FINAL PROJECT REPORT

Project Title: New programs to increase fruit size and improve harvest quality

PI: Todd Einhorn
Organization: OSU-MCAREC
Telephone: 541-386-2030 ext.216
Email: todd.einhorn@oregonstate.edu
Address: 3005 Experiment Station Dr.
Address 2:
City/State/Zip: Hood River, OR 97031

Co-PI (2): David Gibeaut
Organization: OSU-MCAREC
Telephone: 541-386-2030 ext.225
Email: david.gibeaut@oregonstate.edu
Address: 3005 Experiment Station Dr.
Address 2:
City/State/Zip: Hood River, OR 97031

Co-PI (3): Lynn Long
Organization: OSU-Wasco County Extension
Telephone: 541-296-5494
Email: lynn.long@oregonstate.edu
Address: 400 E. Scenic Drive, Suite 2.278
Address 2:
City/State/Zip: The Dalles, OR 97058

Cooperators: Matthew Whiting

Total Project Request: Year 1: $58,388 Year 2: $59,585 Year 3: $0

Other funding sources

None

Total Project Funding:

Budget History:

Item	Year 1:	Year 2:	Year 3:
Salaries	30544	31460	
Benefits	19276	19557	
Wages	5850	5850	
Benefits	585	585	
Equipment			
Supplies	1000	1000	
Travel	1133	850	
Plot Fees			
Miscellaneous			
Total	58388	59585	

Objectives:

1) Large-scale pre-bloom PGR trials to enhance fruit size
2) Accurately reproduce the color and percent of full size cherry for a decision aid tool
3) Create a novel temperature-dependent model to predict phenology and fruit development of sweet cherry

Significant Findings:

1) We do not recommend use of giberellin or cytokinin based on our data
2) Anecdotal evidence for increased fruit size with 20ppm CPPU at full bloom exists
3) A 30-spur sampling method provided a good estimate of orchard condition
4) Pistil growth during dormancy break was quantified with Differential Thermal Analysis
5) Temperature controlled dormancy break experiments showed changing temperature responses as dormancy breaks
6) Relative water content (60-62%) of floral buds can be used as a field ready test for the break of dormancy
7) 50% maximum fruit weight was coincident with an increase in fruit density and darkening of the cherry
8) Two new phenology input values describing dormancy break and color development were determined for six varieties at locations throughout the Columbia Gorge

Objective 1- PGRs: Sampling Methods

One grower hosted non-crop destruct test trials in 2015. Fruit size, set and yield at harvest were measured for cultivars Chelan, Early Robin, Bing and Rainier treated with 250 ppm Promalin prior to bloom, between first white and full bloom. Test and control blocks comprised at least ten contiguous rows each (i.e., ~ 1 tank of Promalin per cultivar). Ten subsamples per cultivar were collected, each comprising the total fruit from 30 spurs. We have previously demonstrated that 30 spurs were an adequate sample size to estimate orchard variability and reduce experimental error so that treatment differences can be detected. At each sampling date, fruit were weighed in the field then photographed for later counting. The data provided good estimates of average fruit weight, set and yield per spur. Statistical analysis revealed no significant differences in weight, set or yield in Promalin versus control treatments, although a slight trend of lower set and larger size was observed. Inconsistent responses between this year and last year (i.e., a significant increase in 'Sweetheart' fruit size) may be attributed to the interaction of environmental factors and phenology stage at the time of application. Irrespective, the small effect on fruit size does not, at present, validate commercial applications

Multiple Range Tests for fruit weight by Cultivar_ Treatment

PGR:		95.0 percent LSD	
Level	*Replicates*	*Mean*	*Groups*
Early Robin control	10	9.57645	a
Early Robin Promalin	10	9.84101	a
Bing Promalin	10	9.84183	a
Bing control	10	9.97351	a
Chelan control	10	10.496	b
Chelan Promalin	10	10.5552	b
Rainier control	10	11.1059	c
Rainier Promalin	10	11.4334	c

A fourth trial was conducted at MCAREC with Regina and ten individual trees per treatment. In addition to a trial of 125 ppm Promalin, trials of NovaGib at 31, 62 and 125 ppm, and one trial of 250 ppm K-Salt were applied at an average bud phenology of first-white that was determined by counting bud phenology per spur. Spurs and the remaining fruit on the limb were collected and the fruit weighed individually for the best estimate of size distribution. All treatments showed a slight increase of fruit weight when spurs were sampled, and slightly more when all fruit including terminal fruit were sampled. Any gains were small and may be attributed to an influence on set and size. An additional objective to increase leaf area, based on visual observation of markedly greater leaf size from previous PGR trials, was also evaluated. No significant differences, however, were observed for any of the treatments relative to leaf area (data not shown).

