2011

Year 2
SCRI Annual Report

A total systems approach to developing a sustainable, stem-free, sweet cherry production, processing, and marketing system

This is a four year project, funded in August 2009 by the USDA NIFA Specialty Crop Research Initiative. Our long term goal is to develop a sustainable, high efficiency sweet cherry production, processing, and marketing system with effective research and outreach programs addressing the total system. This project addresses the stakeholder-identified need to improve harvest labor efficiency and improve fruit's consumer appeal. Our research and outreach program incorporates the entire value chain of sweet cherry production, processing, and marketing. The overall goal is to create a model total systems approach for effectively and efficiently adopting innovation in specialty crop industries.
This annual report summarizes the progress made and tasks completed in year two.

Research partners:

OSU Oregon State University

PickerTECH™

University of California Agriculture and Natural Resources

Michigan State University

Washington State University World Class. Face to Face.

By Tracie Arnold
Washington State University
11/10/2011

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Objective 1: Develop high efficiency, productive angled fruit wall orchard systems, *Whiting, Grant, Long*

Year 2 Milestone: Completed planting test orchards in Washington, Oregon, and California; held tours of completed test orchards; refined management strategies; development of outreach materials.

Progress in 2011:

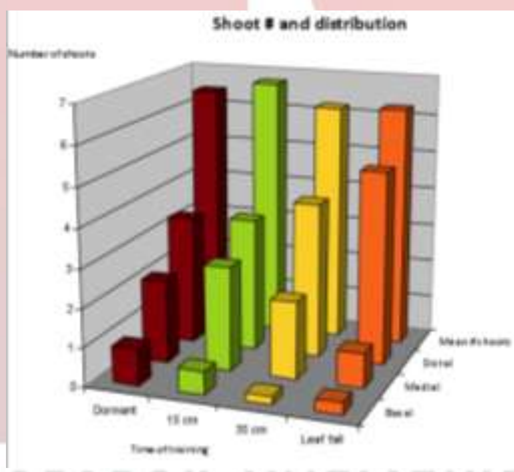
Antonia Sanchez-Labbe joined the SCRI team in January 2011 to conduct her M.S. research on key horticultural issues with the UFO architecture. The research program is addressing:

1. Timing of initial tree training in the year of planting
2. Inducing upright shoots in 2-year-old wood
3. Vigor control tactics for individual uprights
4. Renewal of uprights
5. Managing tree height

1. Timing of initial training

***Objective* – determine the role of timing of training UFO trees horizontal on upright number and length.**

Trees were planted at 45 degrees and clipped to the lowest wire at the time of planting, after new shoots were 15 cm, new shoots were 35 cm, or not until the end of the season.



Average shoot number was similar for all timings at about 6 new uprights per tree. The earlier the trees were tied horizontal appears to improve shoot distribution though – there were more shoots in the basal and medial sections of trees tied at planting (dormant) and after 15 cm new shoot growth. This study is being repeated with collaborators in Chile using 'Bing'/'Gisela®6' trees.

2. Inducing uprights

***Objective* – develop strategies for inducing upright shoots in 2-year-old horizontal wood.**

Two-year-old horizontal scaffold wood in 'Selah' and 'Skeena' trees were treated with Promalin (BA + GA) or Pro-Gibb (GA) at bud break in a staggered start experiment with 3 timings. The number of new shoots were counted and shoot growth was assessed, compared with untreated trees.

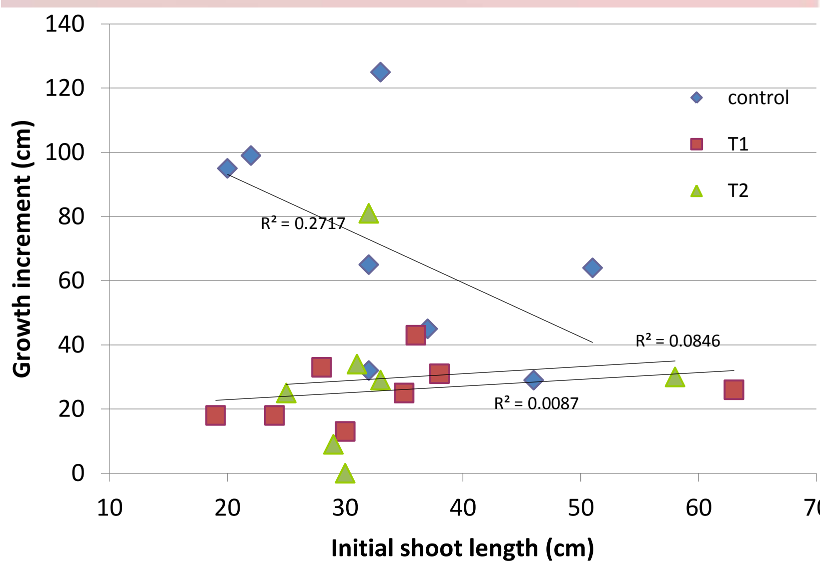
Overall, 70 to 80% of all nodes had new shoots generated. However, trees treated with Promalin and Pro-Gibb had more vigorous uprights compared with the control. The effect this has on system precocity will be assessed in subsequent years. We did observe phytotoxicity from the high PGR rates – leaves on new uprights were yellowed and had lower chlorophyll content that untreated shoots.

3. Controlling vigor in uprights

***Objective* – control excessive vigor in individual uprights and improve fruit bud distribution**

Upright shoots of 'Benton', 'Skeena', and 'Selah', were treated with two applications (23 May and 2 June) of either 125 ppm or 250 ppm Prohexadione-Ca (Apogee®) by spray bottle directly to the shoot meristem region (i.e., not applied to the entire tree). Shoot caliper, length, and leaf number were assessed throughout the season, until terminal bud set.

The "Benton" treatments were effective. Rate did not have an effect – 125 ppm was as effective as 250 ppm



There does not appear to be any relationship between the length of a shoot at the time of application of Apogee® and its growth increment post-application. These trials will be repeated in 2012, including other genotypes.

4. Renewal of uprights

Objective – determine the best time and means for replacing uprights.

Trees were subjected to one of three renewal pruning cuts (stub cut leaving 1-2 live buds, a flush cut, or a 10-cm stub cut) at two different timings (full bloom or after harvest). A third timing (fully dormant) will be included this winter. Trials were established with collaborating growers and included 'Selah', 'Kiona', 'Tieton', and 'Early Robin'. Results are currently being analyzed. However, preliminary results suggest that the most successful means for renewing uprights is a cut leaving 1-2 buds – nearly all stub cuts resulted in the generation of replacement uprights.

5. Managing tree height

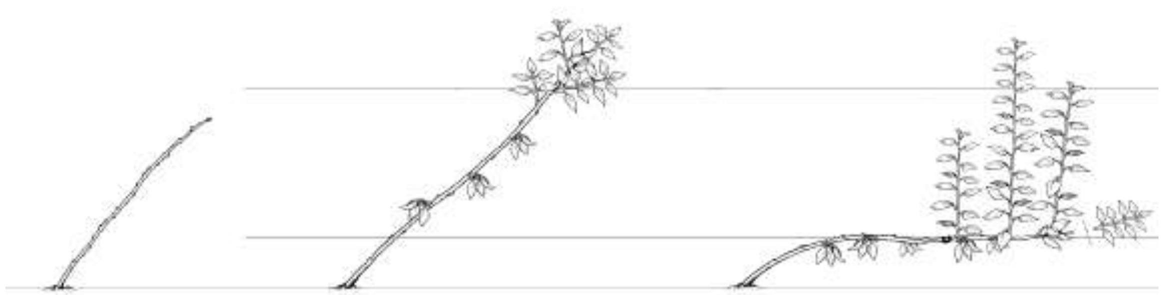
Objective – develop practical pruning strategies for maintaining desired tree height.

'Early Robin'/'Gisela®6' trees in a commercial orchard were subjected to one of four pruning treatments during bloom. Untreated uprights were compared with those which were pruned back to a weak lateral shoot, headed into one-year-old wood (to mimic potential mechanical hedging), or headed twice (at bloom and after harvest). Fruit yield and quality were assessed at commercial maturity.

There were no significant effects of pruning treatment on any fruit quality attribute. Interestingly however, both pruning treatments reduced fruit yield per upright by about 40%. The cause for this reduction is not clear. Perhaps the new growth induced with pruning the uprights altered upright source-sink relations causing fruit drop. This phenomenon will be investigated further in 2012 with multiple cultivars.

Developing outreach materials

We continue to work with Herb Leonhard to develop key illustrations for the UFO "how-to" materials. Currently these are posted online and a 1-page handout will be finalized in 2012. In addition, we will create a video archive of material documenting key stages of the UFO system, from planting, to pruning and harvest.



Objective 2: Establish the genetic basis for sweet cherry abscission, *Dhingra, Oraguzie, Whiting*

Year 2 Milestones: Phenotyped cherry cultivars and advanced breeding selections for pedicel-fruit retention force and fruit texture/flavor attributes; documented expression of known abscission genetic pathways in sweet cherry; evaluated cherry-specific genetic networks involved in abscission using next-generation genomics tools

Objective 2.1: Phenotype existing cultivars and breeding populations for fruit pedicel retention force characteristics and fruit texture and flavor attributes.

Sweet cherry is one of the most labor-intensive fruit crops due to hand harvesting. Successful mechanical or mechanically-assisted sweet cherry harvest requires a low retention force between the fruit and pedicel. To enable the adoption of future harvest technologies, it is necessary to identify cultivars and their progeny that combine low pedicel-fruit retention force (PFRF) with excellent fruit quality.

