulture program at IAREC (http://winegrapes.wsu.edu/frigid.html) to study the potential for differential thermal analysis on apple and cherry.

In 2009 winter, we will evaluate genotypic effects on bud hardiness by assessing hardiness of many cultivars and selections collected from the same orchard (i.e., similar environment). We will include the cultivars of economic importance (e.g., Chelan, Bing, Benton, and Sweetheart) as well as up to 4 advanced selections of the WA/OR sweet cherry breeding and genetics program. Further, the influence of rootstock will be investigated by selecting buds/flowers from these cultivars grown on Mazzard, and Gisela rootstocks. We also will keep record of bloom timing and fruit harvest timing so the influence of these factors on susceptibility or resistance to low temperature damage can also be examined by covariate analysis. Apple cultivars to be included are Fuji, Gala, Golden Delicious, and Red Delicious.

Objective 2. The dissemination of bud hardiness data in a timely, effective manner will be a high priority. We will work with Vince Jones to link hardiness data with the web-based delivery and the decision aid system (DAS).

RESULTS AND DISCUSSION:

We have confirmed the effectiveness of differential thermal analysis for assessing apple and cherry bud hardiness, using our newly setup freezer system. Clearly discernible high and low temperature exotherms are observable (data not shown) and up to 5 dormant buds can be measured per analysis plate. With modification however we were able to double the capacity of the freezer and utilize up to 70 plates. This will allow greater replication and the ability to compare more cultivars at once, up to ca. 350 buds per freezer run. The exotherm data can be analyzed and presented as LT_{10}, LT_{50}, and LT_{90} readily (Fig. 1). From discussions with growers it is clear that LT_{10} is the most relevant data for frost protection decision-making. We posted on our website the up to date LT_{10} under the "what's new" section.

We have identified significant differences among cherry cultivars in their minimum hardiness level (Fig. 2). It appears, from our preliminary analyses, that 'Chelan' is hardier than other test cultivars and that 'Sweetheart' is the least hardy. There is about a 12 F (6.5 ºC) difference among the cultivars tested in their LT_{50} (Fig. 2). These relative differences did not persist during budbreak and flowering however.

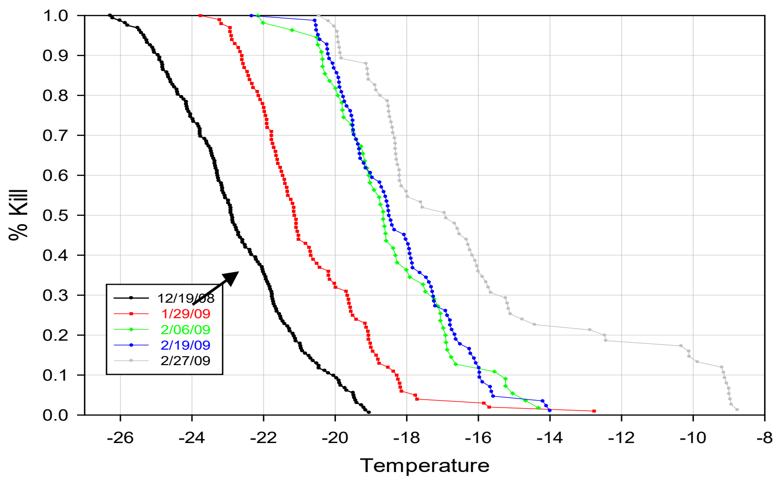

Figure 1. Variability in 'Chelan' fruit bud hardiness over time. Each data point is a recorded low temperature exotherm. Arrow indicates LT_{50} on 12 Dec.

Interestingly, we observed significant variability in hardiness of individual buds within a tree. This hardiness range was as high as 18 F (10 ºC) between the temperature which killed the least hardy flower to the temperature which killed the hardiest flower. Among flowers within a single bud however, there is very little variability in hardiness (i.e., all flowers are killed at a similar temperature, ±0.2 F). This phenotypic diversity in hardiness within a tree/limb/spur is an issue we intend to pursue further.

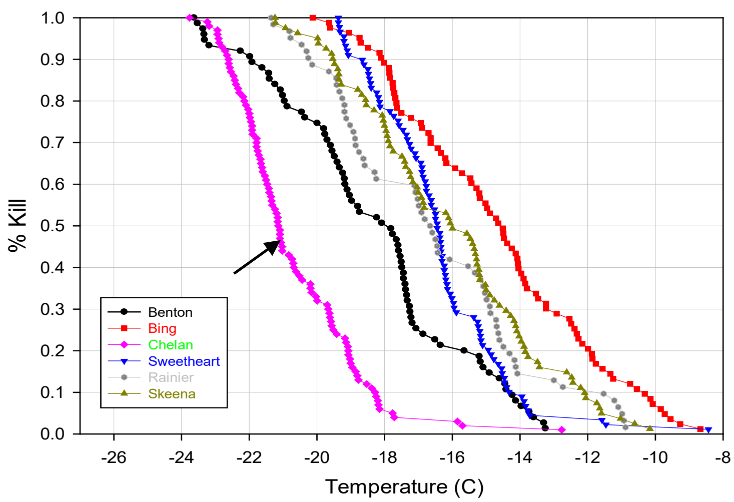

Figure 2. Comparison of fruit bud hardiness among sweet cherry cultivars. Hardiness was assessed on 29 Jan. 2009. Each data point is a recorded low temperature exotherm. Arrow indicates LT_{50} of 'Chelan'.

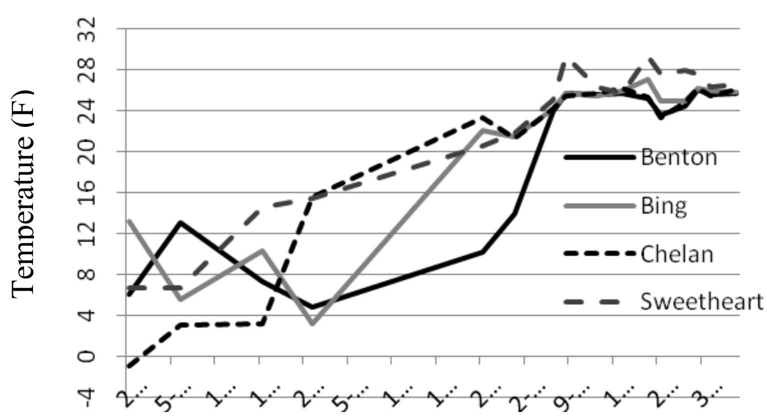

Figure 3. Comparison of LT_{10} of fruit bud and pistils among sweet cherry cultivars. Data prior to 26 March are low temperature exotherms. Data after 26 March are observational for pistil death.

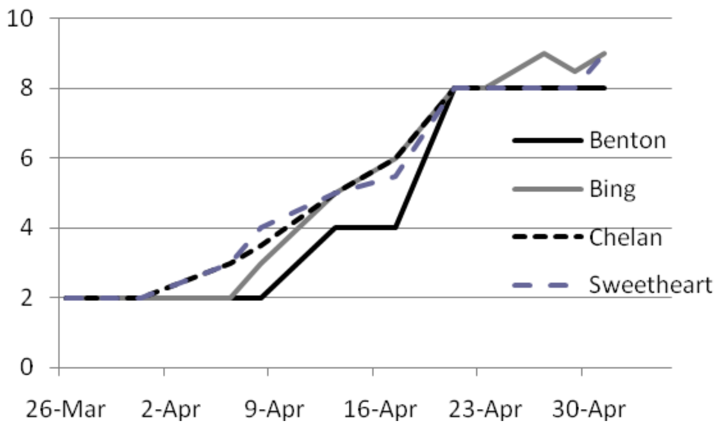

Figure 4. Comparison of fruit bud/flower development among sweet cherry cultivars.

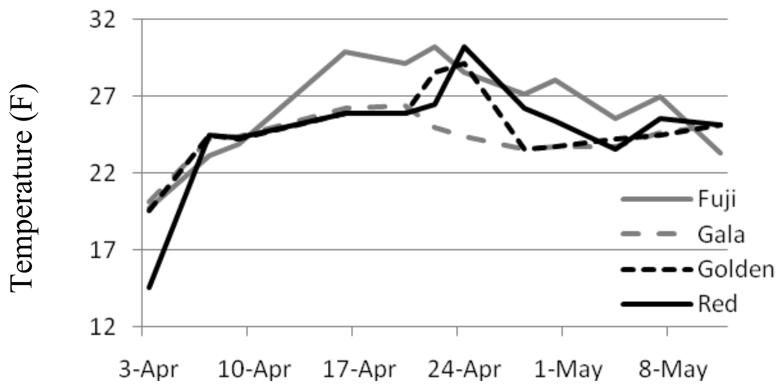

Figure 5. Comparison of LT_{10} of fruit bud and pistils among apple cultivars. Data are observational for pistil death.

We recorded subtle variability among apple cultivars in their hardiness prior to bloom (Fig. 5). Differences became apparent in mid-April with Fuji losing hardiness rapidly compared to other cultivars. Interestingly, the warm weather in mid-April caused a loss of hardiness for Delicious and Golden Delicious but not for Fuji and Gala.

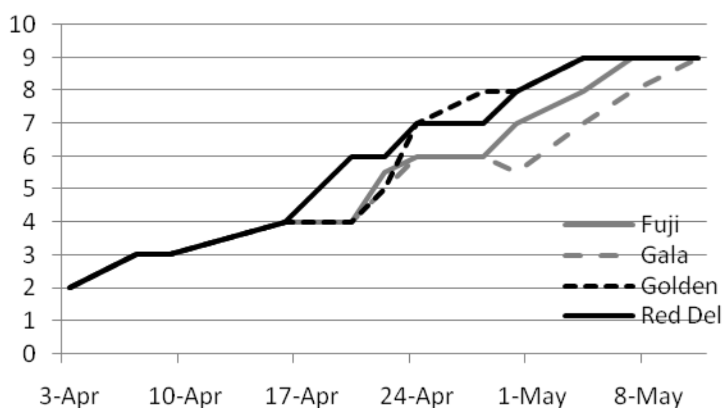

Figure 6. Comparison of fruit bud/flower development among apple cultivars.

CONTINUING PROJECT REPORT **YEAR**: 1 of 3
WTFRC Project Number: TR-09-900

Project Title: Robotic scout for tree fruit

PI: Tony Koselka
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State/Zip: CA 92121

Cooperators: None

Total project funding request: **Year 1**: $275,000 **Year 2**: $275,000 **Year 3**: $275,000

Other funding Sources

Agency Name: USDA – SCRI grant
Amount requested/awarded: $200,000
Notes:

WTFRC Collaborative expenses: None

Budget History:

Item	**2009**	**2010**	**2011**
Salaries	$115,463	$166,926	$167,233
Benefits	$44,037	$63,337	$63,548
Wages			
Benefits			
Equipment			
Supplies			
Travel	$7500	$9500	$8500
Miscellaneous			
Scout Prototype	$8000	$10,237	$10,719
Subcontract to CMU (field expenses for integration)	$25,000	$25,000	$25,000
Total	**$200,000**	$275,000	$275,000

Footnotes:

Objectives

The objective of this project is to create a *Robotic Scout for Tree Fruit*, which is the first phase in the development of robotic mechanization for growing and harvesting fresh apples. Over the three-year project, the goal is to create a market-ready scouting system that will scan of medium and high density orchards to determine the total crop yield. The data will include an accurate count and size distribution, and ultimately, enable a picker robot to reach critical speeds and efficiency.

This collaboration is part of the Comprehensive Automation of Specialty Crops (CASC) project led by Sanjiv Singh at Carnegie Mellon University. The CASC project is part of the Specialty Crop Research Initiative (SCRI) where the USDA matches industry funding, which significantly leverages both VRC and the Commission's funding and technology. In addition to government funding, the project leverages development by other CASC team members such as the autonomous prime mover (APM) vehicle developed by Carnegie Mellon and Toro to tow the Scout through orchards and the GIS system developed during the project.

The goal for 2009 is to add production functionality and advance both the hardware and software significantly towards a production design. The process began with the creation of detailed specifications that drive both this year's and the production design. During the last four months, the objectives were to:

- Complete the fabrication on the next generation, prototype Scout. This platform, called Newton internally at VRC, provides a solid evolutionary step between the proof-of-concept prototype and a finished production design.
- Perform a more detailed analysis of the performance of the existing proof-of-concept prototype.
- Perform an analysis of the worst case lighting conditions, bright sunlight, the Scout may encounter during operation, which presents problems both when looking into the light and when the light is behind the cameras and parts of the trees are very bright and other parts are cast in shadows.
- Test features to enable quality performance across a wide variety of lighting conditions, and begin implementation of the appropriate features.
- Complete the preliminary integration with the Carnegie Mellon Autonomous Prime Mover (APM) and prepare for field tests in late July.

Moving forward, the next major milestone is field tests in Washington in July. The goal of this first set of field tests is to collect enough data to determine the "best" scouting configuration for the hardware and to enable improved benchmarking of the detection software. Using the best hardware configuration, the second set of field tests in September will target green apples.