Multiple Range Tests for weight by spur

Method: 95.0 percent LSD

spurs	Count	Mean	Groups
Control	559	9.27	a
NAA, 250 ppm	226	9.56	b
Novagib, 125 ppm	373	9.57	b
Novagib, 31 ppm	321	9.69	b
Promalin, 125 ppm	456	9.75	b
CPPU/Novagib, 20/125 ppm	250	9.78	b
Novagib, 62 ppm	404	9.82	b

Multiple Range Tests for weight by limb

Method: 95.0 percent LSD

limbs and spurs	Count	Mean	Groups
Control	1280	9.36	a
Novagib, 125 ppm	1045	9.49	ab
Promalin, 125 ppm	1257	9.60	bc
NAA, 250 ppm	591	9.64	bce
Novagib, 62 ppm	1066	9.73	ced
Novagib, 31 ppm	944	9.76	ed
CPPU/Novagib, 20/125 ppm	630	9.92	d

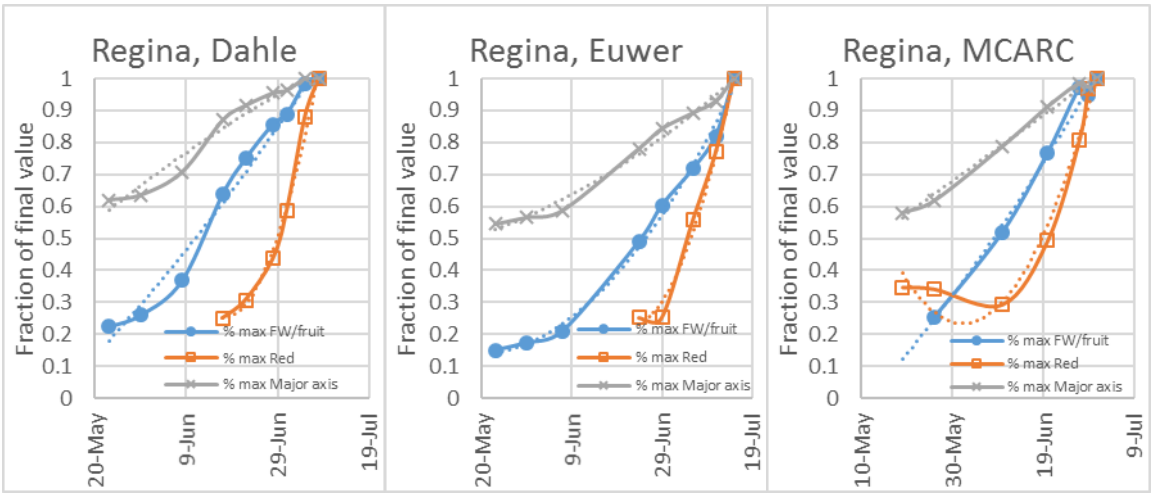
PGR 2016

Large scale trials were again employed in a Bing orchard in The Dalles. One application at three timings around bloom were done. Fruit from whole limbs were taken for size and fruit quality measurements. We found no significant effects of giberrellin (NovaGib, FAL-477) or the synthetic cytokinin, CPPU.

