# Apple Grading, Packing and Storage

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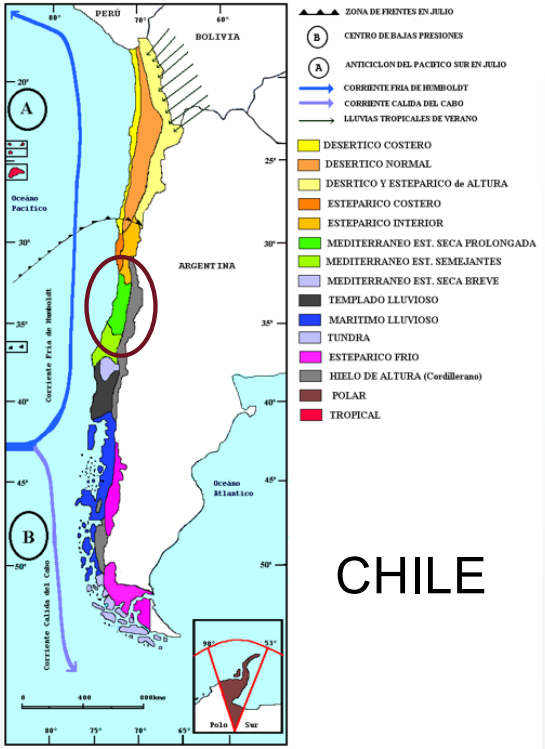
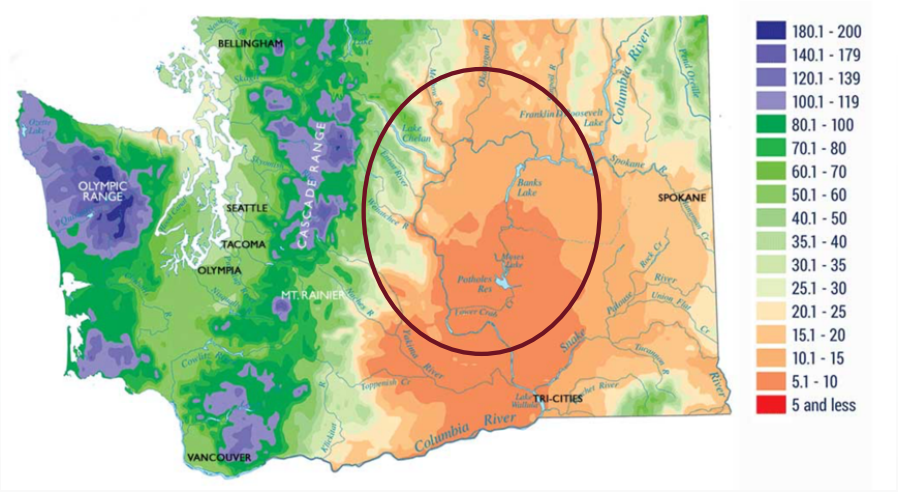



CHILE

Summer: 92-95 C, 30%RH, 2000μmol $m^{-2}$ $s^{-1}$ (4 m +)

Mediterranean with a long dry season




Eastern WA, Summer: 80-90 F, 30%RH, 300 days of sunshine

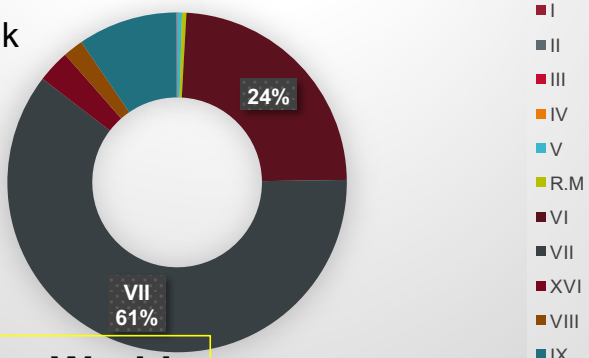
Semi-arid climate

http://choosewashingtonstate.com/research-resources/about-washington/climate-geography/

## APPLES

79,990.7 acres

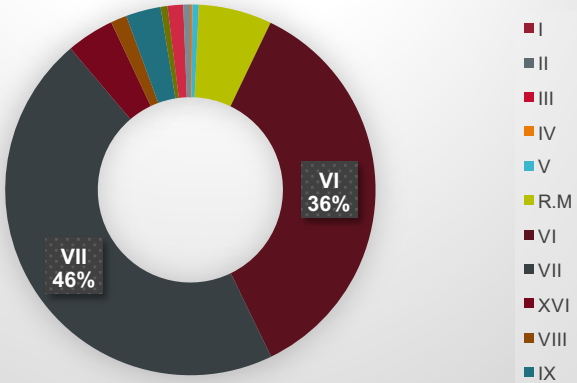
Galas
Fuji
Cripps Pink
Scarlett
(Reds)




**# 9 in the World**

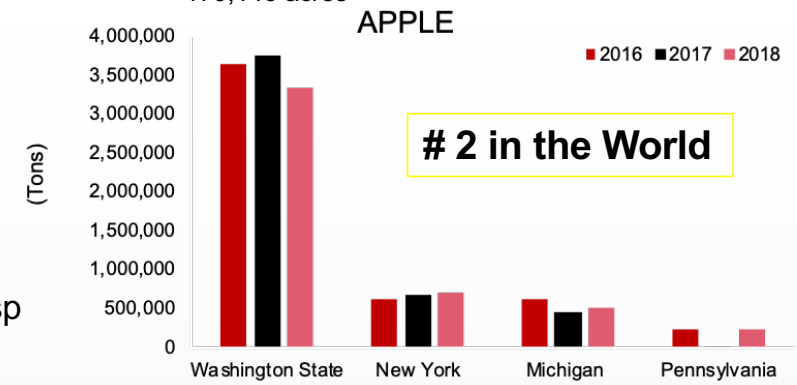
## Sweet Cherries

94,868.7 acres

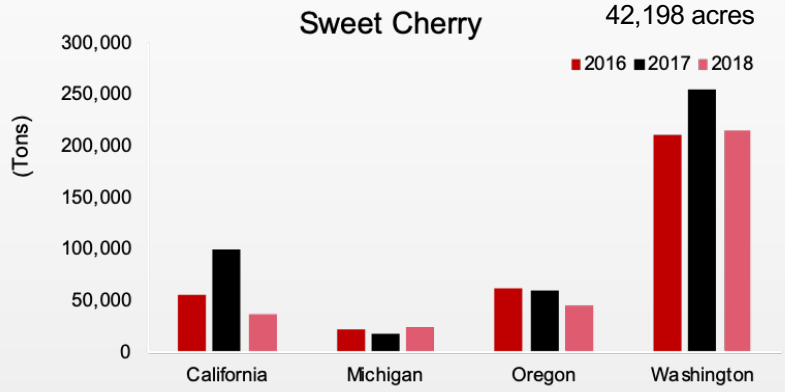



179,146 acres

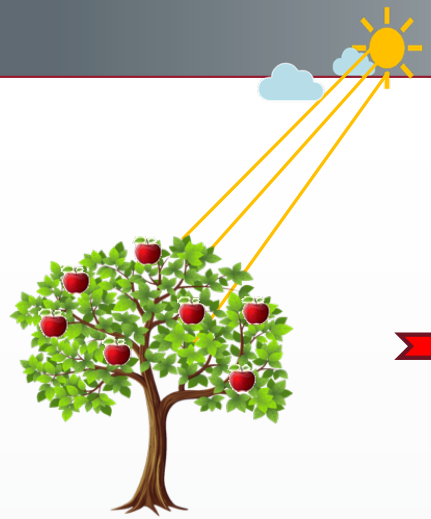
Red delicious
Galas
Fuji
Granny Smith
Honeycrisp