Experiments were conducted during 2009, 2010 and 2011, at the Washington State University Irrigated Agriculture Research and Extension Center, Prosser, WA. A total of 19 cultivars and 12 F1 seedlings in 2009, 29 cultivars and 19 F1 seedlings in 2010 and 29 cultivars only in 2011 were assessed for PFRF and their fruit quality attributes. Identical trees from 18 cultivars were used in both 2010 and 2011. Individuals were evaluated at commercial maturity by experienced horticulturists and assessed within 24 hours of harvest in the lab. PFRF and stem length were recorded in the field in 2009 on fruit harvested with pedicel on, while in 2010 and 2011, PFRF was recorded with the fruit on the tree, to capture the force required to detach the fruit from the tree for comparison with fruit-pedicel retention force which was our main interest. Fifty fruit were randomly sampled from each cultivar in 2009 and 30 in 2010 and 2011, while 10 were tracked in 2009 and 15 in 2010 and 2011 for measurement of fruit weight, size, exocarp color, firmness, and soluble solids content. The remaining samples were divided into 3 groups of 5 fruit for measurement of titratable acidity along with other quality attributes mentioned above, to provide enough replication for statistical analysis.

A total of 1249, 676 and 615 PFRF values were recorded in 2009, 2010 and 2011, respectively. The data was adjusted to account for the force required to separate the pedicel from the tree (recorded in 58% and 71% of the fruit samples in 2010 and 2011, respectively), before analysis of variance for PFRF. Both F1 seedlings and the cultivars assessed showed a wide range of variation for PFRF in all three years, with values ranging from 0.14 to 2.27 kg/f. The frequency distribution showed continuous variation (Fig. 1), suggesting that PFRF is a quantitative trait. The F1 seedlings had lower PFRF (0.56 kgf in 2009 and 0.88 kgf in 2010) compared to cultivars (0.81 kgf in 2009 and 1.03 kg/f in 2010)($P<0.0001$). Correlations between PFRF and fruit quality attributes were generally low (Fig.2), suggesting that PFRF has minimal influence on fruit quality. In 2010 and 2011, significant differences for PFRF were observed among varieties and between years, as well as for the interaction between variety and year ($p<0.0001$). This highlights the importance of both genetics and environment on PFRF. Interestingly, '4.10.5-31', a progeny of 'Lapins' and 'Chelan', had the lowest mean PFRF in 2009 (0.27 kg/f) and 2010 (0.55 kg/f) suggesting transgressive segregation since both parents are high PFRF cultivars. These results suggest that PFRF can be improved by breeding although the significant genotype x year interaction highlights the importance of accurate phenotyping to maximize the genetics.

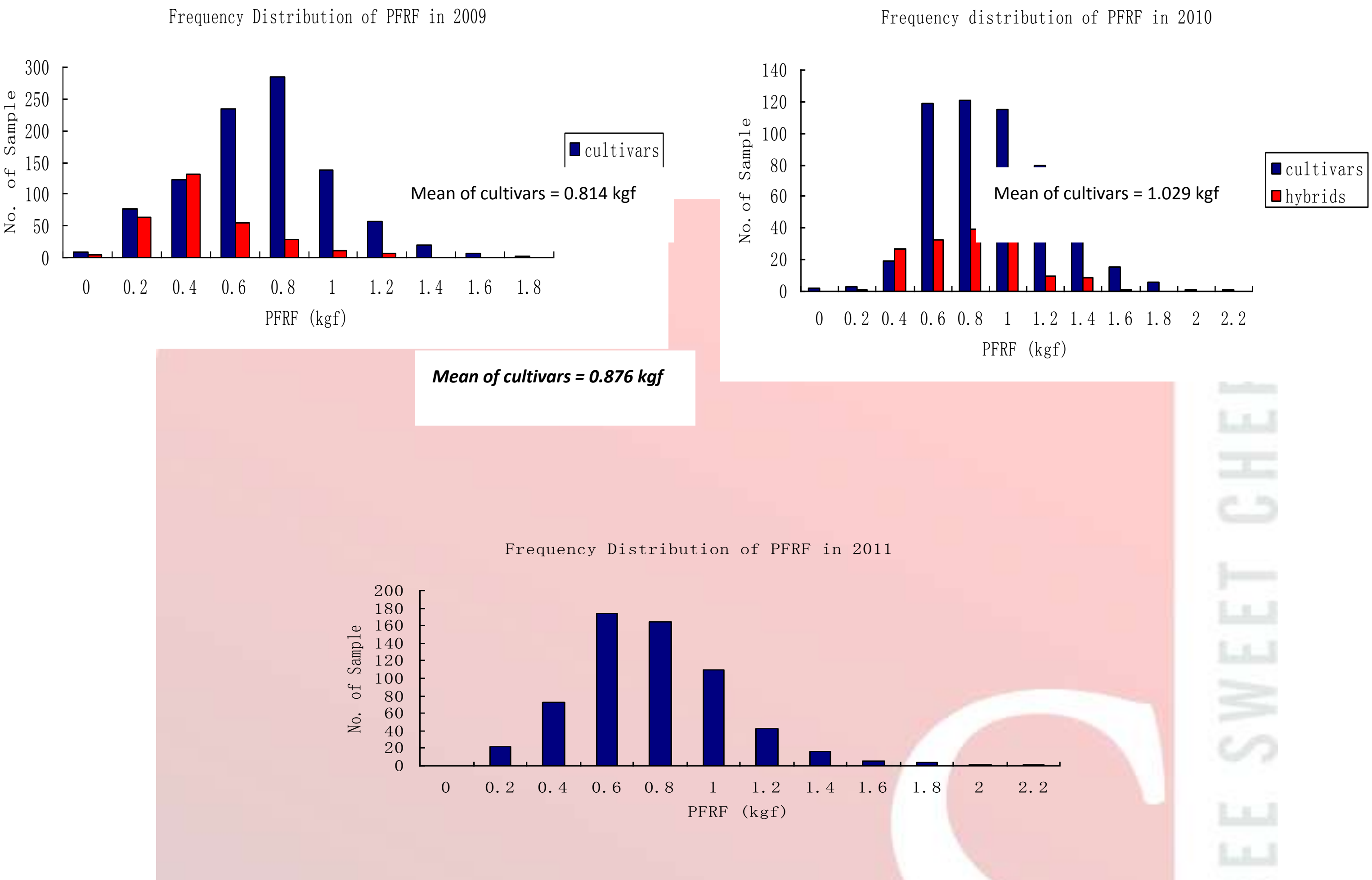
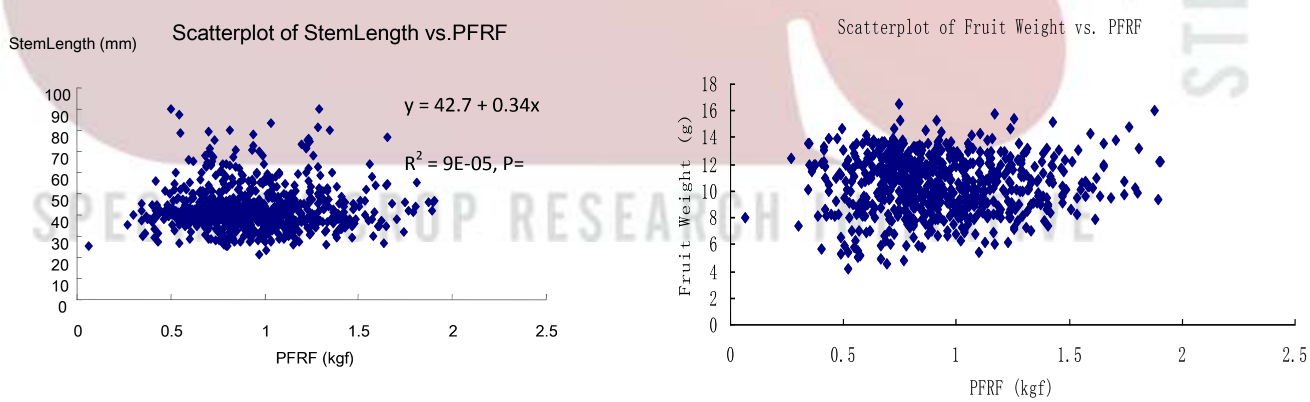


Fig. 1. Frequency distribution of PFRF in 2009, 2010 and 2011.