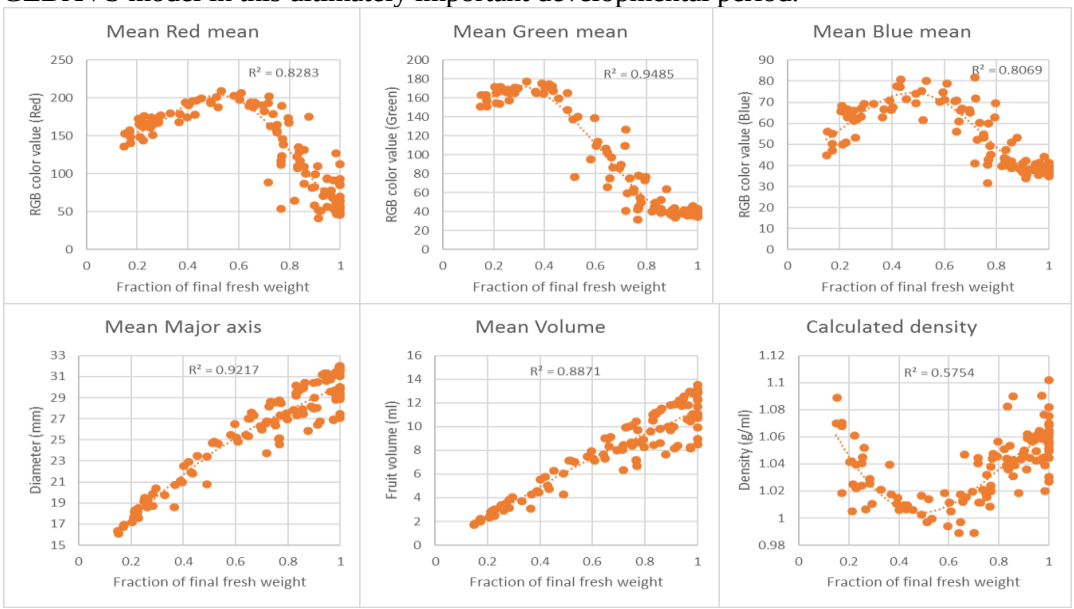
Treatment	avg Fruit Set	Avg Weight (g)	Total Weight (g)	Avg TA	Avg SS	Avg CTIFL	avg ff	avg mm	avg Row size	Avg leaf Area	avg # leaves	Avg area per leaf
UTC	63	9.5	11496.5	0.81	20.42	3.92	284	27.6	9.93	4541	151	30.0
NovaGib 10L	67	8.93	10623.0	0.68	21	4.14	264	27.0	10.1	4529	155	29.2
NovaGib 10L	63	8.83	10551.9	0.81	21.38	3.72	290	26.7	10.2	4762	159	30.0
NovaGib 10L	59	9.14	7205.08	.	23.18	4.23	293	27.1	10.1	4772	151	31.4
NovaGib 10L	79	9.47	9129.06	0.82	22.78	3.84	286	27.6	9.94	4685	156	29.8
NovaGib 10L	73	9.49	9317.31	.	21.3	3.84	293	27.7	9.9	4821	151	31.8
FAL-477	68	9.38	11262.2	.	21.15	3.94	277	27.5	9.97	4871	152	32.0
FAL-477	59	9.21	10886.9	0.81	21.47	3.97	284	27.3	10.0	4707	154	30.5
FAL-477	64	8.91	8876.02	0.89	20.08	3.9	287	27.1	10.1	4272	138	31.0
FAL-477	68	9.43	11268.4	0.82	21.52	4.12	284	27.4	9.98	4872	151	32.1
CPPU	66	9.09	10711.3	0.84	22.64	3.85	295	27.3	10.0	4996	149	33.4
NovaGib 10L	65	8.46	9955.48	0.84	22.08	3.93	288	26.6	10.2	5049	157	32.2
CPPU	55	9.23	10998.9	.	22.2	3.92	299	27.4	9.98	4728	157	30.1
FAL-477	72	9.22	10853.9	0.96	22.05	3.82	296	27.5	9.98	4708	156	30.1
CPPU	74	9.3	10931.6	.	22.92	3.87	298	27.5	9.93	4621	152	30.2
CPPU	68	9.07	10501.2	0.8	22.18	4.13	295	27.2	10.0	4934	155	31.9
CPPU	76	8.9	10654.3	0.84	21.73	3.73	306	27.0	10.1	4212	145	29.0
CPPU	73	8.61	12077.7	.	23.69	4.07	348	26.6	10.3	4580	156	29.3
CPPU	76	9.18	10876.5	0.9	22.55	4.02	305	27.0	10.1	4701	139	33.6

Objective 2- Develop appropriate sweet cherry color chips

The first year of a color index of skin color and fruit size of cherry in the PNW focused on Sweetheart, Bing and Regina. This year we observed Bing, Chelan, Lapins, Regina, Skeena and Sweetheart in 15 of the combinations of cultivar/station that were observed for the RWC-dormancy test. Total fresh weight of the fruit from each sampling were measured, but individuals were measured photographically. Image analysis software was used for maximum and minimum diameters, and RGB color (totalling over 25,000 fruit). Data were analyzed as the fraction of the greatest measurement (generally the final date of sampling). An example for Regina at five locations is shown.



