Machine Harvesting for Fresh Market Quality Blueberry

Yixin Cai (MS Student)

WSU NWREC

Co-presenters:

Chongyuan Zhang

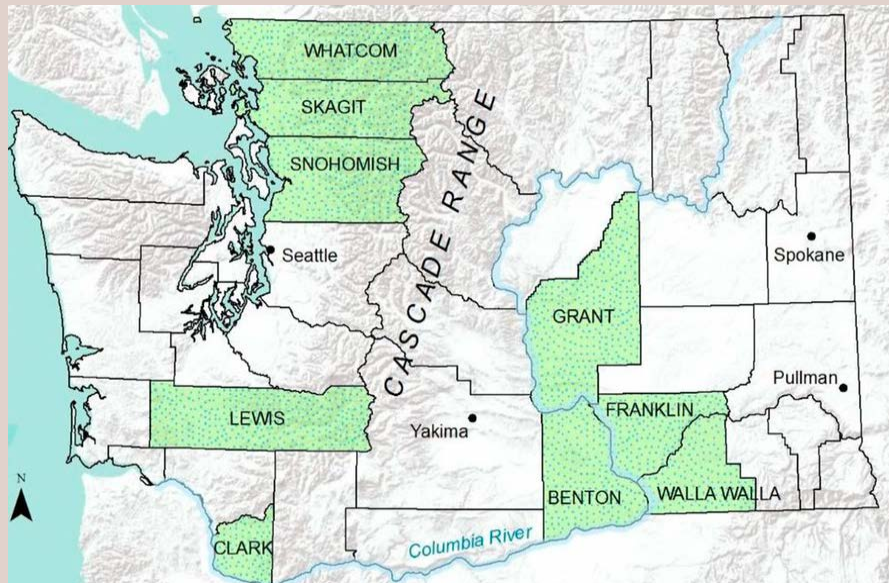**Dr. Sindhuja Sankaran**

Dr. Lisa DeVetter

- **2nd largest national producer**

  - **136.5 million pounds harvested from 14,400 acres in 2018**

  - **Value of utilized production is $139.1 million**

  - **24.2% national production**

- **30.8% is for fresh market production statewide**
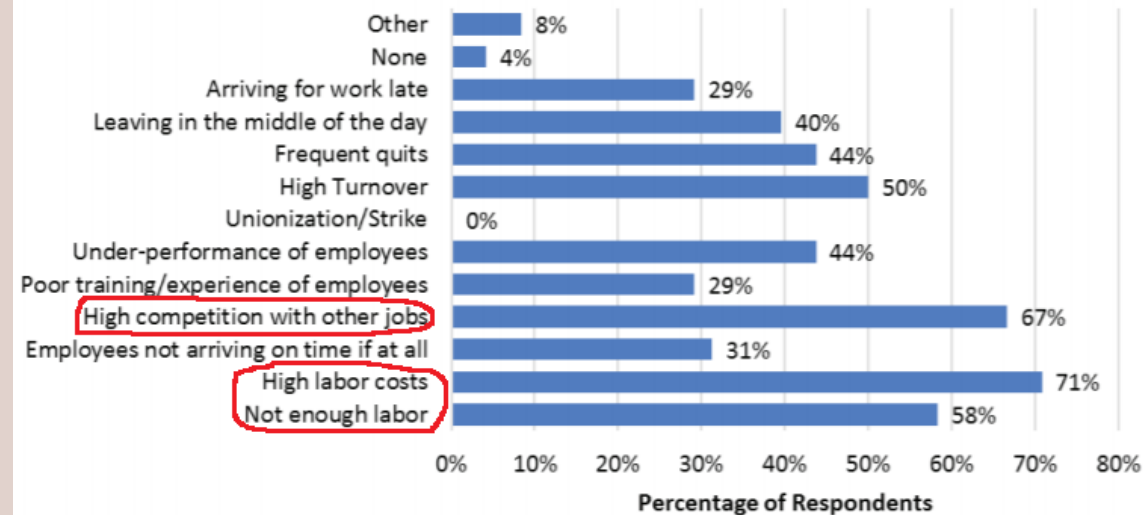
(USDA, NASS 2019)

From DeVetter et al., 2015

- **In the Pacific Northwest, most of fresh market blueberries are hand harvested**

- **Requires up to 600 worker h/acre (Brown et al., 1996)**

- **Costs up to $9,817/acre for harvesting a 20-acre field (Galinato et al., 2016)**

- **Labor issues (increasing costs, decreasing availability and high competition with other jobs) are major constrains**

POLICY BRIEF

Washington state's agricultural labor shortage

What, if any, of the following labor issues did you experience in 2016? (Select all that apply)

Labor issue	Percentage
Other	8%
None	4%
Arriving for work late	29%
Leaving in the middle of the day	40%
Frequent quits	44%
High Turnover	50%
Unionization/Strike	0%
Under-performance of employees	44%
Poor training/experience of employees	29%
High competition with other jobs	67%
Employees not arriving on time if at all	31%
High labor costs	71%
Not enough labor	58%

Percentage of Respondents

Graph from washingtonpolicy.org

Blueberry season is half over. Feds say growers must pay pickers 50% more

BY WENDY CULVERWELL

AUGUST 10, 2019 12:00 AM, UPDATED AUGUST 11, 2019 04:02 PM

From Tri-CIty Herald :https://www.tri-cityherald.com/news/local/article233677522.html

Machine Harvesting as a Solution

- **Over the row (OTR) harvesters reduce labor hours to ~10 worker h/acre (Peterson and Brown, 1996)**

- **OTR can reduce harvest costs by 85% (Brown et al., 1996)**

- **However, harvest efficiency and fruit quality are jeopardized**

- **Yield losses up to 40% in southern highbush blueberry (Casamali et al., 2016)**

- **78% berries severely bruised by OTR vs 23% by hand (Brown et al., 1996)**

Hand Harvested   **OTR machine Harvested**

- **Bruising related to dropping height and surface material (Yu et al., 2014a)**

- **Catching plates are the most important impact site (Yu et al., 2014b)**

- **Soft-catch surfaces in semi-mechinial OTR reduces impact and bruising (Takeda et al., 2017)**

