

# Identifying and mitigating carbon dioxide-related apple internal browning

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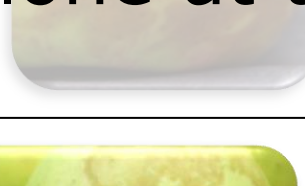
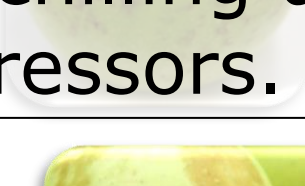
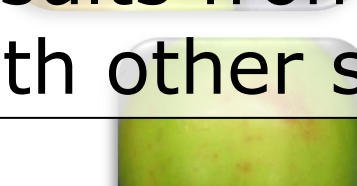
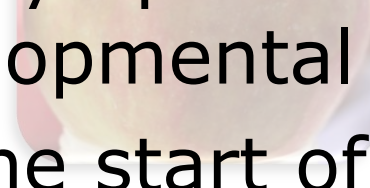
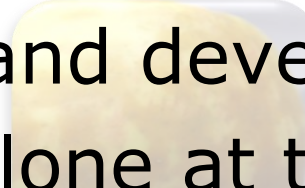
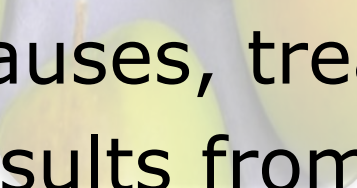
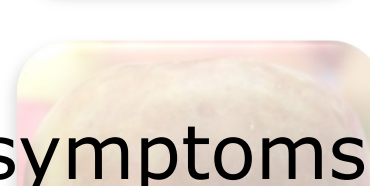
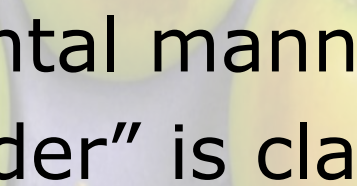
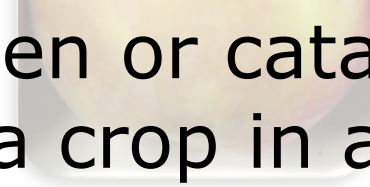
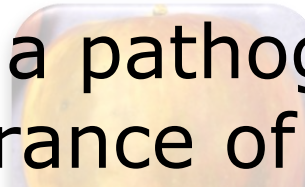
# The Postharvest Group at the Tree Fruit Research Laboratory, Wenatchee, WA and WSU-TFREC

- 5 Scientists: Jim Mattheis (retired), Loren Honaas, Rachel Leisso (ARS-Hood River, OR), David Rudell, Carolina Torres (Endowed chair-WSU).

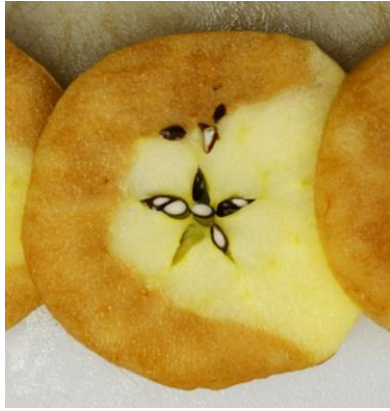


# The bane of the apple and pear cold chains: Physiological Disorders

- ❑ A condition **NOT** caused by a pathogen or catastrophic stress that alters the appearance of a crop in a detrimental manner.
- ❑ A “disorder” is classified by **similar** symptoms and the **same** causes, treatments, and developmental time-line.
- ❑ Often results from chilling alone at the start of storage or along with other stressors.