All cultivars were similar in color progression and final color; however, they varied in the duration of time required for growth and color development, largely dependent on location. Interestingly, we found a strong correlation of the progession of color in relation to a relative measure of fresh weight per fruit. Furthermore, at about 50% maximum fruit weight we observed the beginning of the increase in fruit density during final swell. From these curves the dates of 50% maximum fresh weight provides an important phenological input that can be used for all dark sweet cherries to improve the GEDAVS model in this ultimately important developmental period.



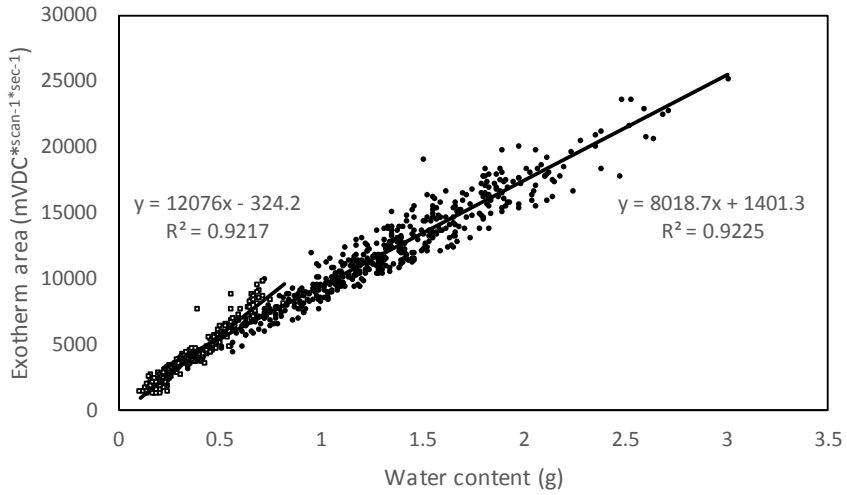
A color chart based on these findings will be presented in PowerPoint at the meeting.

Fraction of final weight	Fraction of major diameter	Color chip	RGB Red	RGB Green	RGB Blue
.2	.57		157	163	57
.3	.65		178	173	66
.4	.72		190	141	73
.5	.78		191	141	74
.6	.83		184	111	70
.7	.88		166	80	60
.8	.92		139	54	49
.9	.96		102	38	39
1	1		55	40	39

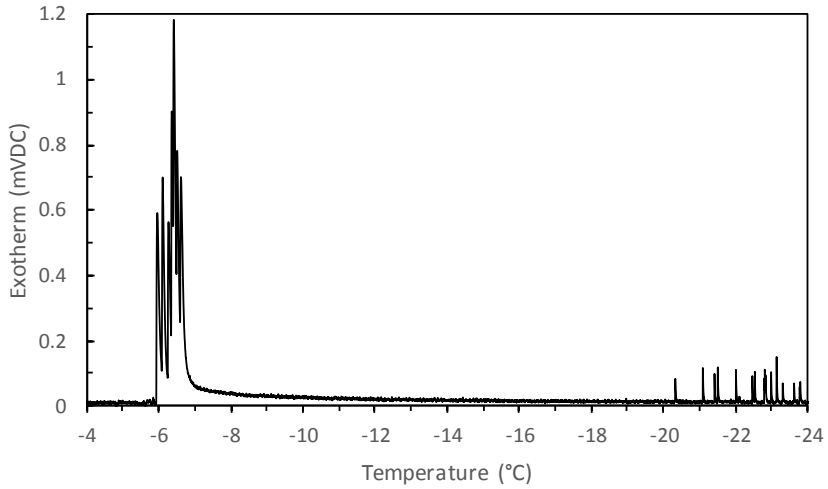
Objective 3: Modelling of Sweet Cherry Development