- **Improved fresh market quality by modified OTR compared to conventional OTR (DeVetter et al., 2019)**
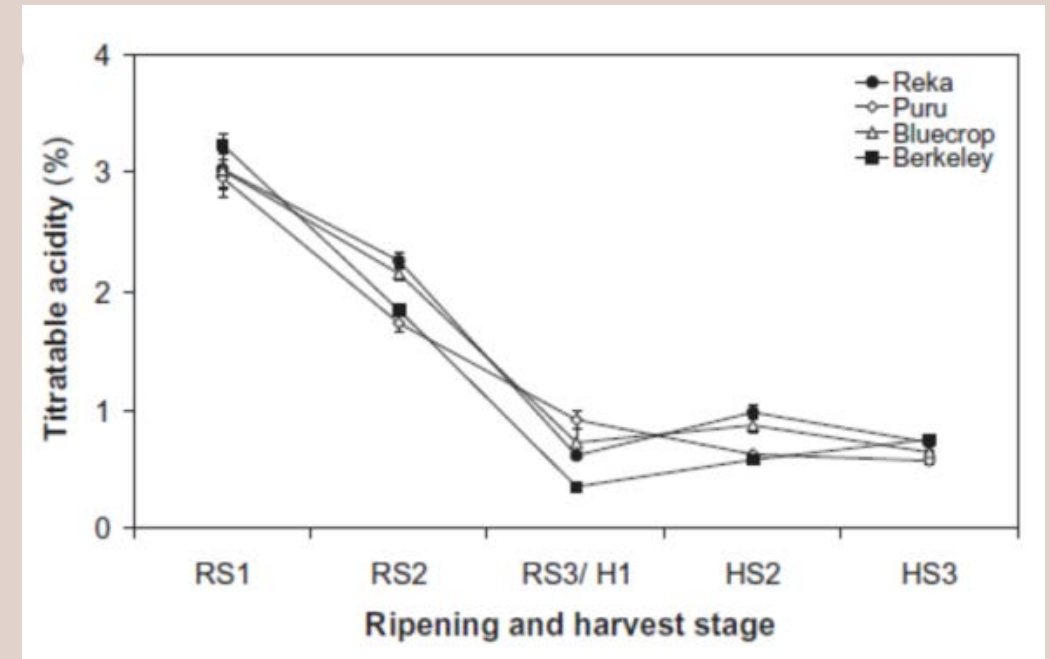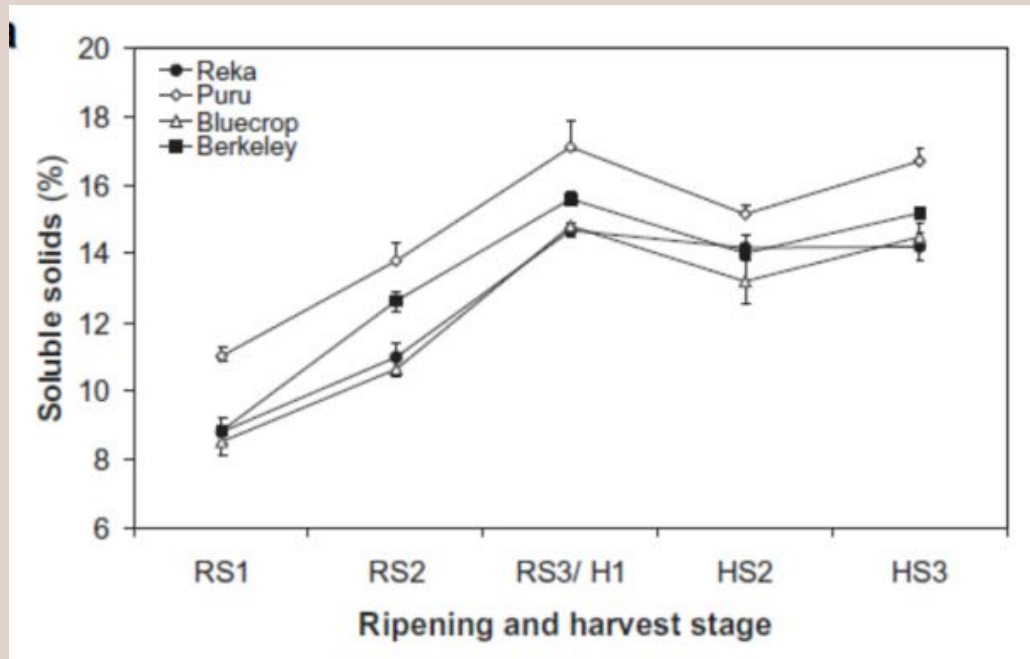

Orbirotor® heads with neoprane soft catching surfaces in an Oxbo 8040 (2018)

- **Machine harvesting starts at higher % blue**

- **Longer harvest interval to increase efficiency and decrease loss**

- **Potential risk and fruit quality change**

From Castrejón et al., 2008

1. Evaluate harvest efficiency and resultant fruit quality in northern highbush blueberry using a modified OTR harvester prototype compared to hand harvest and a traditional OTR harvester

2. Determine optimal blueberry harvest intervals for important cultivars to maximize fruit quality and harvest efficiency
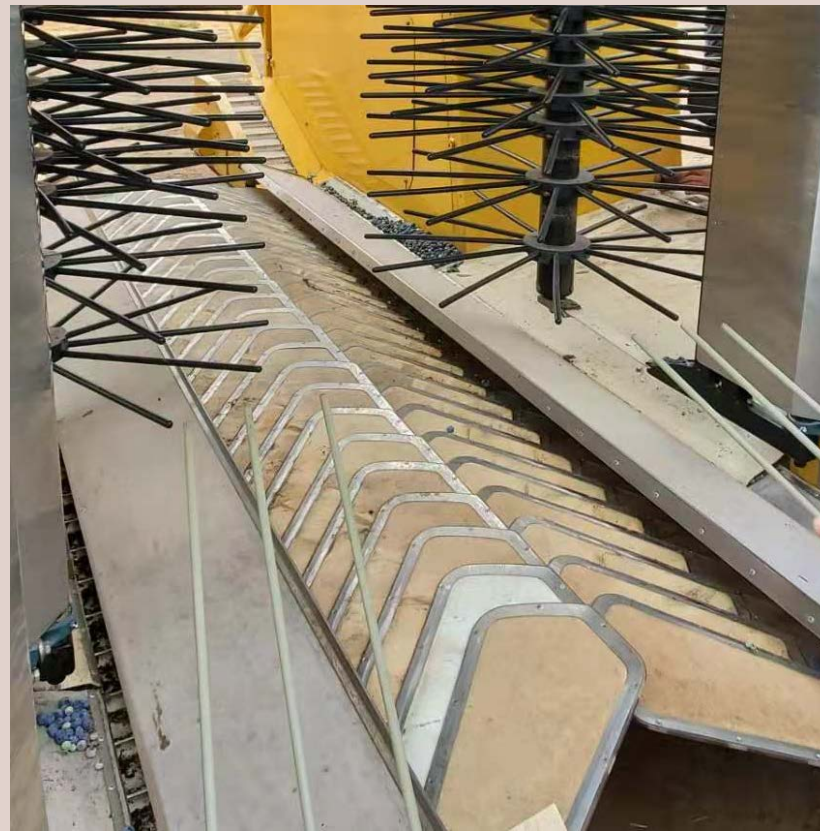
Materials and Methods