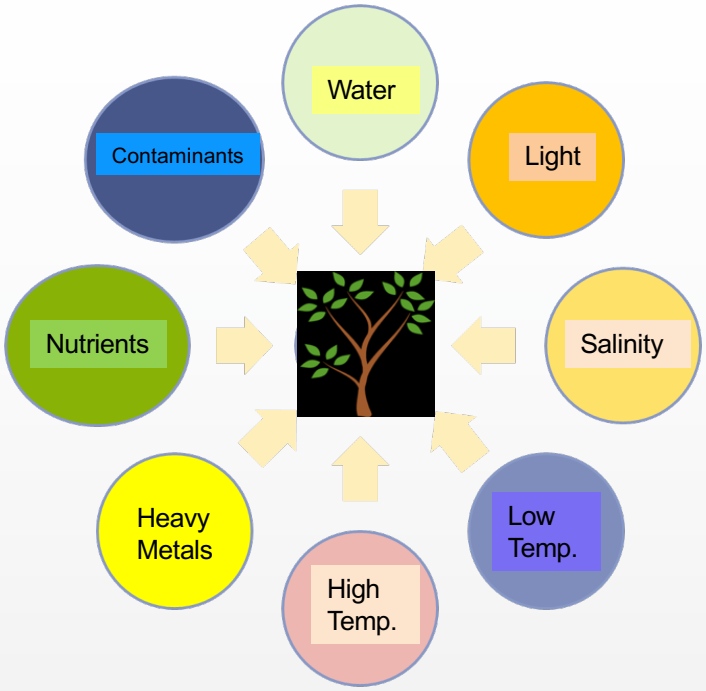

**# 2 in the World**



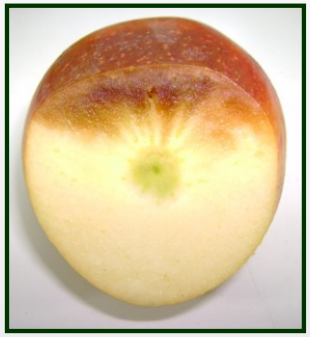

https://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Fruit/2017/FT2017.pdf
Washington State Tree Fruit Association. 2017/18. A Statistical Review of Washington State Fresh Apple Crops
https://www.odepa.gob.cl/wp-content/uploads/2019/09/catastro maule.pdf



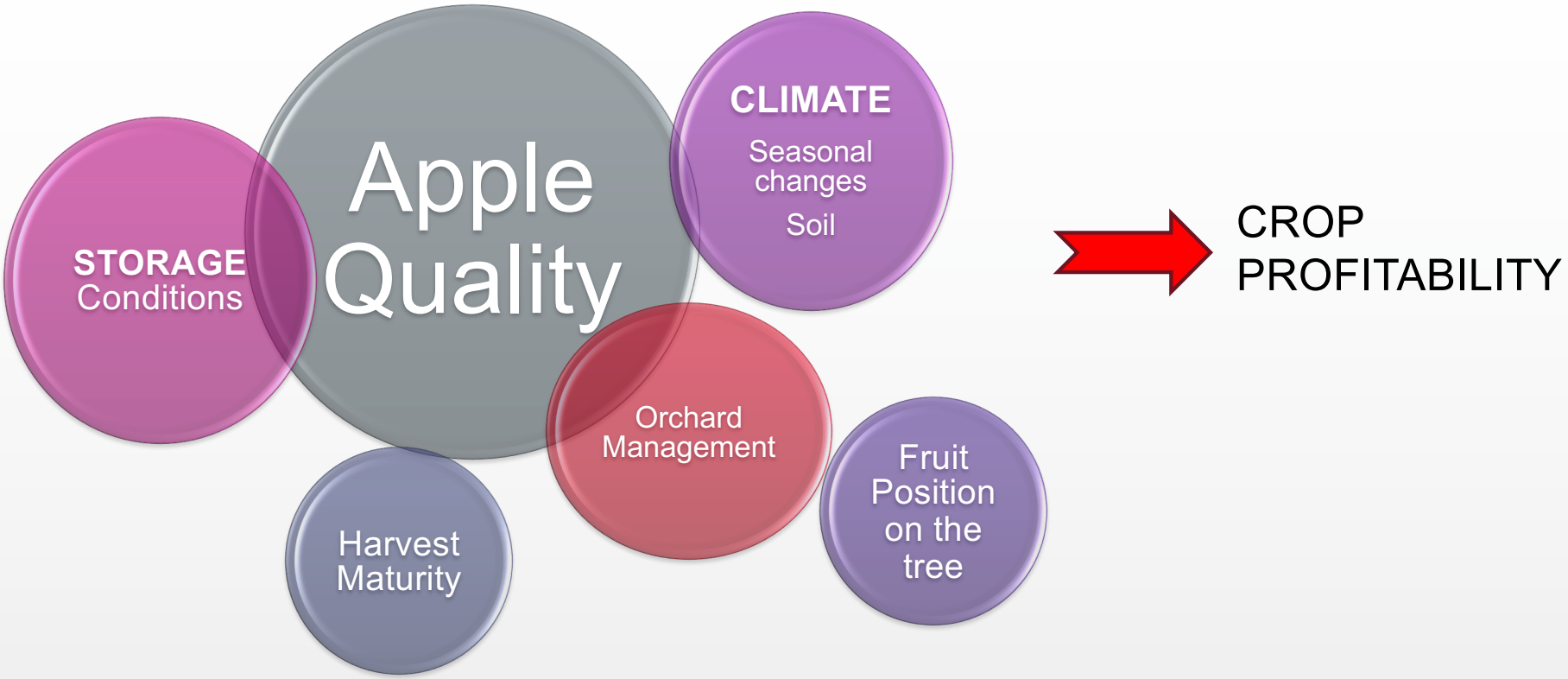

**SHORT- MID– LONG-TERM STORAGE** → **MARKETS**




Fruit Quality
Pre-and Postharvest



**Downgrading/product loss**
**= Waste**


Apple Quality
STORAGE
Conditions
CLIMATE
Seasonal changes
Soil
Orchard Management
Fruit Position on the tree
Harvest Maturity
CROP PROFITABILITY

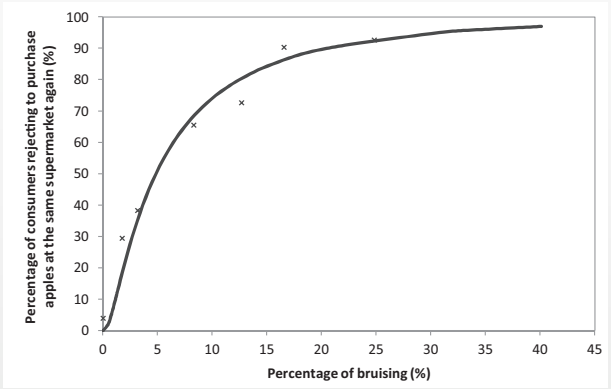
# From the consumer's standpoint…..

EXTERNAL / VISUAL

**DECISION TO PURCHASE**

INTERNAL (discoloration of tissue..)

**DECISION TO RE-PURCHASE**

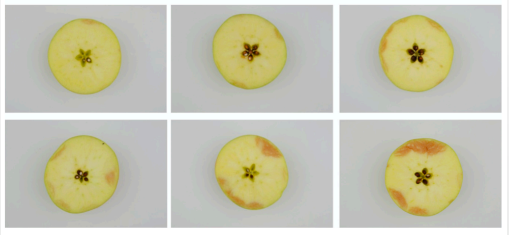



Bruise area

**Table 1**
Average values of the eye-tracking measures for apple images with different degrees of bruising, internal browning and cavities, estimated as the area of the defect, considered in the free viewing task (Obj. 1).

| Defect | Area of the defect (%) | Percentage of consumers who fixated their gaze on the defect (%) | Time to first fixation on the defect (s) | Total fixation duration on the defect (s) | Fixation count on the defect |
|---|---|---|---|---|---|
| Bruising | 3.2 | 21.1[a] | 1.58[b] | 0.56[a] | 1.8[a] |
| | 24.8 | 98.4[b] | 0.10[a] | 0.86[b] | 3.3[b] |
| Internal browning | 5.4 | 30.8[a] | 1.25[c] | 0.56[a] | 1.9[a] |
| | 13.3 | 61.7[b] | 1.05[b] | 0.66[b] | 3.3[b] |
| | 43.4 | 85.4[c] | 0.70[a] | 1.16[c] | 5.9[c] |
| Internal browning and cavities | 1.2 | 9.7[a] | 1.5[b] | 0.22[a] | 1.0[a] |
| | 4.8 | 48.8[b] | 1.1[a] | 0.68[b] | 1.8[b] |
| | 15.8 | 78.8[c] | 1.0[a] | 3.63[c] | 9.8[c] |

Note: for each eye-tracking measure within a disorder, average values with different superscript letters are significantly different at the 95% confidence level.



(Jaeger et al., 2016)

# Harvest Maturity

- Correlated with consumer preferences
- Determined using Maturity Indices/Indicators
- Achieved after physical and chemical changes have started → desirable attributes for consumption (physiological vs horticultural maturity)
    - Apples: On the tree
    - Pears (winter): After harvest

Harvest Maturity

# Maturity Indices

- Simple
- Easy to use
- Low-cost equipment
- Objective
- Correlated with fruit quality

- Always searching for new ones
- Use more than one to improve maturity/quality prediction

# Maturity Indices in Pome fruit

THEY ARE NOT ALWAYS CONSISTENT!

Why? They vary..

- **Growing area/season – CLIMATIC conditions**
- Tree vigor
- Crop load (biennial)
- Cultural practices
- Nutrition
- …..