Significant Findings

- The new Scout, called Newton internally at VRC, has been fabricated, delivered, and is currently being integrated with the electronics and software. The design incorporates lessons learned and has resulted in a significantly more robust system. The basic platform will remain the same for the remainder of the project, and new and refined sub-systems will be incorporated as they become available.
- The results of the fruit detection system determined during previous years were based on a very small ground truth sample. Results of more detailed analysis indicate that actual performance was lower than previously believed. For relatively highly trained orchards, it appears that the Scout identified 60% - 70% of the apples for both green and red colors, which approximately represents more than 80% of the visible fruit.
    - Analysis indicates that approximately 10% of the fruit was obviously visible and should have been detected.

- 10% of the apples were less clearly visible, but still represent objects that can be detected. The final 10% - 15% are largely obscured and very difficult to identify using the current data set of images collected.

- There are a number of mechanical, electrical and system level enhancements that can potentially improve detection performance in bright sunlight.
    - A visor in front of the camera lenses minimizes the angles through which sunlight can strike the lens.
- Rotating the camera mast away from the sun can further decrease the amount of sunlight that can strike the camera lens.
- Polarizing and spectral filters reduce specularities in certain lighting conditions, but do not completely remove them. However, implementation drawbacks are greater than the potential benefits, so filters will not be incorporated into the Scout cameras.
- The apple scouting software uses the available camera modes normal (i.e., LinLog, and companding) and dynamically adjusts the exposure based on image features such as brightness and blur.
- Some pictures have both regions that contain too much and too little light (e.g., both sunlit apples as well as shaded apples on the underside).
    - Collecting successive images at significantly different exposures effectively increases the dynamic range of the cameras.
- Lighting can improve performance and is another way to equalize the contrast throughout the images.
    - A flash appears to help normalize lighting conditions and to illuminate the apples differently than the rest of the tree, which might improve performance.
    - The removal of shadows should simplify the boosting algorithm training sets and improve performance.

Methods

Vision Robotics worked with Ag Industrial Manufacturing (AIM) to design the platform, which AIM fabricated and delivered in late June. As requested by the Commission, Newton is electric powered and has a "super quiet" generator integrated into the design. This four-wheeled trailer converts to two-wheeled for travel between orchards. The electronics are mounted in a standard weatherized enclosure to which thermal management including active heating and cooling may be added.

Figure 1. Newton Prototype Platform

The production Scout will be fully weatherized, but this feature will only be partially implemented this year. No attempt was made to weatherize the mast in order to enable VRC to test several features that affect the design. For example, each camera may be mounted at different angles relative to the mast face. The proper orientation will likely improve detection performance. The required adaptability makes it impractical to seal the mast this year, but a weatherized mast will be included in the future.

The electronics include the computers, a microcontroller for low level system control, cameras, and other sensors. The system uses two computers, which are standard PCs that are linked via a wireless network to a laptop used for the user interface. Sauer Danfoss's Plus+1 mobile control system is used for the low level control. The system is rated to IP68 and will control the motors used to adjust the mast position.

VRC has designed and built two iterations of stereo cameras which include features to improve the system's ability to operate in a broad range of lighting conditions and system robustness. The principle changes between prior year cameras and the current version are:

- Next generation sensor that includes two exposure settings.
- Flash control.
- Synchronization of multiple camera pairs.
- More stable mounting plate and lens holders.
- New lenses with a lower f-number.

VRC has identified and tested several potential methods to improve performance that are described below. As shown in the pictures below, flaring caused by oblique and direct sunlight hitting the camera lens can significantly degrade image quality.

Figure 3. Effect of flaring on image quality

Nominally, the camera has a 56º horizontal field of view but direct sunlight can strike the lens through 180º. Tests indicate that a visor in front of each lens minimizes the angles through which sunlight can strike the lens. The visor must be designed to minimize reflections that can also strike the lens. A flat plate with two rectangular holes located in front of the cameras appears to work best for shielding and minimizing reflections.

Rotating the camera mast away from the sun can further decrease the amount of sunlight that can strike the camera lens. Anecdotal evidence from the other projects indicate that a 15º - 20º degree rotation will not hurt performance. VRC has designed a mast pivot into Newton. Field tests comparing results with the mast perpendicular and pivoted relative to the rows will confirm the effects of a pivot on performance.

Specularities create pixel-blobs with high and nearly uniform intensity value (bright white pixels) that are poor from an information perspective because they contain almost no color information and the intensity values are nearly uniform. Limited pixel information harms classifier performance. Tests indicate that the use of filters decrease specularities, but do not completely eliminate them. Their net effect is very similar to simply reducing exposure and implementation drawbacks are greater than the potential benefits, so filters will not be incorporated into the Scout cameras.

Figure 4. Filters reduce specularities

Previous data collection revealed situations where one region of an image contains too much light, while another contains too little (e.g., a frame containing both sunlit and shaded). One approach to addressing such conditions is to collect successive images with significantly different exposures. One exposure level can be targeted towards the bright areas of the image and one towards the dark areas. As shown in the figure below, this approach works reasonably well, effectively increasing the dynamic range of the cameras. A feature of the new version of the image sensors is the ability to switch between two vastly different exposure settings for successively collected images.

VRC has begun implementation of such a multi-exposure system, which provides the ability to set different exposures for alternate images. The system moves through a variety of different exposure settings, each aimed towards a particular set of lighting conditions. Within each class, the exposure level is adaptively set by analyzing image statistics such as average pixel brightness or the number of pixels above or below a threshold brightness. This supervision of image quality can be performed rapidly in software, with requests to the hardware to change the exposure time performed as needed.

Figure 5. Two pairs of pictures taken at high and low exposure levels

Full sun illuminates with about 1,000 watts per square meter, so several thousand watts of artificial light would be required to compete during worst case times of the day. The artificial light could be achieved using high wattage continuous lights or using fairly high power flashes that are synchronized with the cameras' electronic shutters.

Results of preliminary flash tests are shown in the figure below. The flash appears to help normalize lighting conditions and to illuminate the apples differently than the rest of the tree, which might significantly improve detection performance. Another potential benefit of a flash system relates to the classification software. The current boosting algorithm is trained on images of apples including some with fruit lying in shadows. Thus, the removal of shadows should also provide simplifying assumptions for future training sets. Finally, if the flash is bright enough to compete with the sun, then the illumination of a scene may become invariant with respect to time of day or to camera position with respect to the sun.

Figure 6. Two pictures, one taken with a Flash, the second without a flash

One potential drawback of a flash is that while it may illuminate interior apples, it may also over-illuminate exterior apples. For this reason, the flash may be combined with the multi-exposure system for best performance. The new camera system was designed specifically to operate with a flash and multiple pairs of cameras may be synchronized to enable a single flash to work with all the cameras on the mast. Additional testing is required to further study the effects of the flash and to determine the optimal mechanical configuration.

Results and Discussion

The results of the analysis indicate that actual performance was lower than previously believed. For relatively highly trained orchards, it appears that the Scout identified 60% - 70% of the apples for both green and red colors. This represents more than 80% of the visible fruit.

Analysis indicates that approximately 10% of the fruit was obviously visible and should have been detected. Refining the software to identify these is straightforward. Another 10% of the apples were less clearly visible, but still represent objects that can be detected. The final 10% - 15% are largely obscured and very difficult to identify in the existing images. However, VRC believes that these apples can be made more visible and is configuring a test plan to verify these assumptions. These techniques include:

1. More images:
    - Pictures taken more frequently along the row.
    - More camera pairs on the mast.
2. Better images from using smaller field of view lenses which effectively increase the camera resolution.
3. Tilting the cameras upward relative to the mast. Previously, all the camera pairs have been parallel to the mast. In data collected, it is obvious that more fruit is visible in the top half of the images because leaves tend to obscure apples in the lower half. It appears that the heavier apples tend to hang below the leaves. The new prototype mast enables camera mounting at several angles relative to the mast.
4. Including a flash system which, in the lab, noticeably improves apple visibility.
5. Collect data with the mast at several different orientations relative to the tree such as height and distance. These configurations will help determine whether optimal visibility is based on what have been arbitrary geometric configurations.

VRC has planned two sets of field tests. For the first set of tests, VRC is coordinating Commission and CMU with the goal of collecting data to determine the “best” scouting configuration for the hardware and to enable improved benchmarking of the detection software. VRC will focus on red apples because that enables efficient analysis and minimizes the variability due to training sets for the Boosting system.

During this set of field tests, images from a section of orchard with verified ground truth data will be collected repeatedly while varying different aspects of the hardware and environmental conditions. The plan is to change one variable at a time. Comparing test results from each of these runs will determine which variables improve performance. Because variables will only be adjusted one at a time, analysis will determine the relative effect and the best configuration. Most data will be conducted at the minimum APM speed, which will result in oversampling. Dropping every other or two out three adjacent images will effectively replicate less frequent data collection without additional test runs. The specific tests goals are:

- Integration and functionality with the CMU.
- Collect ground truth for comparison with system performance.
- Collect data of ground truth areas with the different configurations.
- Collect data from entire block in the “best” configuration using the APM towing Newton.
- Display output in the field from one or more tests.
- Collect images of smaller apples.

Using the best hardware configuration, the second set of field tests will occur in September and target green apples.

FINAL PROJECT REPORT
WTFRC Project Number: TR-08-801

Project Title: Automated picking hand development

PI: Tony Koselka
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Cooperators: Dr. David Barrett at Olin College of Engineering

Other funding Sources

Agency Name: California Citrus Research Board
Amount requested or awarded: $10,000
Notes: The project is being worked on as part of the SCOPE program at Olin College

Total Project Funding: $27,500

Budget History:

Item	Year 1: 2008
Salaries	
Benefits	
Wages	
Benefits	
Equipment	
Supplies	
Travel	2500
Miscellaneous	25,000
Total	**27,500**

Objectives

A viable picking hand represents one of the remaining unsolved critical systems for mechanized apple harvesting. The specification for a robot harvester is that it must successfully pick at least 95% of the apples. This is a high hurdle and affects the requirements for the picking hand. During operation, the picking hand must harvest all the fruit from a tree and place each piece into the conveyor that moves the fruit to the bin. The hand must gently hold the fruit of different sizes and work delicately and reliably regardless of whether the fruit is hanging freely; leaning against or partially obstructed by other fruit, branches or leaves. It must cut or snap the stem as desired and function for millions of cycles each year. Further complicating the design is that the picking hand is part of the larger harvester and must compensate to work with the system as a whole.

The major design requirements are listed below:

- Pick apples Ø2” – Ø4”
    - Work effectively with apples of all shapes
- Harvest by snapping and or cutting the apple stems
- Robust
    - Operate 16 hours per day, 7 days per week
    - Temperature range: 35°F – 105°F
    - Sun or rain
- Speed
    - Pick the fruit in approximately ½ second or less
    - Place the fruit in the conveyor system in less than ¼ second
- The can pick starting with the nearest piece of fruit. It does not necessarily need to pluck a piece in the back.
    - The hand cannot damage the fruit it is harvesting
    - The hand cannot damage other fruit if it rubs against it when reaching into the tree
    - The arm may be off center from the center of the fruit by as much as 1”
    - The alignment between the fruit and the picking hand is +/- 15°, which does not include the alignment of the piece of fruit relative to the ground
- Apples are often partially blocked by thin twigs and leaves which cannot prevent picking.
- The picking hand should be lightweight to minimize the load on the arm.
- The overall length of the hand is to be minimized to allow greater freedom for the arm to reach the fruit.
- Able to successfully harvest greater than 95% of the apples in a given orchard.

Background

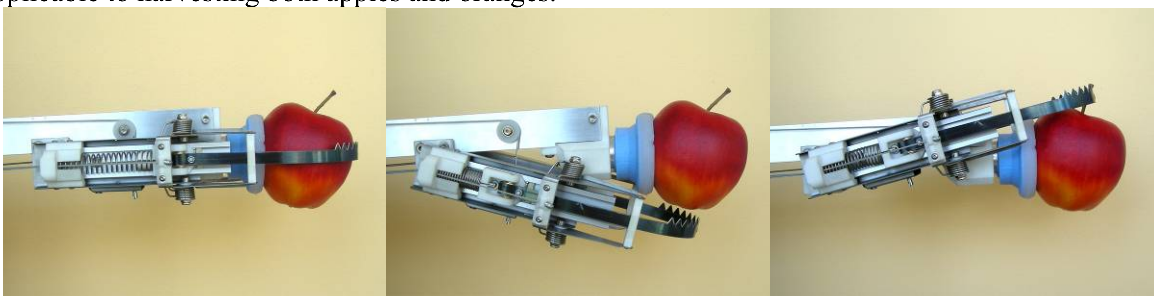
The picking hand project, a collaboration between the WTFRC, the California Citrus Research Board, VRC and Olin College of Engineering, is a continuation of one started in 2007. The technical development is performed through the Senior Consulting Program for Engineering (SCOPE) at the Franklin W. Olin College of Engineering (Olin).

Olin College is dedicated to producing technological leaders for the future. The Senior Consulting Program for Engineering (SCOPE) is the culmination of Olin’s project based curriculum. Olin seniors undertake an authentic engineering challenge for a corporate sponsor, funding through educational grants from the sponsoring company. Each project fields a team of five seniors who work on the project over the course of two semesters. Each team has a faculty advisor and full access to Olin’s resources; holds bi-weekly design reviews; has dedicated work space; provides regular reports to their sponsors.