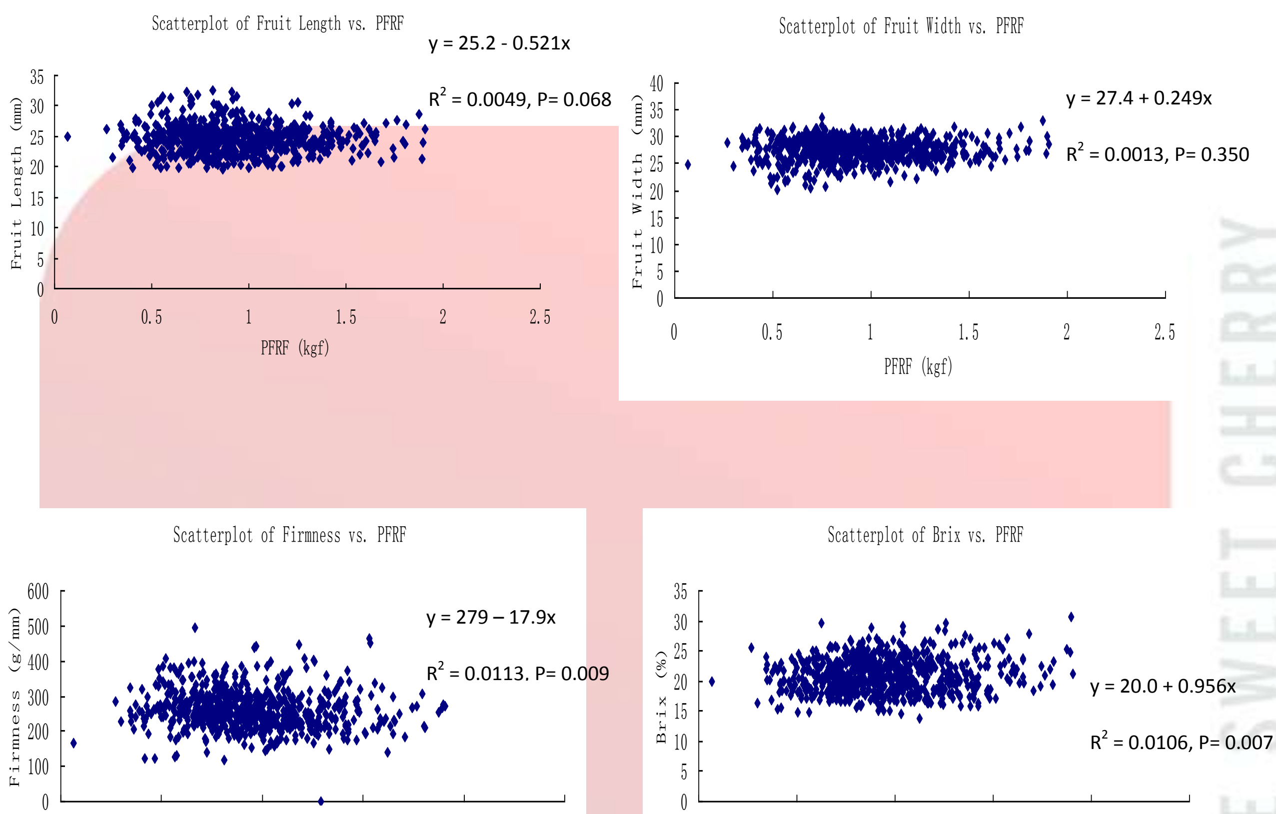
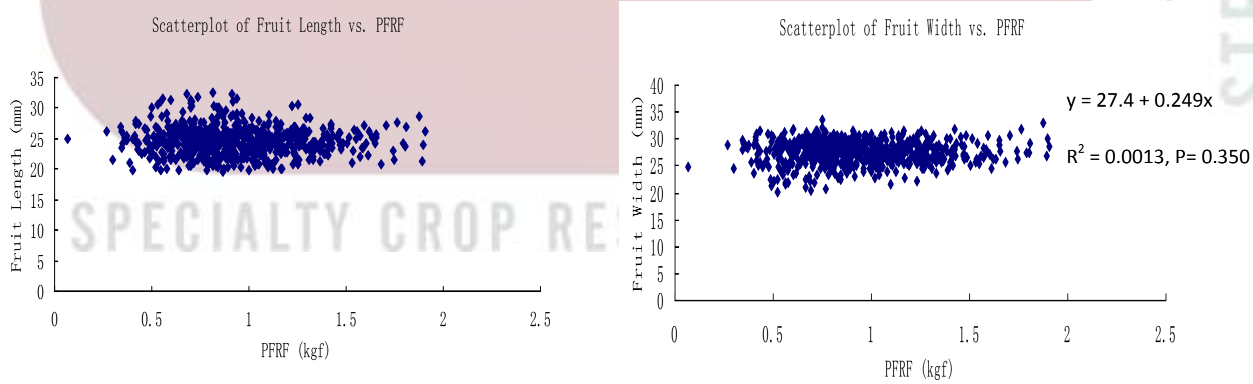


Fig 2. Correlations between PFRF and fruit quality attributes including stem length, fruit weight, fruit length, fruit width, firmness and SSC.

Fig. 3. Correlation between PFRF in 2010 and 2011.



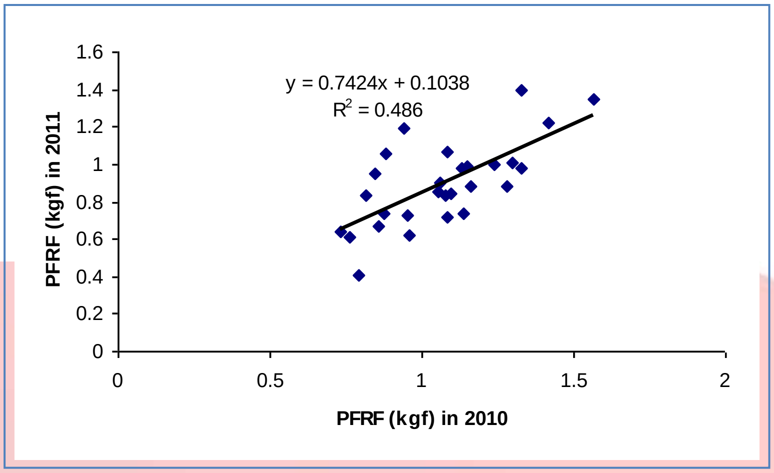


Fig. 3. Correlation between PFRF in 2010 and 2011.

Objective 2.2: Testing the established model of abscission in sweet cherry

Specific Objectives:

1. Testing the established model of abscission in sweet cherry
a. Identify cherry genes homologous to abscission related genes from other species
b. Test gene expression of these known abscission players at the cherry fruit-pedicel abscission zone via qRT-PCR

2. Identification of genetic networks associated with pedicel-fruit abscission in sweet cherry
a. Create a sample-specific, reference transcriptome
b. Quantitatively examine expression levels of these transcripts

Progress in 2011
During Year 2 (2010-2011) we are nearing completion of Objectives 1a and 1b on the samples collected in year 1. Objectives 2a and 2b are underway as samples have been prepared and are being processed to develop the reference transcriptome and the quantitative expression analysis.

Objective 1a: From the draft genome and transcriptome we have assembled for sweet cherry, we identified most sweet cherry abscission-related genes described earlier in other model plant species such as tomato and Arabidopsis. The proposed model of abscission as synthesized from our current understanding is presented in Figure 1. Primers for sweet cherry genes mentioned in the abscission model were designed and quantitative expression analyses were performed. These primers were successfully tested against cherry genomic DNA with each working as expected, validating the presence of these sequences in sweet cherry.

Ethylene ➡ ETR ➡ ERS ➡ HAE/HSL2 ➡ MKK4/5 ➡ MPK3/6 ➡ Abscission

Figure 1. Proposed abscission inducing pathway for sweet cherry. Adapted from Cho et al. 2008.

Objective 1b: Quantitative expression analyses using qRT-PCR are underway in Chelan, Bing and Skeena varieties. Preliminary analyses of seven of these genes in Bing treated with ethylene and no ethylene treatment have been completed and demonstrate that several of the genes have differential expression during development as shown in Figure 2 below. This clearly demonstrates that MKK4/5, MPK3/6 and Beta-galactosidase are differentially expressed in the sampled tissues and HAE/HSL2 is possibly involved in the abscission process in Bing. Comparing similar analyses from the auto-abscising Skeena and non-abscising Chelan will help solidify the role of these genes in abscission. We expect to identify alleles of the genes that are differentially expressed that will be useful for subsequence molecular marker development work.

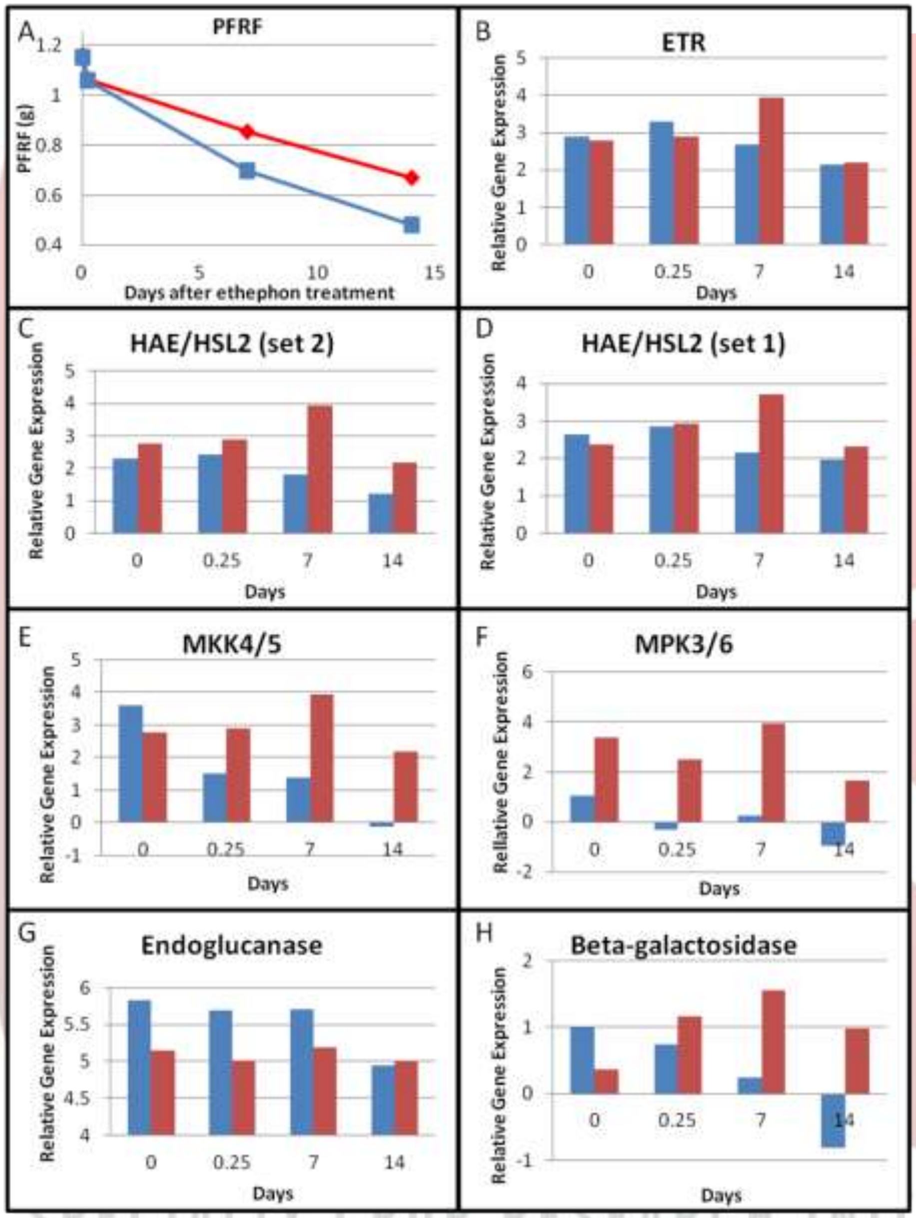


Figure 2. In all panels, control (no ethylene) is red and treatment (ethylene) is blue. A: shows the measure PFRF for the Bing trees during sample collection at days 0, 0.25, 7, and 14. B-H: The relative expression of each gene is shown for each sample time-point.