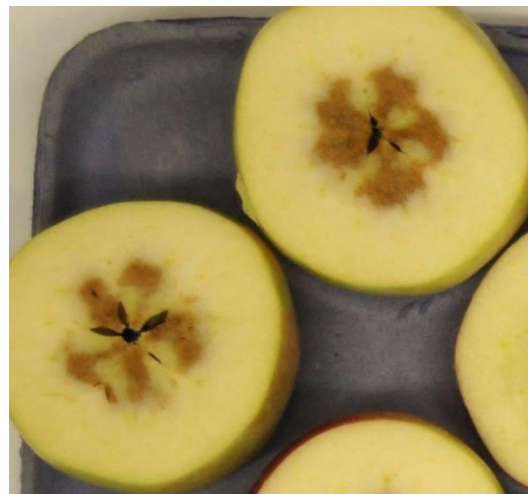
# What types of cold chain disorders do we see?



# Typical symptoms of CO<sub>2</sub> sensitivity



# Symptoms of the same disorder can be diverse—cortex



- Symptoms vary with genotype making diagnosis difficult

# Symptoms of the same disorder can be diverse—peel



- Symptoms vary with genotype challenging diagnosis.

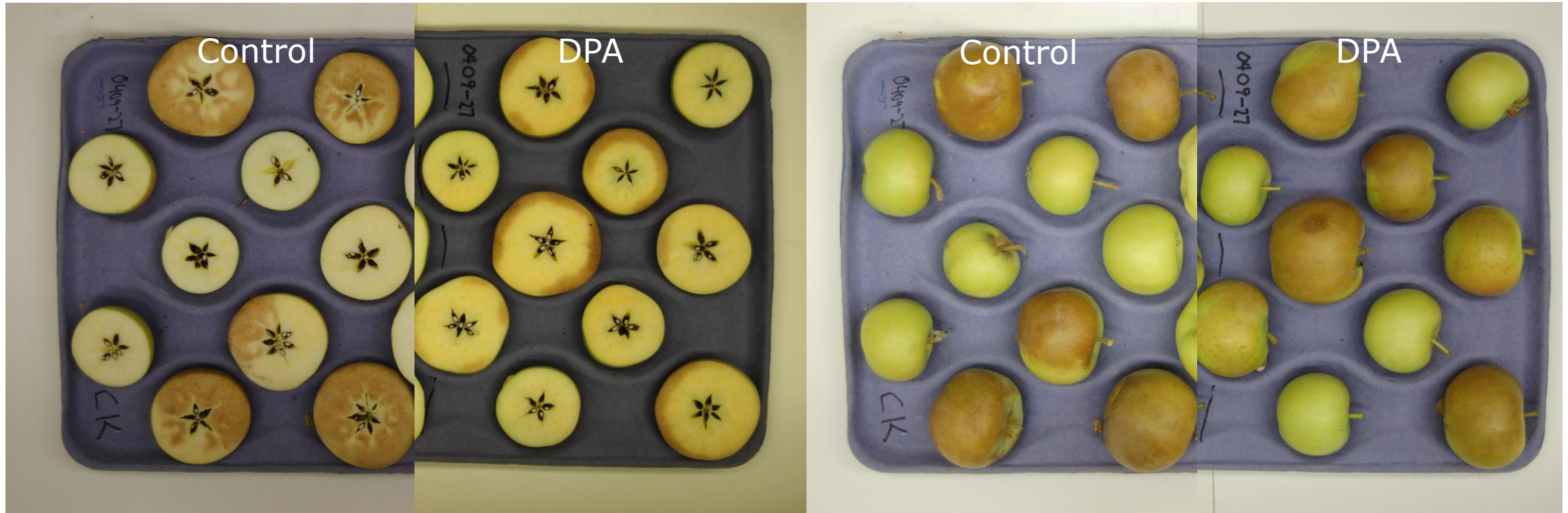
# Using DPA to find CO<sub>2</sub> sensitivity