This year’s SCOPE team consisted of five Olin College seniors and a faculty advisor. There are four Mechanical Engineers on the team: Katie Kavett (Project Manager), Michael Boutelle (Budget Coordinator), Gabe Greeley (Mechanical Lead), and Will Yarak (Safety and Ethics Coordinator).

There is one Electrical and Computer Engineer, Scott McClure (Electrical Lead). The team is advised by Dave Anderson, a professor of Mechanical Design and Fabrication, who has extensive experience in design and fabrication.

During the 2007-2008 project, the students determined that the process of mechanically picking tree fruit can be broken into two distinct functional tasks, holding the fruit and removing the fruit from the tree. The team selected a design direction incorporating high flow suction with a single hoop for the picking hand and designed and built a series of picking hand prototypes that were applicable to harvesting both apples and oranges.



The high flow, low pressure suction coupled with a padded suction cup holds the apple without bruising even if small obstructions such as twigs and leaves are caught between the apple and the suction cup. The hoop can be scaled in size to match the shape of a wide range of apples. The size adjustment also enables the hoop to closely follow the surface of apple to fit between clusters or between apples and branches. The method through which the hoop detaches the apple from the tree was not determined, but it was assumed that an appropriate snap or cutting mechanism could be integrated into the hoop.

Lab tests demonstrated the design potential. The project was continued this year with the goal to advance the design as far as possible.

Significant Findings

2007-2008

- There is a significant body of prior work applicable to picking hands that can be separated into two broad categories: mechanical aids for fruit harvesting and handling, and non-fruit picking robot end effectors.
- The apple picking process can be broken into two distinct functional tasks, holding the apple and detaching it from the tree.
- Suction was deemed the best approach to hold the apples:
    - High flow suction system allows for holding apples of any size even in the presence of obstructions
    - Suction gripping systems can be designed not to bruise fruit even in the presence of small obstructions
- An orbiting hoop was selected as the most viable approach for detaching the fruit, and it can be designed to either snap or cut the stem.
    - The hoop should follow the apple contour as closely as possible.
    - Adjusting the hoop size enables minimal profile yet can still harvest apples of all sizes.
- The proposed design can assume a small enough profile for effective tree penetration

2008-2009

- Field tests demonstrated suction's viability as a means to hold the apples when picking.
    - High flow suction was strong enough to successfully grab an apple in nearly every case, even when leaves or branches got stuck between the apple and the suction cup.

- The suction cup is a good shape and material and the soft material allows leaves and branches to get caught between the suction cup and the apple without causing bruising.
- Sharp edges anywhere on the picking hand can damage apples.
- A number of apples would come off the tree simply when the suction cup grabbed the apple and the arm moved slightly, i.e., without the hoop. However, the number was not nearly sufficient to use this method exclusively and using the suction cup to pull the apples would, on occasion, cause adjacent apples to fall off the tree.
- In addition to following the contour of the apple, the hoop surface should remain parallel to the apple surface in order to approach the stem perpendicularly for best cutting and snapping.
- It is not practical to grab and pull of the fruit to orient the stem in a preferred location because this motion requires a complex mechanism and, as noted above, pulling too hard on an apple can cause others to fall off the tree. This confirms the selection of a complete hoop to detach the apple rather than a smaller discrete cutting mechanism that operates in a small area relative to the picking hand.

Upon completion of the field trials the team brainstormed and tested various design improvements focusing primarily on the hoop culminating in the building of a new prototype. The primary features of the new design were to make the hoop concentric to the apple and incorporating a reciprocating mechanism to detach the fruit. The concentric design ensures that the hoop is always in the optimal orientation when it hits the stem. Tests with this prototype yielded the following significant findings:

- Neither apples nor oranges are round enough to simply program a size and have the hoop closely follow the shape. Typically, non-roundness caused the hoop to scrape the apple.
  - The two solutions are to actively control the hoop size as it orbits the fruit or to estimate a large size and ensure the hoop design is such that it does not damage the apple if it scrapes against it.
- As a first and second pass, meeting all the requirements require a large and/or complex mechanism.
- Active mechanisms on the hoop are required and can both cut and snap apple stems. Possible active systems include:
  - A reciprocating (hedge trimmer) cutter.
  - Sliding a blade along the hoop to cut the stem.
- Lab tests do not accurately recreate actual field conditions, so care is required to make accurate decisions based on results.
- The suction should be controlled to minimize debris caught in the suction cup and to clear the debris after picking the apples.
- An orbiting mechanism, such as a hoop, with a leveraging cross member that can press on the stem emulates the motions used by human pickers.
- The hoop must follow the contour of the fruit very closely to cut the stem in the correct location and pick the fruit.
- The shape of the leading edge of the hoop is critical because it is intended to closely pass over apples for each pick and will push between apples that rest against each other. Any sharp features will scrape the fruit, but blunt shapes as thick as 3/8” can slide between fruit in clusters.
- There is often a preferred orientation for the hoop to orbit the apple to minimize orbit time and the likelihood of scraping apple surfaces. The arm, picking hand and hoop should be thought of as a single system in order to optimize the hoop motion relative to the tree.

Results and Discussion

In general, the variability in size, orientation and location of the fruit as well as the delicateness of apples makes the picking hand design challenging. This year's objectives were to test and evaluate the last year's prototype in orchards and refine as appropriate. This project was to include four phases:

- **Phase 1:** Complete extensive field testing of the prototype and analyze its strengths and weaknesses.
- **Phase 2:** Complete ideation based on the conclusions of Phase 1 and select a design direction.
- **Phase 3:** Develop the ideas selected in Phase 2, build a new prototype and test in orange groves in California.
- **Phase 4:** Based on the field tests, refine design and test specific modules of the prototype, and prepare a final report.

During the Phase 1, the team was to test the existing 2007-2008 prototype for:

- General functionality
- Long term potential
- Strengths
- Weaknesses
- Operation in all appropriate environmental conditions

Prior to testing, the team had to restore the prototype to working condition. Field tests were conducted during three visits to Lookout Farms in Natick, MA. The tests consisted of selecting an apple, estimating its diameter and entering the value into the software. The picking hand was moved by hand into place next to the apple and the apple was drawn into the suction cup. The hoop was then activated to move around the apple, with the intent of breaking the stem. Once this motion was complete, the arm was pulled out of the tree, ideally with an apple held in the suction cup with its stem still intact. Each pick with the final prototype was evaluated for success.

1. **Suction:** Was the apple grabbed with the suction cup? Did the apple remain in the suction cup?
2. **Hoop motion:** Was the apple scraped? Did the hoop closely follow the contour of the apple? Did the hoop find the stem?
3. **Stem cutting:** Was the stem broken at the branch? Was the stem still attached to the apple?
4. Observations about the location of the apple, as well as any additional observations about each pick were recorded.

Testing conclusions

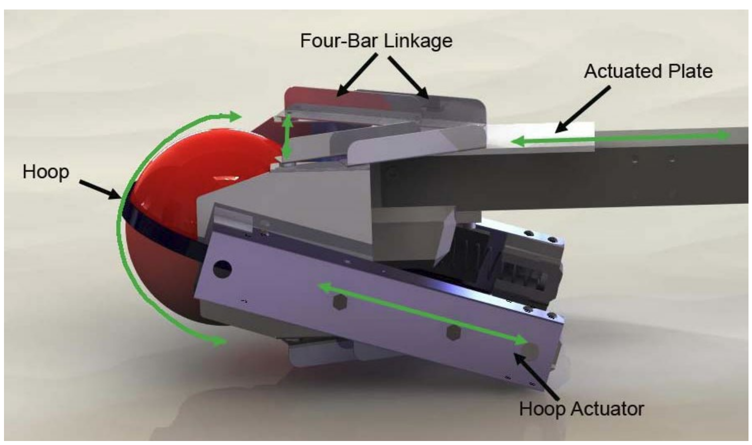
Through testing, the team determined that the grabbing mechanism of the prototype, which consisted of a shop vac and suction cup, had a high enough success rate to be deemed effective at grabbing apples. In a few cases, it was possible to pick an apple solely through the use of suction. However, this technique is not viable as the production means to detach the apples, i.e., some sort of active mechanism is required. The last set of field tests were conducted very late in the harvest season and shaking the branches caused some adjacent apples to fall from the tree. The team also discovered a number of repeated issues with the existing hoop:

- Hoop cannot pass between the apple and the branch off of which it is growing for apples with short stems.
- Hoop hits nearby branches
- Hoop cannot pass between two apples growing very closely together
- Leaves and/or branches get stuck in suction cup

Although the team brainstormed some ideas that did not use the suction mechanism, they concluded that suction was very successful, and so should be retained. The team determined the most significant flaws were that the hoop did not tightly orbit the fruit with the hoop always in good position to reach the stem and that the hoop must have an active mechanism to detach the apples.

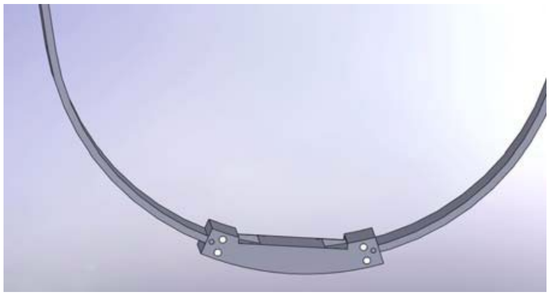
A brief brainstorming session yielded several design directions. Ultimately, the team decided to keep the hoop adjustments for width and hoop length, but to move the hoop motion to be concentric with the apple. This requires moving the mechanism further out on the hand. The drawback is that the new configuration creates a larger picking hand. It was decided to prototype and test the design as conceived and shrink and refine the mechanism if it proved successful.

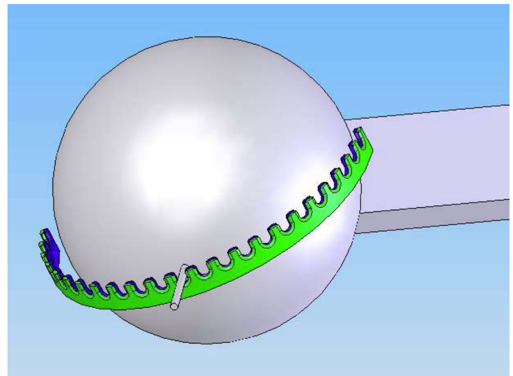
The team developed a computer model that moved the axis of rotation of the hoop to be concentric with the center of the fruit. The new concept moves the rotation point of the base of the hoop to be in line with the base of the suction cup. A four bar linkage on the top of the arm controls the width of the hoop. The new design is very bulky and will be difficult to maneuver in tight spaces in a tree and the hoop is too far away from each side of the fruit. However, this design theoretically would solve many of the issues observed, such as approaching the stem perpendicularly and gaining better access to very short stems.



CAD model showing potential implementation of the concentric hoop

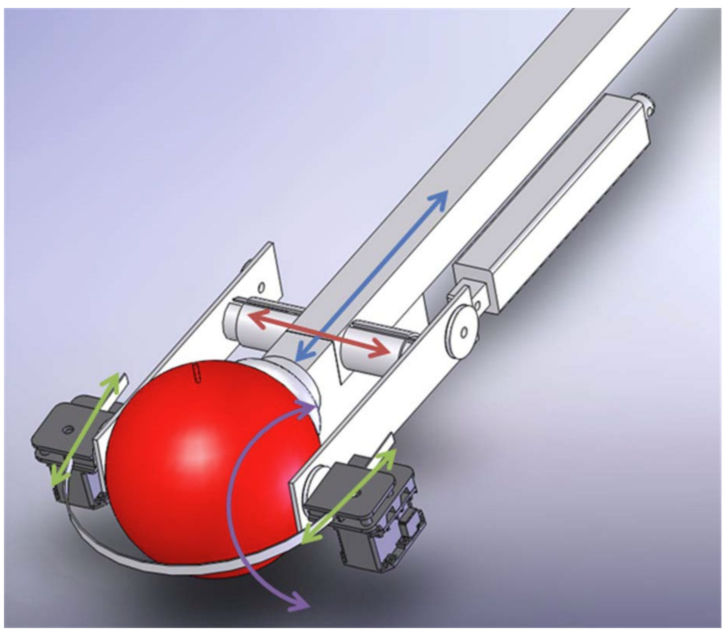
In addition, the team brainstormed active stem detachment mechanisms and additional sensors to improve performance. Examples of sensors include those to detect engagement of the apple in the suction cup and determine the distance between the hoop and the fruit. Ultimately, the team focused on two detachment mechanisms: a reciprocating or hedge trimmer incorporated into the hoop; and a cutter that slides along the hoop that strikes the stem at the point of contact.