Objective 2: Tissues were ground and RNA was extracted and prepared for sequencing. Future assembly of these sequences will produce both the desired transcriptome and the quantitative data on the genes in the transcriptome.

We have also developed around 2200 high quality single nucleotide polymorphisms (SNPs), Bing and Rainier transcriptome sequences and demonstrated their use as molecular markers in identifying the allelic variation in 8 parental cultivars and 13 seedlings derived from one of the crosses (Koepke et al. *in press*). Since these were developed from transcriptomic sequences, they are gene-based molecular markers which will more directly be linked to traits of interest in sweet cherry breeding. A similar approach will be undertaken on the data generated from objective 2.

Planned work for Year 3

1. The remaining quantitative expression analyses using qRT-PCR will be completed.
2. RNA sequencing will be completed along with the required transcriptome analysis. We expect to find three classes of genes. First class of genes will be the ones that remain constant in their expression for all three varieties with or without the ethephon treatment. This set will be removed from our analysis. Second class of genes will be the ones that are either present or absent in their expression in between the three varieties. Lastly, third class of genes will be the ones that are differentially expressed between the three varieties under the two physiological conditions. We will examine the last two classes of genes and place an identity on these genes using available software and classify them into different biological processes like abscission, ethylene-related pathway, cell division etc. to name a few. Genes that are observed to be significantly different between the treatments and the three varieties will be further analyzed using quantitative reverse transcription PCR. Additionally, the RNA sequencing data will provide information on the genes we are currently testing via qRT-PCR including gene sequences that will be analyzed for differences. These sequences will be analyzed for nucleotide changes to develop molecular markers on abscission related genes as previously reported (Koepke et al. *in press*). Using C*is*SERS (Koepke and Sharpe et al, *in preparation*), a computational tool developed in our lab, we will analyze any sequence differences for different restriction sites to create molecular markers from this expression data to be used in the breeding program.

Objective 3: Improve labor efficiency and safety by developing mechanical and/or mechanical-assist harvest technologies, *Zhang, Picker Tech, LLC, Whiting, Seavert, Ampatzidis*

Year 2 Milestones: Improvements in shake and catch harvest assist systems completed and field-tested. Picker Technologies LLC tube transport and fruit handling system completed. Yield monitoring system for sweet cherries developed and tested. All systems field-tested for efficiency and impact on

Objective 3.1: Improve labor efficiency and safety by developing mechanical and/or mechanical assist harvest technologies.

CHERRY HARVEST PLATFORM:

A first harvest platform prototype was successfully demonstrated in the 2011 cherry harvest despite the fact that the start and duration of testing and observation was delayed due to our prototype fabricating resource being diverted to work on sprayers for powdery mildew. The WSU vibrating actuator with a frequency between 10 – 20 HZ was incorporated onto the remote control Cherry Harvest Platform (CHP). The remote control system enabled the operator to gain the best visual perspective for navigating the platform within the cherry tree canopy. An adjunct olive shaker was used to pull the branches into position because most of the test orchards have not been optimally trained and pruned for mechanical harvesting.

This prototype exhibits a conveyor-less 'louvered' catch frame which gently controlled the fall of the cherries and protected the fruit against significant impacts. The WSU vibrating actuator is located in the lower middle of the catch frames.

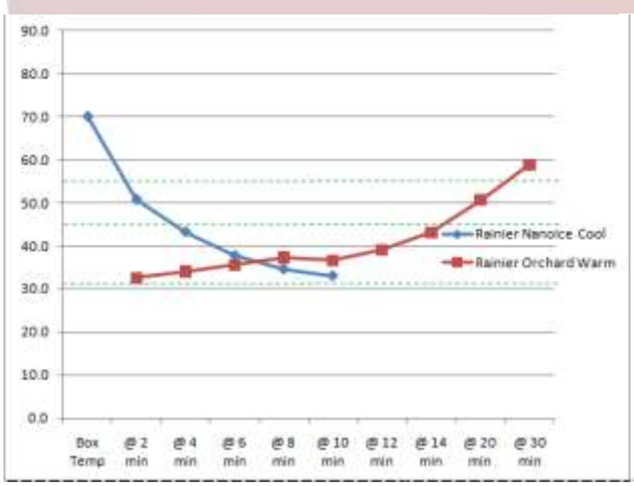
Picker Tech Mobile Platform Harvest Testing in July 2011

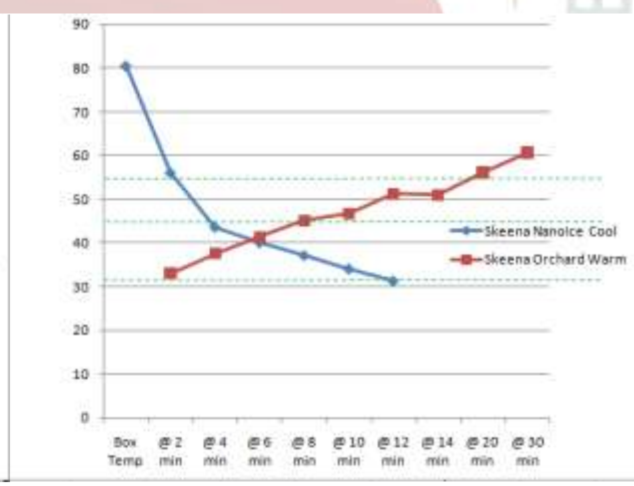
Mobile Platform Catching Frames

When using this initial prototype platform configuration to harvest Skeenas, little bruising was observed. Some drawbacks were the catch frame was probably twice as big as it needs to be and the large footprint made negotiation in the tree canopy sometimes challenging.

IN-FIELD COOLING:

A propriety chilling and ice generation system from Nano-Ice effectively chilled Rainiers and Skeenas from 80°F to under 55°F in less than 2 minutes; under 45°F in less than 4 minutes; and near 32°F in 10 minutes. The Cherries maintained a temperature between 50° and 55°F for at least 20 minutes after being removed from the Nano-Ice. Ambient air temperature was from 79°F to 88°F. See sample results below:





The NanoIce water-ice mixture was made from CaCl at a temperature of 29°F. Chilled ice/water mixture from the USDA approved NanoIce system can be generated in less than 3 minutes at a volume of approximately 4 gal/min. Initial testing suggests that possible chilling applications include, on the CHP mobile harvest platform, chilling dump station or direct application by the dispensing system into harvested totes or bins.

In-field cooling tests conducted near Prosser, WA in July 2011

TEST RESULTS:

Matt Whiting of WSU produced fruit quality and assessment results (8800 data points) from the following samples: orchard lot and 4 min chill/treat lot in NanoIce.

A. Color Grade was assessed on a scale from 1 to 5 for the ‘un-chilled’ and ‘chilled’ sample lots. The ‘chilled’ lots in NanoIce showed a 6% improvement and visual examination of the lots indicated a better quality for the chilled samples which translates into improved storability.
B. Firmness increased by 3.6%
C. Pedicel (stem) retention increased by 35%
D. FTA (Fruit Texture Analyzer) for firmness increased 5.4%
E. BRIX decreased by 6%
F. The pH did not appear to be affected between the two groups.

GROWER COLLABORATION:

Picker Technologies has formed a grower’s council consisting primarily of upper Columbia Basin growers. The aim of the grower’s council is to better understand and target needs and to help implement new technologies to address those needs. On several occasions during the harvest, the Cherry Growers Council, the Mathison family and WSU participants observed the function of the CHP. WSU has numerous pictures and videos of the demonstrations and related orchard configurations. For purposes of our testing and demonstration, the best canopy configuration was the Sweetheart orchard at the WSU Roza Experimenal Orchard in Prosser.

DEVELOPMENT NEXT STEPS:

1. Develop smaller shake and catch platform.
2. Incorporate ‘add on’ chilling wand over cherries
3. Investigate chilling effects of NanoIce made from Fruit and Vegetable wash-solution.
4. Investigate transport of a bulk package with Picker Tech’s Core Technology.

Objective 3.2: Evaluate effects of harvest technologies on labor efficiency and fruit quality.

Based on year one research results, we designed and built a new actuator which could provide repeating low intensity impacts. This actuator runs under a slider-crank mechanism which was adapted from the STIHL SP200 shaker and can provide up to 27 impacts per second. It has been tested in the UFO & V trellis architectures this year. For fruit catching devices, a novel buffering apparatus was assembled onto the existing USDA harvester. The performance of this buffer installation was evaluated during harvest. In addition, the concept of hydraulic-driven hand-held shaker was developed and demonstrated to the public. The specific goal of year 2's study was to define each concept and make improvements upon those concepts.

1. New developed actuator for cherry harvesting

(a) (b)

Figure 1. New actuator developed by CPAAS-WSU: (a) on-site demo; (b) in-field trial

2. Periodic impact on V trellis and UFO cherry tree

(a) (b) (c)

Figure 2. Periodic impact test of new-developed actuator: (a) new actuator with tractor-towed bench; (b) sensors on the tree; (c) data acquisition system

Periodic impact tests were carried out on V trellis and UFO cherry trees. The objectives of this test were to experimentally evaluate the newly developed actuator for the mechanical cherry harvester, observe the response of cherry trees to periodic impact, and choose the appropriate working parameters for periodic impact for the actuator. The test results reveal that trees vibrated with high displacement under low frequency impact and vibrated with high acceleration under high frequency impact. Low resonant frequency (10 Hz) impact resulted in high vibration on the excited branch but low vibration on the neighbouring branches. High resonant frequency (14-16 Hz) impact resulted in whole tree vibration with high acceleration.

3. Energy evaluation of excitation modes

In order to identify the energy consumption and energy distribution in the tree by the new harvesting shaker, three different working conditions were conducted to excite the selected V-trellis Bing cherry tree under different excitation frequencies. The results show that, clamping needs highest energy consumption, also the clearance between shaking head and impacting point effects energy consumption, smaller clearance gets higher energy consumption. The results also show that excitation branch can get bigger maximum kinetics than non-excitation branches, and clamping gets larger maximum kinetics in non-excitation branches than impacting condition.