Machine Harvest Experiment

Oxbo 7440 with Orbirotor® picking heads

Soft-catch material installed as catching surface

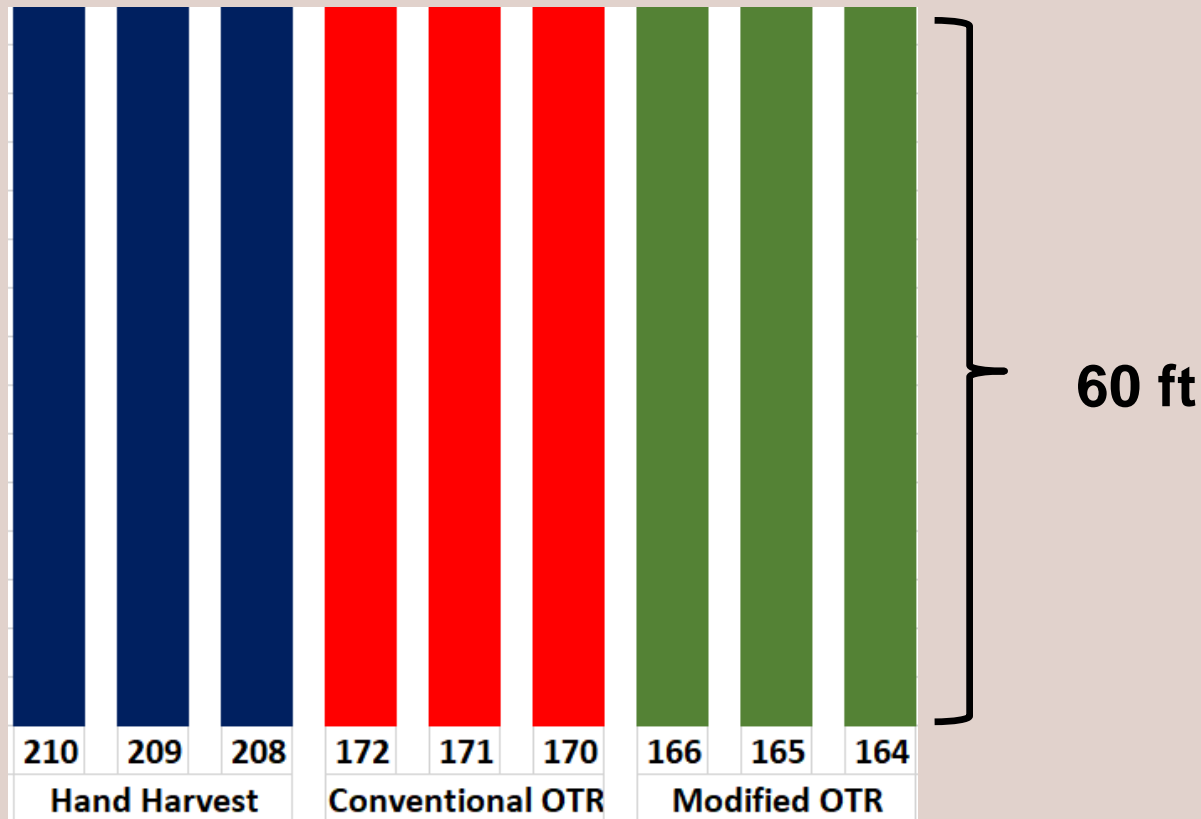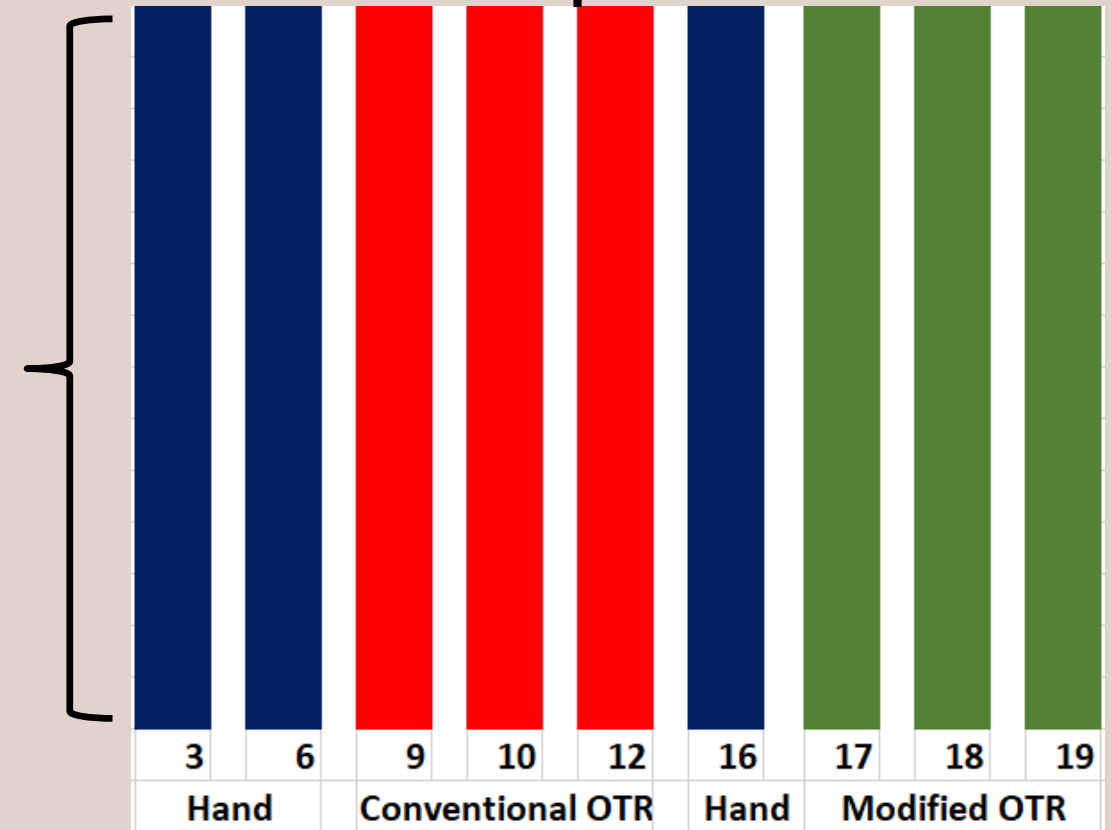**Soft material inserted above one conveyor belt**

Plot Maps

'Duke' Field

210	209	208	172	171	170	166	165	164
Hand Harvest			Conventional OTR			Modified OTR		

'Draper' Field

3	6	9	10	12	16	17	18	19
Hand		Conventional OTR			Hand	Modified OTR		

60 ft

- Harvested at 95% blue on 7/19/19, in Lynden, WA
- Packed on 7/19/19
- Conventional Harvester: Korvan 7420
- Modified Harvester: Oxbo 7440

- Harvested at 85 to 90% blue on 7/31/19, in Lynden, WA
- Packed on 8/1/19
- Conventional Harvester: Oxbo 7420
- Modified Harvester: Oxbo 7440
- Soft cushion insertion in conveyor belt

In-Row Ground Loss

- Enumerate and weigh berries from a 1 m^2 quadrat

- Quadrats placed in the center of two random plants four times per plot
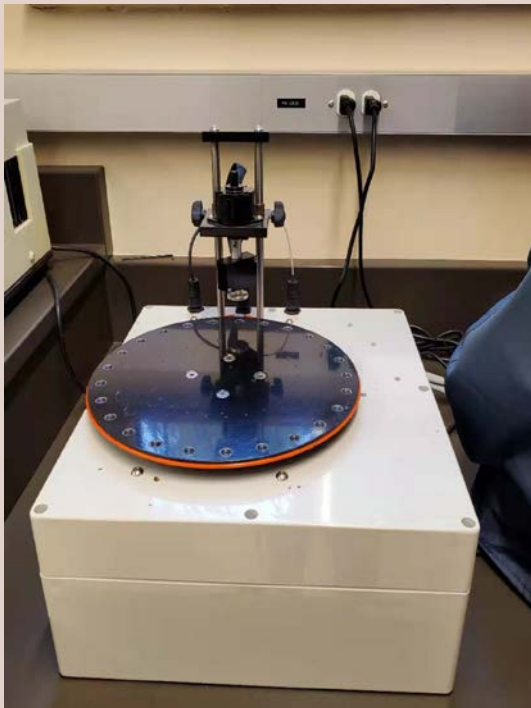
Percent packout

- Packout weight / Initial weight x 100%

- **Berries stored at 4℃ and 95% humidity for 28 days**

- **Measured 1, 7, 14, 21 and 28 days after packing**

- **Firmness measured using a FirmTech II (Bioworks, Wamego, KS, USA)**

- **Water loss: $(\text{weight}_{Day0} - \text{weight}_{DayX}) / \text{weight}_{Day0}$**

