Project Title: Sweet cherry cultivar-specific export suitability
Report Type: Final Report

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Cooperators: Sweet cherry packinghouse personnel and other industry members in the Pacific Northwest; Dr. Ashley Thompson

Project Duration: 2-year*
* Due to ability to complete the 2024 season with 2023's budget, the 2024 budget was not disbursed.
Total Project Request for Year 1 Funding: $54,944

Other related/associated funding sources: Awarded
Funding duration: 2023-2024
Amount:
Agency Name: USDA-ARS base funds
Notes: Support for base-funded research assistants and travel.

Budget 1
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	Item	2023
1	Salaries	$25,329
2	Benefits	$9,042
3	Wages	$7,208
4	Benefits	$551
5	RCA Room Rental	$1,319
6	Shipping	
7	Supplies	$4,000
8	Travel	$2,000
9	Plot Fees	
10	Miscellaneous	
11	Indirect cost	$5,494
	Total	$54,944

Footnotes:

1. **Salary for part-time research assistant pay grade GS-8 (0.425 full-time equivalent [FTE])**

2. **Benefits for part-time research assistant pay grade GS-8 (0.425 full-time equivalent [FTE])**
3. **Wages for summer research assistant pay grade GS-5 (approximately 0.5 FTE for 4 months each year)**
4. **Benefits for pay grade GS-5 (approximately 0.5 FTE for 4 months each year)**
5. **Cold room rental is per Oregon State University-Mid Columbia Research and Extension Center (OSU-MCAREC) rates.**
6.
7. **Supplies include data loggers and sensors, reagents, packing supplies, shipping costs, laboratory consumables.**
8. **Travel is for collecting samples.**
9. **NA**
10. **NA**
11. **Indirect cost at 10%.**

Objectives

1. **Postharvest sweet cherry cultivar comparison under potential export conditions.** Project goals were to evaluate stem quality, fruit quality, and physiology before and after simulated export handling (4-week hold) for present or potential Pacific Northwest export cultivars, in both air and modified atmosphere (MA) bags and in optimal (31 °F) and high (40 °F) temperatures, with the latter representing a break in cold chain. Based on discussion with industry stakeholders, a mix of both traditional cultivars and newer sweet cherry cultivars were selected for year 1: **Coral Champagne, Black Pearl, Chelan, Bing, Santina, Skeena, and Regina**, and in year 2**: Coral Champagne, Black Pearl, Chelan, Santina, Bing, Burgundy Pearl, Regina, Skeena, and Sweetheart**. There were four collaborating packinghouses in 2023 and five in 2024 representing major Washington and Oregon cherry production districts.

2. **The influence of transport stresses on sweet cherry quality**. Primary potential transport stresses evaluated in Year 1 were temperature (40 °F) and duration of holding (4 weeks). The effects of regular and MA bags were also contrasted in year 1, 2023.

Significant Findings

- For fruit commercially sized and packed, and combining data from 2023 and 2024, at pickup (shortly after packing) and after a 4-wk hold in a modified atmosphere (MA) bag at either 31 °F or 40 °F, sweet cherry cultivar specific differences relevant for export are detailed in Tables 1, 2, and 3 (below). No single cultivar outperformed all other cultivars on all fruit and stem characteristics; optimal export cultivars may vary based on supply chain or market priorities for particular quality attributes.
- Although cultivars differ in retention of quality over a 4-wk hold and in response to storage temperature, there is no evidence suggesting that all early season cultivars are less suitable for export than later season cultivars.
- Modified atmosphere bags prolonged stem and fruit quality longevity irrespective of cultivar or temperature, and in high temperature storage (e.g. cold chain breaks), retained quality better than non-MA bags (data from 2023). Only MA bags were utilized in 2024.
- Postharvest espiration rates differed among cultivars (measured at 1 wk and 4 wk into storage). Respiration rates (carbon dioxide [CO_2] production) varied with lot and over the course of storage and were higher at higher temperatures. While higher relative respiration indicates fruit are using stored carbohydrates at a higher relative rate, likely decreasing quality potential, in an all-lots, all-cultivars statistical correlation analysis no single measured fruit or stem characteristic consistently strongly correlated with respiration rate, suggesting a potential cultivar-specific effect of high respiration on gross indicators of quality. At present, respiration rate at 1 wk cannot be used an indicator of potential storage longevity.