Controlled Environment Chamber: Dormancy Break Forcing

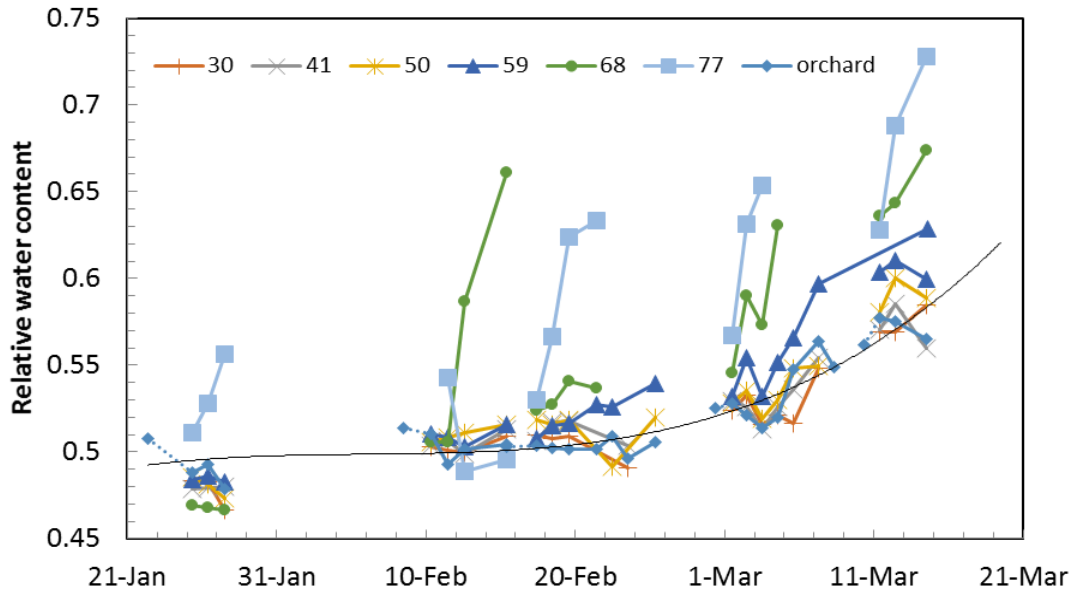
Of the three cardinal points of cherry development, dormancy break, bloom and maturation, dormancy break is the most difficult to determine. Loss of dormancy is deemed complete when the pistil loses the ability to supercool. This irreversible physiological process is assumed to be accompanied by growth of the pistil; however, evidence for the timing of dormancy, supercooling and growth are scant. Visible changes in bud size and color are too subtle to be reliable, and dissection of pistils for photographic measurement is far too tedious. We realized through our work with Differential Thermal Analysis (DTA) that pistil growth could be determined by measuring the height of the DTA response because of the direct and linear relation of water content and DTA response.



An Excel program was written to digitally remove noise and baseline drift and automate peak detection so that hundreds of pistils could be measured in a single analysis.

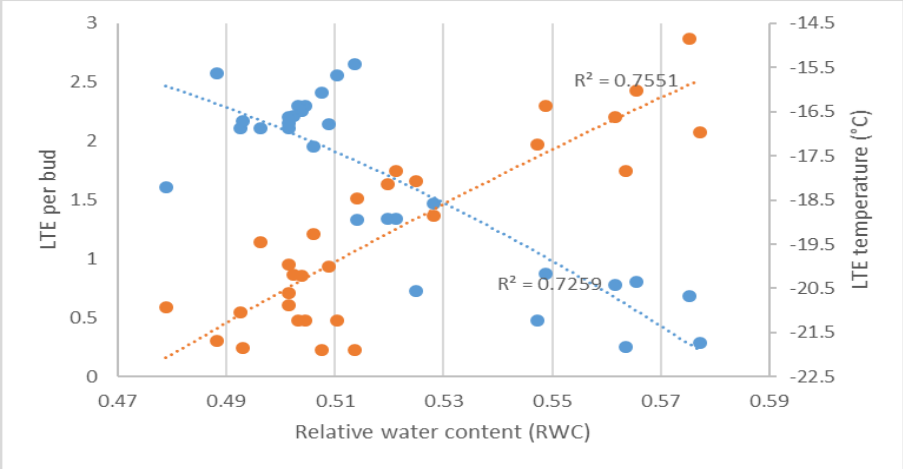


Similar to our bloom-forcing experiments of last year, we again used 1.5 ft-sections of fruiting wood placed in controlled environment chambers. Spur buds were analyzed by DTA and some dissection and measure of pistils was done to confirm the DTA results. Five separate experiments were set up as the season progressed from dormancy to bud swell. Each experiment was compared to the natural progression in the orchard. Forcing this material to develop at six temperatures in comparison to the orchard helped establish a developmental response curve needed in our improvement of the temperature dependent GEDAVS model.