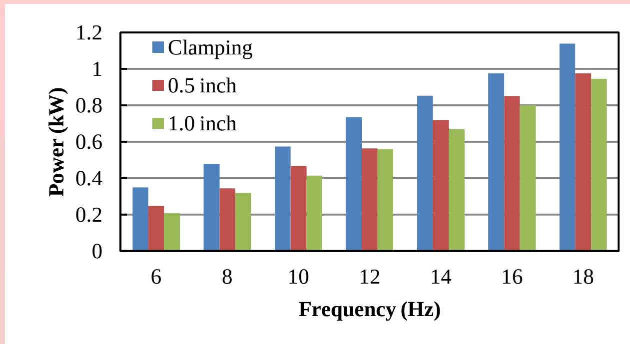
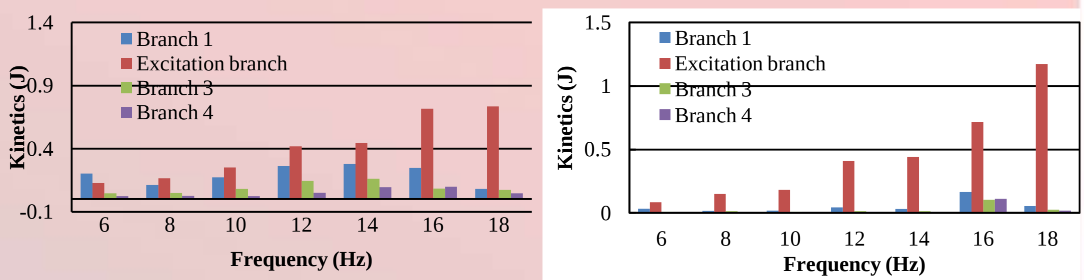


Figure 3. Mean value of hydraulic motor input power under different shaking frequency and different working condition in one period time, which can represent the energy consumption of the whole system



(a) (b)

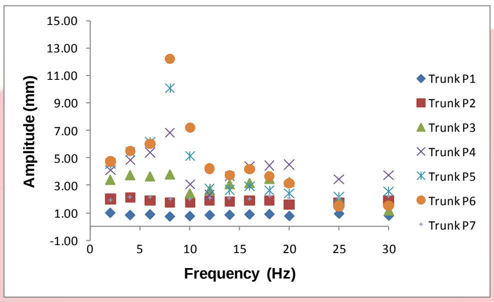
Figure 4. Maximum kinetic energy in each branch of excitation side under different frequency and different working condition: (a) clamping condition; (b) Impacting condition with 1.0 inch clearance

4. Frequency response test on central leader tree

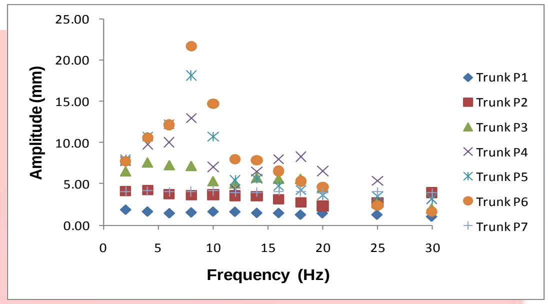
This study was conducted to investigate the dynamic response of woody structure under forced excitation.

Figure 5. Frequency response test on a central leader tree

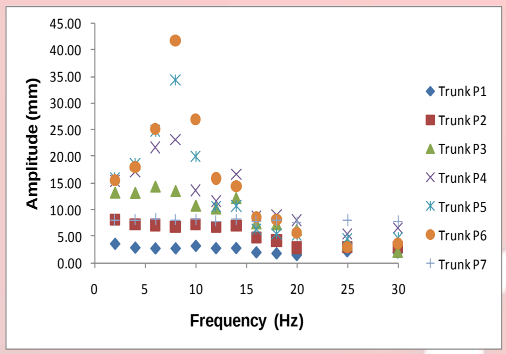
From preliminary results, we found that the resonant frequency of tested woody structure was 8 Hz in the tested range from 2 Hz to 30 Hz (figure 2). And the displacement of measured position increased as the excitation amplitude increasing. The largest displacement was found near the top of the trunk. Further study will be conducted to analyze the effect of tree growth pattern on the dynamic response of tested woody structure, especially the branch orientation and height.



(a)



(b)



(c)

Figure 6. Trunk displacement under forced excitation with variable frequency and amplitude: (a) 1mm excitation amplitude; (b) 2mm excitation amplitude; (c) 4mm excitation amplitude

5. Harvest efficiency test by newly developed actuator

The objectives of these tests were to evaluate and compare harvest efficiency of the WSU harvester in different tree architectures, different maturities, different harvesting times, and different frequencies. Before and after each harvest test, the pedicel-fruit retention force (PFRF) was sampled on each tree. The sampled and harvested cherries were sent for laboratory quality assessment. This data is still under analysis and will be provided in the coming year.

Table 1 Statistics results of cherry harvesting under different impact time

	Impact time /s	Harvest percentage	w/ stem : w/o stem	PFRF /N		Weight /g		Brix		Firmness	
				Prior	After	Prior	After	Prior	After	Prior	After
Tree 1	5	30.1%	3:1	8.72	8.73	8.16	7.73	14.7	15.1	342.9	332.1
Tree 2	10	41.0%	3.7:1	8.33	8.46	8.92	8.46	14.5	14.2	340.2	325.5
Tree 3	15	32.0%	2.5:1	9.39	7.62	8.29	8.17	15.8	16.3	371.9	295.6

6. Novel buffering apparatus experiment

A buffering apparatus was built to test its capability of reducing fruit bump and increasing fruit recovery rate. The buffering apparatus was assembled on the USDA harvester which could move into the V trellis cherry orchard. The buffer was made of several plastic strips which had four sets of angle layout (30°, 45°, 60°, and 90°). The angle is between the plastic strips and the catching frame. Each angle layout was tested on three trees of Skeena cultivar. Three more trees were harvested without the buffering apparatus. During the test, USDA harvester was driven to stop beside the target tree. Operator ran a hand-held shaker to release fruit from the tree. The fruit caught by the catching frame and bumping out of the frame were collected and weighed respectively. The damage to fruit during harvest was assessed and classified into 'Good', 'Tear', and 'Bruise' conditions.

(a) (b)

Figure 7. Harvesting test using buffering apparatus

Damage assessment results are listed below. Based on the results, the buffering apparatus mounted on the catching frame has positive effect on catching fruit and avoiding damage. In the chosen angle layout, '60°' test has the best result which collected the most fruit and caused the least damage to the fruit.

Table 2 Results of buffering apparatus experiment

Buffering angle	60°	90°	30°	45°	Control
Lost fruit	6.9%	9.5%	12.9%	10.0%	7.4%
Good fruit	90.1%	89.8%	76.4%	88.0%	85.6%
Torn fruit	1.6%	9.6%	10.5%	6.0%	5.2%
Bruised fruit	8.2%	0.6%	13.1%	6.0%	9.2%

CPAAS-WSU Year 3 Mechanical Cherry Harvester Plans

1) Design a self-propelled harvesting platform.
2) Develop a continuous harvesting system.
3) Test the system to find an optimal working condition.

Objective 3.4: Develop a yield monitoring system for mechanical assisted or fully mechanized sweet cherry harvest

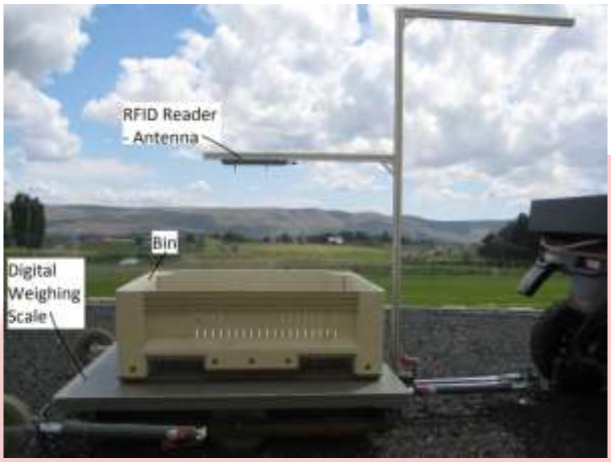


Figure 1. Prototype system for monitoring picker efficiency.

There is great interest in improving harvest efficiency and traceability in specialty crop production. These crops are characterized generally by high costs of production, heavy dependence upon manual labor, and high crop value. Harvest costs for sweet cherries (Prunus avium L.), for example, account for approximately 60% of total cost of production. This research, which is part of the greater SCRI project, is studying the role of key harvest efficiency factors in sweet cherries. This will help us to better understand the relative importance of harvest efficiency factors and to develop more efficient harvest systems. The goals of this research are:

- Modeling Activities during Manual Fruit Harvesting.
- Modeling Mechanical Harvester Work Flow.
- System for Monitoring Picker Efficiency.
- System for Monitoring Harvester Efficiency.
- Management and Optimization of Harvest Operations.

Figure 2. Picker's datalogger records and displays weight of harvested fruit.

Figure 3. RFID Wristbands

The system was utilized multiple times during the 2011 harvest season. Testing was conducted throughout the Yakima Valley and Columbia Basin, along with The Dalles, Oregon area. A real-time labor monitoring system with the ability to track and record individual picker efficiency was developed. This system utilizes existing commercial harvest equipment and integrates a digital weighing scale, RFID reader, computational unit and wearable datalogger. A portable datalogger housed in a protective enclosure is attached to the picker's belt (Fig. 1).The RFID

reader, the digital scale and the computational unit are assembled on a common chassis as a portable unit (Fig. 2). As fruit is dumped into a standard collection bin, the system can read simultaneously a picker's ID (RFID tag) and measure the weight of fruit (Fig. 3). The weight value can be transmitted wirelessly to the picker's datalogger which records and displays, via LCD, the incremental and total weight of harvested fruit (Fig. 1).
Table 1 presents the harvest data in two different orchards (different training systems). The same crew harvested the two orchards to calculate how the tree architecture influences the picker's efficiency.