- Stem width-to-length ratio (an indication of stem thickness) differences post-storage were influenced primarily by cultivar; storage temperature did not statistically influence outcomes. In addition, relative losses from pickup to 4-wk post-storage were not statistically significant according to experimental factors, suggesting additional unevaluated factors influencing outcomes. Previous studies indicate that humidity is an important factor in stem desiccation as is in-field temperature management. Humidity was not specifically evaluated in the present study but presumably well maintained in the tightly closed MA bags.
- Pedicel retention force (force required to separate stem from fruit) differed according to cultivar and post-pickup storage temperature (with higher temperatures leading to more loss in pedicel retention force).
- Stem retention/stem loss was primarily influenced by storage temperature (more loss at higher temperature) and "year" (possibly pre-harvest environment), and not by cultivar.
- Fruit firmness was affected by both cultivar and post-pickup storage temperature, with colder storage (31 °F) optimal. Fruit gained firmness in storage at 31 °F in MA bags.
- Lightness of color (colorimeter) and cracking incidence were too variable lot-to-lot to indicate statistically significant cultivar differences; neither storage temperature nor year (pre-harvest management/environment) affected outcomes.
- Pitting and pebbling (a fruit surface defect indicating desiccation) differed among cultivars; present results summarize incidence, which does not indicate affected fruit were necessarily in unmarketable condition. Since fruit were obtained post-commercial packing, fruit were sized and graded prior to project inception, which affects results at pickup and throughout. Changes in pitting incidence between pickup and 4-wks post-storage were too variable lot-to-lot to be statistically significant. We rated fruit marketability in 2024, but results were not statistically significant, perhaps due to an inability to have the same person rate fruit throughout the experiments.
- All °Brix levels were in acceptable ranges for cultivars at harvest. °Brix lost between pickup and 4-wk post-storage differed among cultivars, potentially suggesting cultivar-specific postharvest utilization rates.
- High temperature storage (40 °F) most clearly negatively affected pedicel retention force, fruit firmness, and titratable acidity. Cultivar-specific interactions with high temperature storage were most definitive for pedicel retention force (loss of pedicel retention force).
- Packinghouse (which, statistically speaking, was inclusive of all aspects of pre- and postharvest management) did not have a consistent influence on postharvest outcomes.
- Stem quality is an important visual attribute of cherry fruit quality that can quickly be negatively affected by suboptimal postharvest conditions, yet information on specific stem quality attributes affecting shelf-life longevity, marketing and consumer preference is limited; placing present results in the context of these considerations is challenging.
- Published research-based comparison of practices supporting maintenance of postharvest stem quality in the context of commercial handling is an area of research need.

Tables summarizing cultivar comparison at pickup (shortly after packing) and after 4-wk MA bag storage are on the following pages.

Table 1. Sweet cherry cultivar-specific stem and fruit summary shortly after commercial packing ("pickup") as well as after a 4 wk hold in modified atmosphere bags at either 31 °F (optimal) or 40 °F (simulating cold chain break), with the latter intended to assess cultivar-specific fruit and stem resilience. All fruit were sorted and packed before evaluation; no information on fruit size is discussed.

Early season	**Early season cultivars 'Black Pearl' and 'Chelan'** 'Chelan' had a higher stem weight-to-length ratio (stem thickness) at pickup, but differences were not significant after 4 weeks storage. Pedicel retention force (force required to separate stem from the fruit) was similar for both cultivars at either optimal or high storage temperatures and were the highest of all the cultivars evaluated; fruit firmness was also the highest of all the cultivars evaluated, both at pickup, and at either optimal or high temperature postharvest. Results indicate 'Black Pearl' is an unusually low titratable acidity (TA) cultivar; values were lowest among the varieties evaluated, both at pickup and post-storage. Post-storage percentage loss of TA (relative to other cultivars) for 'Black Pearl' was mid-range relative to other cultivars. Levels of pitting or pebbling were statistically similar.
Early mid-season	**Early mid-season cultivars 'Coral Champagne' and 'Santina'**. Of all the varieties evaluated, 'Coral Champagne' had the nominally lowest pedicel retention force post-storage, although this was not statistically different from 'Bing', Regina', or 'Santina'. 'Santina' had more pitting at pickup than 'Coral Champagne', but post-storage, 'Coral Champagne' was lowest of the cultivars evaluated. Note that fruit were graded on commercial lines prior to storage; the portion of pitting developing post-packing is unknown. 'Coral Champagne' (and 'Bing') had the lowest pebbling incidence of the cultivars evaluated. Both 'Coral Champagne' and 'Santina' had relatively lower loss of titratable acidity than many of the other cultivars evaluated. 'Santina' had mid-range respiration at 31 °F but the highest respiration at 1 week and 4 weeks storage at 40 °F.
Mid-season	**For mid-season cultivars, 'Bing' is the traditional standard. Only one lot for each of 'Cristalina' and 'Burgundy Pearl' were evaluated so no statistical analyses were performed, and results could be lot-specific.** 'Bing' stem characteristics at pickup and post-storage were mid-range relative to other varieties. The single lot of 'Cristalina' had low stem retention, but nominally lower cracking and pitting than either 'Bing' or 'Burgundy Pearl'. Firmness was nominally higher and color darker for both 'Cristalina' and 'Burgandy Pearl' relative to 'Bing' shortly after packing, but 'Bing' had higher firmness than both after a 4 week hold, both at optimal and high temperatures. 'Bing also had the highest titratable acidity of all the cultivars evaluated, and one of the lowest incidence rates of pebbling.
Late-season	**Late-season cultivars 'Regina' and 'Skeena'** After 4 weeks, late season cultivars 'Regina' and 'Skeena' had the highest stem thickness (potentially indicating resistance to desiccation, although percent loss of stem thickness between pickup and post-storage had weak statistical significance according to cultivar) and mid-range pedicel retention force. 'Regina' had the lowest firmness of the cultivars evaluated at pickup; 'Skeena' had higher fruit firmness post-storage than 'Regina', although postharvest 'Regina' retained firmness better than 'Skeena' (e.g. lost relatively less firmness). 'Skeena' and 'Santina' lost more firmness than other varieties postharvest. Pitting and pebbling where statistically similar for 'Regina' and 'Skeena', although values for 'Regina' were nominally lower. Fruit were graded on commercial packing lines prior to storage; the percentage of pitting attributed to harvest, transport, or packing, and the portion developing in storage is unknown.
Extra-late	**'Sweetheart'** is harvested so much later than other cultivars that it deserves a category of its own. We had challenges evaluating sufficient 'Sweetheart' due to overlap with pear harvest and staffing limitations. The one lot evaluated indicated that 'Sweetheart' stems are relatively resilient to high temperature provoked changes in stem weight-to-length and pedicel retention force. 'Sweetheart' had high firmness at pickup, but also high relatively high cracking and pitting incidence. With just one lot evaluated, this data should be viewed as preliminary and lot-specific.