FirmTech II

Berries in walk-in cooler

Incidence of bruising or tissue injury quantified using a digital imaging system

•**Berries were cut in half equatorially**

•**Captured images in "phenotyping box"**
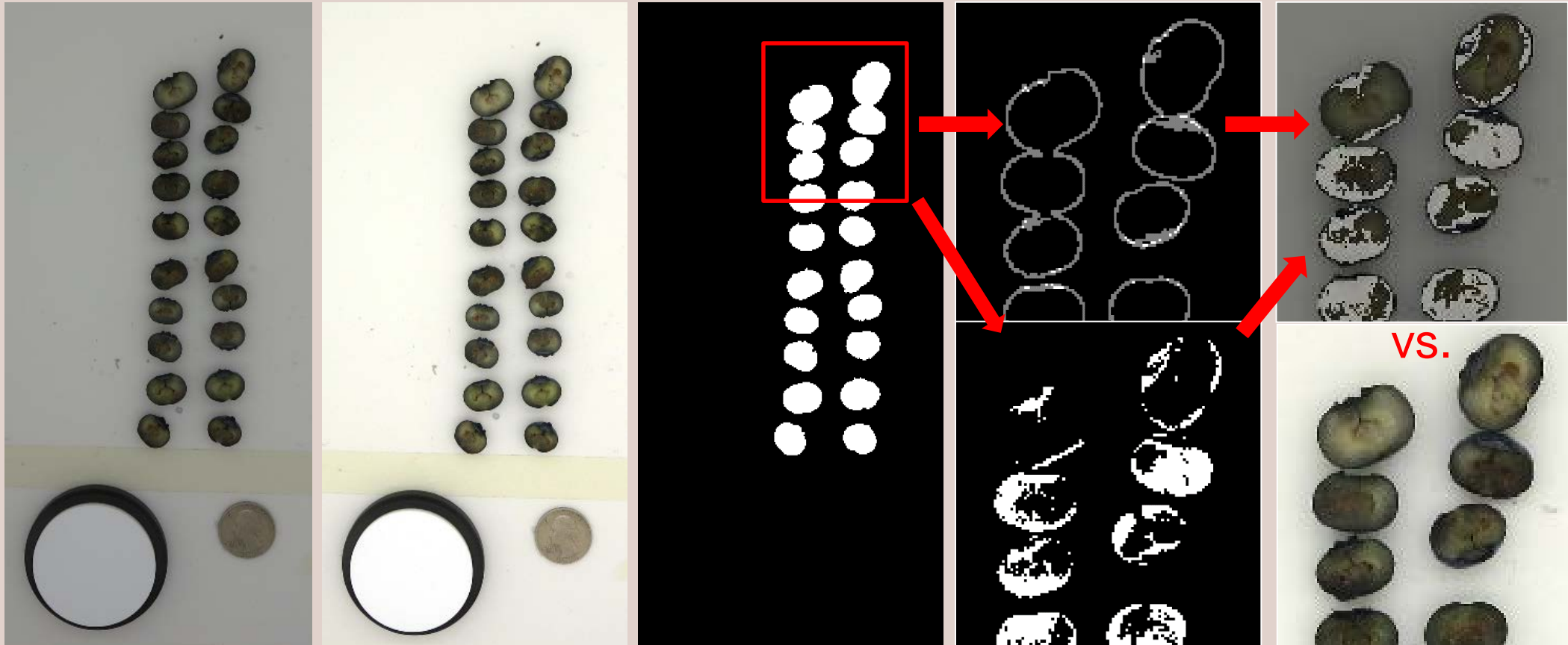

Phenotyping box

One images captured through phenotyping box

Bruise and injury detection using processed images

VS.

Data acquisition

Radiometric calibration

Blueberry detection
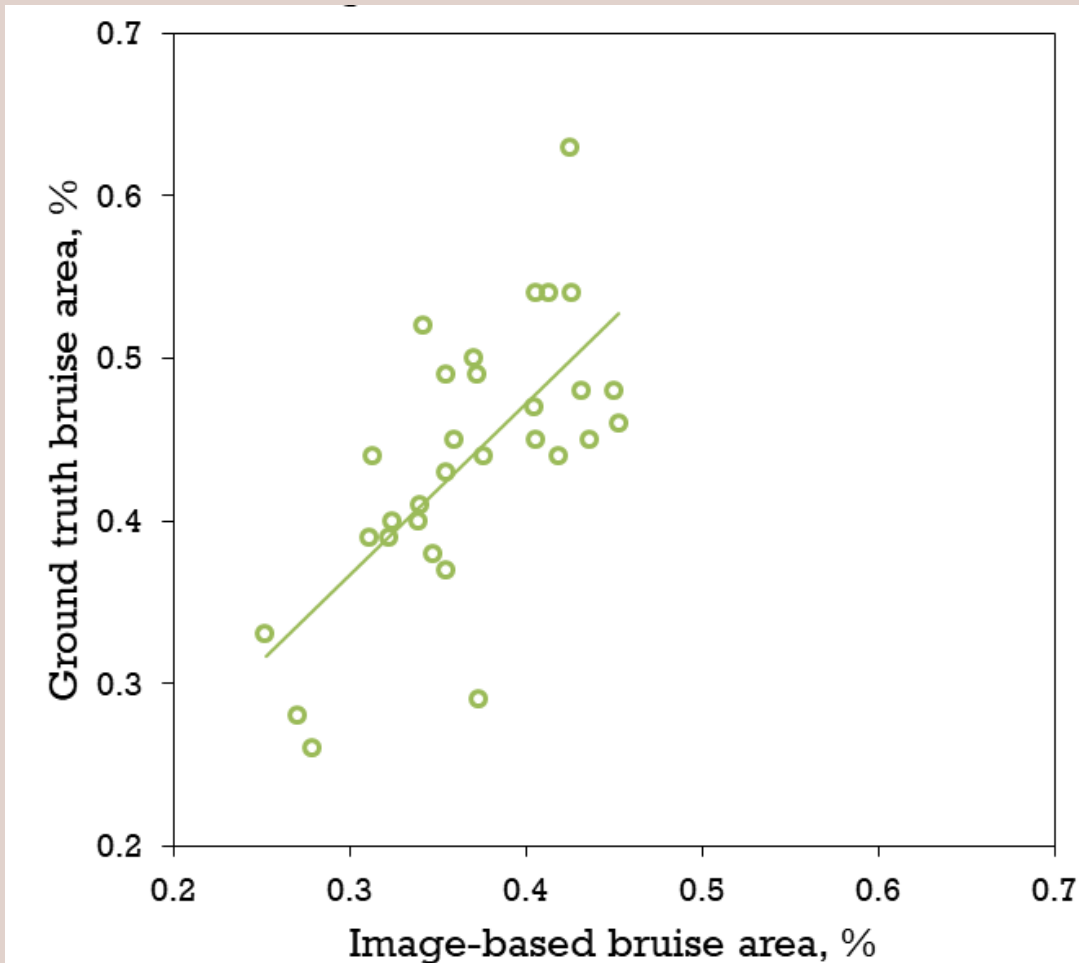
Skin & bruise detection