# Maturity Indices in Pome fruit

- Starch index
- External color (background, skin)
- Flesh firmness
- Soluble solids content
- **Ethylene production**
- Days after full bloom
- Growing degree days accumulated

Cultivar-dependent

## When to harvest?

Start monitoring 2-3 wks before – more frequently close to harvest

- Flesh firmness
- SSC
- Days after full bloom
- Starch index

Other non-destructive:

DA meter (chlorophyll degradation-Available, http://treefruit.wsu.edu/article/da-meter-maturity-indicator/)

Electronic nose (Cyranose 320, Cyrano Science Inc.)

NIR spectroscopy (F-750, Felix Instruments)

# APPLES

## Early Harvest

- Less size
- Less color
- Less developed flavor, (- volatiles, sourness…)
- Susceptible to:
  - Bruising
  - Dehydration
  - Scald…

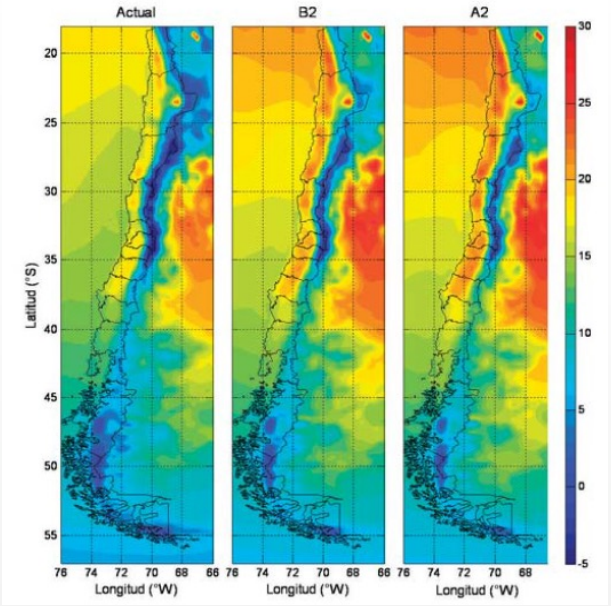
## Late Harvest

- Fruit drop
- Less flavor
- + yellow backgroumd color
- ++ softening rate
- Susceptible to:
  - Rots
  - Mealiness
  - Internal Browning
  - Watercore

# CLIMATE CHANGE

**CLIMATE**

Seasonal changes




Av.Temp. Oct-Mar

GDD

(Montes, 2010)

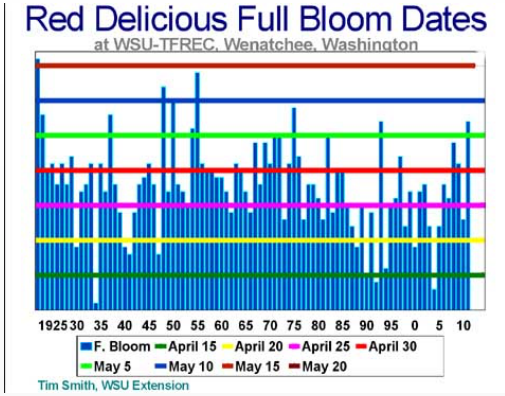
**CLIMATE**

Seasonal changes

## In WA State

- Annual average temperature round 1.5 F in 115 years, and projected to increase up to 9.7 F (next 50 years)
- Warmer winters/ earlier spring snowmelts
- Variable annual precipitation – increase extreme pp
- More frequent and intense HEAT WAVES

(Houston, 2018)




https://extension.wsu.edu/chelan-douglas/agriculture/treefruit/horticulture/bloomdatesrdapples/

- Hotter days (higher than average)
- Heat waves
- Drought
- Unexpected climatic events (hail, frosts…) ….

Earlier and shorter bloom, shorter growing seasons, less volátiles, less red color, less yield, less acidity/firmness…

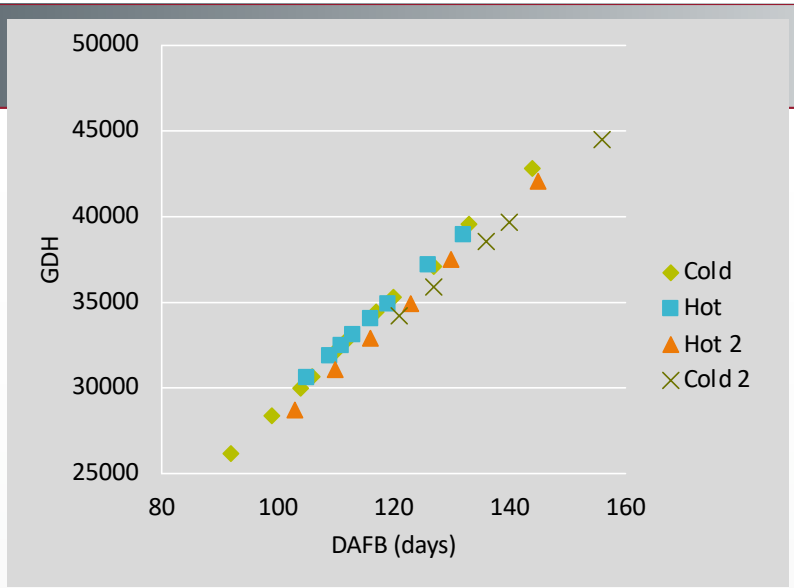
(Montes, 2010; Tromp, 1997, Warrick et al., 2011; Sugiura et al., 2013)

**CLIMATE**

Seasonal changes

Galaxy/M9
Established in 1999
Location: San Clemente, Maule- CHILE
Same group trees (20), four seasons
2006/07, 2007/08, 2012/13, 2014/15