Table 2a (continued on following page). Sweet cherry stem and fruit characteristics at pickup (shortly after packing by commercial entities). Size is not included as fruit were sized and graded prior to pickup. We requested export quality fruit from cooperators. 'Burgundy Pearl', 'Cristalina' and 'Sweetheart' only had one lot in the study; results should be considered preliminary.

Cultivar	Year	Notes	Stem retention (%)		Stem weight-to-length ratio		Stem pull (kg force)		Stem length (mm)		Cut stems (%)		Firmness (mm g^{-1})		Lightness (colorimeter)	
Bing			80	ns[1]	2.6	bc[2]	0.58	b	48	bc	41	ns	280	abc	28	ns
Black Pearl			90	ns	2.5	c	0.78	ab	48	b	28	ns	319	a	26	ns
Chelan			89	ns	3.1	a	0.80	ab	42	bc	20	ns	324	a	26	ns
Coral Champagne			78	ns	3.0	ab	0.60	b	39	c	0	ns	282	abc	27	ns
Regina			87	ns	3.0	a	0.95	a	56	a	39	ns	243	c	26	ns
Santina			85	ns	2.9	ab	0.70	ab	44	bc	37	ns	256	bc	25	ns
Skeena			89	ns	3.0	ab	0.56	b	43	bc	27	ns	304	ab	26	ns
Burgundy Pearl		one lot, preliminary	97		3.4		0.98		43		.		259		26	
Cristalina		one lot, preliminary	.		3.0		0.20		49		.		340		22	
Sweetheart		one lot, preliminary	89		2.9		0.94		42		.		334		26	
	2023		78	ns	2.8	a	0.40		47	ns	40	ns	280	b	26	b
	2024		93	ns	3.0	a	1.02		46	ns	30	ns	293	a	27	a
Pr < F[3]			0.0506		0.0298		<0.0001		0.0500		0.4237		0.0154		0.1937	
Cultivar			0.5036		0.0183		0.0326		0.0070		0.2177		0.0060		0.1965	
Year			0.0003		0.0213		<0.0001		0.3328		0.7605		0.3378		0.0170	
Cultivar*Year			0.7767		0.4190		0.3961		0.7814		0.6096		0.1801		0.6694	

1. ns, not statistically significant, that is, based on data analyses, numerical differences in a column are not indicative of true cultivar-specific differences.
2. Values in a column followed by different letters are statistically different per Fishers LSD *post hoc*, that is, differing letters indicate cultivar-specific differences.
3. The overall model (Pr < F) must have a value lower that 0.0500 to consider contributions of experimental factors such as cultivar and year, whose relative contributions to explaining differences in dependent variables (characteristics measured) must also have a value less than 0.0500 to be statistically significant.

Table 2b (continued from previous page). Sweet cherry stem and fruit characteristics at pickup (shortly after packing by commercial entities). Size is not included as fruit were sized and graded prior to pickup. We requested "export quality" fruit from cooperators. 'Burgundy Pearl', 'Cristalina' and 'Sweetheart' only had one lot in the study; results should be considered preliminary.

Cultivar	Year	Notes	Cracking incidence (%)		Cracking severity[4]		Pitting incidence (%)		Pitting severity[5]		Pebbling incidence (%)		°Brix		Titratable acidity (%)		Brix-to-acdity ratio	
Bing			15	ns	0.62	ns	61	a	1.06	ns	27	cd	22	a	0.96	a	23	cd
Black Pearl			16	ns	0.63	ns	40	b	0.81	ns	55	ab	20	ab	0.60	d	34	a
Chelan			14	ns	0.61	ns	54	ab	0.92	ns	76	a	19	ab	0.91	ab	22	d
Coral Champagne			6	ns	0.58	ns	31	b	0.78	ns	8	d	20	ab	0.77	bc	27	bc
Regina			16	ns	0.60	ns	51	ab	0.93	ns	37	abcd	21	b	0.81	b	26	bc
Santina			24	ns	0.72	ns	66	a	1.13	ns	47	abcd	18	c	0.64	cd	29	b
Skeena			20	ns	0.68	ns	54	ab	1.00	ns	53	ab	20	ab	0.80	b	25	cd
Burgundy Pearl		one lot, preliminary	8		0.13		4		0.36		1		19		0.63		31	
Cristalina		one lot, preliminary	13		1.25		16		1.00		30		19		0.71		27	
Sweetheart		one lot, preliminary	12		0.16		25		0.71		8		21		0.86		25	
	2023		14	ns	1.05	a	46	ns	0.71	b	51		20	ns	0.84	a	24	a
	2024		17	ns	0.22	b	55	ns	1.18	a	35		20	ns	0.73	b	28	b
Pr < F			0.4978		<0.0001		0.0122		<0.001		0.0172		0.0148		<0.0001		<0.0001	
Cultivar			0.6039		0.6352		0.0977		0.2645		0.0142		0.0026		<0.0001		<0.0001	
Year			0.7214		<0.001		0.5190		<0.0001		0.0857		0.9836		0.0041		0.0002	
Cultivar*Year			0.2827		0.2024		0.0054		0.0136		0.0917		0.3026		0.9437		0.1031	

4. Cracking severity: 0, none; 1, pitting present but marketable; 2, pitting renders fruit unmarketable
5. Pitting severity: 0, none; 1, pitting present but marketable; 2, pitting renders fruit unmarketable

Table 3a (continued on following page). Sweet cherry quality characteristics following 4 wk storage in a MA bag at either 31 °F (optimal) or 40 °F (high) temperature storage. ‘Burgundy Pearl’, ‘Cristalina’ and ‘Sweetheart’ only had one lot in the study; results should be considered preliminary.