- Storage conditions:  
0.6 °C, 0.5% O<sub>2</sub>,  
5% CO<sub>2</sub>





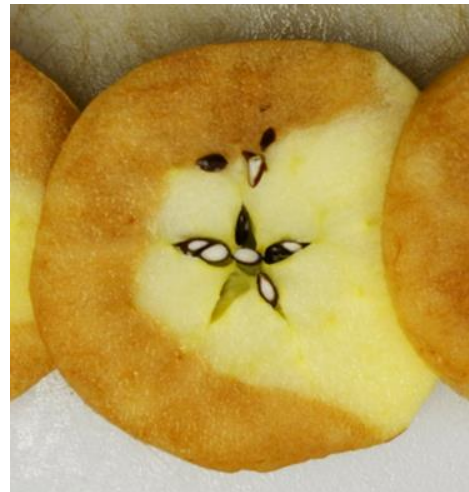
# Storage injuries with different causes on the same fruit



- Disorders caused by CO<sub>2</sub> sensitivity can be distinguished from others using the proposed protocol.

# Honeycrisp can develop 2 different flesh disorders

- ❑ Soggy breakdown is caused by the transition to storage temperatures.
  - Not caused by elevated CO<sub>2</sub> and DPA does not reduce symptoms.
- ❑ Also, can be highly sensitive to elevated CO<sub>2</sub> during CA.



# Simple CO<sub>2</sub> sensitivity screening



- ❑ JUICI vs Delicious
- ❑ Drench portion with DPA.
- ❑ Sealed in bags with zip ties and placed in 0.6 °C air.
- ❑ CO<sub>2</sub> reached above 3% and O<sub>2</sub> down to 9% between 1 and 2 weeks.
- ❑ Radial browning in JUICI by 2 months.

# Storage variables that influence CO<sub>2</sub> sensitivity

## □ 1-MCP

## □ Harvest maturity

- Relatively immature CO<sub>2</sub> sensitive cultivars prone to peel symptoms
- Apples of advanced maturity of CO<sub>2</sub> sensitive cultivars prone to flesh symptoms.
- Even symptoms can look different depending on harvest maturity.

## □ Altered sensitivity over the storage period

- When is CO<sub>2</sub> control necessary?

## □ O<sub>2</sub> levels in CA

# CO<sub>2</sub> mitigation strategies

- Scrubbers (energy intensive)
- Slaked lime (moderately effective, waste intensive)
  - Evidence of CO<sub>2</sub> sensitivity later in storage
- Diphenylamine drenching is very effective at reducing or eliminating CO<sub>2</sub>-related disorders.
- Acclimation
  - Delayed CA
  - Temperature

# CO<sub>2</sub> sensitive cultivars in WA production

- DPA treatment: 2000 ppm DPA drench at harvest.
- Atmosphere: Combinations of 0.6 or 1% O<sub>2</sub> and 1 and 5% CO<sub>2</sub>.
- Delayed CA: 1 ppm 1-MCP then 0, 2, or 4 week delay until 0.6% O<sub>2</sub>:5% CO<sub>2</sub>.

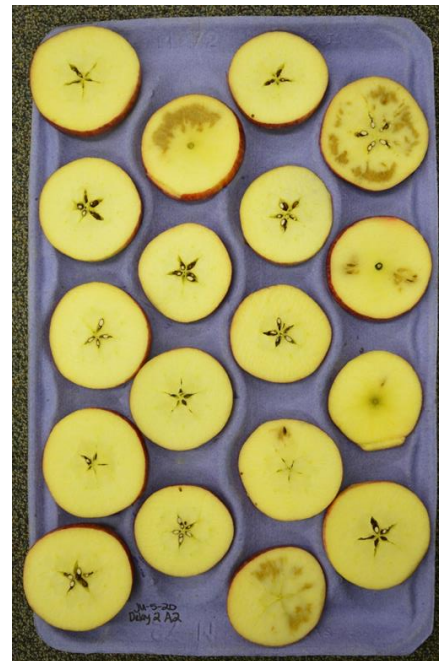
<b>Cultivar</b>	<b>DPA reduces symptoms</b>	<b>Reduced by low CO<sub>2</sub></b>	<b>Delayed CA test effective</b>	<b>Non-CO<sub>2</sub> related symptoms</b>
<b>Golden Delicious</b>	Yes	No	Yes	Yes
<b>JUICI</b>	Yes	Yes	Yes	No
<b>Pazazz</b>	Yes	Yes	No	Yes
<b>Plumac</b>	Yes	N/A	N/A	No
<b>Scilate</b>	Yes	Yes	No	No
<b>Honeycrisp</b>	Yes	No	No	Yes
<b>Braeburn</b>	Yes	Yes	-	No
<b>WA 38*</b>	Yes*	No	Yes	Yes
<b>Fuji</b>	Yes	Yes	No	Yes
<b>Cripps Pink</b>	Yes	-	-	No
<b>Smitten</b>	Yes	-	-	Yes