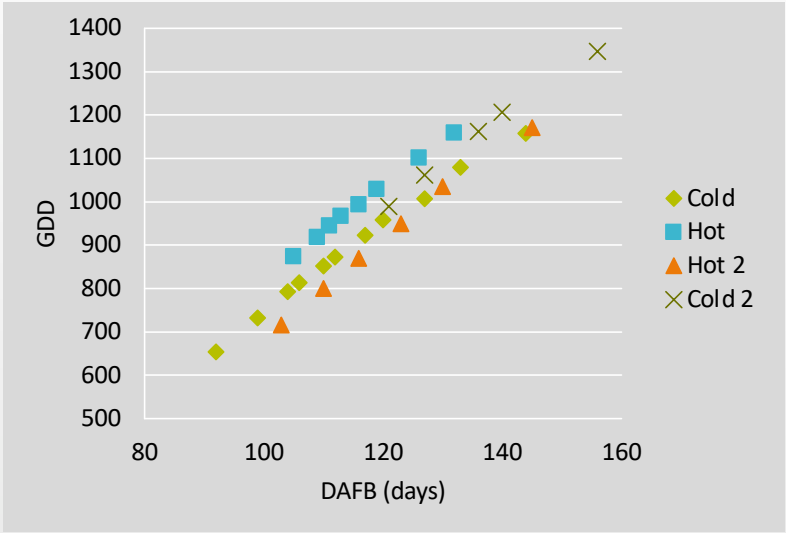
# Climatic Conditions

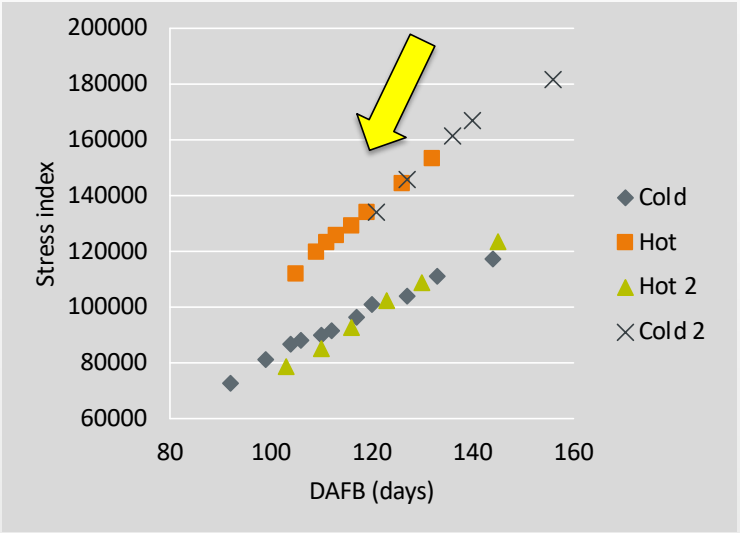


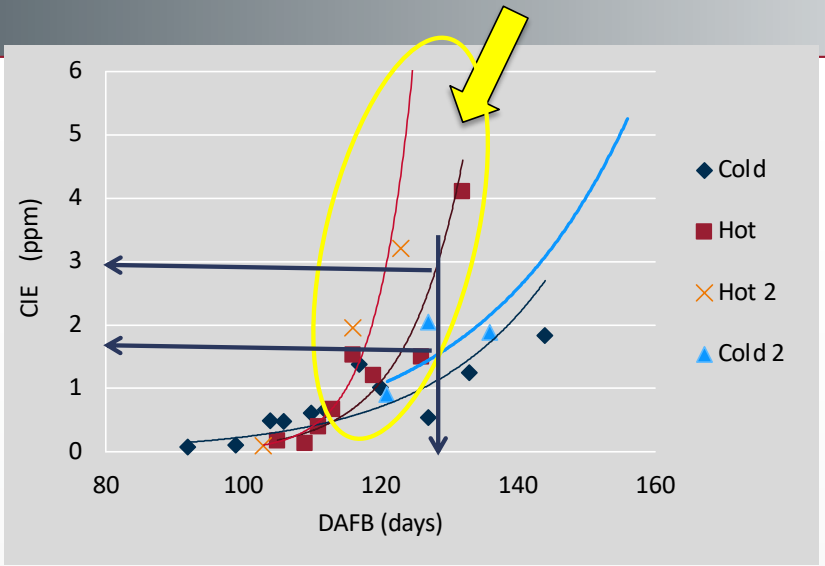

GDD: Growing degree days (>10°C)
GDH: Growing degree hours

'Cool': 30% below average 'Warm': 30% above average

**Stress units**= (*T°air*-10) (-0,2*RH* + 15)



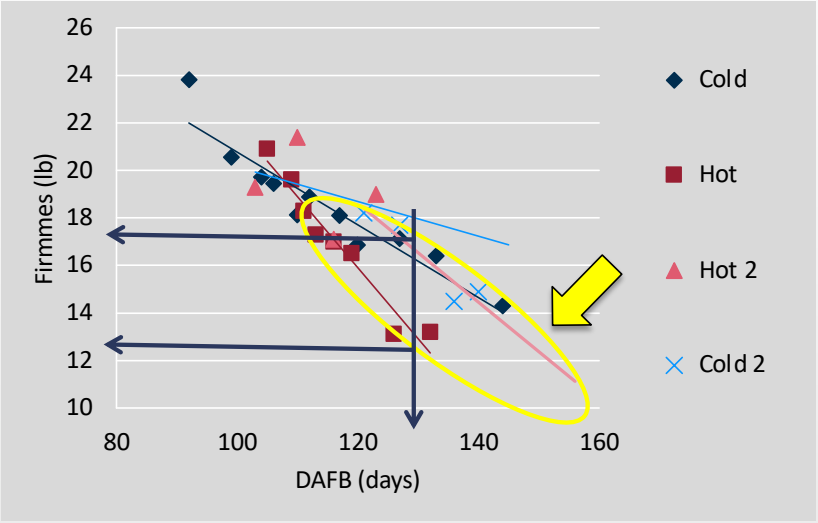






Warmer season

→ Sharper increase of ethylene

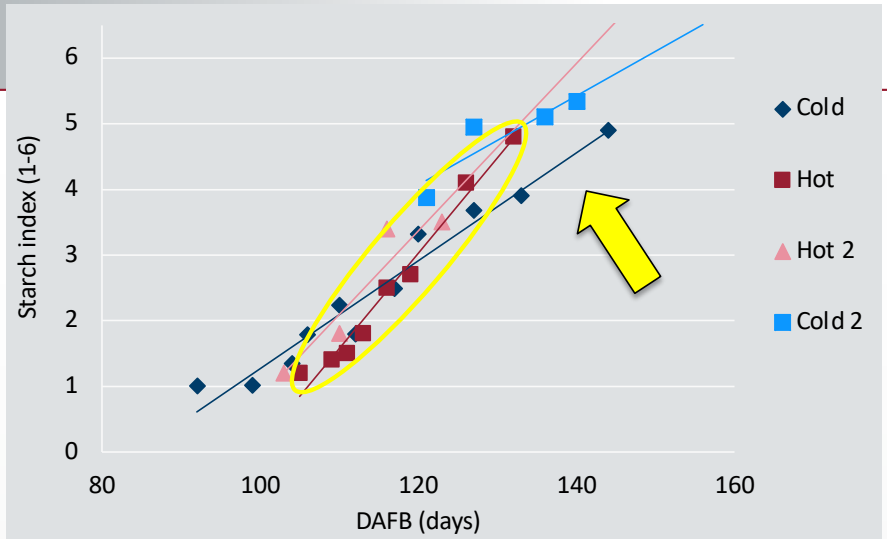
→ Faster decline of Pressures

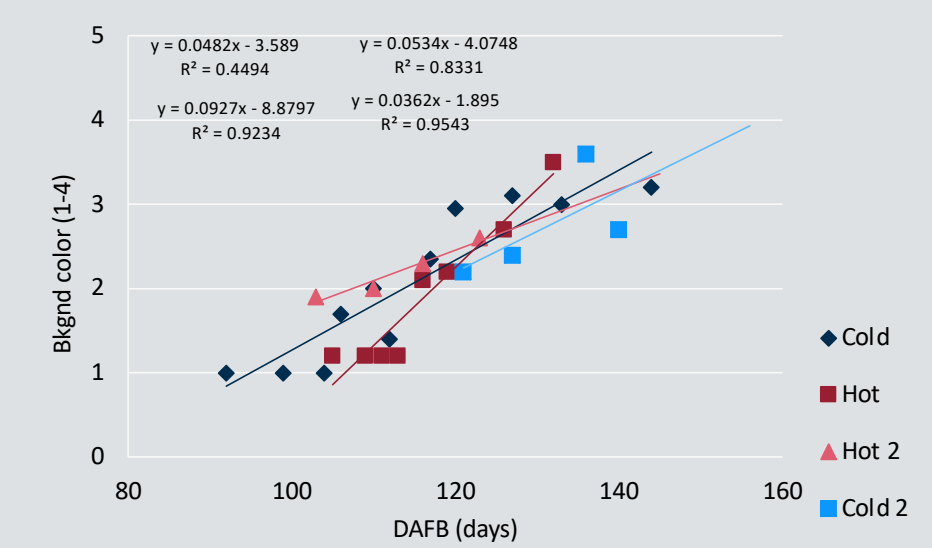


Warmer season
→ Faster starch degradation

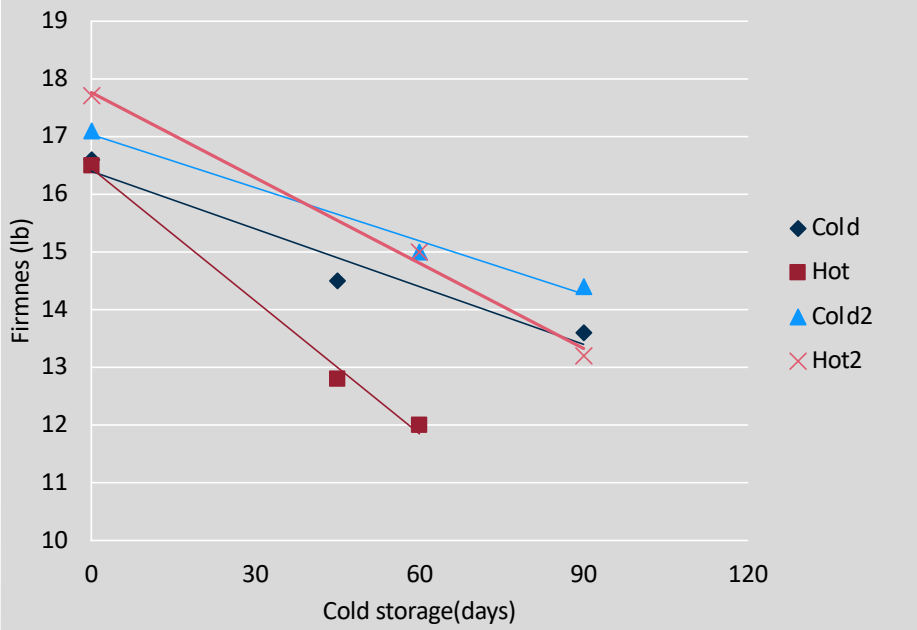
So…