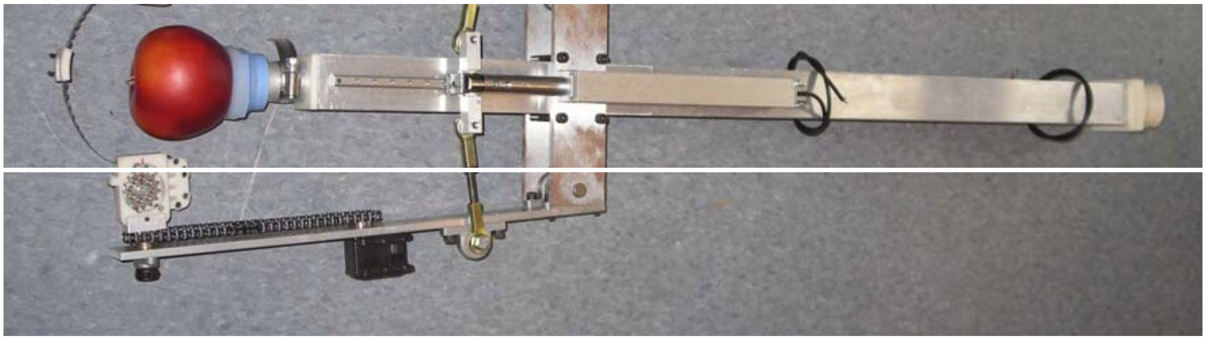


CAD sketches of stem detachment mechanisms

As shown conceptually below, the team selected a design direction where the system can control the position of the apple relative to the hoop pivoting mechanism by moving the suction cup in and out (blue arrow); the width of the hoop may be adjusted to fit snugly around the apple (red arrow); and the length of the hoop adjusted to remain snug around the apple (green arrow). Once the system has the correct size input, the hoop orbits the fruit (purple arrow). The cutting mechanism is not shown.



The prototype uses linear actuators, stainless steel bars, servos, the servo mounts, chains, sprockets, the hedge trimmer hoop, and other hardware. The team decided ease of implementation was more critical that reducing the size.



Three team members tested the picking hand in orange groves in March and discovered a number of issues with the design.

- **Blade size:** The orange stem diameters were larger than anticipated and many did not fit into the groves in the cutter. The team also discovered that orange stems are tough and difficult to cut.
- **Clumps:** Similarly to apples, many oranges grew in clumps. The large size of the prototype and the made it impossible to fit between oranges that were growing very close together. Also, the shape of the hoop was such that it damaged fruit if it had to squeeze between adjacent oranges.
- **Suction cup:** the design of the cup needs to be tuned to the fruit. A softer cup worked better for apples, but a harder design better for oranges.
- **Control system:** the design was completed the night before the trip to California and the control had not been sufficiently debugged. The effectiveness of the system as a whole was compromised during the tests.
- **Hoop direction:** both last year's and this year's team envisioned the hoop orbiting the fruit from below regardless of the position of the fruit. This is often both the long path and the path that requires squeezing through tight fits with branches and other pieces of fruit. The field trials demonstrated that orbiting in the other direction is preferred for the same reasons. This realization improves the efficacy of the hoop.
- **Cutter mechanism:** the hedge trimmer implementation did cut stems due to a series of design issues that are correctable. There is nothing inherently wrong with the concept except the implementation had a sharp edge that must be designed out in order to not damage the fruit.
- **Hoop motion:** it was intended that coupling an estimate of the apple size with a concentric

orbit would enable the hoop to closely follow the shape of the fruit. However, neither apples nor oranges are round enough. The options are to increase the diameter of the hoop or to actively control the hoop size using sensors.

The final phase was intended to evolve the design. After the field trials, we changed the project plan to work on:

- Refining the hedge trimmer in mechanism and cutter design to operate effectively and to add a blunt leading surface to prevent damage to the fruit.
- Test a sliding cutter in place of the hedge trimmer.
- Implement dynamic control of the hoop size using appropriate sensors.

Due to the nature of the school project, limited progress was made on the three objectives listed above. The team demonstrated that it was possible to add a blunt surface, 3/8” or thicker, and still fit through fruit clusters without damage. The team also built a sliding cutter and demonstrated that it had sufficient strength to cut stems. However, practical implementations were not completed.

Other viable suggestions include reversing the vacuum as the suction cup approaches the fruit to blow leaves away from the path of the picking hand. The team also noted that apples and oranges have different requirements so some of the specific implementation aspects will be different. For example, all orange stems are to be cut, but it is better to snap some apple stems. It is worth noting that simply replacing the sharp hedge trimmer with a blunt version will likely snap the stems.

General conclusions

It is Vision Robotics’ belief that the existing picking hand concept is viable. The biggest question is whether it will be capable of successfully picking 75% or 99% of the apples, which represents the difference between success and failure in design. The development process will likely require at least two more design iterations before the system is capable of testing extensive enough for that determination.

This year’s student team did not make as much progress as desired. This is likely because of their relative inexperience. This past year’s and future development rely on quickly implementing ideas, testing and making decisions about the pros and cons. The students are smart and skilled, but had problems making quick decisions and quickly finalizing improved designs.

The SCOPE program was cost effective at generating a diversity of ideas and narrowing them to a viable approach. VRC feels that the next stage should move towards a viable production design including ruggedness and robustness, which would be best done using experienced design engineers. It is our recommendation to continue the project, but to use experienced engineers rather than continuing with the SCOPE program. Through testing during the last two years, Vision Robotics has watched the progress and is comfortable with the design direction. We believe that the hoop / detachment mechanism is the critical feature that is not complete. However, there is an obvious development direction that builds upon existing work. Our best estimate of the design is:

- Simplify the mechanism by reducing adjustability. Instead of starting with the most complex, work from simplest and add adjustment as it is proven necessary.
    - Eliminate width and hoop length adjustments. Design for the median size apple.
    - Nominally size the width of the hoop to fit the largest apple. This eliminates an adjustment mechanism that simplifies and shrinks the system. It is likely that there is only a small net increase in width, which will not greatly affect performance.
    - Should the resulting motion create large gaps between the hoop and the apple, add degrees of freedom to optimize the design.
- Continue with the suction cup and hoop concept using a hedge trimmer cutting / snapping mechanism.
- Move the suction cup relative to the hoop to enable a tight fit of the hoop around the apple and relatively good orientation between the hoop and stem. The motion will seldom be perfectly concentric, but close enough for detaching the apple from the tree.
- Implement an effective reciprocating cutter including blunt leading edge.
- Implement touch sensors to actively control hoop size adjustment. Once concept is demonstrated, replace touch sensors with non-contact proximity sensors.
- Test to determine efficacy and refine as needed.

Executive Summary

A viable picking hand represents one of the remaining unsolved critical systems for mechanized apple harvesting. Successfully picking at least 95% of the apples is a high hurdle for the picking hand. The hand must gently hold the fruit of different sizes and work delicately and reliably regardless of whether the fruit is hanging freely; leaning against or partially obstructed by other fruit, branches or leaves. It must cut or snap the stem as desired and function for millions of cycles each year.

The project, a collaboration between the WTFRC, the California Citrus Research Board, VRC and Olin College of Engineering, is a continuation of one started in 2007. The technical development is performed through the Senior Consulting Program for Engineering (SCOPE) at the Franklin W. Olin College of Engineering (Olin) where a team of five seniors work on the project over the course of two semesters.

During the 2007-2008 project, the students determined that the process of mechanically picking tree fruit can be broken into two distinct functional tasks, holding the fruit and removing the fruit from the tree. The design direction incorporates suction to hold the apple with a single hoop to detach the fruit from the tree.

This year's team was to field test the existing prototype, refine the design as appropriate and build an improved prototype. Testing revealed significant flaws in the design, primarily with the hoop. However, the team concluded that the approach was both viable and the best available idea. In particular, suction appears the best way to hold the apple during picking and a full hoop is necessary to reach the stem if the orientation of every apple to be picked is not known prior to reaching for it. The team determined the most significant flaws were that the hoop did not tightly orbit the fruit with the hoop always in good position to reach the stem and that the hoop must have an active mechanism to detach the apples.

The team decided to move the hoop motion to be concentric with the apple. A reciprocating cutter (hedge trimmer) was incorporated into the hoop for active detachment of the stem from the tree. For maximum flexibility, the new prototype had four adjustments to enable it to work optimally regardless of the size of the apple. These adjustments added complexity and significant size to the system.

While the field tests were not successful for a variety of reasons, the prototype did reveal significant insight into design requirements. It is Vision Robotics' belief that the existing picking hand concept is viable, but more development is required to determine whether it will successfully meet the requirement of being able to pick almost all the apples in an orchard. It is Vision Robotics recommendation to continue the project, but to use experienced engineers rather than continuing with the SCOPE program. Our belief is that suction with a hoop that orbits the apple and includes a reciprocating detachment mechanism is the most promising design approach. However, we recommend simplifying the mechanism by reducing adjustability if possible. Instead of starting with the most complex, work from simplest and add adjustment as it is proven necessary. This work will likely require two more iterations to refine the design sufficient to fully assess the viability of the approach. However, given sufficient funding the two iterations could be completed efficiently within six to nine months if desired.

CONTINUING PROJECT REPORT **YEAR**: 2 of 2
WTFRC Project Number: TR-07-703

Project Title: Expanding and stabilizing WSU-decision aid system

PI:	Vincent P. Jones	**Co-PI(2):**	Jay F. Brunner
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Co-PI(3): Gary Judd
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State/Province/Zip Canada V0H 1Z0

Cooperators: Jerry Tangren, WSU-TFREC; Leo Garcia, Wen. Valley College

Total Project Request: **Year 1:** $80,965 **Year 2:** $79,960

Other funding Sources

Agency Name: Washington State Commission on Pesticide Registration
Amount awarded: $22,834
Notes: This supplements WTFRC funding for DAS.

Other funding sources is for informational purposes only, for WTFRC to understand the scope of the project. These estimated costs are not presented as formal cost-sharing and therefore do not constitute a cost-share obligations on the part of Washington State University. Moreover, there is no requirement for WSU to document this other support of project as part of any cost-share or matching obligation.

Budget 1:
Organization: WSU **Contract Administrator:** ML Bricker, Kevin Larson
Telephone: 509-335-7667 / 663-8181 x221 **Email: MLB**: mdesros@wsu.edu / kevin_larson@wsu.edu

Item	**Year 1: 2007**	**Year 2: 2008**
Salaries[1]	58,093	57,297
Benefits[2]	20,372	20,063
Supplies[3]	2,000	2,080
Travel[4]	500	520
Total	$80,965	$79,960

Footnotes:
[1]Programmer 1 FTE, Web Programmer, 4 mo. 50% FTE, Callie Baker 16.7% FTE
[2]Programmer 35%, Web Programmer 36%, Callie Baker 34%.
[3]Cell phone charges are allowed
[4]Within State Travel

Objectives:

- Stabilize and extend the current DAS program, including extensive documentation, help files, improving the overall interface, and better integration with AWN. We will also add the ability for models to interact to help improve pesticide recommendations when a single pesticide may control multiple pests or diseases at the same time.
- Improve the current disease models and add the model for shot-hole of stone fruit.
- Develop organic control recommendations.
- Once the program is stabilized, implement a bilingual interface for Spanish-speaking users.
- Investigate methods to improve the codling moth model.

Significant Findings:

- We have hired a full time manager/educator for DAS who will arrive 1 September and take over responsibility for the day-to-day operation of DAS.
- The 2009 pesticide database is on-line and we are refining the filters to help with resistance management and natural enemy conservation. We hope to have these changes for beta testers to review this fall and to test next year.
- The beta version of the shot hole disease model has been coded and Gary Grove and Brad Petit (our programmer) are making adjustments. This should be on line for beta users next year.
- We have been working with AWN to eliminate problems associated with AWN making unexpected changes in the AWN database.
- We are currently evaluating the usefulness of Google Translation as a way to quickly get the Spanish version on-line. This should be checked and implemented by the next progress report.
- We finished the laboratory experiments on the effect of the length of the pre-chilling period on codling moth emergence. Our data show that the length of time is unimportant, but that temperature that occurs during the pre-chilling period has a highly significant effect on emergence. We are designing new experiments to quantify that effect.

Significant Progress:

Objective 1. We have hired a full time manager/educator of DAS who will arrive 1 September and take over the responsibilities for the day-to-day operation of DAS. Dr. Ute Chambers received her PhD from one of the top insect ecology working groups in the world (Drs. Silvia Dorn and Jörg Samietz were her co-advisors) and her research was on codling moth phenology and how it is affected by thermoregulation. She has been in a post-doctoral position for the past few years at Oregon State working on hazelnut IPM with Dr. Vaughn Walton. A large part of Ute's responsibilities will be to improve and expand the help system on DAS, work with our programmer to ensure that we are on track, and to expand the educational component built into DAS and provide hands-on training for users. I expect that her participation should greatly improve our ability to get certain tasks finished and provide a new viewpoint that may expand our ability to maintain DAS as the premier decision support system for tree fruits world-wide.

Much of the changes in DAS during this last period have been focused on removing bugs, and integrating the 2009 spray guide recommendations into the system. Future updates to the spray guide should not take as long as during the past few years, mostly because we now have the ability to query the pesticide database via a custom program written by Jerry Tangren (WSU-TFREC IT). That program provides us the data stream and we merely format it as we desire, so that our task is simpler.

We are also working on new filters for the pesticides to allow us to simplify some of the resistance management recommendations provided by PMTP and to provide a filter that allows users to better understand the effects of pesticides on natural enemies. These two filters along with our current efficacy filters should greatly simplify pesticide choices for users. We expect these filters should be working next season; they will require interactions with our beta group once we have gotten the features finalized.