Storage temperature		Notes	4-wk stem weight-to-length ratio[1]		% loss, 4-wk stem weight-to-length ratio relative to pickup		4-wk pedicel retention force (kg force)[1]		% loss, 4-wk pedicel retention force (kg force) relative to pick-up		4-wk stem retention (%)		4-wk firmness (mm/g)[1]		firmness % loss, 4-week vs pickup[1]		4-wk L (colorimeter "lightness")	
31 °F	Bing		2.1	B	14	ns	0.48	BC	-2	c	87	ns	332	B	-20	B	26	ns
	Black Pearl		2.2	B	11	ns	0.68	A	-2	c	92	ns	413	A	-31	B	24	ns
	Chelan		2.5	AB	18	ns	0.77	A	4	bc	94	ns	410	A	-27	B	25	ns
	Coral Champagne		3.0	A	-1	ns	0.38	C	29	abc	83	ns	376	B	-33	B	25	ns
	Regina		2.8	A	6	ns	0.61	BC	39	ab	93	ns	295	C	-23	B	25	ns
	Santina		2.4	AB	16	ns	0.63	ABC	9	abc	85	ns	291	C	-14	A	25	ns
	Skeena		2.6	A	13	ns	0.50	BC	1	c	93	ns	351	B	-15	A	25	ns
	Burgundy Pearl	preliminary data (one lot)	2.8		17		0.70		.		97		264.92		-2		26	
	Cristalina	preliminary data (one lot)	2.9		15		0.16		.		73		259.44		-39		26	
	Sweetheart	preliminary data (one lot)	2.1		29		0.57		.		88		375.47		-10		27	
40 °F	Bing		2.2	B	13	ns	0.36	BC	26	abc	77	ns	296	B	-6	B	26	ns
	Black Pearl		2.1	B	14	ns	0.59	A	19	anc	89	ns	349	A	-10	B	24	ns
	Chelan		2.3	AB	23	ns	0.51	A	35	ab	84	ns	343	A	-7	B	25	ns
	Coral Champagne		2.5	A	15	ns	0.2	C	65	a	68	ns	279	B	1	B	25	ns
	Regina		2.7	A	10	ns	0.42	BC	59	a	75	ns	267	C	-11	B	25	ns
	Santina		2.3	AB	20	ns	0.34	ABC	57	a	83	ns	213	C	17	A	25	ns
	Skeena		2.5	A	15	ns	0.28	BC	46	a	85	ns	278	B	9	A	25	ns
	Burgundy Pearl	preliminary data (one lot)	2.5		17		0.30		.		95		225.32		34		27	
	Cristalina	preliminary data (one lot)	3.3		.		0.09		.		10		238.08		22		26	
	Sweetheart	preliminary data (one lot)	2.1		26		0.51		.		80		321.79		4		26	
	Year	2023	2.4	ns	12	ns	0.28	B	22	ns	77	B	320	ns	-9.72	ns	25	ns
		2024	2.5	ns	15	ns	0.69	A	33	ns	93	A	321	ns	-14.74	ns	25	ns
	Temperature	31 °F	2.5	ns	11	ns	0.58	A	11	B	90	A	352	A	-23.37	B	25	ns
		40 °F	2.4	ns	16	ns	0.39	B	44	A	80	B	289	B	-1.07	A	25	ns
	Pr < F		0.0339		0.4004		<0.0001		0.0342		0.0289		<0.0001		<0.0001		0.1420	
	Cultivar		0.0019		0.5435		0.0004		0.0449		0.3439		<0.0001		0.0007		0.1574	
	Year		0.5358		0.3663		<0.0001		0.1435		0.0001		0.6083		0.0277		0.0690	
	Temperature		0.1605		0.2408		<0.0001		0.0003		0.0190		<0.0001		<0.0001		0.5840	
	Cultivar*Year		0.1844		0.0979		0.0145		0.3704		0.4793		0.0585		0.0665		0.1213	
	Cultivar*Temperature		0.9657		0.9831		0.7067		0.0337		0.9121		0.4970		0.4046		0.9705	
	Cultivar*Year*Temperature		0.8547		0.9204		0.06445		0.9597		0.7525		0.9132		0.6639		0.9949	

1. Where the interaction of cultivar*temperature is not statistically significant, *post hoc* statistically significant separations are according to cultivar (capitol letters). Significance of other main effects (year and temperature) are also indicated. Abbreviations: ns, not statistically significant, that is, based on data analyses, numerical differences in a column are not indicative of true cultivar-specific differences. Values in a column followed by different letters are statistically different per Fishers LSD *post hoc*, that is, differing letters indicate cultivar-specific differences.

Table 3b (continued from previous page). Sweet cherry quality characteristics following 4 wk storage in a MA bag at either 31 °F (optimal) or 40 °F (high). 'Burgundy Pearl', 'Cristalina' and 'Sweetheart' only had one lot in the study; results should be considered preliminary.