Quality inspection

Bruise and injury detection using image processing

Correlations between image-based and ground truth bruise/injured area

• **Positive correlation**

• r = 0.68

• **Slight underestimate of bruise area**

• **Ongoing improvement of image-based bruise and injury detection**

Materials and Methods

Harvest Interval Experiment

- **Modified Harvester: Oxbo 7440**

- **Location: Lynden, WA**

- **1st harvest (8/12): Hand plot A, Row 44 - 52**

- **3 days interval (8/15): Hand plot A, B, Row 47, 51, 52**

- **10 days interval (8/22): Hand plot A, B, C, Row 46, 48, 49**

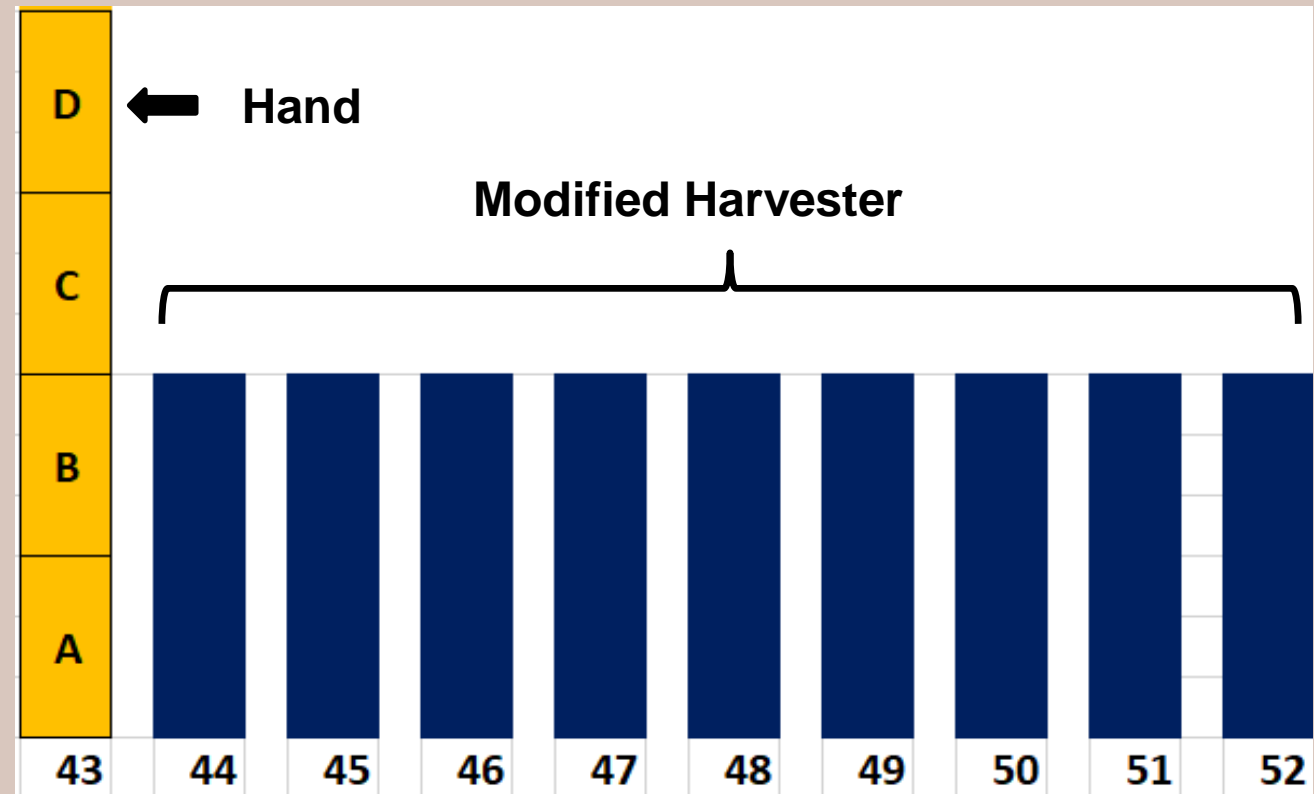- **14 days interval (8/26): Hand plot A, B, C, D, Row 44, 45, 50**

- **Pack on the same day as harvest**

Plot Map: 'Liberty' Harvest Interval Experiment

- **Modified Harvester: Oxbo 7440**

- **Location: Lynden, WA**

- **1st harvest (8/12): Hand plot A, Row 44 - 52**

- **3 days interval (8/15): Hand plot A, B, Row 47, 51, 52**

- **10 days interval (8/22): Hand plot A, B, C, Row 46, 48, 49**

- **14 days interval (8/26): Hand plot A, B, C, D, Row 44, 45, 50**

- **Pack on the same day as harvest**

Percent blue before and after machine harvest

• Randomly tagged 20 clusters in one plot for the 1st harvest

• Compared remaining blue fruit before and after harvest

• Visually estimate % blue before and after harvest for 2nd harvest

Percent packout

• Packout weight / Initial weight x 100%

Before

After

- **Berries stored at 4℃ and 95% humidity for 28 days**

- **Measured at 1, 7, 14, 21 and 28 days after packing**

- **Firmness measured using FirmTech II (Bioworks, Wamego, KS, USA)**

- **Soluble solids measured by H19680 Refractometer (Hanna Instruments, Woonsocket, RI)**

- **pH and titratable acidity measured by HI-84532 titrator (Hanna Instruments, Woonsocket, RI)**

- **Incidence of bruising by digital imaging system**

Digital refractometer

Digital titrator
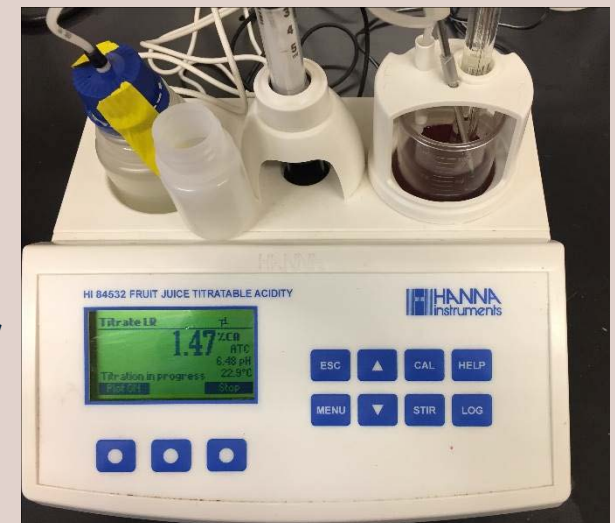
Results

Machine Harvest Experiment

Harvest Efficiency: In-Row Ground Loss

	'Duke': In-Row Ground Loss (%)	'Draper': In-Row Ground Loss Weight (g)
Conventional OTR	0.5 a[z]	170
Modified OTR	0.4 a	240
Hand (control)	1.4 b	██████████
p Value	0.0004	0.64

[z] **Means followed by same lower case letter within a column are not statistically different at α=0.05**

	Percent (%)			
	Packout	**Color**	**Soft**	**Undersized**
Conventional OTR	**91.8**	**3.1**	**1.6 a^z**	**0.3**
Modified OTR	**92.7**	**5.0**	**2.0 a**	**0.6**
Hand (Control)	**93.2**	**3.7**	**0.8 b**	**0.4**
p **value**	**0.14**	**0.09**	**0.001**	**0.08**

^{Z} **Means followed by same lower case letter within a column are not statistically different at α=0.05**

Harvest Efficiency: Packout Data ('Duke')

	Percent (%)			
	Packout	**Color**	**Soft**	**Undersized**
Conventional OTR	91.8	3.1	1.6 a^z	0.3
Modified OTR	92.7	5.0	2.0 a	0.6
Hand (Control)	93.2	3.7	0.8 b	0.4
p value	0.14	0.09	0.001	0.08

^{z} **Means followed by same lower case letter within a column are not statistically different at α=0.05**

	Percent (%)		
	Packout	**Color**	**Soft**
Conventional OTR	83.7	10.8	4.9
Modified OTR w Insertion	83.0	10.6	6.5
Modified OTR w/o Insertion	84.2	9.7	7.4
Hand (Control)	87.5	7.9	5.6
p **value**	0.26	0.25	0.63

Fruit Quality: 'Duke' Firmness (g/mm)

	Day 1	Day 7	Day 14	Day 21	Day 28
Conventional OTR	121.0	117.6	108.3	100.5 b[z]	89.5 b
Modified OTR	126.5	113.3	112.0	104.4 ab	92.8 ab
Hand (Control)	133.9	123.8	120.0	119.0 a	103.5 a
p value	0.09	0.06	0.10	0.03	0.03

[z] **Means followed by same lower case letter within a column are not statistically different at α=0.05**

Fruit Quality: 'Draper' Firmness (g/mm)

	Day 1	Day 7	Day 14	Day 21	Day 28
Conventional OTR	192.5	192.3	182.4	151.4 b[z]	137.7
Modified OTR w/o Insertion	189.5	191.4	181.5	161.9 ab	139.6
Modified OTR w Insertion	183.8	192.7	192.4	175.7 a	144.5
Hand (Control)	197.9	198.9	186.8	164.9 ab	136.8
p value	0.17	0.56	0.36	0.03	0.62

[z] **Means followed by same lower case letter within a column are not statistically different at α=0.05**