Objective 2. The changes in the fireblight model are complete at this time. The cherry powdery mildew model is also on-line, but we are currently working with Gary Grove to implement an irrigation component that triggers the model earlier. That part has been coded and we have tentative approval from Gary. The apple scab model is also completely re-coded and on-line. The final model is the shot hole model, which has been coded, and Gary and our programmer are currently fine-tuning the interface and checking to be sure that predictions are correct.

Objective 3. The organic recommendations are complete and on-line for the different insect models. The fireblight recommendations do provide organic options at this time, but the organic recommendations for scab, cherry powdery mildew, and shot hole are still being worked on. This should be on-line next year.

Objective 4. Brad Petit (our programmer) has been working with Google Translation®, which can automatically translate an entire web site on the fly. We will be evaluating this in the coming weeks to determine the accuracy of the translations. If they translations are reasonable, we will implement this feature, but will likely form a Spanish-speaking beta user group to be sure that the translations make sense and convey the correct information. If Google Translation® is up to the job, this opens the door to other translations if demand is high enough.

If the translations are not reasonable, we will translate the current status and management options and use them rather than Google Translation®. We hope to have this on-line for the Spanish user group by early winter.

Objective 5. Our data collection from last years' experiments that were devised to evaluate the effect of the length of the pre-cold period on spring emergence is complete. Our review of the literature suggested that the length of the cold period would have an effect on the emergence of CM and potentially help us to improve the CM model so that we could better account for the "b" peak of codling moth emergence in the overwintering generation.

Our experiment was set up so that we had two different temperatures (15 and 25 °C) at which we held CM for either 7, 21, or 42 days before they were placed in cold storage for two months. After 2 months, the larvae were placed in a growth chamber set at 25°C and with a 16:8 (day: night) photoperiod. We ran the two temperatures because we expected that there should be an interaction between the length of time larvae were held and the temperatures, which would allow us to determine if physiological time (DD) in the pre-cold period would improve predictions.

Results:
Our data showed that the length of pre-chilling period larvae were held at did not significantly affect the emergence curve when done on either a calendar data basis or a DD basis for either males or females. However, surprisingly, the temperature that they were held at (before the cold period) made a significant difference in both the mean emergence period and the variability around that emergence period on both calendar date and DD scales (Figs. 1 & 2). *This result was completely unexpected and not predictable from the literature data we reviewed*. Recall that the larvae enter diapause in the last instar larval stage, so that development after the chilling period should be similar and occur with a given mean and standard deviation of times. As all moths entering the chilling period were held the same length of time at the same temperatures both during and after the chilling period, we would

expect very little change in emergence period, because they are all overwintering in roughly the same physiological state.

Our data suggest that there is a sensitive period in the fifth instar that must occur within 7 days of the larvae molting to the fifth instar when the temperature affects the timing of emergence from diapause. We will collect more larvae this year from bands in the field and re-run this experiment, but expose larvae to temperatures of 15, 20, 25, and 30°C in the pre-chilling period for a fixed period and then evaluate emergence patterns after chilling to determine if we can predict emergence variability by the holding temperatures. We will also get diapause-destined larvae from the USDA-ARS colony and attempt to narrow the window to determine the exact period when larvae are susceptible to temperatures. The idea would be to determine the sensitive period, combine that with the data we've been collecting for the past 2 years on the phenology of diapause induction, and then evaluate the codling moth model to better predict emergence of the spring generation.

Fig. 1. Boxplots showing emergence times in days after chilling period was over of field collected codling moth that were held for 7, 21, or 42 days at either 15 (blue) or 25°C (red) before chilling. All larvae were exposed to the same chilling and heating regimes after the pre-chilling treatments.

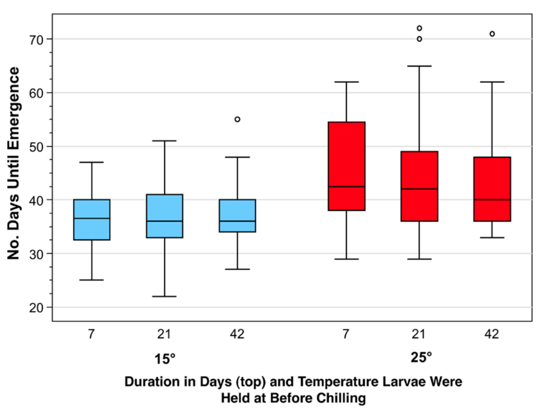
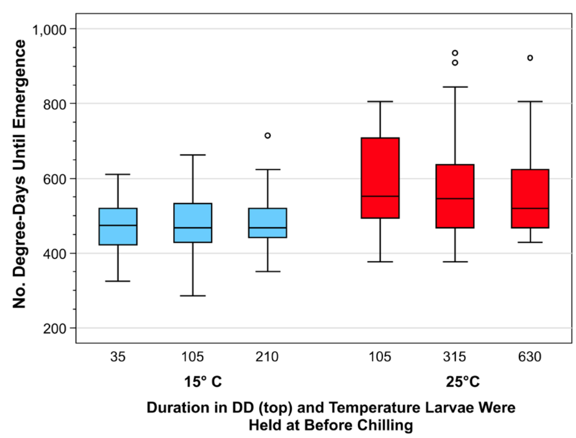


Fig. 2. Boxplots showing emergence times in DD after chilling period was over for field collected codling moth that were held for 7, 21, or 42 days at either 15 (blue) or 25°C (red) before chilling. All larvae were exposed to the same chilling and heating regimes after the pre-chilling treatments.



FINAL PROJECT REPORT
WTFRC Project Number: TR-06-600

Project Title: Orchard automation and mechanization

PI:	Karen Lewis	**Co-PI (2):**	Tom Auvil
Organization:	WSU	**Organization:**	WTFRC
Telephone/email:	509.754.2011 X 407 kmlewis@wsu.edu	**Telephone/email:**	509.665.8271 auvil@treefruitresearch.com
Address:	POB 37	**Address:**	1719 Springwater
City:	Ephrata	**City:**	Wenatchee
State/Province/Zip	WA 98823	**State/Province/Zip:**	WA 98801

Co-PI (3):	Jack Maljars
Organization:	Vinetech
Telephone/email:	509.788.0900 jackm@vinetechequipment.com
Address:	335 N. Gap Road
City:	Prosser
State/Province/Zip	WA 99350

Cooperators: Grower Cooperators, Grower Committee

Total project funding request: **Year 1:** 108,175 **Year 2:** 5,646

Other funding Sources: USDA - SCRI – CASC $690,000

Other funding sources is for informational purposes only, for WTFRC to understand the scope of the project. These estimated costs are not presented as formal cost-sharing and therefore do not constitute a cost-share obligations on the part of Washington State University. Moreover, there is no requirement for WSU to document this other support of project as part of any cost-share or matching obligation.

WTFRC Collaborative expenses:

Item	2007	2008	2009
Stemilt RCA room rental			
Crew labor		$4,646	
Shipping			
Supplies			
Travel		$1,000	
Miscellaneous			
Total		$5,646	

Footnotes: Crew Labor and travel is for OTR operation

Budget 1:
Organization Name: Washington State Univ. **Contract Administrator:** M.L. Bricker
Telephone: 509.335.7667 **Email address:** mdesros@wsu.edu

Item	2007	2008	
Salaries	17,190		
Benefits	4,985		
Wages			
Benefits			
Equipment	11,000		
Supplies	1,600		
Travel	16,000		
Miscellaneous			
Total	**50,775**		

Footnotes:

Budget 2:
Organization Name: Vinetech **Contract Administrator:** Kathy Schmidt
Telephone: 509.665.8271 **Email address:** kathy@treefruitresearch.com

Item	2007	2008	
Salaries			
Benefits			
Wages			
Benefits			
Equipment	57,400		
Supplies			
Travel			
Miscellaneous			
Total	**57,400**		

Footnotes: Paid in full

Objectives:

1. Field evaluate Over the Row (OTR) machine and compare labor efficiencies and quality of work to tasks completed on ladders and mobile platform.
2. Identify best management practices for multi platform equipment.
3. Determine optimal number of platforms for OTR machines.
4. Incorporate OTR in comprehensive automation studies
5. Incorporate OTR in on-going vision studies
6. Incorporate OTR in application technologies field projects
7. Construct prototype f the energy absorbing grate and field test several energy absorbing foams for application to passive bin filling.

Objectives 1-6 have been met. I have not been successful in securing transportation for OTR. OTR is currently housed at WSU Prosser.
Objective 7 is a new objective. This work is being done in partnership with Carneigie Melon and Penn State.

Significant Findings: OTR travels through the orchard quite well – it is stable and responsive. It can maneuver around obstacles; all functions (hydraulics, E stops, multidirectional and turning mechanisms) were tested and performed as expected.

Materials and Methods:

1. Efficiency measurements:

1) # feet / time unit
2) # trees/ time unit
3) Tops only
4) Complete tree

2. Economic Assessment:

1) Cost per unit (tree/row/block)
2) AgProfit Assessment for IRR/ROI/NPV

3. Quality of work:

1) Subjective / Qualitative

4. Best Management Practices:

1) Number of people per platform
2) Employee interview/survey
3) Ergonomic mitigation

5.Green Fruit Thinning Treatments

1) OTR
2) Mobile Platform (Blueline)
3) Ladder

CONTINUING PROJECT REPORT **YEAR**: 1
WTFRC Project Number:

Project Title: Mechanized Cropload Management with Mueller (Uni Bonn) String Thinner

PI: Karen Lewis
Organization: WA State University
Telephone: 509.754.2011
Email: kmlewis@wsu.edu
Address: POB 37
Address 2: Courthouse
City:Ephrata, WA
State/Zip: 98837

Cooperators: WTFRC Internal Staff, Jim Schupp (PSU), Michael Blanke U Bonn), Craig Hornblow (Ag First NZ), Neil McCliskie Heartland Fruit (New Zealand), David Slaughter (UC), Scott Johnson (UC), WA, NZ, PA and CA producers

Total project funding request: **Year 1**: 14,500

No report submitted

CONTINUING PROJECT REPORT **YEAR**: 1 of 3
WTFRC Project Number: TR-09-901

Project Title: Technology roadmap support

PI: James Nicholas Ashmore
Organization: James Nicholas Ashmore & Associates
Telephone: (202) 783 6511
Email: nickashmore@cox.net
Address: 400 North Capitol Street, N. W., Suite 363
City: Washington,
State/Zip: District of Columbia 20001

Cooperators: None

Total project funding request: **Year 1**: $30,000 **Year 2**: $33,000 **Year 3**: $33,000

Other funding sources: None

WTFRC Collaborative expenses: None

Budget
Organization Name: James Nicholas Ashmore & Associates
Contract Administrator: James Nicholas Ashmore
Telephone: (202) 783 6511 **Email address:** nickashmore@cox.net

Item	2009	2010	2011
Salaries	$30,000	$33,000	$33,000
Benefits			
Wages			
Benefits			
Equipment			
Supplies			
Travel			
Miscellaneous			
Total	**$30,000**	$33,000	$33,000

OBJECTIVES

1. To protect funding for ongoing research programs and to seek funding for new proposals identified as significant and beneficial to the Washington tree fruit industry;
2. To continue cooperative efforts with other specialty crop stakeholder groups and to work to educate the new Administration about the importance of the Washington tree fruit industry and its economic importance to the Pacific Northwest and to the nation;
3. To insure that research activities and requests for research proposals made by the new Administration are constructed in such a way as to address the needs of the Washington state industry and to give the flexibility to the Commission to participate in the process;
4. To keep the Commission informed of developments in both the Congress and the Administration that impact on ongoing or future research funding;
5. To pursue specific activities related to high priority research initiatives
    a. USDA-ARS apple root stock breeding program, Geneva, New York
    b. Expansion of pear research in pear genomics, genetics, and breeding in the Pacific Northwest
    c. Expansion of automation and precision ag efforts in the Pacific Northwest
    d. Expansion of research and extension efforts in sustainable tree fruit production and handling.

ACTIVITIES TO DATE

The following bullet points summarize activities taken since the previous Continuing Report filed in March 2009.