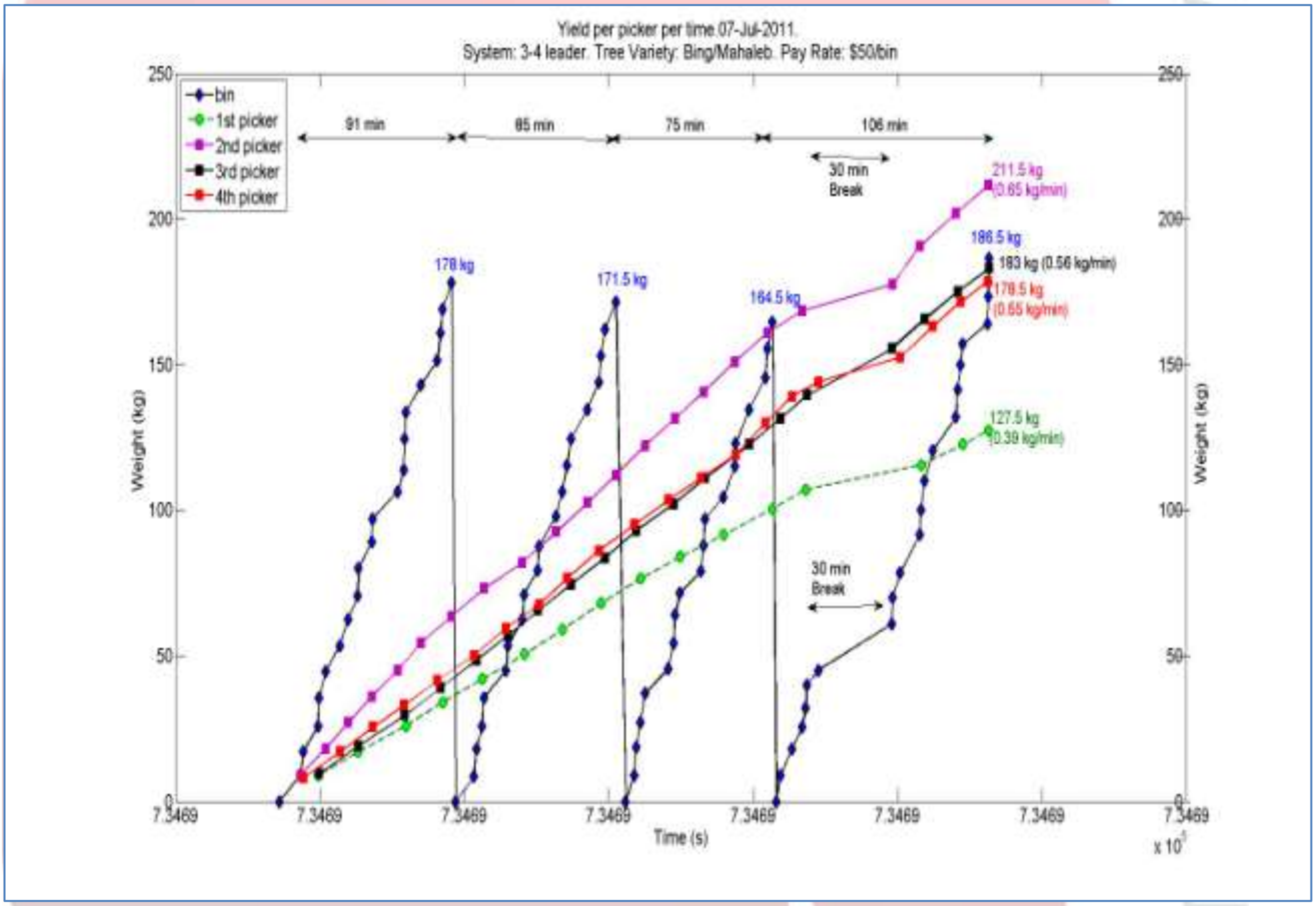


Figure 4. Example of cherry harvest rate data

Table 1. Harvest data in two different training systems

Picker			1st	2nd	3rd	4th	Mean
Sex			F	F	F	F	*F*
Age			17	42	40	43	*35.5*
Experience (years)			7	15	5	7	*8.5*
1st Orchard							
Experiment Data		**Harvest Data**					
Date	7/7/2011	**Harvest rate (kg/min)**	0.39	0.65	0.56	0.55	*0.54 ± 0.11*
Cultivar	Bing/Mahaleb						
Architecture	3-4 leader	**Picking cost ($)**	36.58 (127.50 kg)	60.41 (211.50 kg)	52.00 (183.00 kg)	51.01 (178.50 kg)	*50.00 ± 9.89 (175.13 ± 9.38 kg)*
Pay rate	$50/bin	**Number of harvested buckets**	16	22	20	21	*19.75 ± 2.63*
Average fruit weight (kg/bin)	175.13 ± 9.38	**Range in fruit weight per bucket (kg)**	6.50 - 9.00	7.50 - 13.00	8.00 - 11.50	5.00 - 11.00	*5.00 - 13.00*
Number of harvested bins	4	**Mean fruit weight per bucket (kg)**	8.17 ± 0.77	9.61 ± 1.09	9.21 ± 0.87	8.50 ± 1.23	*8.88 ± 1.23*
2nd Orchard							
Experiment Data		**Harvest Data**					
Date	7/9/2011	**Harvest rate (kg/min)**	0.79	1.06	0.64	0.76	*0.81 ± 0.18*
Cultivar	Cowiche						
Architecture	UFO	**Picking cost ($)**	65.60 (265.50 kg)	87.61 (356.00 kg)	63.68 (257.00 kg)	63.11 (255.50 kg)	*70.00 ± 11.79 (162.00 ± 10.99 kg)*
Pay rate	$40/bin	**Number of harvested buckets**	30	36	26	28	*30 ± 4.32*
Average fruit weight (kg/bin)	162.00 ± 10.99	**Range in fruit weight per bucket (kg)**	7.00 - 11.00	9.00 - 11.00	8.50 - 11.50	8.00 - 10.50	*7.00 - 11.50*
Number of harvested bins	7	**Mean fruit weight per bucket (kg)**	8.85 ± 0.90	9.89 ± 0.56	10.02 ± 0.67	9.33 ± 0.62	*9.58 ± 0.79*

Objective 4. *Extend shelf-life/consumer appeal of sweet cherries.* *Almenar, Harte, Ross, Whiting*

Year 2 Milestones – completed study of effects of modified atmosphere packaging on fruit quality and shelf life; completed study of effects of harvest technology on fruit quality and shelf-life; investigated effect of time of harvest on quality and storability; developed outreach materials.

Objective 4.1: Develop novel, sustainable packaging that extends shelf-life and reduces environmental footprint

Objective 4.2: Evaluate effects of harvest technology on fruit shelf-life

Progress made in Year 2:

(1) Based on the results of the research conducted in Year 1, changes in the packaging system has been made. A bio-based container with two microperforations has been shown to be effective in prolonging the shelf life of fresh, sweet, stem-free and stem-on cherries when stored at low temperature. A packaging concept to respond to changes of temperature throughout the supply chain is being developed to fulfill current needs.
(2) Thirty individuals have been selected and trained to participate in discrimination tests In addition; consumer acceptance sensory tests have been designed and conducted.
(3) Dissemination of results.

Procedures used in Year 2:

(1) Package testing: Various experiments have been conducted to assess the effect of number of microperforations (CO_2/O_2 atmospheres), gas flushing and temperature changes, on the shelf life of fresh sweet cherries. Two different packaging systems have been compared: (1) a rigid tray closed with microperforated lidding material, both made from a bio-based plastic (poly(lactic acid) (PLA)) and (2) the current commercial package for sweet cherries, a macroperforated flexible bag made from a petroleum-based plastic (polyethylene (PE)). Primary packages have been evaluated with or without secondary packaging (corrugated box). Two different temperatures (3 and 23 ºC (fixed or combined)) have been studied. The experiments are summarized below:

a) *Experiment 1*: *Effect of gas flushing and temperature change on cherry shelf life*. Stem-free Skeena at different ripening stages and without (older fruit) or with stem (younger fruit) were packaged in containers with 2 microperforations (gas flushed (15%CO_2/5%O_2) or not) and in macroperforated bags. All packages were stored at 3 ºC and 65% RH for 2 weeks and subsequently moved to room temperature. Physico-chemical (weight loss, pH, titratable acidity, total soluble solids, firmness, color, and oxygen and carbon dioxide levels) and microbial evaluations were carried out. Some cherries were liquid nitrogen frozen for testing of anthocyanins and flavors in fall and winter. Three packages (repetitions) of each group (type of package, cherry type and day of analysis) were analyzed.

b) *Experiment 2. Effect of number of microperforations and temperature change on cherry shelf life*. Effect of stem-on and stem-free Skeena cherries at the same ripening stage were packaged in containers with different number of microperforations and in macroperforated bags (controls). Packages were initially stored at 3 ºC and 65% RH for 48 hours and subsequently, at 23 ºC and 50% RH for another 48 hours. The same physico-chemical and microbiological evaluations, and repetitions as described above were carried out. Again, some cherries were liquid nitrogen frozen for testing of anthocyanins and flavors in fall and winter.

c) *Experiment 3. A new packaging approach to overcome temperature changes across supply chain*. Stem-on and stem-free Skeena cherries were packaged in a new packaging concept to respond to changes of temperature through the supply chain. Packages were stored under different conditions simulating domestic and international supply chain. To achieve a more realistic approach, secondary packaging (liners and corrugated boxes) was used. This experiment is still in progress.

(2) Sensory testing: Two types of sensory evaluations have been conducted to provide insights into consumer preferences and acceptance for cherries packaged in different containers and for the containers per se. Triangle tests provided feedback from trained panelists over differences among cherry samples stored in different containers. Rating tests (using a hedonic scale) were used to identify consumer acceptance of fresh cherries in different containers and ranking tests to measure consumer appeal for the developed packages.

a) Trained panel: Following the IRB guidelines regarding experiments with human subjects, 40 adult volunteers from the local community of East Lansing, MI, were screened for their ability to identify different samples of fresh, sweet cherries. Participants who were odor- and color- blind were excluded from this study and only the ones with the highest scores of correct answers were considered for training. Panelists were trained to identify differences between samples, taking into consideration attributes like color, odor, flavor and texture of fresh, sweet cherries over a period of 14 days.

b) Consumer acceptance panel: Adult fresh cherry consumers were recruited from the local community of East Lansing, MI, with flyers, email announcements and social network events according to the IRB guidelines regarding experiments with human subjects, to participate in a series of sensory tests with fresh, sweet cherries. More than 75 participants have currently participated and are scheduled to participate in each of the consumer acceptance tests.