# Delaying CA: JUICI (0.6% O<sub>2</sub>:5% CO<sub>2</sub>)

No delay

2 week delay

4 week delay



- Delayed CA reduced injury even under the harshest conditions for a CO<sub>2</sub> sensitivity.



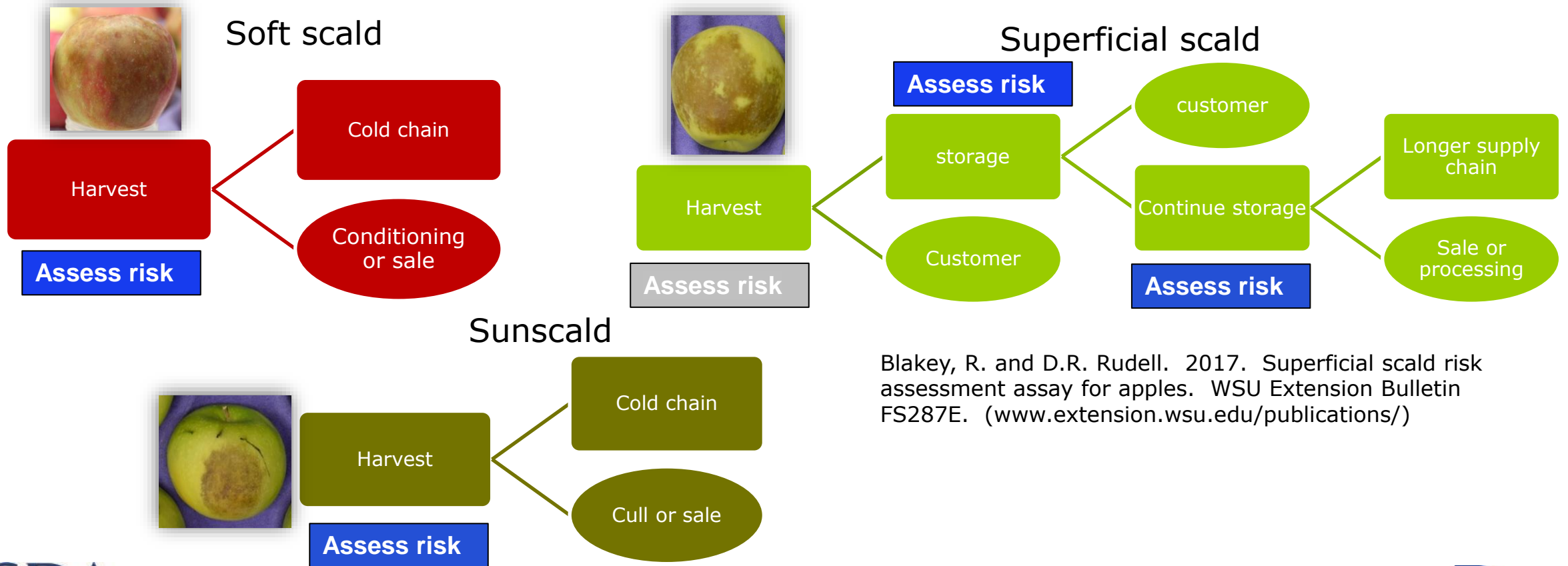
# Risk assessment

- Levels of chemicals that indicate risk at some timepoint prior to symptom development.
  - Can indicate disposition to develop a disorder at harvest.
  - Can indicate whether a stressor compromised fruit storability.
  - Can indicate whether cold chain conditions are reducing risk.