- Continued to monitor efforts by the Department of Agriculture to implement provisions of the General Farm Act designed to restructure and better coordinate USDA agricultural research efforts;
- Continued to emphasize in discussions with congressional staff the strong interest of the Washington tree fruit industry in insuring that these efforts result in real changes in how USDA views and structures research efforts in agriculture;
- Monitored closely the implications of the stimulus program on the U. S. economy and how that program and the Omnibus Appropriations legislation enacted by Congress for the remaining portion of fiscal 2009 will affect demands on U. S. agriculture and associated research needs;
- Reviewed the President's detailed budget submission for the upcoming fiscal year to determine its implications for USDA programs, especially as they relate to agricultural research and other USDA programs of importance to the Washington tree fruit industry;
- Worked with Commission Manager, leaders of the Northwest Horticultural Council, and staff of the Washington congressional delegation to protect and restore funding for programs important to the Washington tree fruit industry, focusing especially on funding for market promotion programs, the Clean Plant Network, and the Agriculture Chemical Use survey conducted by NASS, an agency within USDA;
- Worked with Commission Manager and leaders of the Northwest Horticultural Council to develop and discuss with Washington state delegation staff alternative methods of achieving the goal of enhancing and expanding pear genome, genetics, breeding research in the Pacific Northwest;
- Discussed with Commission Manager the appointment and Senate confirmation of Dr. Rajiv Shah as the Under Secretary of Agriculture for Research, Education, and Economics and Chief Scientist at USDA, focusing on Dr. Shah's interests in nutrition, obesity, and world

hunger and how those interests could be used in formulating our approaches to him and to the Administration;

- Monitored developments in the food safety debate and the movement of legislation out of the House Committee on Energy and Commerce and discussed those developments with leaders of related interest groups such as Northwest Horticultural Council, focusing especially how the legislation as it is currently written could impact on sustainable tree fruit production and handling; Interestingly, the bill reported from the Energy and Commerce Committee has a section on research, but it is open-ended and appears to lack the type of coordination and structure favored by the Washington tree fruit industry and it also lacks both a specific authorization for research funding and an established delivery mechanism for such research;
- Monitored and worked with associated interest groups on a wide range of environmental issues that could have significant implications to the Washington tree fruit industry, focusing especially on steps to insure that Federal regulatory decisions are based on sound science; these efforts included but were not limited to EPA's proposed actions on fumigants, enforcement actions taken by EPA pursuant to court decisions in the 9th Circuit under the Endangered Species Act, and possible EPA actions to comply with the recent 6th Circuit Court decision relative to Clean Water;
- Continued to work with key House Committee staff and Northwest Delegation offices to insure that the new Under Secretary for Research and his staff realize the strong support of the Washington tree fruit industry and others in the specialty crops research coalition for competitive agricultural research funding;
- Worked with Commission Manager to expand the knowledge base and support for continued research emphasis on engineering and automation technology, specifically working to set up and attend a meeting with officials of CropLife America relative to the engineering research proposal submitted to obtain funding to develop a roadmap to design efforts to go forward with research to develop different application technologies for pesticide application that will allow changes in orchard agricultural structures and will also address the growing pressures from environmental concerns and court decisions affecting spray drift problems; and,
- Worked to insure that to the extent possible relevant congressional offices are provided with sound information about the advances that have been made to date in the specialty crops area and why it is important to the nation as a whole that those advances remain in place and that further progress continue to be made in these areas.

SIGNIFICANT FINDINGS TO DATE

- Presidential appointments to USDA positions have moved forward and Secretary Tom Vilsack and Deputy Secretary Kathleen Merrigan and Under Secretary Rajiv Shah are in place as is Under Secretary Jim Miller, a Washington State native, who has primary responsibility for general farm programs;
- As of this date, the process of completing the so-called "Schedule C" appointments has not been completed, although it is ongoing;
- USDA interests to date seem to be focused on safety net programs, rural development and waste water programs, and nutrition and hunger programs;
- It is important to note that UDA under Secretary Vilsack's leadership has taken an active and open role in the development of climate change legislation, other environmental legislation and issues, and food safety legislation;
- This Congress will have to address reauthorization of world hunger legislation; it is not clear at this point if that will occur in this session or go over and be addressed in the 2nd Session that will begin in January 2010; How this legislation is crafted could provide some opportunities that could be beneficial to the Washington tree fruit industry;

- It appears that one of the guiding principles of this Administration will be to seek to broaden the base of support for USDA programs; the primary political issue will be to accomplish that goal without alienating the traditional base of support;
- If USDA can achieve its goal of broadening its base of support while maintaining its existing support base, this should be of significant long-term benefits to the specialty crops and their interests;
- The House of Representatives is continuing to work its way through the various appropriations bills for fiscal 2010 and is expected to take up several measures this week; the Senate Appropriations Committee has reported several measures, including its version of the Agriculture appropriations bill, but Senate Floor debate as not as yet kept pace with the House process;
- At this point in time, it appears that with the help of the Washington delegation offices, especially the two Washington State appropriators, we have been successful in maintaining funding for research programs and other key programs of importance to the Washington tree fruit industry;
- Much of the congressional debate continues to focus on the extent to which "earmarks" or "congressionally directed spending" appear in the legislation. The controversy over this issue has restricted the use of this type of language in the appropriations bills;
- Working with leaders of the Northwest Horticultural Council we were able to get a strong commitment to continue to pursue our interests in expanding pear genome, genetics, breeding research in the Northwest;
- The most controversial element of the President's overall budget document relates his proposals in the area of payment limitations; those proposals were rejected in the final version of the Congressional Budget Resolution, which has been approved and which has served as the basis to proceed with the appropriations measures;
- There is still strong support for "pay – go" budget requirements that establish that new funding has to be offset (or paid for), through either program cost reductions or through "revenue enhancement" or a combination of those cost savings and increased revenue;
- The Administration remains committed to a fact-based approach to policy determinations and to competitive research funding; the Administration is also continuing to emphasize the role of sound science and its use by Administration agencies in reaching decisions. That effort is designed to depoliticize science in the decision-making process while insuring that there is transparency and that there is the use of sound science supporting Federal decisions.

Next Steps

- Continue to monitor the continued movement of the agriculture appropriations bill through the Congress and work to insure that the final version that results from reconciling the differences between the House and Senate versions continues to have funding for ongoing research programs of importance to the Washington tree fruit industry and also continues to provide funding for other programs of importance to the industry;
- Continue to monitor and support efforts to broaden the base of support for engineering research proposals important to the Washington industry;
- Continue to work with the Delegation offices and with Commission Manager to encourage further movement in efforts to expand the pear genome, genetics, breeding research;
- Continue to monitor developments in the public debate over food safety issues and the movement of the Energy and Commerce bill through the House and Senate, focusing especially on insuring that the programs established by the legislation will work and make sense and that research undertaken pursuant to the legislation will be broad enough to address the needs and unique problems of the tree fruit industry and other specialty crops;

- Continue to stress the importance of research funding to provide the sound science that the Administration is seeking to use in agency decision-making processes;
- Continue to work with the Northwest Horticultural Council, U. S. Apple Association, and other specialty crop interest groups to insure that we have continued broad-based agreement on going forward with the Administration and the Congress on all of these issues.
- Continue to work with the Northwest House Members and Senators in preparing for development of appropriations legislation for future years, focusing especially on what information those offices need to help us advance our interests;
- Continue to work with USDA officials to insure that the views and concerns of the Pacific Northwest and especially the Washington State tree fruit industry are considered carefully within the Department.
- Monitor possible upcoming action by Congress on water and air issues to determine their implications to the state tree fruit industry and work to insure that there are adequate scientific studies available or that there is recognition of the need for further research into these areas.
- Continue to work closely with senior professional staff in the House and Senate, especially those directly involved with agriculture legislation or those working closely with Members and Senators who have strong specialty crops interest.

Methods

We are making slow but steady progress toward our goals and we have developed a great reputation for honesty and transparency and for an absolute commitment to sound science. We have, I believe, gained support and recognition for our commitment to competitive research funding and for being willing to work well in coalitions and with the Administration.

We have achieved one of our major objectives in protecting the existing funding base. We have also achieved what I see to be a strong commitment from this Administration and this Congress to stay on course with respect to specialty crops research.

We have also done well in expanding our base of support and helping other groups in agriculture understand and appreciate our industry and where we would like to move that industry to meet our domestic needs and to insure that we can remain competitive in the world market.

We are not, however, home free on this and there will have to be continued strong efforts to work together with other agricultural groups. We will need to be cognizant of and work to insure that there is a strong degree of cooperation between the specialty crops interests and those of the so-called program crops. If we can achieve that, we will be helping the new Administration expand the base of support for USDA programs while also reassuring the existing base of its value and importance.

I believe that there is no real reason to fix something that isn't broken. In summary, then, I am recommending that we continue our present course of being cooperative but persistent and that we continue to insure that all parties are informed as well as possible and that we continue to be interested more in getting the research done in a credible manner by the best scientists rather than seeking to direct who will be do the research or where it will be done.

We have made friends and we have established the channels of communication necessary to insure that we will continue to have access and the opportunity to participate in the development and implementation of these programs. While I do not envision that this will happen, should circumstances change, we will be able to adjust as necessary.

Results and Discussion

I believe that the Administration and Congress are working to create a climate that could be quite favorable to further movement toward insuring better and more research to address the needs of the Washington tree fruit industry.

There are potentially major problems that have surfaced, most of which are associated with overall controversies outside of our control: the extent and depth of the current economic crisis, the political debate over the use of the so-called "earmarks" or "congressionally directed spending" in appropriations legislation and the extent to which the various programs being advocated by the Administration will affect the Federal budget deficit and the national debt.

Having said that, I believe we are making good and steady progress in all of the areas of interest to the Washington tree fruit industry. I am encouraged by the continued interest of the Washington State Delegation in pursuing and protecting our interests. I believe, for example, that these offices appreciate our willingness to consider options and be open to different ways to approach and achieve our goals.

I would particularly recommend that we keep reviewing the various opportunities that might come up to determine possible other research initiatives that we might want to pursue based on the interests and policies of the leaders in the Administration and Congress. This should, I believe, include some examination and discussion of food safety issues or research into environmental and rural development issues that would lead to enhancing the quality of life in rural areas.

Finally, I continue to believe that it is essential to continue to work in concert with other agricultural interest groups and that we focus on what steps we need to follow to direct the process of the debate surrounding how to move from the general interest in getting enough funding for agriculture to the specific details of where and how that money will be spent.

As I indicated in my March 2009 Continuing Report, I very much appreciate the opportunity to work with the Commission and I look forward to going forward in achieving another profitable year where we can not only protect what we have gained to this point but also lay the groundwork for further success in the coming years.

FINAL PROJECT REPORT

Project Title: ABI 3730 DNA analyzer to augment tree fruit breeding and research

PI: Cameron Peace
Organization: Washington State University
Telephone: (509) 335 6899
Email: cpeace@wsu.edu
Address: Department of Horticulture & Landscape Architecture
Address 2: 39 Johnson Hall
City: Pullman
State/Zip: Washington 99164

Cooperators: Deven See (USDA-ARS Western Regional Small Grains Genotyping Laboratory, Pullman), Kate Evans (WSU-TFREC, Wenatchee), Nnadozie Oraguzie (WSU-IAREC, Prosser).

Total Project Request: **Year 1:** $50,000

Other Funding Sources

Agency Name: Washington Wheat Commission (WWC)
Amount awarded: $50,000
Notes: WTFRC funds were matched with $50,000 from the Washington Wheat Commission (separate award, PI: Dr. Deven See).

Agency Name: Washington State University - Agricultural Research Center
Amount awarded: $100,000
Notes: Funds provided to Dr. Peace for equipment purchase to support tree fruit genetic screening.

Agency Name: Various
Amount awarded: Approximately $80,000
Notes: $50K from WWC, $3K from ARC, $8K from USDA-ARS, and $8K from ARC (part of above $100K) for a Biomek "robot".

Total Project Funding: $50,000

Budget History:

Item	**Year 1: 2008-2009**	**Year 2:**	**Year 3:**
Salaries			
Benefits			
Wages			
Benefits			
Equipment	$50,000		
Supplies			
Travel			
Miscellaneous			
Total	**$50,000**		

Footnote: The analyzer expense was less than estimated and $1973.25 was returned to WTFRC.

RECAP ORIGINAL OBJECTIVES

1. Obtain an ABI 3730 for high-throughput genotyping capability to support marker-assisted breeding needs of the WSU apple and sweet cherry breeding programs.

2. Establish the Pacific Northwest Tree Fruit Genotyping Laboratory (PNWTFGL), based in Pullman.

SIGNIFICANT FINDINGS

- A refurbished 48-capillary ABI 3730 DNA Analyzer was installed in the laboratory of collaborator Dr. Deven See in April 2009.

- A Cooperative Utilization Agreement between the PNWTFGL and the WRSGGL (Western Regional Small Grains Genotyping Laboratory; Program Leader Dr. Deven See, USDA-ARS) governing ownership, access, and use of the ABI 3730 was created.

- WSU-ARC provided Dr. Peace with $100,000 for various smaller equipment items for the genetic screening process, particularly for the steps prior to genotyping on the ABI 3730, to remove technical bottlenecks and enable routine marker-assisted seedling selection on many thousands of tree fruit seedlings every year. Much of this equipment has been purchased and is being installed in the PNWTFGL.

- A Beckman Biomek NX^p laboratory automation station (total cost approximately $80,000) is currently being purchased, with approximately $50,000 from the WWC, $8000 from Dr. See's funds, and $8000 from the ARC's provision to Dr. Peace.

- Use of the ABI 3730 is well underway, and the machine is utilized on daily basis. Its high-throughput capacity has previous scheduling difficulties and allows many labs to conduct genotyping. A per-datapoint fee is paid by external users for a repairs & maintenance fund.

- Use of the ABI 3730 is contributing to several current tree fruit projects.