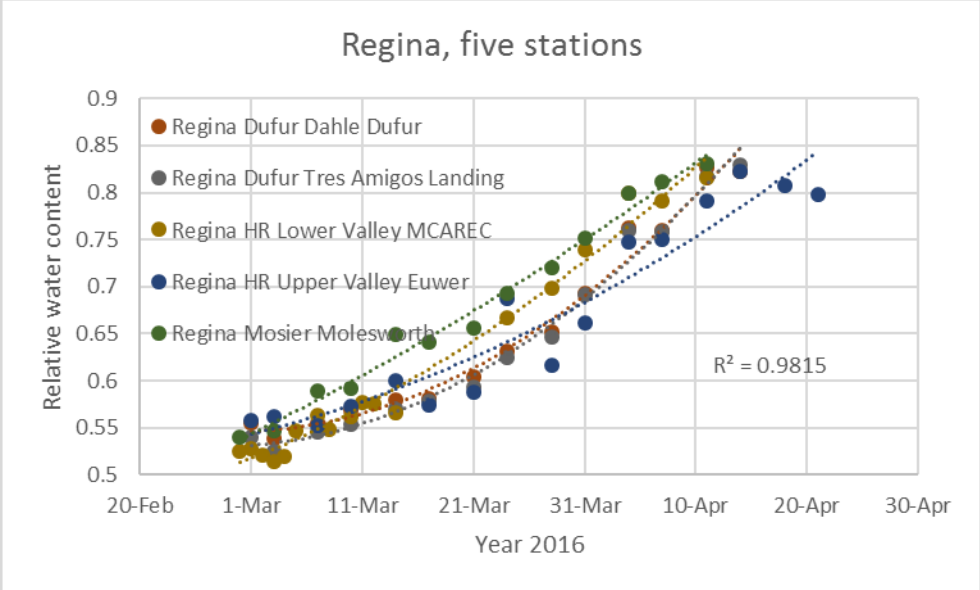


Relative Water Content (RWC) of Floral Buds: A Field Ready Test for Dormancy

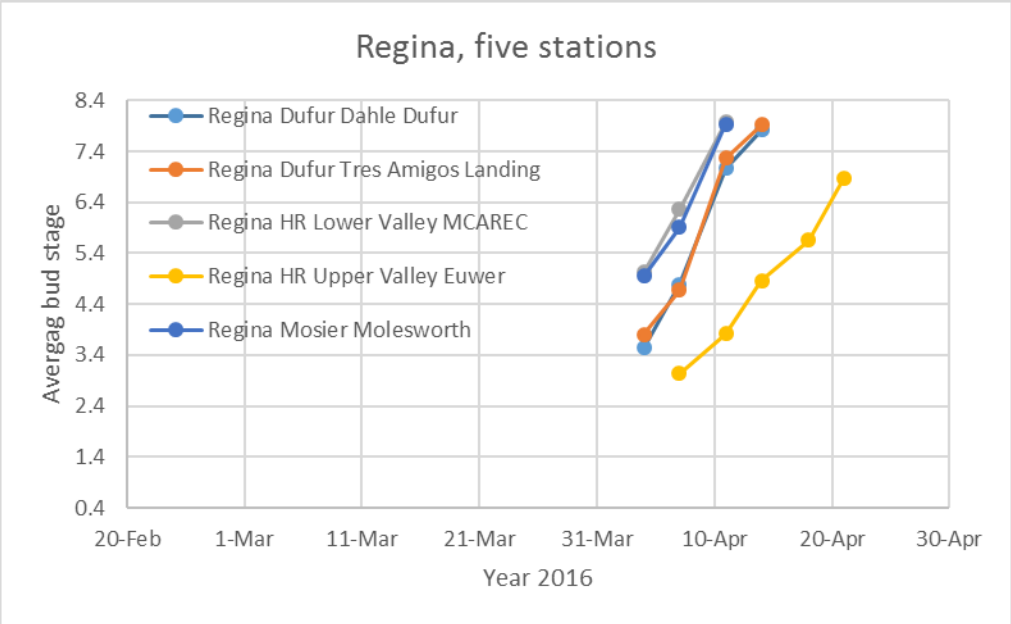
As useful as DTA was for determining dormancy break, it is still limited by the lengthy freezer-process run time and post-analysis. A simple measure that can be correlated to the loss of dormancy was needed so that the dormancy status of many orchards could be determined. RWC of floral buds was found to be such a measure. As the RWC increased from January to March in Regina at MCAREC, the LTE50 temperatures increased and the number of detectable peaks per bud decreased until approximately 60% RWC was reached and all DTA signal was lost. We concluded that 60-62% RWC is a good indicator of the irreversible loss in dormancy.