Storage temperature		Notes	Cracking incidence (%)[2,3]		Pitting incidence (%)[3]		Pebbling incidence (%)		Brix		Brix % loss, 4 wk vs. pickup		Titratable acidity (%)		Titratable acidity % loss, 4 wk vs.		Brix-to-Acdity ratio		Brix-to-acidity ratio % loss 4 wk vs.	
31 °F	Bing		12	ns	72	A	23	C	22	A	1.7	ABC	0.80	A	18	AB	28	DE	-20	ns
	Black Pearl		21	ns	49	BC	53	AB	19	CD	3.8	AB	0.50	D	17	AB	39	A	-17	ns
	Chelan		11	ns	57	ABC	87	A	19	D	3.1	A	0.70	B	22	AB	27	E	-26	ns
	Coral Champagne		8	ns	39	C	5	C	20	BC	0.0	BC	0.67	BC	13	BC	31	BC	-15	ns
	Regina		10	ns	58	AB	41	BC	21	B	-0.2	C	0.61	C	24	A	34	C	-35	ns
	Santina		33	ns	74	A	47	ABC	18	D	0.8	BC	0.60	C	6	C	31	B	-6	ns
	Skeena		17	ns	68	A	62	AB	19	CD	1.5	ABC	0.66	BC	18	AB	29	CD	-20	ns
	Burgundy Pearl	preliminary data (one lot)	70		74		8		17		1.7		0.39		9		43		-7	
	Cristalina	preliminary data (one lot)	9		15		48		18		11.3		0.48		38		37		-40	
	Sweetheart	preliminary data (one lot)	7		91		12		21		4.8		0.78		32		27		-1	
40 °F	Bing		13	ns	60	A	22	C	22	A	3.0	ABC	0.73	A	25	AB	30	DE	-29	ns
	Black Pearl		21	ns	48	BC	68	AB	19	CD	2.8	AB	0.46	D	24	AB	43	A	-28	ns
	Chelan		15	ns	54	ABC	81	A	18	D	8.3	A	0.68	B	25	AB	27	E	-23	ns
	Coral Champagne		6	ns	31	C	21	C	20	BC	-0.1	BC	0.59	BC	22	BC	34	BC	-29	ns
	Regina		21	ns	61	AB	58	BC	20	B	-0.7	C	0.60	C	27	A	34	C	-37	ns
	Santina		28	ns	69	A	58	ABC	18	D	-0.9	BC	0.52	C	19	C	36	B	-24	ns
	Skeena		20	ns	62	A	78	AB	19	CD	3.2	ABC	0.60	BC	25	AB	32	CD	-28	ns
	Burgundy Pearl	preliminary data (one lot)	66		81		0		18		-1.4		0.37		10		49		-12	
	Cristalina	preliminary data (one lot)	6		27		43		18		5.6		0.40		41		43		-59	
	Sweetheart	preliminary data (one lot)	4		93		3		22		-15.2		0.77		-8		28		-5	
	Year	2023	12	ns	45	B	51	ns	19	B	3.81	A	0.66	A	21	ns	35	ns	-24	ns
		2024	21	ns	69	A	49	ns	20	A	-0.04	B	0.59	B	19	ns	30	ns	-24	ns
	Temperature	31 °F	16	ns	50	ns	45	ns	20	ns	1.53	ns	0.65	A	2	B	31	B	-20	ns
		40 °F	18	ns	54	ns	55	ns	20	ns	2.24	ns	0.60	B	2	A	34	A	-28	ns
	Pr < F		0.5493		0.0003		0.0066		0.0005		0.0200		<0.0001		0.0070		<0.0001		0.3192	
	Cultivar		0.3493		0.0308		0.0008		<0.0001		0.0227		<0.0001		0.0089		<0.0001		0.0501	
	Year		0.0447		<0.0001		0.8109		0.0491		0.0007		0.0010		0.2352		<0.0001		0.8715	
	Temperature		0.7477		0.3937		0.1843		0.5568		0.4432		0.0223		<0.0001		0.8453		0.0095	
	Cultivar*Year		0.1756		0.0001		0.0189		0.1334		0.2914		0.4797		0.3275		0.0154		0.4173	
	Cultivar*Temperature		0.9890		0.9894		0.9845		0.9784		0.6432		0.9860		0.8055		0.6552		0.6350	
	Cultivar*Year*Temperature		0.8599		0.9979		0.9282		0.9891		0.5804		0.9890		0.8830		0.9779		0.8874	

Methods

This 2-year project evaluated cultivar-specific sweet cherry storage longevity, cultivar-specific resilience to higher than optimal storage temperatures, and related physiological indicators. In 2024, storage conditions were 4-weeks in modified atmosphere (MA) bags at optimal temperature (31 °F) and higher than optimal temperature (40 °F), with the latter simulating an extended cold chain break during transport. In 2023, regular polyethylene bags were also evaluated; MA led to superior quality outcomes and this data is not revisited in this report. Per stakeholder request, sweet cherries were obtained shortly after packing from commercial packinghouses (number of lots by year are listed in **Table 4**). Upon receipt, fruit were transferred from packinghouse-specific materials to modified atmosphere (MA) bags (LifeSpan, Amcor, Inc.) according to manufacturer's specifications regarding weight per bag. Respiration rates and bag atmosphere were evaluated at 1 wk storage for a subset of fruit stored in polyethylene bags (opening MA bags would alter the atmosphere), as well as after 4 wk storage (from MA bags). At pick-up and after a 4-week storage, sweet cherry fruit and stem quality were evaluated (attributes listed in **Table 5)** with 30 fruit evaluated per lot for continuous data and 100 fruit for binary data for each treatment combination. To avoid pseudoreplication, prior to statistical analysis, data for each attribute were averaged within each lot and treatment combination. Statistics were performed in a statistical software program (SAS, SAS Institute Inc, Cary, NC) with the programs PROC GLM (continuous data) and PROC FREQ or PROC LOGISTIC (binary data) or PROC CORR (Spearmans r) for correlations.