**Earlier Harvest** --- with similar maturity indices (starch index ??...) than normal..

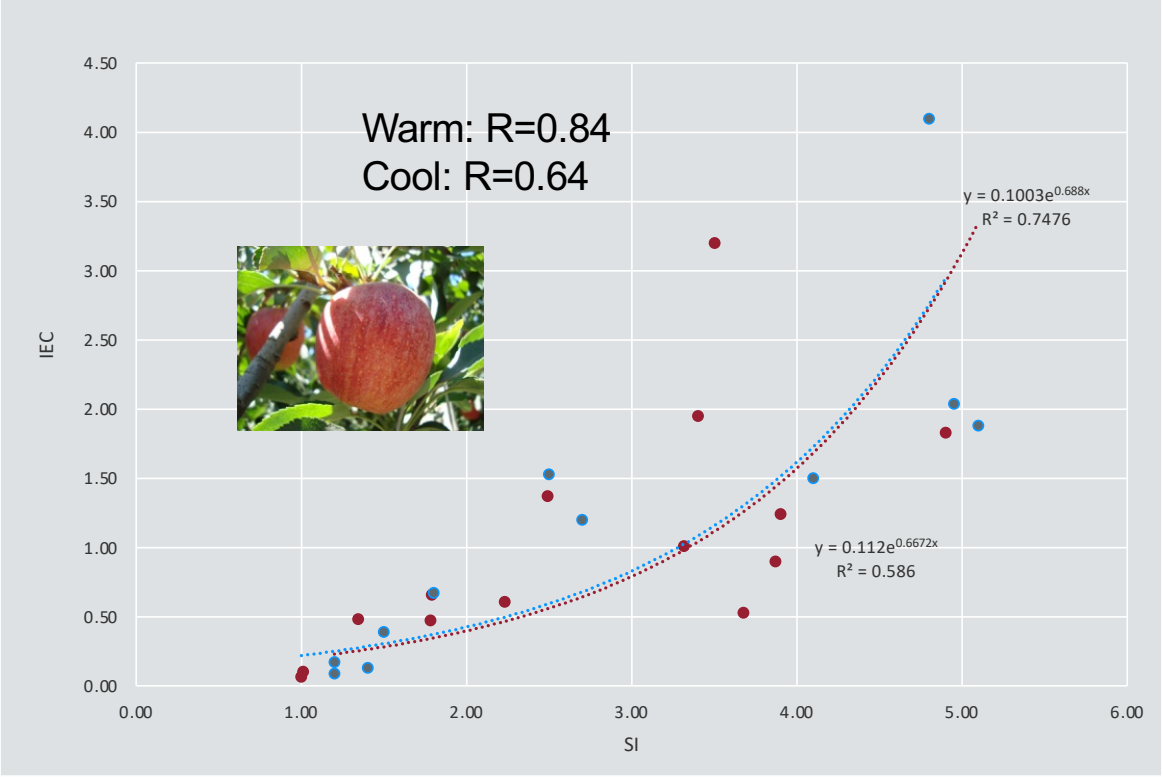


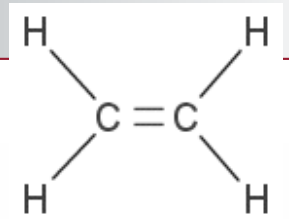
# Postharvest

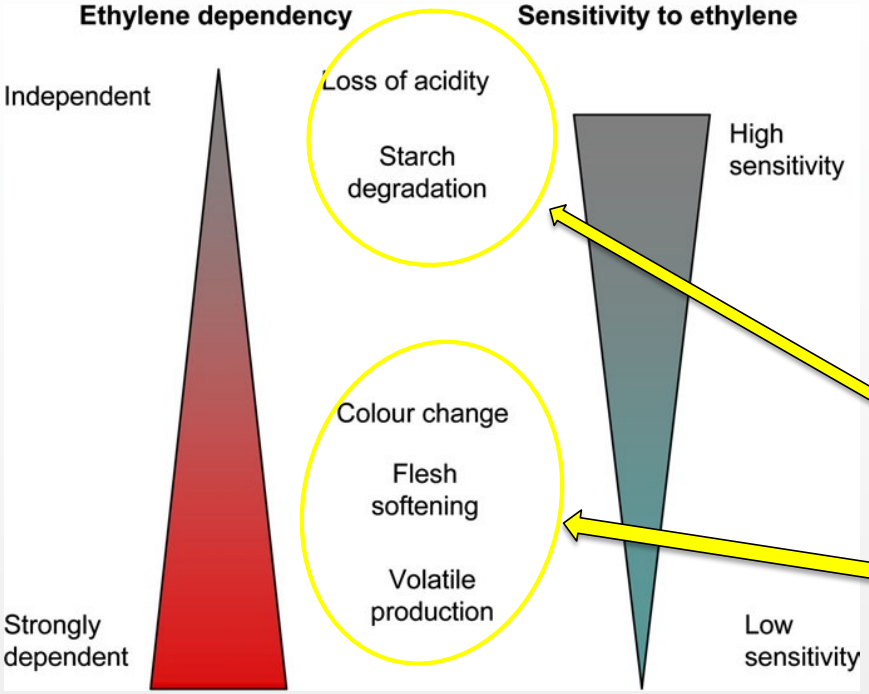



Cool Season: 1 lb/month in RA
Warm Season: 1.5-2.5 lb/month in RA


Warm: R=0.84
Cool: R=0.64
y = 0.1003e^0.688x
R² = 0.7476
y = 0.112e^0.6672x
R² = 0.586
IEC
SI
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00

# ETHYLENE

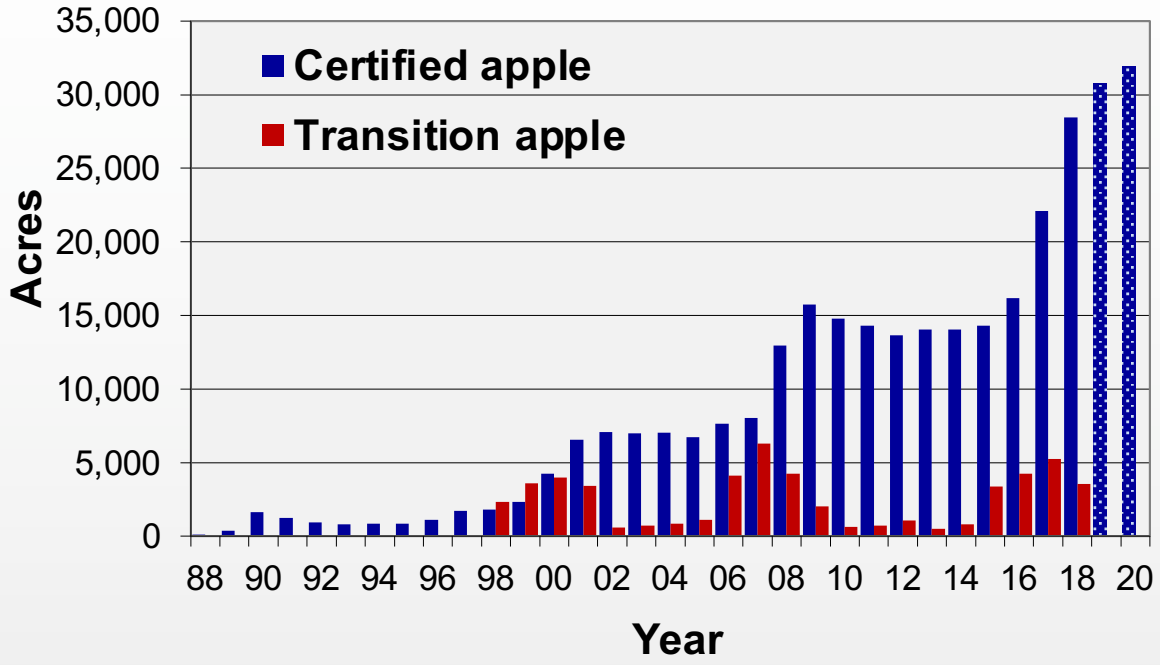



Conceptual model for control of individual ripening characters in apples (**Royal Gala**) (Johnston et al., 2009)