With this in mind we sampled orchards using one replicate of the 30-spur sampling method (described in Objective 1) of RWC as a stand-in measurement for the loss of dormancy. We visited 14 orhards ranging from 500 to 2000ft in elevation and in each region of the Columbia Gorge. Six cultivars in 21 combinations of cultivar/station were observed. Approximately twice weekly, buds from 30 spurs were photographed for individual bud size and color. The buds were then weighed in bulk for fresh weight and later for dried weight. An example for Regina at five locations is shown. From these curves the date of dormancy break was determined for use in the GEDAVS model.



Open Bud Phenology and Bloom Timing:
The 30-spur sampling was continued in these orchards to assess bloom timing. Once buds opened individual flowers were graded for phenology. Scores were given for each stage, 4 for tight cluster , 5-open cluster, 6-first white, 7-balloon and 8-bloom. Weighted scores were plotted versus date such that a weighted score of 7.5 was 50% bloom. An example for Regina at five locations is shown. From these curves the date of 50% bloom was determined for use in the GEDAVS model.



GEDAVS: Gibeaut, Einhorn, Diurnal, Annual, Variation, Simulation (GEDAVS)
The algorithm for a new growing degree model of sweet cherry growth is given below. Calculations are performed in Excel spreadsheets. Improvements to this model are underway and will include additional phenology date inputs and temperature response curves for dormancy break and maturation. Dates for dormancy break provide an end date for accumulating heat units required for the release of ecodormancy. A temperature response curve for this period of development was defined by the forcing experiments described above. Maturation in the current model was based upon growth in volume; however, with the new color and fruit density data the temperature response in the final days of ripening will be modified to better describe ripening.

PHENOLOGY DATE INPUTS
Start = starting date of simulation (can be set to 1-January)
Origin = date of 50%-anthesis, germination
Exponential = end date of increasing temperature indices
End = date of maturation, %growth

TEMPERATURE INPUTS

Base temperature;	base; start, origin, exponential, end
Optimum temperature;	opt; start, origin, exponential, end
Critical temperature;	crit; start, origin, exponential, end
Negative temperature;	neg; start, origin, exponential, end

DIURNAL SUNRISE-SUNSET
Naval observatory data location specific Sunrise Sunset tables (account for Day-light savings time and leap day)
Solar radiation time offset = typical time to positive net PAR (set to 3 hr)
Dawn = Sunrise + solar radiation time offset
Dusk = Sunset

ASSIGN DFA TO TIME STAMP
Create year specific date series in 1 day steps from 1-January, and variable DFA series
Lookup (time stamp, date step series, DFA series)
DFA = date step series – P1
Dusk = Sunset
Day-time > Dawn <= Dusk
Night-time > Dusk <= Dawn

GROWING DEGREE GD

Interval average temperature; int = $(\text{temperature}_1 + \text{temperature}_2) / 2$

PRE ANTHESIS
(P0 to P1)
IF, int < base, GD = (int – base) / (base – neg)
Else IF, int <= opt, GD = ((opt – base) / 2) · (1 + cosine ($\pi + \pi \cdot$ ((int – base) / (opt – base)))
Else IF, int <= crit,GD = (opt – base) · (1 + (cosine π) / 2) + π / 2 · ((int – opt) / (crit – opt)))
Else IF,int > crit,GD = 0

DAY-TIME
(P1 to P3)