Table 4*. Sweet cherry cultivars evaluated, harvest timing, and corresponding quantity of lots evaluated, 2023-2024. Lots were obtained from four packinghouses in 2023 and from five packinghouses in 2024.*

CULTIVAR[1]	HARVEST TIMING (DAYS RELATIVE TO 'BING'	NUMBER OF LOTS IN 2023	NUMBER OF LOTS IN 2024
CHELAN	-11	2	3
BLACK PEARL	-8	3	3
CORAL CHAMPAGNE	-5	1	2
SANTINA	-6	1	2
BURGUNDY PEARL	-4	-	1
CRISTALINA	-3	1	-
BING	0	3	3
SKEENA	+11	3	3
REGINA	+10	3	3
SWEETHEART	+20	-	1

1. *In addition to evaluated cultivars, 'Staccato' (-8 d), 'Suite Note' (-5 d), 'Royal Hazel' (-10 d), 'Royal Helen' (+10 d), 'Royal Edie' (+11 d) were cultivars of interest but were not evaluated due to trademark issues, young trees, or inability to source fruit.*

Table 5*. Sweet cherry characteristics evaluated in this study.*

VISUAL QUALITY		INDIRECT SENSORY/PHYSIOLOGICAL	PHYSIOLOGICAL
Stem browning	Pitting	Firmness	Respiration
Stem presence	Pebbling	Brix (soluble solids) (sweetness)	Bag atmosphere
Stem quality	Cracking	Titratable acidity (TA)	
Cut stems	Rot	Pedicel fruit retention force (PRF)	
Color (lightness, hue, chroma)			

Results and Discussion

"New sweet cherry cultivar suitability for export" was a 2023 Oregon Sweet Cherry Commission research priority. Exporting cherries can involve a multi-week transport period, and therefore cultivars suitable for export 1) maintain fruit and stem quality for relatively longer periods postharvest and are 2) resilient to breaks in cold chain temperature, e.g. maintain quality through high temperature. Critical to this study, therefore, was defining what measurable characteristics of sweet cherries could indicate export suitability, e.g. what characteristics of fruit and stem quality that packers, buyers, and consumers utilize when choosing sweet cherries.

Determining characteristics to experimentally evaluate as indicators of export suitability was challenging as published information on supply-chain preferences and product factors influencing purchase-decision for sweet cherry are limited. A study by Gallardo et al. (2014) indicated that the potential for a longer shelf-life is a key characteristic influencing decision makers in the supply chain but defining "shelf-life" was beyond the scope of that study. Research often has emphasized consumer preference only (excluding other players in the supply chain) and typically includes emphases on fruit attributes, including flavor (for example, Ye, 2023; Zheng et al., 2016). Considering that many consumers do not taste fruit before they purchase and sweet cherries are typically marketed as "red" or "blush" both domestically and internationally, not according to cultivar, with "red" encompassing 10+ main cultivars, and "blush" 2-3 primary cultivars (e.g. 'Rainier'), research emphases on cultivar-specific flavor leaves knowledge gaps. The consumer is not choosing among an array of sweet cherry varieties based prior experiences with certain cultivars (as is possible with apples or pears), they are simply deciding – to buy or not to buy?

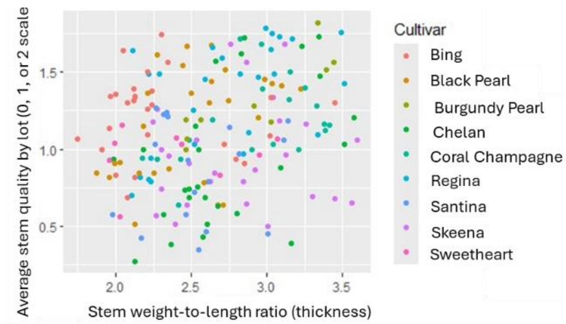
The information we gathered from informal interviews with industry members indicated that greater attention to postharvest post-storage stem quality is also necessary. Where published research is available, it has often emphasized fruit characteristics of size, flavor, and texture. There is sparse information on stem appearance or quality, although stem quality is, when results are considered as percent of change, potentially more quickly affected by at-harvest handling (Golding et al., 2017) and are more affected by postharvest packaging than fruit (Wang and Long, 2015; Zhi et al., 2023) and are thereby arguably a better tell of fruit "freshness" than the fruit itself. **In summary, based on the formal and informal information available, when determining cultivars-specific export suitability this study emphasized retention of visual quality and firmness, greater inclusion of stem characteristics than typical, as well as physical and physiological characteristics that could influence longevity of these qualities.**

Post-packing and post-storage stem quality and resilience to high temperature storage