Fruit Quality: 'Draper' Firmness (g/mm)

	Day 1	Day 7	Day 14	Day 21	Day 28
Conventional OTR	**192.5**	**192.3**	**182.4**	**151.4 b^z**	**137.7**
Modified OTR w/o Insertion	**189.5**	**191.4**	**181.5**	**161.9 ab**	**139.6**
Modified OTR w Insertion	**183.8**	**192.7**	**192.4**	**175.7 a**	**144.5**
Hand (Control)	**197.9**	**198.9**	**186.8**	**164.9 ab**	**136.8**
p **value**	**0.17**	**0.56**	**0.36**	**0.03**	**0.62**

^{z} **Means followed by same lower case letter within a column are not statistically different at α=0.05**

Fruit Quality: 'Duke' Water Loss (%)

	Day 7	Day 14	Day 21	Day 28
Conventional OTR	**2.4**	**5.0**	**6.0**	**8.3**
Modified OTR w/o Insertion	**1.9**	**4.1**	**5.7**	**7.7**
Hand (Control)	**2.2**	**4.5**	**5.7**	**7.2**
p value	**0.27**	**0.10**	**0.93**	**0.58**

Fruit Quality: 'Draper' Water Loss (%)

	Day 7	Day 14	Day 21	Day 28
Conventional OTR	1.6	2.9	4.5	6.1 a^z
Modified OTR w/o Insertion	1.9	4.7	6.4	8.2 b
Modified OTR w Insertion	1.7	3.2	5.0	6.5 ab
Hand (Control)	1.7	3.3	4.7	6.0 a
p value	0.20	0.08	0.07	0.05

^{z} Means followed by same lower case letter within a column are not statistically different at α=0.05

Fruit Quality: 'Draper' Water Loss (%)

	Day 7	Day 14	Day 21	Day 28
Conventional OTR	**1.6**	**2.9**	**4.5**	**6.1 a^z**
Modified OTR w/o Insertion	**1.9**	**4.7**	**6.4**	**8.2 b**
Modified OTR w Insertion	**1.7**	**3.2**	**5.0**	**6.5 ab**
Hand (Control)	**1.7**	**3.3**	**4.7**	**6.0 a^z**
p **value**	**0.20**	**0.08**	**0.07**	**0.05**

^{z} **Means followed by same lower case letter within a column are not statistically different at α=0.05**
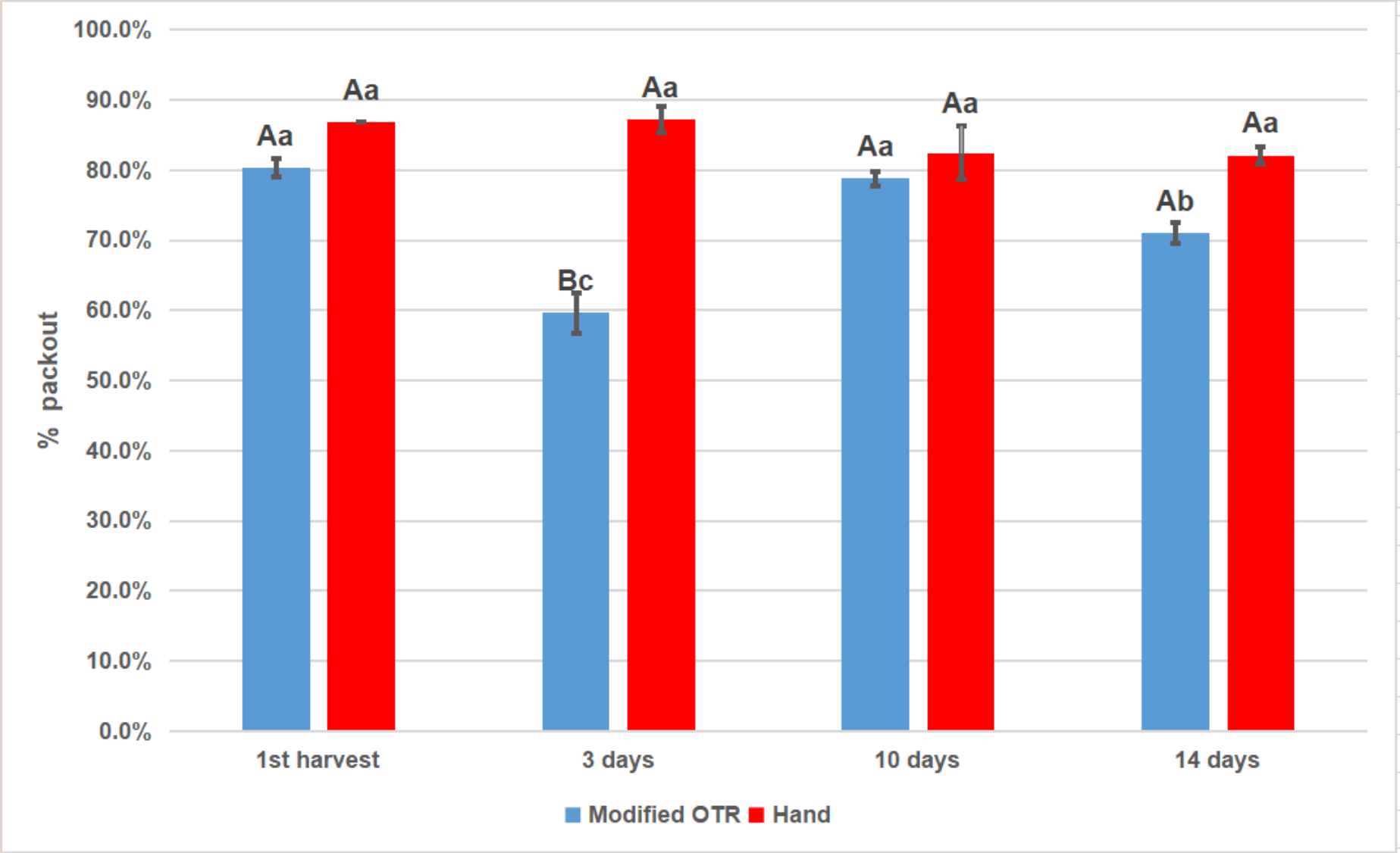
Results