IF, int <base, GD = 0
Else IF, int <= opt, GD = ((opt – base) / 2) · (1 + cosine (π + π · ((int – base) / (opt – base)))
Else IF, int <= crit, GD = (opt – base) · (1 + (cosine π) / 2) + π / 2 · ((int – opt) / (crit – opt)))
Else IF, int > crit, GD = 0

NIGHT-TIME
(P1 to P3)
(Exponential, Maturation)
IF, int <base, GD = 0
Else IF, int <= opt, GD = ((opt – base) / 2) · (1 + cosine (π + π · ((int – base) / (opt – base)))
Else IF, int <= crit, GD = (opt – base) · (1 + (cosine π) / 2) + π / 2 · ((int – opt) / (crit – opt)))
Else IF, int > crit, GD = (int - crit) / (crit – neg)

VARIABLE TEMPERATURE INDICIES
Create four columns of temperature (base, opt, crit and neg) for each growth phase (P0 to P1, P1 to P2, > P2)

IF DFA < P1, Trend (P0temp: P1temp, DFA)
P0temp = P0 (base, opt, crit)

IF DFA <= P2, Trend (P1temp: P2temp, DFA)
P1temp = P1 (base, opt, crit)

IF DFA <= P3, Trend (P1temp: P3temp, DFA)
P2temp = P3 (base, opt, crit)

IF DFA > crit

GROWING DEGREE HOURS
$GDH = GD \cdot (\text{time stamp}_2 – \text{time stamp}_1) \cdot 24$

GROWING DEGREE HOUR ACCUMULATED

IF P0 >= time stamp < P1
Sum PRE ANTHESIS

Else IF time stamp < P2
Sum DAY-TIME EXPONENTIAL
Sum NIGHT-TIME EXPONENTIAL

Else IF time stamp <= P3
Sum DAY-TIME MATURATION
Sum NIGHT-TIME MATURATION

GEDAVS Seasonal Growing Degree Hours Accumulated = PRE ANTHESIS + DAYTIME EXPONENTIAL + NIGHTTIME EXPONENTIAL + DAYTIME MATURATION + NIGHTTIME MATURATION

Executive Summary

Three years of trials in the use of PGRs near bloom has given mixed results. Any gains in size we observed may be related to the variability of fruit set on a given tree or limb. During the course of these trials we performed two sampling methods, whole limb sampling versus 30-spurs chosen at random. Size estimates were similar for both methods. Replication of the 30-spur samples up to 10 replicates reduced the variation of the means but can only differentiate a size differential of about 0.5 gram. The 30-spur technique has the advantage over whole limb sampling because of a broader sample pool for estimating orchard conditions. If a single replicate 30-spur method is employed over a time course of sampling such as twice weekly, very good estimates of developmental progression can be obtained. We encourage the adoption of the 30-spur method.

Dormancy break can be determined by a change in relative water content of buds from about 50-55% in dormancy to 60-62% at first swell. Differential thermal analysis of floral buds forced to break dormancy in controlled environments established this value and the changing developmental response to temperature during springtime bud development. The dates of this 60-62% relative fresh weight value will now be incorporated in the GEDAVS model of fruit development.

During our efforts to develop a robust, predictive fruit growth model we digitally imaged thousands of individual dark sweet cherries of six cultivars at 14 different locations to objectively identify their stage of maturation, according to skin color. This work resulted in 3 key findings: 1) The ctifl color chart ***does not*** adequately represent the progression of cherry skin color; and, 2) we can significantly advance the precision with which the industry assesses color development by producing a color wheel that optimizes harvest timing and fruit quality of cultivars commercially produced in the PNW. Additionally, we found the onset of the development of red color intensity was related—across cultivars and locations—to fruit development at 50% of the final fruit weight. The dates of this 50% fresh weight/fruit value will now be incorporated in the GEDAVS model of fruit development.

The GEDAVS model combines accurate phenology estimates with a new method of calculating growing degree accumulation that accounts for daily and annual variations and location. We have shown previously that temperature dependent difference on the predicted average harvest date of Sweetheart over several years and locations was about to +/- 1.5 days. Addition to the model of the dates for the attainment of 60% RWC in buds, and 50% final fruit weight will now be added to GEDAVS to more accurately predict the beginning and end of the sweet cherry season. Geographic latitude is accounted for in GDAVS by solar time tables; however, this effect has not been tested over a wide range of latitude. Further work in Washington will be needed to fully validate GDAVS.