Stem retention and pedicel retention force were affected by year and storage temperature (**Tables 1, 2, and 3**), indicating an environmental component to these characteristics, while stem weight-to-length ratio (an indicator of thickness and/or relative desiccation) and stem length did not significantly differ according to year, indicating a relatively stronger fixed genetic component; all of these parameters are objective data, e.g. not influenced by technician. Pedicel retention force (force to separate stem from fruit) was affected by cultivar and post-pickup storage temperature (with higher temperatures leading to more loss in pedicel retention force). Stem width-to-length ratio (thickness/desiccation) differences post-storage were influenced primarily by cultivar; storage temperature did not statistically influence outcomes. In addition, relative losses from pickup to 4-wk post-storage were not statistically significant according to experimental factors, suggesting additional unevaluated factors influencing outcomes. Previous studies indicate that humidity is an important factor in stem desiccation (Golding, 2017) as is in-field post-harvest temperature management (unpublished data by the authors in a separate study). Humidity was not specifically evaluated in the present study but presumably well maintained in the tightly closed MA bags. Stem retention/stem loss was primarily influenced by storage temperature (more loss at higher temperature) and "year" (possibly pre-harvest environment), and not by cultivar.

Overall stem quality, which is a subjective determination, and, despite detailed descriptors for numerical ratings, could be influenced by differing technician judgment, was recorded only in 2024, while stem browning (which is also subjective and confounded by abrasions from the cluster-cutter) was reported on more extensively in 2023 and is not reported here, due to inclusion of browning in overall "stem quality". Furthermore, neither were statistically significant according to cultivar, potentially due to confounding by relative portion of cut stems contributing to browning. Correlations between stem quality rating and stem weight-to-length ratio were statistically significant but very weak (**Figure 1**).

Figure 1. There was a significant ($p < 0.0003$) but not strong ($r = 0.26$) correlation (Spearman) between overall stem quality (subjective) and stem thickness (objective); the lack of strong correlative relationship is demonstrated in the plot below (2024 data only).



When a stem is cut on the cluster-cutter during packing, losing its fat distal end, stem weight-to-length values indicate that cut stems desiccate more relative to uncut stems (**Table 6**).

Table 6. *A cut stem results in lower postharvest stem weight-to-length, presumably due to desiccation. Data includes all cultivars, all lots.*

STEM CONDITION	STEM WEIGHT-TO-LENGTH (THICKNESS/DESICCATION)[1]
Not cut	2.74 a
Cut	2.38 b

1. Values in a column followed by differing letters differ statistically at $p < 0.0001$.

Statistically, there were no differences in cut stems according to cultivar (**Table 2**). As cluster-cutting could be influenced by packinghouse equipment or practices, the influence of packinghouse was specifically examined in more detail for subset of cultivars in 2024; there was no consistent influence of packinghouse apparent based on present data (**Table 7**).

Table 7. *Packinghouse did not consistently influence percentage of cut stems within a cultivar in 2024.*

Packinghouse	Chelan	Black Pearl	Bing	Skeena	Regina
1	23	-	-	48	42
2	29	34	26	42	32
3	-	32	-	40	32
4		-	29	-	-
5	9	32	37	-	-
	*	ns	ns	ns	ns

1. Wald's chi-square; ns, not statistically significant; *, significant at $p < 0.05$

<u>Post-packing and post-storage fruit quality and resilience to high temperature</u>

Post-storage firmness, pitting, pebbling, °Brix, and titratable acidity differed among cultivars and all of these except firmness differed according to year as well, indicating an environmental or management component for these characteristics (**Tables 1, 2, and 3**). Fruit firmness was affected by both cultivar and post-pickup storage temperature, with colder storage retaining higher firmness. Mean °Brix values at pickup were within recommended ranges for harvest maturity (Long et al., 2021). °Brix lost between pickup and 4-wk post-storage differed among cultivars. Post-storage titratable acidity and percent lost relative to initial values at pickup were influenced by temperature, with higher temperature leading to a greater reduction in titratable acidity. Color and cracking did not differ among cultivars, reflecting a high lot-to-lot variability for these characteristics; neither storage temperature nor year (pre-harvest management/environment) affected outcomes. Cracking and pitting are reported simply as incidence; even small cracks or pits that may not be market-limiting are included in presented results. Severity data for cracking and pitting was not evaluated post-storage as results were not statistically significant at pickup according to cultivar. Rot is not reported here due to overall low incidence and lack of statistical significance according to cultivar. All cherries darkened with 4-wk storage (data not shown), as has been previously documented in 2023 and by other research (Wang and Long, 2014).

Physiology and physical characteristics influencing storage longevity

Carbon dioxide production is an indicator of respiration rate and may reflect how quickly fruit may be using carbohydrate reserves. Researchers have suggested that a higher respiration rate could indicate decreased storage potential as fruit that are respiring more quickly may utilize reserves more quickly (Tapia Garci-a, 2017; Wang, 2014). After about 1 wk in storage, respiration rates were typically at their lowest and would begin to increase thereafter (data from 2023). Holding temperature influenced respiration rates, with an increase in respiration rate at 40 °F relative to 31 °F. At ideal holding temperatures (31 °F) 'Black Pearl', 'Chelan', 'Coral Champagne', and 'Santina' had the lowest respiration rates, and 'Coral Champagne', 'Black Pearl', 'Chelan' remained among the lowest at 40 °F. 'Santina' was the highest at 40 °F both at 1 week and 4 weeks (**Table 8**).