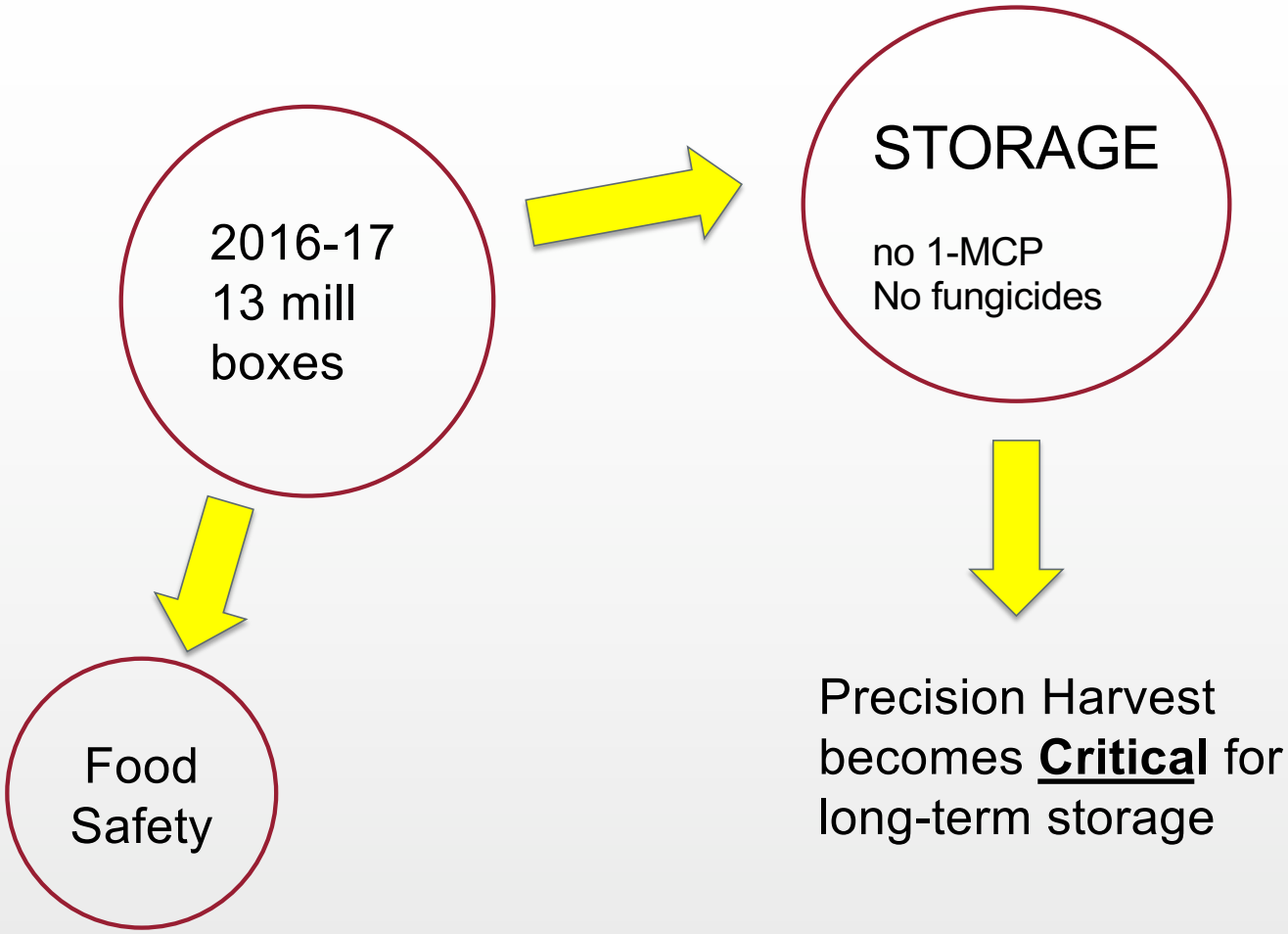
..not only triggering. Sustained exposure required to maintain ripening…

# Organic Apples




David Granatstein

Great challenge for postharvest……



# Final Remarks

- Warmer climates cause a sharper increase in ethylene, faster decline in fruit firmness, and increase in starch index .
  - Although fruit might be harvested with same 'indices' values, it has a different metabolic makeup, favoring the development of certain physiological disorders (potential prediction tools…).
  - New maturity indices?

# QUALITY DEFECTS

Abiotic Stress

Light + Heat

HARVEST

Hot and dry environments

Low temperature

Maturity/Ripening & Physiological disorders (onset)

AFTER 2,3,4,5,6.. months of storage

# Hot and Dry Environment…

Sunburn

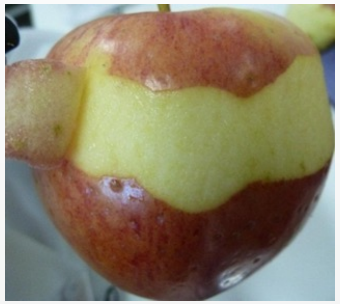
- Splitting – Checking - Cracking
  - Cv. dependent
  - Overmaturity
  - Rain prior harvest – presizing
  - Low RH during fruit growth

# Lenticel Issues

- Nutricional → Calcium-related
- Abiotic stress+Processing postharvest (LBD)





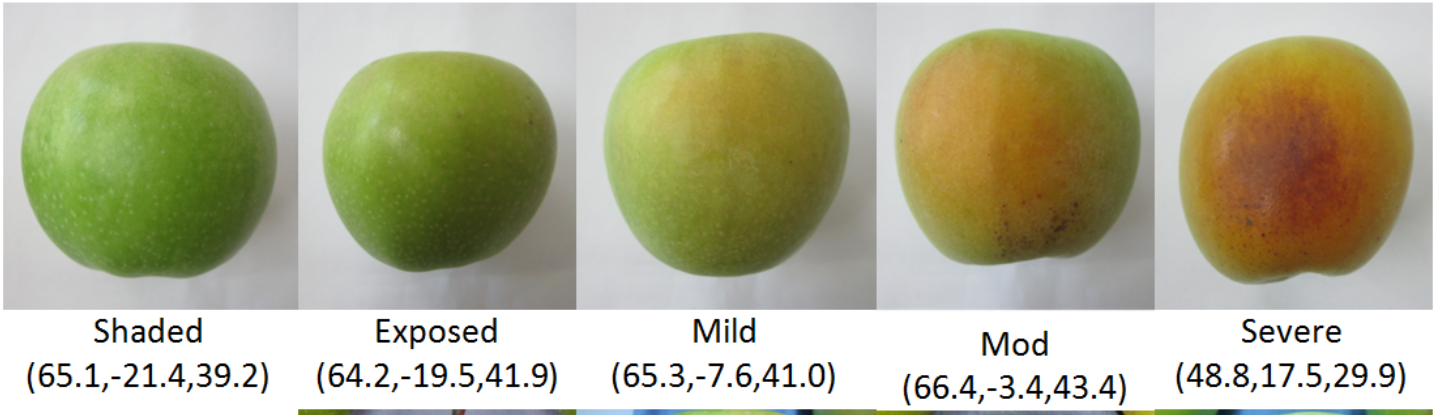

# Peel Browning/ Discolorations

## Sunscald

## Stain

High Light
+
High
Temperature

# Sunburn → Sunscald



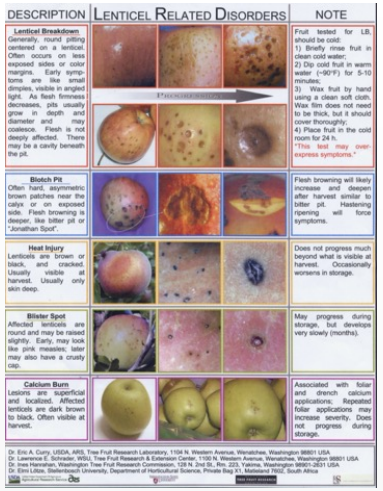
| Shaded | Exposed | Mild | Mod | Severe |
|---|---|---|---|---|
| (65.1,-21.4,39.2) | (64.2,-19.5,41.9) | (65.3,-7.6,41.0) | (66.4,-3.4,43.4) | (48.8,17.5,29.9) |

NO CONTROL

| (62.5,-17.9,39.6) | (61.3, 2.9, 41.3) | (57.9, 5.4 39.3) | (44.4,16.3,25.7) |
|---|---|---|---|

Sunscald symptoms after cold storage

# Identification is a MUST…

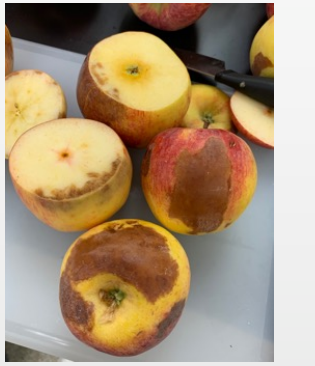


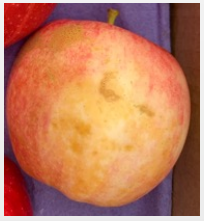



# Lack of acclimation…

+ Chilling Stress

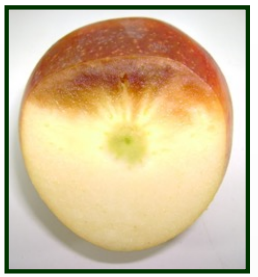
Skin browning
Superficial Scald
Soft Scald
Internal browning
…





# Internal Browning

- Hot environments→ watercore (IB)
- Susceptible cv. (Fuji, Crisp Pink, Gala)
- Storage atmosphere (daños por $CO_2$/ Largo) – celullar structure
- Physiological disorder
  - Preharvest factors
  - Postharvest factors



# Pardeamientos Internos

**In general, 2 groups…**

- Low-temperature …chilling injury

- Ripening and senescence…(- correlated with fruit firmness (harvest maturity..))

(Watkins, 2007)

Fast cooling, low storage temp.