RESULTS & DISCUSSION

The ability to screen thousands of plants in a single season allows genetic marker technologies to truly interface with modern breeding programs for enhanced cultivar development. We have partnered with the Western Regional Small Grains Genotyping Laboratory, run by USDA-ARS scientist Dr. Deven See, to develop a WSU Genotyping Center for crop improvement. WSU's apple and sweet cherry breeding programs are now supported by the Pacific Northwest Tree Fruit Genotyping Laboratory, physically located on the Pullman campus.

In 2009, existing resources were strategically improved with the addition of an Applied Biosystems (ABI) 3730 DNA Analyzer (Figure 1), obtained through grants from WTFRC and the Washington Wheat Commission (WWC). Dr. See's USDA-ARS lab previously used an ABI 3130xl (33% capacity of the 3730), capable of more than 100,000 cereal samples in a season, and we had successfully trialed that machine for apple. The new ABI 3730 can be loaded at a time with up to 16 plates of 384 samples (6144), each "sample" having four different tests, taking 5 hours to process each 384-well plate. So for example, we could prepare tests for 6000 different apple seedlings with each seedling undergoing four genetic tests, and come back to see all the results about three days later. The ABI 3730 therefore provides sufficient capacity for genotyping needs of WSU's tree fruit breeding programs (apple, cherry, pear) and tree fruit research colleagues, the USDA-ARS's cereal genotyping needs, and surplus capacity for breeding and research programs of other crops.

Figure 1. The ABI 3730 DNA Analyzer of the Pacific Northwest Tree Fruit Genotyping Laboratory.

In addition to genotyping, an advantage of the ABI 3730 is that it can also be efficiently used for DNA sequencing. Such sequencing is at a different scale (fewer sequences) and different screening capacity (more individual samples) than Dr. Amit Dhingra's newly acquired Roche 454 machine. Together, this sequencing capacity will significantly enhance WSU genomics activities.

This key piece of equipment is combined with further equipment support from the Agricultural Research Center (ARC), for DNA extraction (plate centrifuge, waterbath, UV gel imager, pipettes) and Genotyping (384-well thermocyclers, freezer). Our next purchase in 2009 will be a Beckman Biomek NX^p laboratory automation station, which eliminates much repetitive labor in sample preparation, and reduces consumables. The Biomek "robot" is being purchased primarily with WWC funds, as well as operating funds of Dr. See and ARC funds for Dr. Peace.

Availability of such equipment has positioned WSU's tree fruit genomics, genetics, and breeding team in a highly competitive position for obtaining federal funding. The equipment (and available expertise) is also enabling current projects to be completed more efficiently.

We believe the Genotyping Center concept, partnering with the USDA-ARS cereals lab for full access to combined resources for both groups and managed by See and Peace, is an efficient approach to meet tree fruit breeding needs and enhance the scope of research capability. The momentum of obtaining the ABI 3730 has enabled the addition of $100K in WSU-ARC support, and soon a Biomek laboratory automation station. These various equipment items were chosen to strategically remove technical bottlenecks and reduce labor costs, allowing high-throughput genetic marker assistance for the region's tree fruit breeding programs and industry.

EXECUTIVE SUMMARY

We seek to establish the Pacific Northwest Tree Fruit Genotyping Laboratory (PNWTFGL), served with an ABI 3730 DNA Analyzer for high-throughput genotyping capability to support marker-assisted breeding needs of the WSU apple and sweet cherry breeding programs.

- A refurbished 48-capillary ABI 3730 DNA Analyzer was installed in April 2009.

- A Cooperative Utilization Agreement between the PNWTFGL and the WRSGGL (Western Regional Small Grains Genotyping Laboratory; Program Leader Dr. Deven See, USDA-ARS) governing ownership, access, and use of the ABI 3730 was created.

- WSU-ARC provided Dr. Peace with $100,000 for various smaller equipment items for an efficient genetic screening process.

- A Beckman Biomek NX^{P} laboratory automation station (total cost approximately $80,000) is currently being purchased as the last major technical component of our efficient genetic screening process.

- Use of the ABI 3730 is well underway, and the machine is utilized on daily basis. The machine is contributing to several current tree fruit projects.

FINAL PROJECT REPORT

Project Title: Chemical genomics

PI:	Tianbao Yang	**Co-PI(2)**:	Dorrie Main
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Address:	Dept. of Horticulture	**Address**:	Dept. of Horticulture
City:	Pullman	**City**:	Pullman
State/Zip:	WA 99164-6414	**State/Zip**:	WA99164-6414

Co-PI(3):	BW Poovaiah	**Co-PI(4)**:	Matt Whiting
Organization:	WSU	**Organization**:	WSU
Telephone:	509 335 2487	**Telephone**:	509 786 9260
Email:	poovaiah@wsu.edu	**Email**:	mdwhiting@wsu.edu
Address:	Dept. of Horticulture	**Address**:	IAREC
City:	Pullman	**City**:	Prosser
State/Zip:	WA 99164-6414	**State/Zip**:	WA 99350

Cooperators:

Other funding Sources: None

Total Project Funding: 60,000

RECAP ORIGINAL OBJECTIVES:

In this collaborative project, we proposed to apply a chemical genomics approach to rosaceous crops, and help solve some of the problems facing the Washington tree fruit industry. One of the major issues is how to improve fruit size and fruit quality. It has been well documented that fruit development and ripening are regulated by plant hormones such as auxin, gibberellins, and ethylene. For sweet cherry (*Prunus avitum*), we will focus on the effect of gibberellic acid (GA) on fruit size and quality, as well as tree size.

The plant hormone gibberellin has long been known to modulate development throughout the plant life cycle. Mutants that are impaired in GA biosynthesis or response tend to have small dark green leaves and reduced stem length. Thus understanding the regulatory mechanisms of GA could help to produce dwarf crops. GA mutants are also often defective in seed germination and floral development, and are delayed in flowering time (Fleet and Sun, 2005). In cherry, GA application is currently used by growers worldwide for improving fruit quality and delaying maturity (Lenahan et al., 2006; Maib et al., 1996). Vigorous shoot growth in sweet cherry trees can also be controlled with gibberellin-biosynthesis inhibitors such as such as prohexadione-Ca (Manriquez et al., 2004).

Our specific objectives were:

1. To screen the available chemical libraries and identify the chemical compounds which affect the GA pathway,
2. To study the effect of selected chemicals on gene expression and identify the marker genes involved in fruit development, ripening, and tree size using subtraction cloning and microarray technologies,
3. To study the effect of the chemical compounds on fruit shelf life, and quality, as well as tree size.
4. To train Washington State students in the cutting-edge discipline of chemical genomics.

SIGNIFICANT FINDINGS

1. Screened a 100,000 chemical library using strawberry and Arabidopsis.

2. 252 and 165 chemicals have been isolated from Arabidopsis and strawberry screenings, respectively. Among them, 125 chemicals exhibit the similar effects on both Arabidopsis and strawberry.

3. Of 125 chemicals, 77 have inhibitory effects, and 48 have stimulatory effects.

4. Twenty-five chemicals were selected for large scale field test in Bing in Prosser, WA, 2007. These chemicals were chosen because they showed best effects on seed germinations in both Arabidopsis and strawberry.

5. Several chemicals were effective in controlling skin color, flesh color immediately after application.

6. These chemicals affected the buds per spur and flower numbers per bud in following season.

7. Six chemicals were further selected for large scale field test in Pullman, WA, 2008. Selection of these chemicals was based on their performance in the field test of year 2007. The chemicals affected the fruit size, and fruit color, which were consistent to the results in Prosser, WA, 2007.

8. In conclusion, we have identified a few very effective chemicals which control fruit color and flower numbers.

RESULTS & DISCUSSION

In last report, we indicated that 25 selected chemicals were used to spray in Prosser orchard on May 30, 2007. The normal spray with GA3 was used as control. Each chemical was sprayed on the cherries in a branch of one tree. The experiment was repeated twice in two different trees. The cherries were harvested on June 22. We further analyzed the cherry weight, skin color, flesh color, firmness and Brix.

As shown in Figure 1-4, the 25 compounds had a variety of impacts on the traits we measured as compared to control. The most obvious effects were the skin color and flesh color which are desirable traits for consumers, while they did not show significant changes on the fruit firmness.

In 2008, we selected 6 chemicals for a large scale field test. These chemicals were selected based on their performance (positive and negative effects) in 2007 test. Since the Prosser orchard had no many fruits because of the bad weather this spring, we did the field test this year in Tukey Orchard, Pullman, WA in July 2008. We also changed the sweet cherry variety from Bing to Rainier in order to observe the color effects clearly. Two independent trees were used for all treatments.

Figure 5 shows that six chemicals can be separated into two groups, negative group (No. 2, 3) and positive group (No. 1, 4, 5, 6) based on their effects on the fruit weight. They all increased fruit color as compared with GA control. As for fruit firmness, No. 4, 5, 6 had no significant difference as compared with GA control. Among six chemicals, No. 4 showed the best in all measurements. Figure 6 are the photos exhibiting the effects of No. 4 chemicals on fruit ripening. In the same tree, the fruits sprayed with No. 4 chemical were ripen a week to 10 days later than no spray fruits in the same tree. The fruit weight in sprayed fruits was significantly improved (~40% increase). It also had better effects on fruit weight, skin color than GA control. However, the fruit firmness was comparable with GA control. We made efforts on isolation of RNAs from cherry fruits treated with different chemicals, but the quality of RNA was not very good to proceed the subtraction cloning.

In conclusion, we have identified a few powerful chemicals which affect sweet cherry fruit quality and flower numbers. The tests on different locations and different varieties in different years indicate that these chemicals are more effective than GA. These chemicals may also have the potential for other tree fruits such as apple and pear.

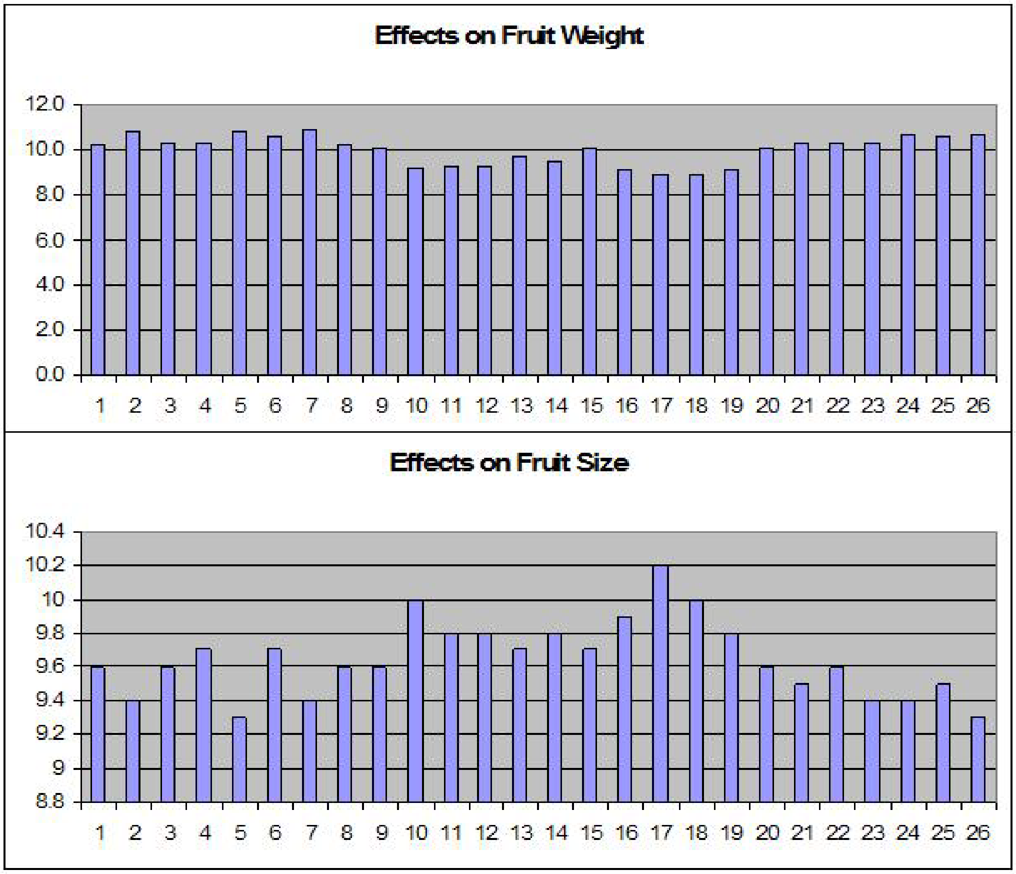

Figure 1. The effect of 25 selected compounds on the fruit weight and size. No. 26 represents the control which was treated with GA3. (Prosser, WA, 2007)