Table 8. *Sweet cherry respiration at 1 wk (air) and 4 wk (immediately after removal from MA).*

Cultivar	CO_2 ppm g^{-1} h^{-1}, 1 wk at 31 °F		CO_2 ppm g^{-1} h^{-1}, 1 wk at 40 °F		CO_2 ppm g^{-1} h^{-1}, 4 wk at 31 °F		CO_2 ppm g^{-1} h^{-1}, 4 wk at 40 °F	
Bing	60	ab	66	c	499	ab	607	abc
Black Pearl	45	c	58	cd	550	a	667	ab
Chelan	47	bc	56	cd	532	a	594	bc
Coral Champagne	46	bc	47	d	453	bc	627	abc
Regina	71	a	89	a	499	ab	541	c
Santina	48	bc	91	a	406	c	705	a
Skeena	68	a	73	b	434	bc	603	abc
Burgundy Pearl	130		126		662		638	
Cristalina	37		45		no data		no data	
Sweetheart	113		114		294		395	
Pr < F	<0.0001		<0.0001		<0.0001		<0.0001	
Cultivar	<0.0001		<0.0001		<0.0001		<0.0001	
Year	<0.0001		<0.0001		no data, 2024 only		no data, 2024 only	
Cultivar*Year	0.0012		<0.0001		no data, 2024 only		no data, 2024 only	

Values in a column followed by differing letters differ statistically at p <0.0001. 'Burgundy Pearl', 'Cristalina', and 'Sweetheart' represent one lot only; results could be lot specific and should be viewed as preliminary.

Correlation between respiration and fruit and stem quality

In an all-lots, all-cultivars statistical correlation analysis no single measured fruit or stem characteristic consistently strongly correlated with respiration rate (data not shown). Correlation or multivariate analysis of characteristics within a cultivar and respiration rate remain to be explored.

Bag atmosphere

Average oxygen and carbon dioxide levels in modified atmosphere bags were higher for fruit held at higher temperatures and increased with storage duration (**Table 9**). Values were in line with optimal atmospheres per Wang and Long (2014).

Table 9. *Average MA bag atmosphere according to storage duration and temperature.*

Timepoint	Storage temperature	% CO_2	% O_2
1 wk	31 °F	9	13
	40 °F	11	11
4 wk	31 °F	11	12
	40 °F	15	7

Conclusion and research directions

This report details cultivar-specific sweet cherry characteristics post-long-term storage to provide guidance for decisions involving export or for orchard planning. In this two-year study containing multiple lots from multiple years for each cultivar (and data averaged within lot to impose more stringent comparison), there were cultivar-specific differences in both stem and fruit quality following storage and in response to storage temperature. Results further indicate that some sweet cherry quality attributes are more readily influenced by cultivar, whereas others are more greatly affected by storage conditions (such as temperature and packaging) and pre-packing factors beyond the scope of this study, likely including environmental conditions and management strategies. Knowledge of specific quality attributes more sensitive to postharvest management practices, whether cultivar specific or general challenges, can enable proactive planning or treatment to mitigate potential problems.

In addition, while the topics below may be considered common knowledge in industry, further study or publicly available documentation would expand the capacity to do informed research surrounding postharvest sweet cherry quality and export considerations:

1. Stem physical, biochemical characteristics, or stem management connected to general retention of stem quality postharvest, including post-cluster-cutter, e.g. attributes or management leading to minimal abrasion and browning of abrasions and retention of fully intact stems
2. Documentation of propensity of cultivars to produce fruit singly vs. in clusters, combined with stem dimensionality, to determine whether these characteristics in combination influence the percentage of fruit that retain fully intact stem through packing, given that this report documents a decrease in stem thickness (indicating desiccation) during storage for cut stems

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Executive Summary

Project Title: Sweet cherry cultivar-specific export suitability

Key words: sweet cherry, postharvest, export, cultivars, varieties, cold chain, modified atmosphere, Bing, Black Pearl, Burgundy Pearl, Chelan, Coral Champagne, Cristalina, Santina, Skeena, Sweetheart, Regina

Abstract: Sweet cherries destined for certain export markets must retain fruit and stem quality for 2 to 6 weeks postharvest, and be resilient to breaks in the cold chain. The goal of this two-year study was to contrast traditional sweet cherry cultivars with newer sweet cherry cultivars to determine relative export suitability. Cultivars selected for evaluation were based on stakeholder input and included Bing, Black Pearl, Burgundy Pearl, Chelan, Coral Champagne, Cristalina, Santina, Skeena, Sweetheart, and Regina. Export-quality sorted and packed fruit were obtained from commercial packinghouses and evaluated at pickup (shortly post-packing) as well as after 4 wk storage, where fruit were held at optimal (31 °F) or a high (40 °F) temperature in modified atmosphere bags, with the latter temperature simulating an extended break in cold chain. No single cultivar outperformed all other cultivars on all fruit and stem characteristics and post-storage contrasts in quality between cultivars maturing in similar harvest timeframes are detailed in this report. To inform cultivar selection and postharvest management practices, the influence of cultivar versus storage factors on quality outcomes were also compared. Some stem and fruit quality attributes, including stem weight-to-length ratio (an indicator of stem thickness and/or relative desiccation) and °Brix had definitive cultivar-specific differences irrespective of storage conditions, while others, like stem retention, were more greatly affected by storage temperature and pre-packing factors and no cultivar-specific influence was apparent, while additional characteristics such as stem pedicel retention force, firmness, and titratable acidity were influenced by both cultivar and storage conditions. In addition, respiration rates at 1 wk into storage were not meaningfully predictive of post-storage quality outcomes at 4 wk storage. Knowledge of specific quality attributes more sensitive to management practices postharvest, whether cultivar specific or general challenges, can enable choosing particular cultivars, proactive planning, or treatment to mitigate potential problems.