# Risk-based cold-chain management

- Informed decisions using risk assessment.

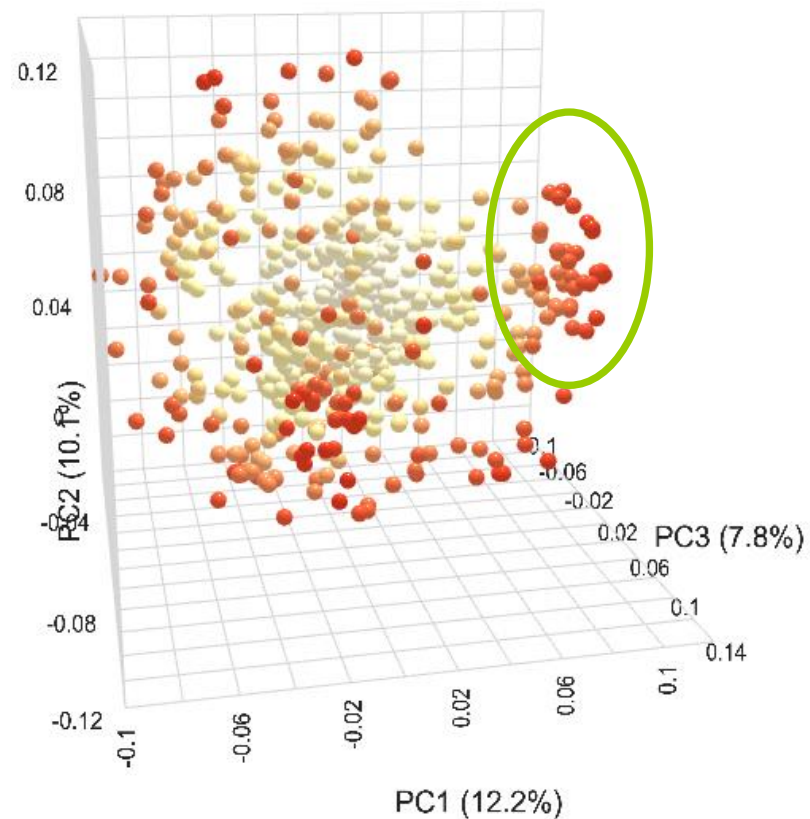
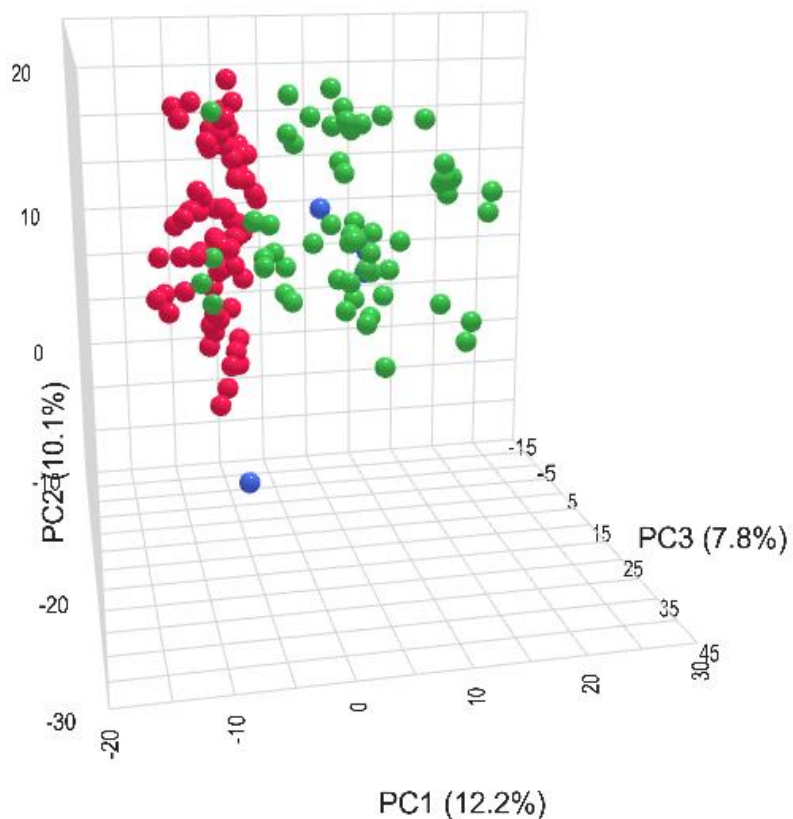