Research findings of Year 2 (up to date):

- The shelf life of packaged stem free and stem on cherries was notably affected by the number of microperforations, packaging design, and temperature changes.
- The replacement of the atmospheric air with a gas mixture did not affect the quality characteristics of the packaged fresh, sweet cherries based on the similar results found for headspace composition (***Figure 1***), firmness (***Figure 2a***), color (***Figure 2b***), SSC, microbial growth and others in all containers during storage.

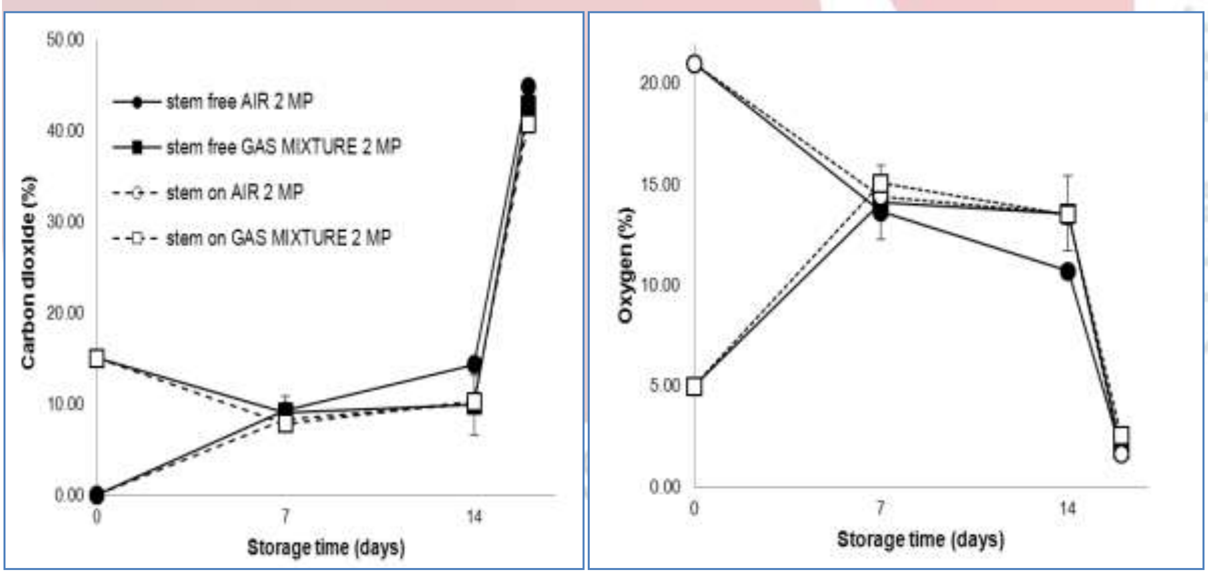


Figure 1. *Evolution of the oxygen and carbon dioxide concentrations in the headspace of the bio-based packages (2 microperforations) stored for 14 days at 3 ºC and 65% RH and subsequently placed at room temperature.*

- Bio-based containers with two microperforations were shown to be effective in prolonging the shelf life of fresh, sweet, stem-free and stem-on cherries when stored at low temperatures based on a better maintenance of firmness (***Figure 2a***), color (***Figure 2b***), SSC, weight, and other quality parameters in the cherries in comparison to those in current commercial packages. However, no significant differences (P<0.05) were identified by a trained panel (N=30).

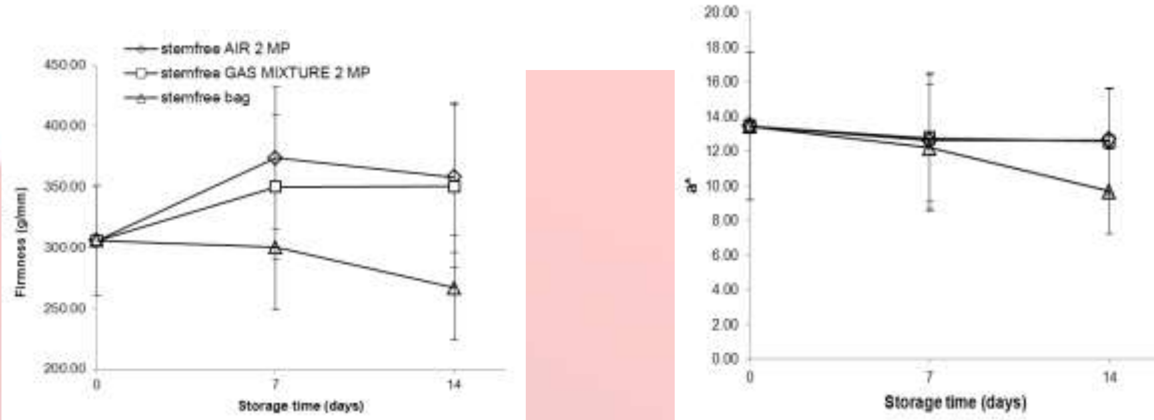
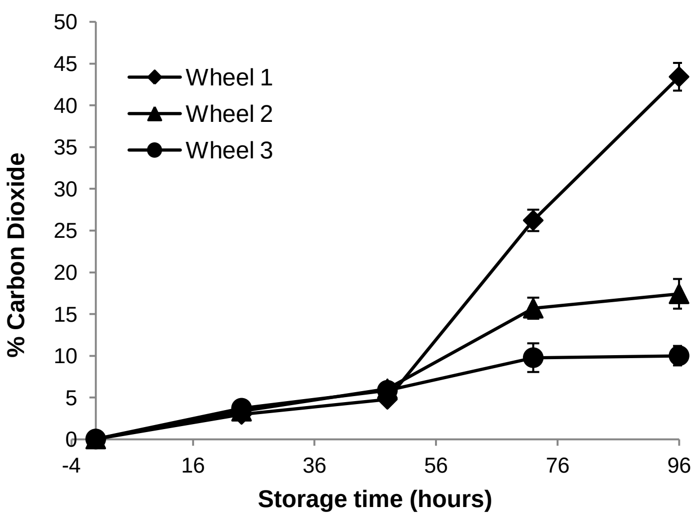


Figure 2. *Evolution of the firmness (a) and red color (a*) (b) of cherries in bio-based packages (2 microperforations) and petroleum- based bags and stored for 14 days at 3 ºC and 65% RH.*

- Although cherries in the proposed bio-based containers with 2 microperforations successfully maintained the quality of cherries during storage at 3 ºC, important changes in gas concentrations were noticed when the containers were moved to 23 ºC (***Figure 1***).
- Different gas mixtures were generated inside the containers by using wheels differing in the number of micro needles. The micro needles providing the best gas composition for the storage of cherries were selected and used to develop the containers evaluated in experiment 3 (***Figure 3***).



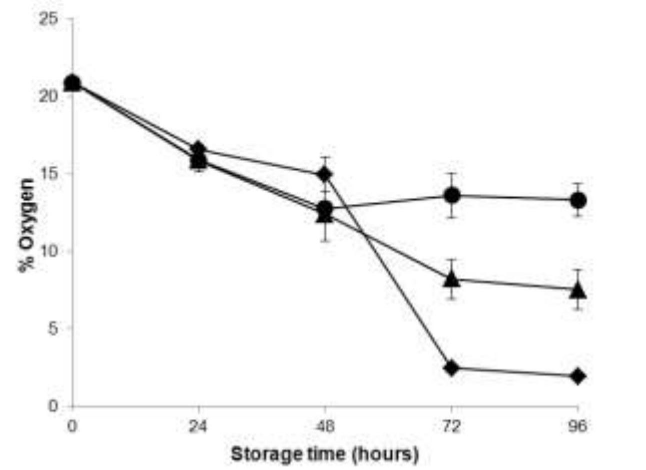


Figure 3. *Evolution of the oxygen and carbon dioxide concentrations in the headspace of the bio-based packages stored 48 hours at 3 ºC and 65% RH and consecutively another 48 hours at 23 ºC and 50% RH.*

Future work

- Collection, analysis and interpretation of physico-chemical, microbial and sensory data from studies in progress (experiment 3 and frozen fruit).
- Optimization of an innovative packaging concept to respond to changes of temperature throughout the supply chain. Physico-chemical, microbiological and sensory evaluations will be performed for the evaluation of the quality of the cherries in the new containers.

Objective 5. *Develop markets for stem-free sweet cherries* , *Ross, Harte, Almenar, Whiting*

Year 2 Milestones – complete consumers' perception studies (role of pedicel); conduct test marketing with retail partners; develop outreach material.

Skeena cherries harvested at WSU IAREC and utilized for consumer acceptance testing in 2011

Consumer acceptance of Cherries cv. Skeena

Objective: To determine the impact of the cherry stem on acceptance of cherries by consumers. To evaluate the effect of ethephon treatment on consumer acceptance of cherries.

Materials & Methods

Cherries: "Skeena" sweet cherries were received from Prosser, WA, approx. 500 of each treatment.

For the July 15 panel, the treatments were as follow:

1. Ethephon – treated stem-free
2. Untreated with stems
3. Untreated stem-free

For the July 29 panel, the treatments were:

1. Untreated with stems
2. Untreated without stems
3. Untreated without stems (in duplicate)

For both sensory panels, cherries were received one day prior (July 14 and July 28). Cherries were washed and sorted, with approximately 400 cherries of each treatment separated. Cherries were kept at 7 ºC overnight. The following day (the day of the sensory panel), cherries were removed from the cold room 1 hour prior to the panel and allowed to equilibrate at room temperature.