Harvest Interval Experiment

Harvest Efficiency: Percent Blue Before and After Machine Harvesting

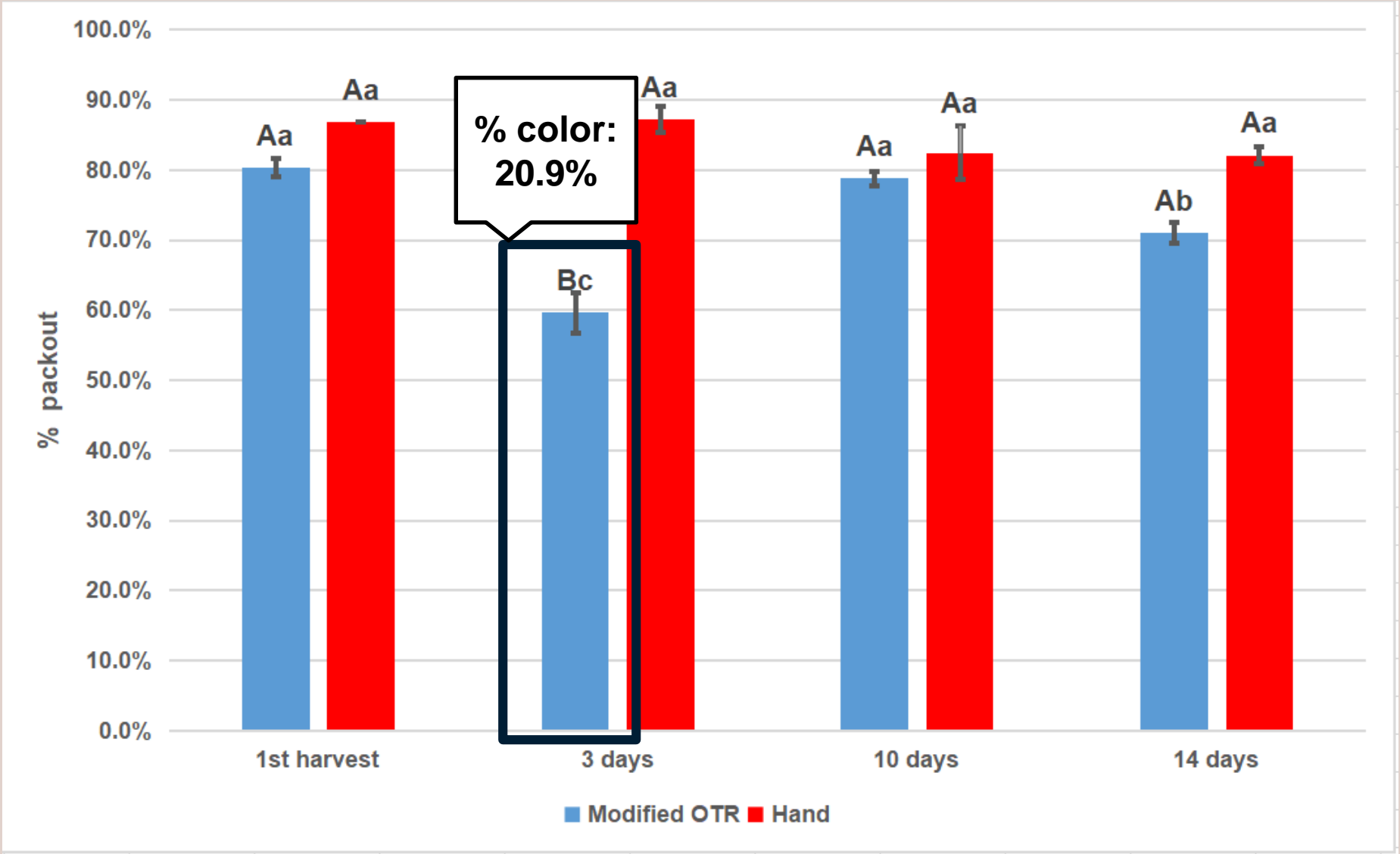|	% Blue Before	% Blue After
1st Harvest	64	9
3 Day Interval	60	10
10 Day Interval	70	15
14 Day Interval	70	10

Harvest Efficiency: Packout Data

Different lower case letter: significant difference between harvest type in each interval
Different upper case letter: significant difference between harvest interval in each harvest type
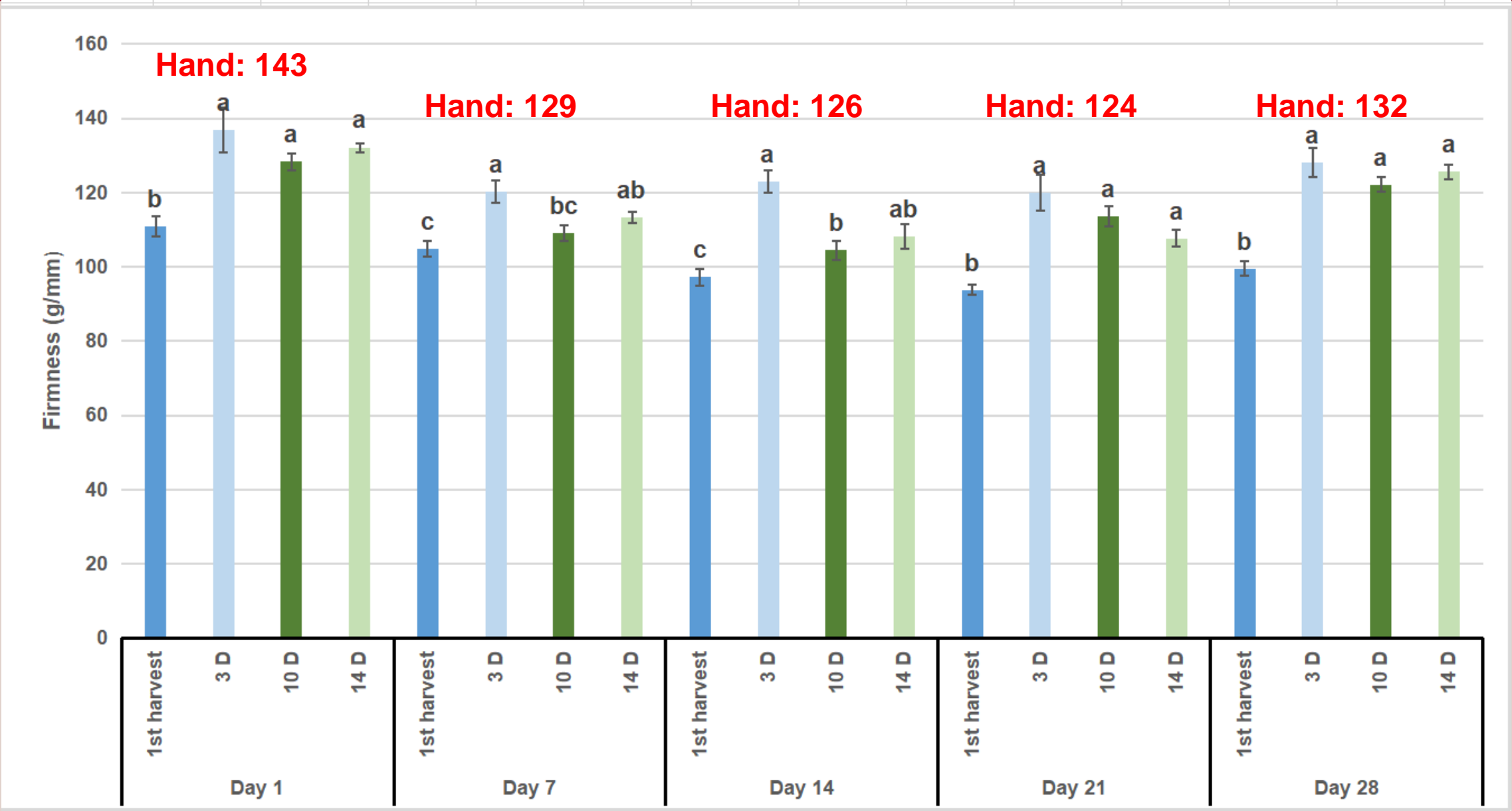
Harvest Efficiency: Packout Data