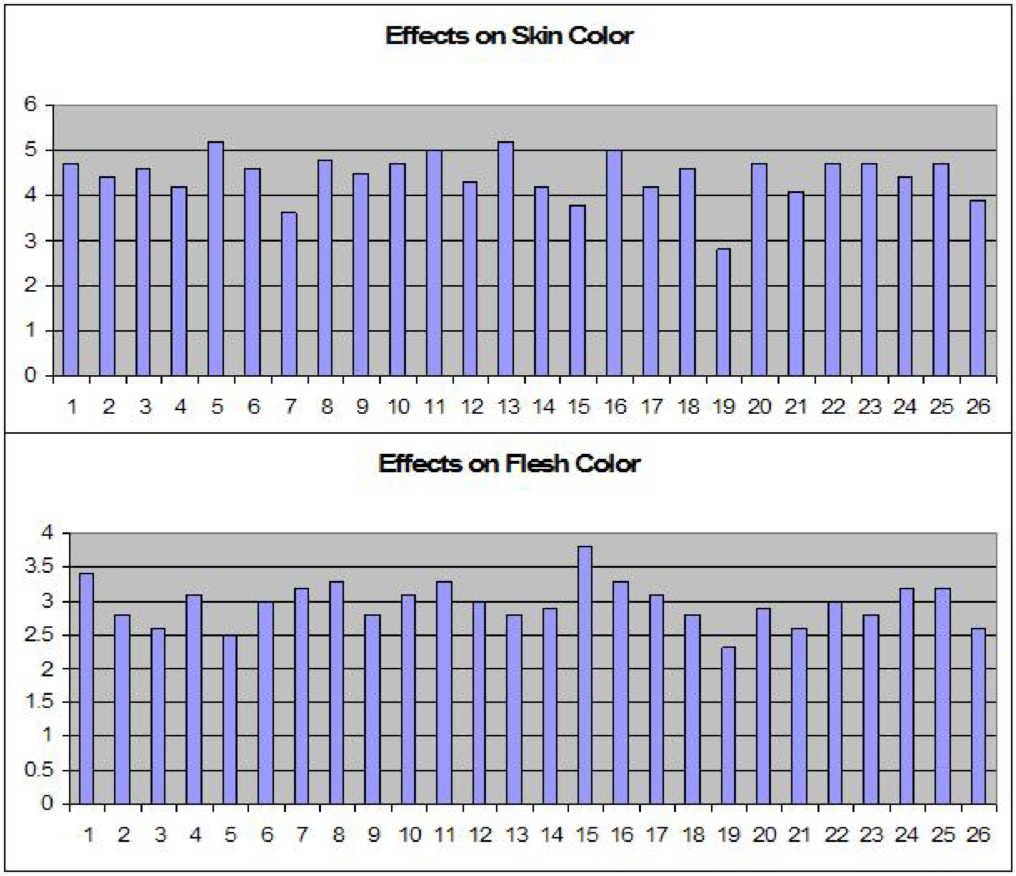

Figure 2. The effect of 25 selected compounds on skin color and flesh color. No. 26 represents the control which was treated with GA3. (Prosser, WA, 2007)

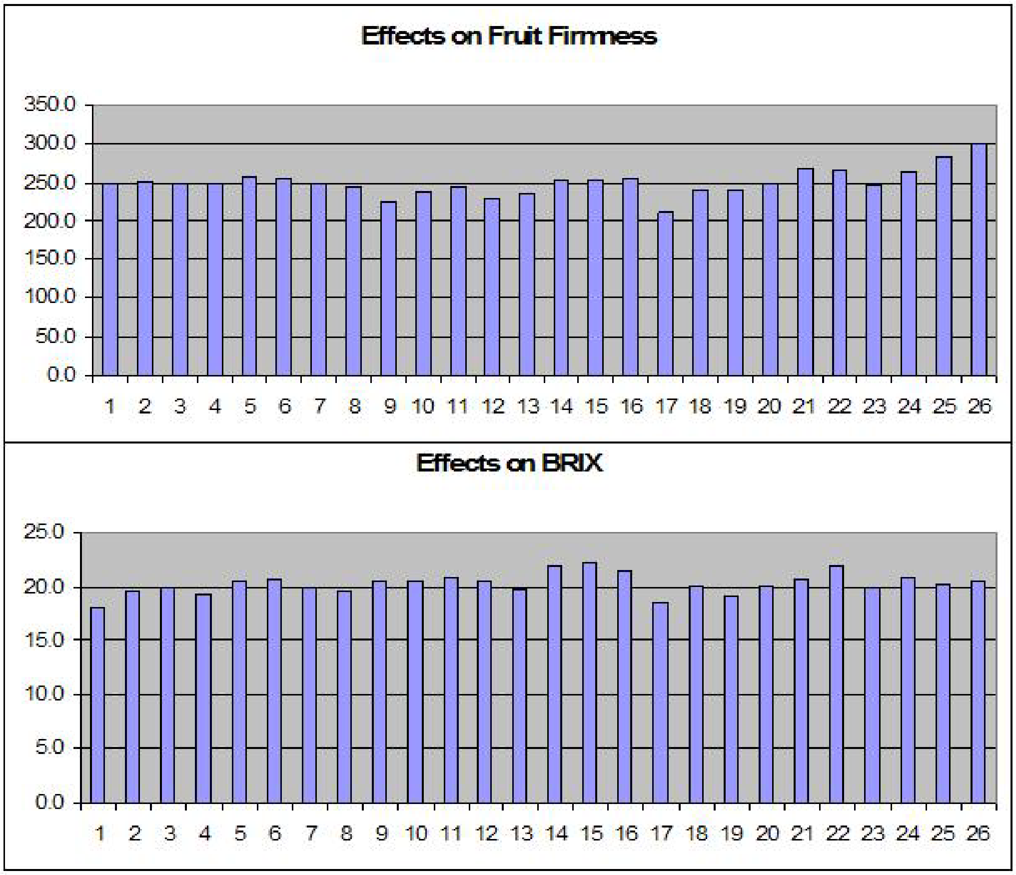

Figure 3. The effect of 25 selected compounds on fruit firmness and Brix. No. 26 represents the control which was treated with GA3. (Prosser, WA, 2007)

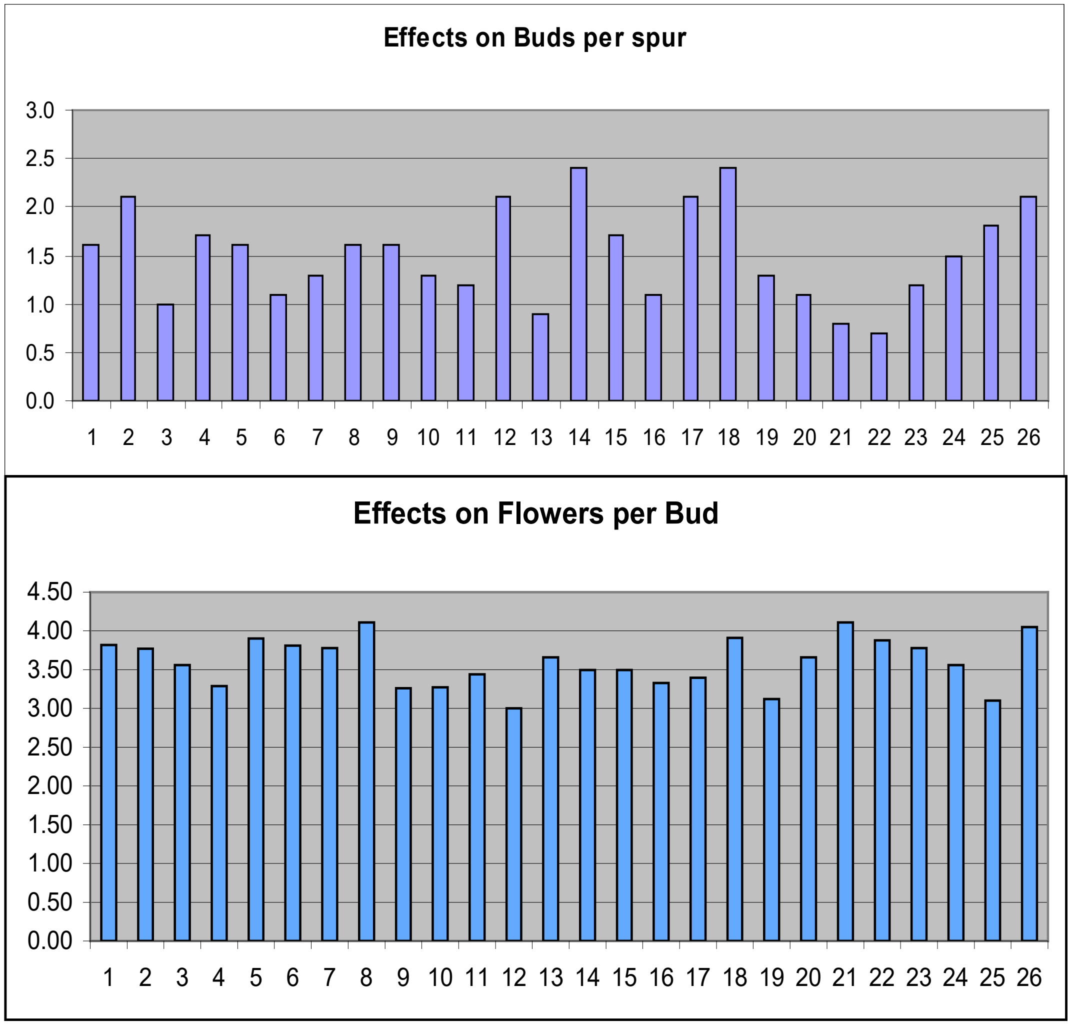

Figure 4. The effect of 25 selected compounds on bud numbers and flower numbers. No. 26 represents the control which was treated with GA3. (Prosser, WA, 2007)

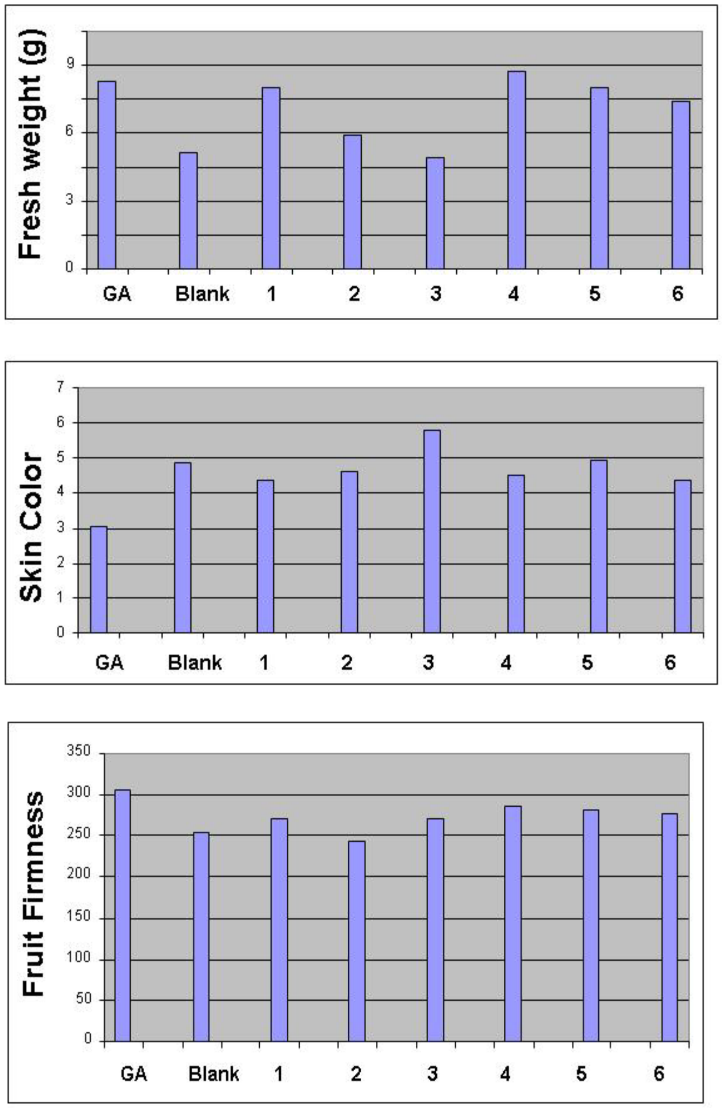

Figure 5. The effect of 6 selected compounds on the fruit weight, fruit size and fruit firmness. (Pullman, WA, 2008)

Figure 6. The effect of a small molecule (No. 4) on sweet cherry fruit ripening and fruit size. The photos show the fruits with treated and untreated from the same tree. This chemical can delay the fruit ripening and increase the fruit size. (Pullman, WA, 2008)

EXECUTIVE SUMMARY

Chemical genomics is a new high-throughput approach for determining gene function using small bioactive molecules to activate/inactivate gene products (i.e., proteins). Recently, chemical genomics has been used to better elucidate hormonal signaling in Arabidopsis. In this report we summarize our use of a chemical genomics approach for sweet cherry improvement.

From screening a 100,000 format chemical library, we identified more than 100 bioactive molecules that affect (elicitors and inhibitors) the gibberellin pathway. Twenty-five of these were applied to fruiting sweet cherry limbs in the field. We observed a variety of effects on fruit color, firmness, soluble solids, and weight. Furthermore, several compounds inhibited floral bud initiation and show potential as crop load management tools. A larger scale test using 6 selected chemicals in different location and different variety showed the similar results.

To sum up, we have identified a few very powerful chemicals which affect sweet cherry fruit quality and flower numbers. These chemicals are more effective than GA. Besides, these chemicals which are effective in sweet cherry may work in other tree fruits such as apple and pear, too. Our results indicate that using chemical genomics approach can save time and money for tree fruits gene disco very and crop improvement.