Blakey, R. and D.R. Rudell. 2017. Superficial scald risk assessment assay for apples. WSU Extension Bulletin FS287E. ([www.extension.wsu.edu/publications/](http://www.extension.wsu.edu/publications/))

# Symptoms alter natural chemical fingerprint

## **Contrast:**

- Diphenylamine (antioxidant)
- Elevated pCO<sub>2</sub>, reduced pO<sub>2</sub> (controlled atmosphere)

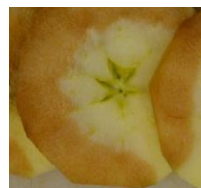
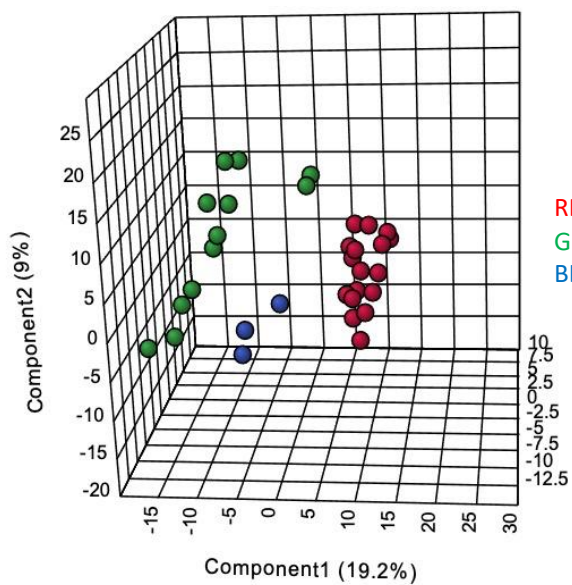