↓

Lower metabolism

↓

Induce chilling injury

Stepwise cooling

↓

Acclimate fruit to cold

↓

Decrease fruit quality and accelerate ripening

Susceptibility ?
(CLIMATE)

# HONEYCRISP

Minnesota, 1960
Keepstake x MN1627

Bitter Pit

Multi-factorial (nutrients, vigor, harvest maturity)

Soft scald

Soggy Breakdown

Chilling injury

**Table 3**
Physiological disorders in 'Honeycrisp' apples after storage at 0.5 or 3 °C with or without one week of conditioning (C) at 10 °C in 2013, 2015, and 2016..

| Treatment | Bitter pit (%) | Soft scald (%) | Soggy breakdown (%) | Senescent browning (%) | Cavities (%) | Wrinkly skin (%) | Flesh browning (%) | Decay (%) |
|---|---|---|---|---|---|---|---|---|
| 0.5 °C | 2.2 | 7.6 | 0.9 | 0.3 | 0.2 | 6.4 | 0.8 | 0.5 |
| C + 0.5 °C | 13.0 | 0.9 | 0.7 | 0.7 | 0.1 | 4.9 | 0.2 | 0.9 |
| 3 °C | 10.6 | 0.0 | 0.1 | 1.3 | 0.2 | 0.0 | 0.0 | 3.4 |
| C + 3 °C | 20.6 | 0.0 | 0.0 | 1.1 | 0.1 | 0.0 | 0.0 | 1.6 |
| ***P* value** | **< .0001** | **< .0001** | **0.0006** | **0.09** | **0.6** | **< .0001** | **0.0006** | **0.0002** |

(Shoffe et al. 2020)

C: 7 d a 10°C

Good correlation with flesh firmness & ethylene

**Table 1. Soft scald and soggy breakdown incidence in Honeycrisp apples stored at 33ºF or 36ºF with or without a conditiong treatment of 50ºF for 7 days (modified from Watkins et al., 2004).**

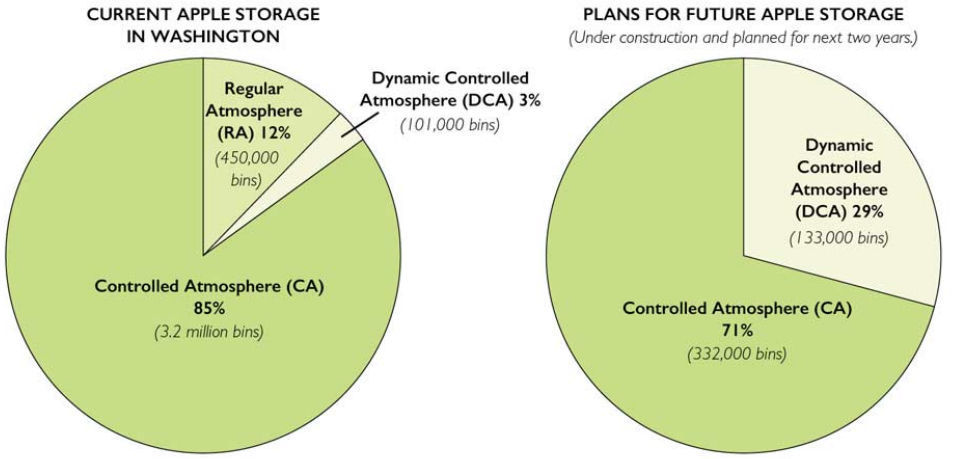
| Temperature (ºF) | Conditioning | Soft scald and soggy break-down (%) | Bitter pit % |
|---|---|---|---|
| 33 | No | 28a | 14c |
| 33 | Yes | 2d | 11c |
| 36 | No | 19b | 20bc |
| 36 | yes | 0d | 34a |

Means with different letters indicate that disorder incidence is significantly different at P=0.05.

(Shoffe et al. 2016)

# A dynamic increase in apple storage

*Controlled atmosphere (CA) is the primary storage method in Washington and is expected to stay that way, with a 10 percent increase in capacity by 2020, according to a survey of storage facilities. Survey responses shown below only account for about half the total Washington apple volume, but the trends are clear. Dynamic controlled atmosphere (DCA) storage is on the rise, making up 29 percent of rooms under construction or planned for completion by 2020. Half of the survey respondents said their primary reason for building DCA rooms was for long term storage of organic fruit. None of the respondents are building more regular atmosphere (RA) rooms.*




SOURCE: WASHINGTON STATE UNIVERSITY EXTENSION JARED JOHNSON/GOOD FRUIT GROWER

- Chlorophyll fluorescence
- Ethanol concentration
- Respiratory quotient ($CO_2/O_2$)
- Low pressure/vaccum

| Cultivar | Huerto | Fecha de cosecha | Acondicionamiento | Atm. Dinamica |
|---|---|---|---|---|
| Honeycrisp | Warm 1 | 8/31/2019 | 10 days/10°C | CF: (LOL≈ 0.3%O2)- 3.0% $O_2$/ 0.5% $CO_2$<br>ILOS: 0.5% $O_2$/ 0.5% $CO_2$- 7-11d; 1.0% $O_2$/0.7% $CO_2$<br>RQ: 3.0% $O_2$/0.5% $CO_2$<br>Low pressure chambers (0.5°C & 3°C) |
| | Warm 2 | 9/02/2019 | 10 days/10°C | |
| | Cool 1 | 9/10/2019 | 10 days/10°C | |
| | Cool 2 | 9/06/2019 | 10 days/10°C | |

| | Bitter Pit (%) | | | | | |
|---|---|---|---|---|---|---|
| **Block (A)** | 6m | 6m+4wk+1d | 6m+4wk+7d | 9m | 9m+4wk+1d | 9m+4k+7d |
| **W42** | 8.9 | 11.6 | 15.1 | 0.2 | 13.8 | 11.1 |
| **W25** | 0.4 | 1.8 | 3.3 | 2.7 | 2.9 | 2.7 |
| **C21** | 7.6 | 10.2 | 11.0 | 0.4 | 5.1 | 5.5 |
| **C802** | 1.3 | 1.8 | 3.9 | 1.7 | 4.3 | 5.9 |
| **P value** | | | | * | ns | ns |
| **Trat(B)** | | | | | | |
| **DCA1** | 3.7 | 4.7 | 8.1 | 8.0 | 11.3 | 10.7 b |
| **DCA2** | 5.3 | 7.7 | 8.2 | 3.7 | 12.7 | 11.0 b |
| **DCA3** | 4.7 | 6.7 | 8.9 | 4.3 | 8.3 | 9.0 b |
| **RL 33** | n/a | n/a | n/a | 4.0 | 1.8 | 1.8 a |
| **RL 37** | n/a | n/a | n/a | 0.3 | 3.0 | 3.1 a |
| **P value** | | | | ns | * | * |
| **A x B** | | | | * | * | * |