Different lower case letter: significant difference between harvest type
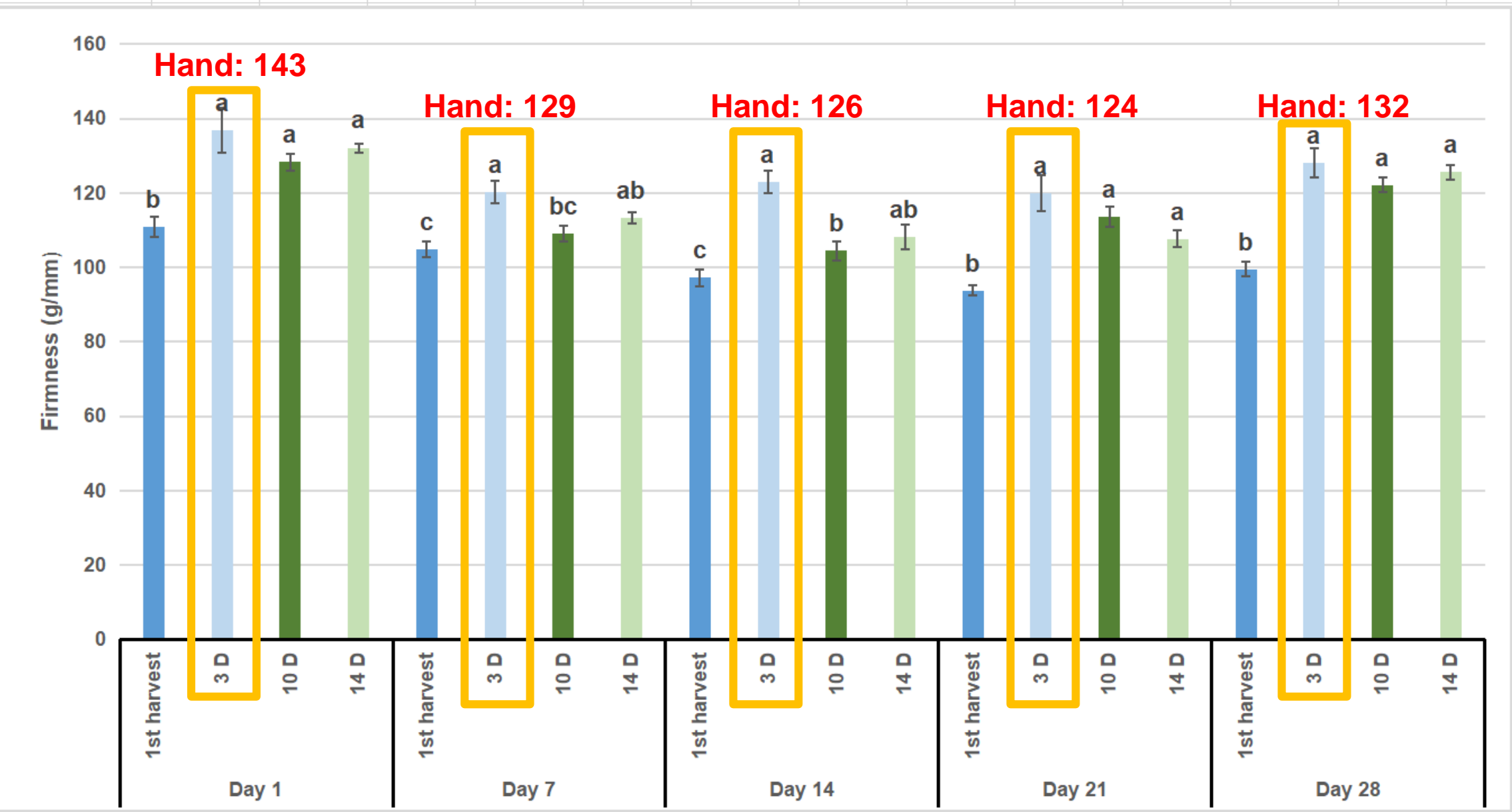**Different upper case letter: significant difference between harvest interval**
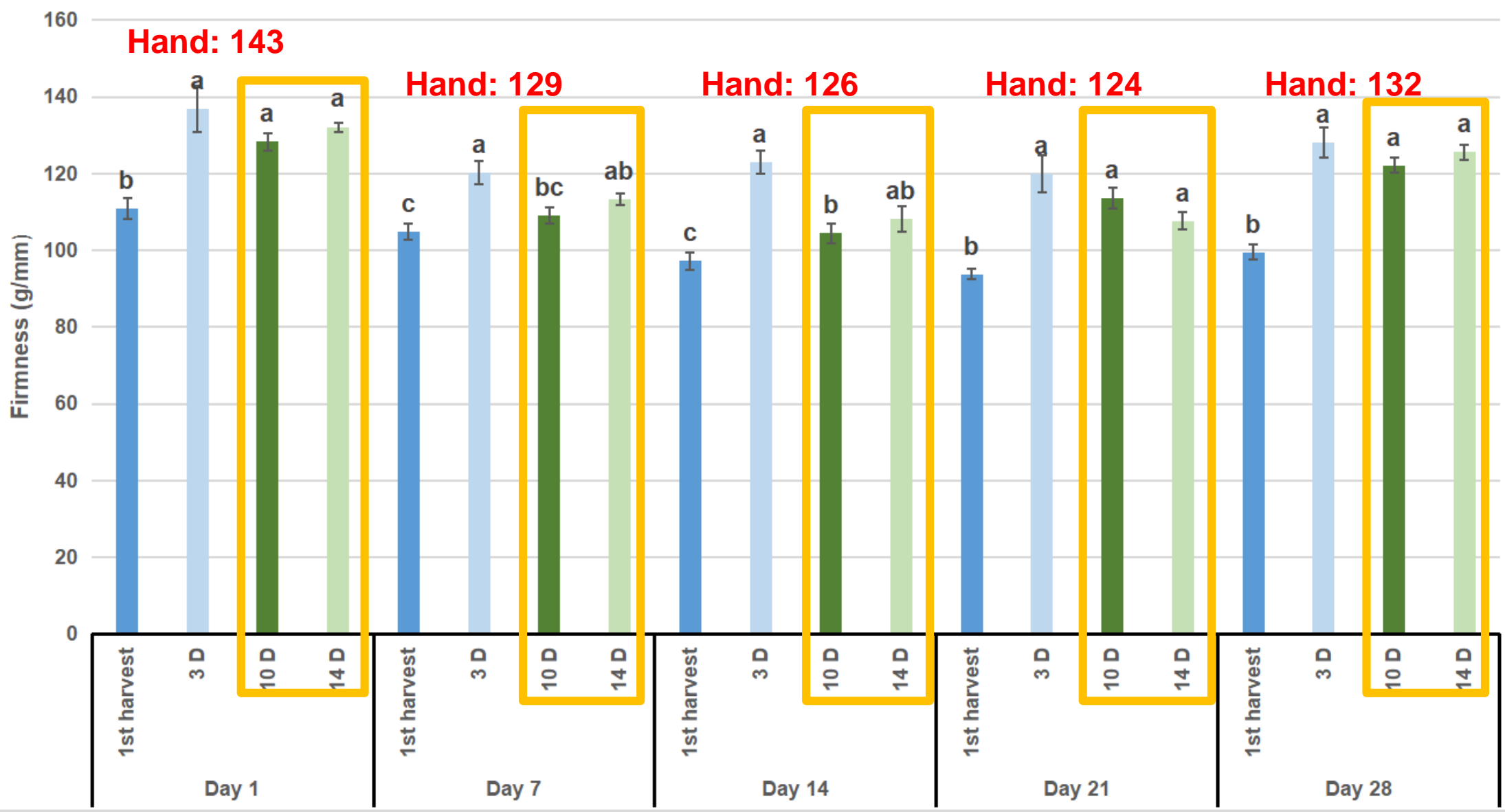
Fruit Quality: Firmness in Machine Harvested Fruit

Hand vs Machine: $p < 0.001$; Different lower case letter: significant difference between harvest interval

Fruit Quality: Firmness in Machine Harvested Fruit

Hand vs Machine: *p* < 0.001; Different lower case letter: significant difference between harvest interval

Fruit Quality: Firmness in Machine Harvested Fruit

Hand vs Machine: *p* < 0.001; Different lower case letter: significant difference between harvest interval

Machine Harvest Experiment

•No in-row ground loss difference between modified OTR and conventional OTR

•No packout difference between harvest type in 'Duke' and 'Draper'

•Better firmness in 'Duke' and 'Draper' harvested by modified OTR than conventional OTR

Harvest Interval Experiment

•Lowest OTR harvest packout with 3 day harvest interval

•10 and 14 day harvest interval are better choices in terms of harvest efficency and fruit quality in 2019 for 'Liberty'

These are the first-year results - The experiments will be repeated in 2020

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Q & A

Contact Info:
yixin.cai@wsu.edu

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