- Honeycrisp
- Braeburn
- Scilate
- Pazazz
- JUICI
- Smitten

# $\beta$ -sitosterylglucosyl palmitate levels reflect CO<sub>2</sub>-related symptoms



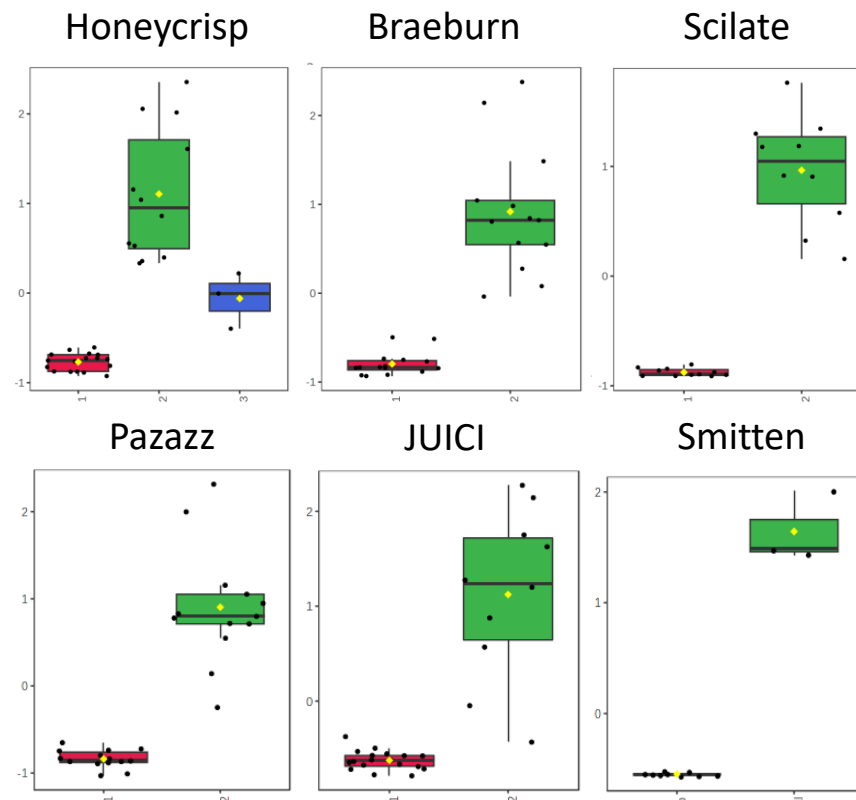
Honeycrisp



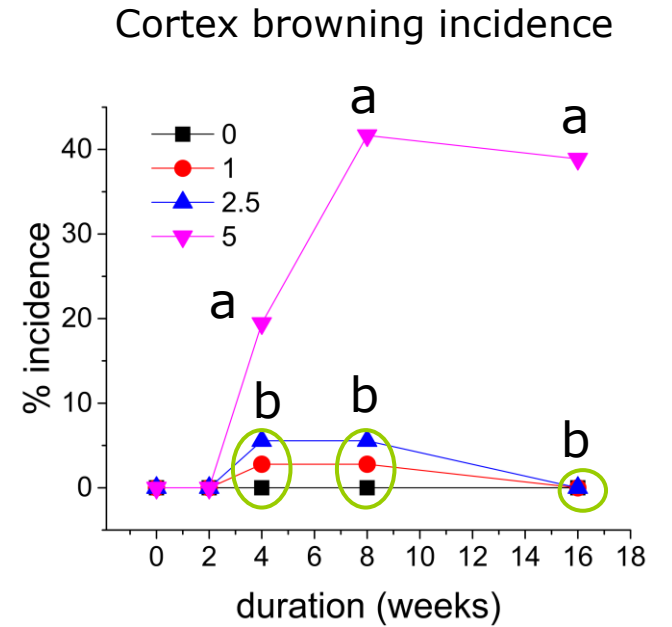
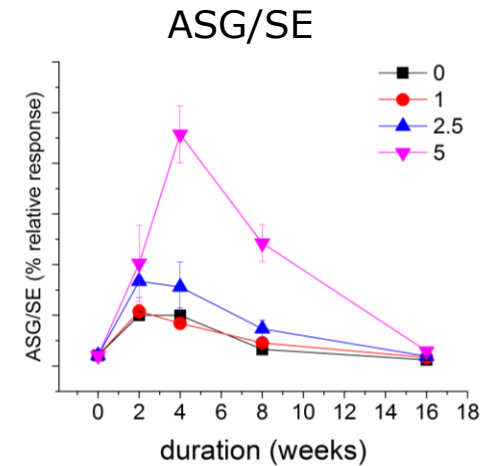
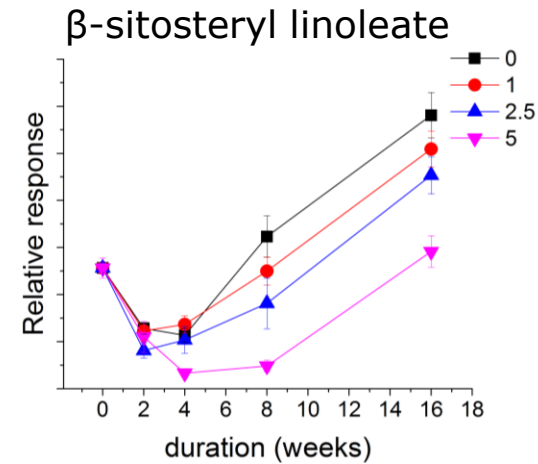
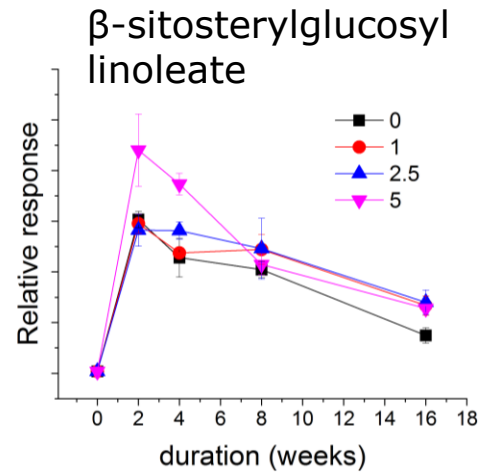
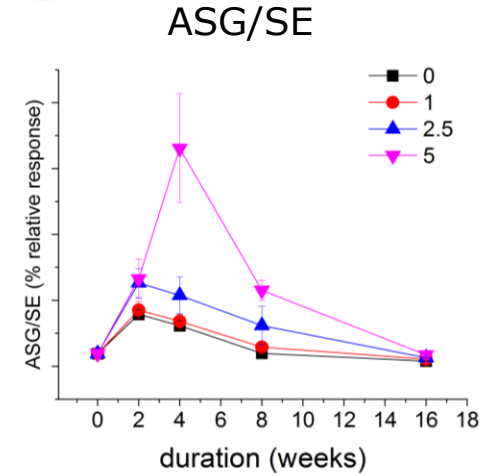
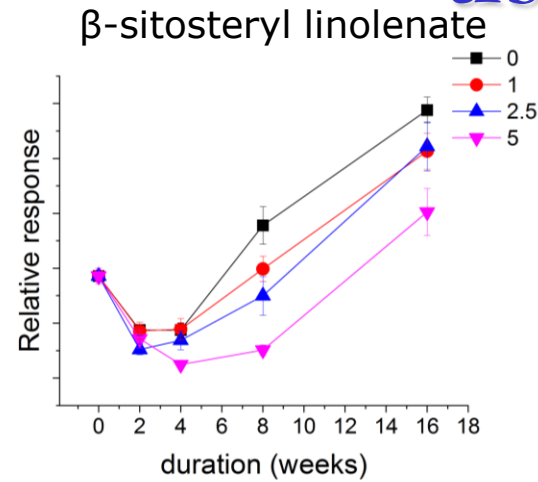
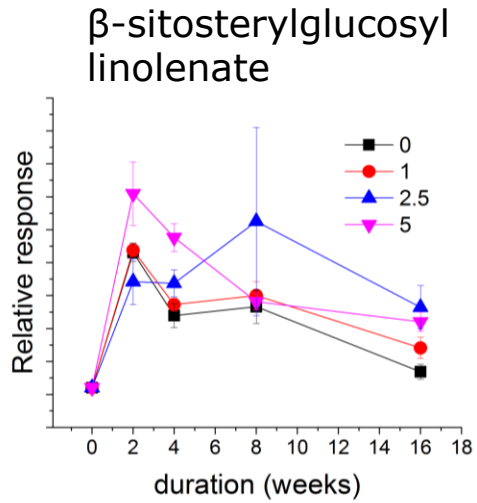
Braeburn



Scilate



# pCO<sub>2</sub> impacts ASGs and SEs in asymptomatic tissue



Different lower case letters indicate difference determined using Z test.

Error bars indicate standard error (SE).

# The apple and pear supply/cold chain



## ■ Stressors trigger disorders

- Orchard conditions
- Ripening
- Cold stress
- CA stress
- Combination

# Acknowledgments

- David Buchanan, Christine McTavish, Emmi Klarer, Dr. Carolina Torres, Dr. Rachel Leisso, Dr. Jinwook Lee, Dr. Rob Blakey, Dr. Nigel Gapper, Dr. James Mattheis, Dr. Ines Hanrahan, Dr. Chris Watkins, Erin Tudor, Ed Valdez.