Sensory evaluation:

The project was approved by the Washington State University Institutional Review Board and all participants signed a consent form. Panelists were required to be at least 18 years old. The sensory panel was composed of untrained consumers who were recruited from the Washington State University community. Consumers were asked some demographic questions regarding gender, age and frequency of consumption of cherries during fresh cherry season before the sample evaluation. On each of the two panel days, 100 consumers evaluated the cherries.

Two cherries of each treatment were placed in 4 oz. soufflé in duplicate for evaluation of appearance and flavor/texture and labeled with two different 3-digit codes for the same treatment. Thus, panelists had six flights of 2 cherries, with each treatment evaluated for appearance and flavor/texture.

For appearance, samples were evaluated under white light and under red light for flavor/texture in booths equipped with a computerized system and sensory software (Compusense®five software (release 5.2), Guelph. Panelists were asked to rinse their palates with Milli-Q water and unsalted crackers between samples during the flavor/texture evaluation.

***Consumer acceptance**:*

Consumer acceptance was determined using a 7-point hedonic scale anchored with dislike very much (1) and like very much (7) of each attribute. The panelists were asked to indicate how much they like each sample based on the following attributes:

Appearance: overall appearance, fruit color, size and shape

Flavor/Texture: overall appearance, juiciness, firmness, cherry flavor

Consumers were also asked to evaluate the convenience of each sample using a 5-point hedonic scale anchored with extremely inconvenient (1) and extremely convenient (5).

In addition, for each cherry, two sets of Willingness to pay questions were included. The consumers were asked about their willingness to pay according to the following:

- The first set ($2.99-3.99-2.49) was sent to panelist numbers 1-27 and from 52-78 for appearance; and panelist numbers 28-51 and 79 -100 for flavor/texture.

- The second set ($2.99-3.49-1.99) was sent to panelist numbers 1-27 and from 52-78 for flavor; and panelist numbers 28-51 and 79 -100 for appearance.

Following the evaluation of the samples for appearance and flavor/texture, panelists were asked the following questions and forced to choice between Cherry with no stem (stem free) and with stem. The specific questions were:

- Overall, which cherry is more convenient to eat?
- Which cherry is less messy to eat?

Data were collected using Compusense®five software (release 5.2, Guelph, ON) and analyzed for significant differences using two-way analysis of variances (ANOVA) and mean separation via Tukey's HSD multiple comparisons using XLSTAT (version 2009.2; Addinsoft, Paris, France) at the $p \leq 0.05$ confidence level.

Results

Over the two panel days, consumer gender was in the ratio of 47 % male and 53% female. 63.5% of the panelists were in the age range of 18-34 years old. 40.5% reported that they consume cherries during fresh cherry season once to several times per week and 39.5% once to a few times per month.

Day 0 Cherries

Table 1 show the ANOVA results for the appearance and flavor/texture sensory attributes of "Skeena" sweet cherries at Day 0 (July 15). These results show significant differences in all attributes of appearance.

For all appearance attributes, the untreated cherries with stems were the most accepted (**Table 2**). Specifically, for overall appearance, stem-free cherries (either treated or not), were both significantly lower compared to the cherry with the stem (untreated). Fruit color and size were significantly higher for the untreated cherries (with or without stems) compared to the treated cherry. Finally for shape, the untreated with stems was the most accepted, along with stem-free cherry (treated). Ethepon treatment did not significantly impact the consumer acceptance of the cherries.

For willingness to purchase, no significant differences were observed between treatments **Table 3** shows the results for the first set of 50 consumers while **Table 4** shows the results for the second set of 50 consumers.

Day 14 Cherries

At day 14 of storage, significant differences were found between the cherries for all appearance attributes (**Table 5**). This was the same results as seen at Day 0. As we did not received ethephon-treated cherries, we were not able to examine4 the effect of ethephon on the acceptance of cherries following storage.

Specific attributes within appearance differed between the stem-free and the stemmed cherries (**Table 6**). The stemmed cherries were more accepted overall by the consumers compared to the stem-free cherries. In addition, the stemmed cherries were more accepted for the specific appearance attributes of fruit colour, size and shape compared to the stem-free cherries. Compared to the cherries evaluated at Day 0, these cherries were not as liked by the consumers.

No significant differences in willingness to purchase stemmed vs. stem-free cherries were found.

Convenience

Over both panel days, consumers found the cherries with stems more convenient and "less messy to eat" than cherries without stems. Over both panels, regarding cherry convenience, 70.5% of the panelists selected the cherry with stem as more convenient to eat. 60% of the panelists selected the cherry with stem as less messy to eat.

On both Day 0 and 14, the cherries with stems were rated as significantly more convenient than the stem-free cherries ($p<0.05$).

Conclusions

Significant differences in overall appearance acceptance, as well as acceptance of fruit size, color and shape were observed between the stemmed and stem-free cherries. Based on these appearance attributes, stemmed cherries were more accepted than stem-free cherries ($p<05$).

No significant differences in other sensory attributes (flavor, taste and texture) were observed between stemmed and stem-free cherries.

Ethephon treatment on the cherries did not significantly impact consumer acceptance of any sensory attributes.

No significant differences in willingness to purchase were found among the cherry treatments.

Consumers found stemmed cherries to be more convenient and less messy to eat compared to stem-free cherries.

Objective 6. *Analyze system profitability, market potential, and develop economic models for outreach and adoption*, *Seavert*

Year 2 Milestones – Continue collecting field data on harvest efficiency of technologies; verification that economic and financial information are representative of growers in each state; publish cost of production budgets; develop AgProfitTM and AgFinanceTM budget files and schedule and advertise grower workshops

Year 2 Goals

Approach	Activities
1. Develop interactive economic models that validate the potential profitability and feasibility of mechanical harvesting of sweet cherries, by using the AgProfit™ software program. to determine the profitability of mechanical harvesting.	Verify with growers of each farm size that economic and financial information are representative of growers in in WA, OR, CA and MI.
	Cost of establishing and producing sweet cherry publications
2. Establish baseline farm sizes and financial criteria representative of the Northwest sweet cherry industry.	a) Develop a case farm for each of three farm sizes – small, medium and large – and their costs to produce sweet cherries in WA, OR, CA and MI as well as the financial information to construct balance sheets for each farm size.
	b) Use the financial information from each farm size in AgFinance™ software program to determine the feasibility of mechanical harvesting by farm size.
3. AgTools™ workshops	a) Develop AgProfit™ and AgFinance™ budget files
	b) Schedule and advertise grower workshops.

Notable results:

- Developed AgProfit™ budget files to estimate a Grower's Financial Indifference Value (gFIV) mechanically harvested stem-free sweet cherries.
- Convened growers in The Dalles to update the costs of establishing & producing sweet cherries in Wasco County.
- With the help of these growers, developed a case study representing a typical 200-acre sweet cherry orchard in The Dalles Irrigation District.
- Met with area lenders to develop typical financial ratios and performance measures critical for long-term liquidity, solvency and profitability, which include the current ratio, working capital, debt-to-asset ratio, net Income, and term debt coverage ratio.
- Developed a case study that will be used in orchard renewal workshops.
- The development of the AgTools website allows growers, processors, packers, and technology providers access to risk management tools. These tools can assess the profitability and feasibility of mechanical harvesting sweet cherries.
- At the annual International Fruit Tree Association Annual meeting in Kennewick, Washington in February 2010, 150 participants were asked three specific questions about orchard renewal and technology adoption: 1) Do you have an orchard renewal plan? If so, at what rate do you annually renew acreage? 2) How are you financing orchard renewal and/or expansion? and 3) What is/was the top three barriers to adopting an orchard platform?
- Of the 115 responses to having an orchard renewal plan, 33 percent said they did not have an orchard renewal plan while 49 percent said they replace six percent or less of their orchards each year. Seventy-five percent of 118 respondents said they finance orchard renewal from annual cash flow or short-term debt. Eighty-five respondents said the top barriers to adopting an orchard platform were the cost of the platform, orchard architecture, and orchard terrain, respectively.
- It was observed by the meeting hosts that these participants represented the top tier tree fruit managers from around the world, which infers that the results were weighted towards the better managers in the industry. The results were surprising, however, in that nearly 80 percent of participants had no plans to replace or did not replace orchards in a timely manner. Additionally, the majority of growers who finance most orchard renewal with cash from annual operating could jeopardize their business' cash flows if inclement weather affected crop yields and prices. These factors could affect the business' financial liquidity, solvency and profitability.
- To increase the rate of technology adoption we need to have a better understanding of the reasons growers do not borrow funds to renew orchards and if AgTools™ could be a tool for them to assess their current business practices and management decisions.

Project Outreach & Communications

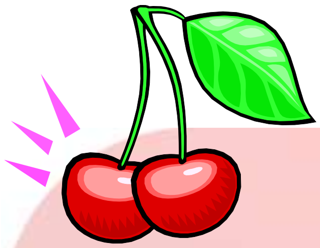


Figure 1 SCRI Annual Meeting November 2010, Hood River, OR

Picker Tech growers council demonstration

Eva Almenar listens to industry during packing shed tour

Our overall goal is to have every professional in the U.S. sweet cherry value chain to be familiar with the project's progress or to at least have tools to access the information. Our outreach plan is integral and flexible and has continued to build upon the communication mediums established in year one.

- over 30 research and outreach presentations were given in year 2
- industry information sessions in Oregon and Washington
- Technology field demonstrations
- Tours of grower-collaborator orchards
- Radio interviews
- monthly e-newsletter sent to subscribing members
- dynamic website presence including:
    - Research results
    - Photo journals
    - Videos of presentations, demonstrations
    - Outreach materials
- publications in popular press and extension bulletins
- Social Media outreach including a Facebook Page, Twitter, Youtube, Flickr and Vimeo accounts.

Each PD has been responsible for summarizing research into effective formats for outreach with support from the project coordinate/communications specialist. We recognize also that our audience is not growers only. To achieve our project's goals we need to inform and educate stakeholders in the entire value chain, from nurserymen to produce buyers to the public in general .

2011 Cherry Field Day and Collaborative Orchard Tours featuring the SCRI project

STEM-FREE SWEET CHERRY

SPECIALTY CROP RESEARCH INITIATIVE