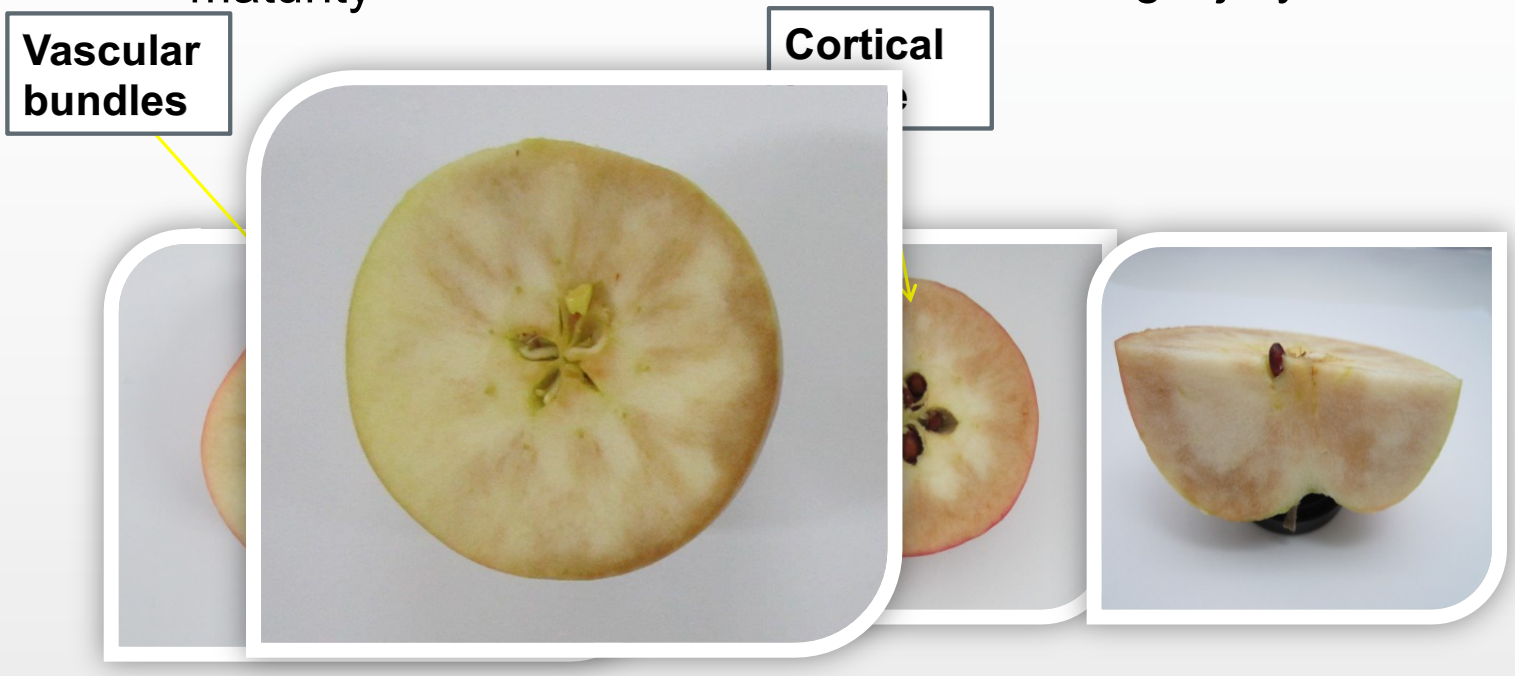
Respiration
$O_2$
Ethylene

# Internal Browning


John Cripps, Australia
1973
Lady Williams x Golden Delicious
Long storage – firm

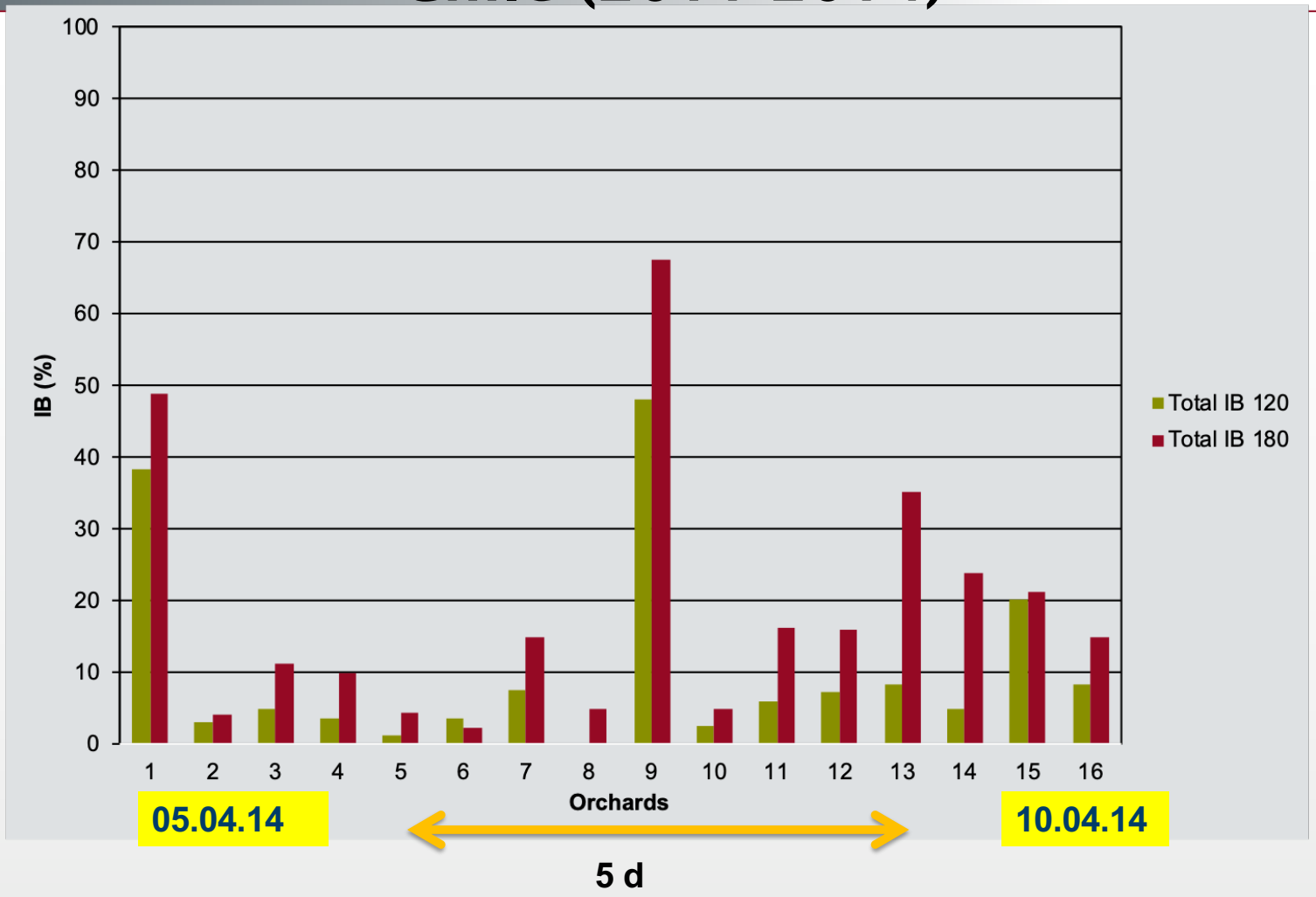
# Symptoms

- Radial browning
  - associated with fruit maturity
- Diffuse browning
  - associated with chilling injury

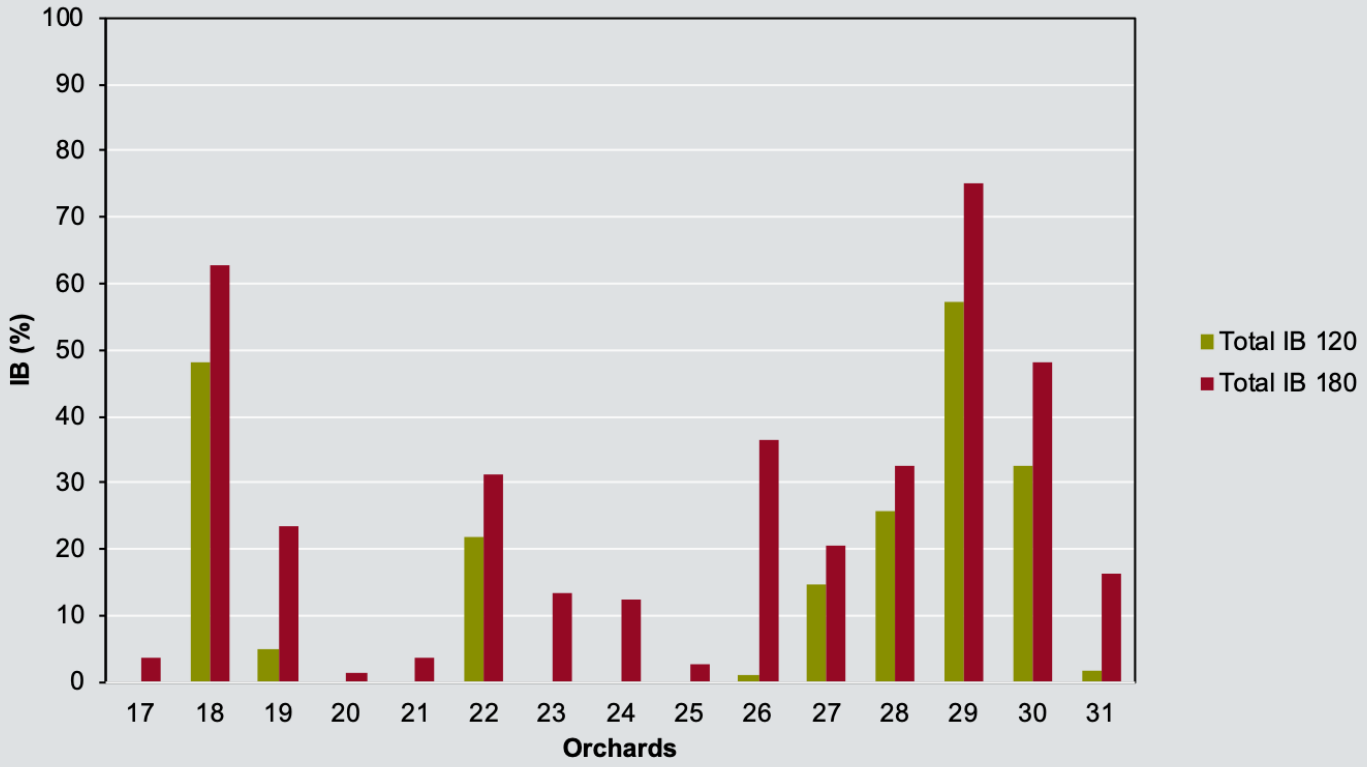



(James et al., 2005; James & Jobbling, 2009).

# Chile (2011-2014)

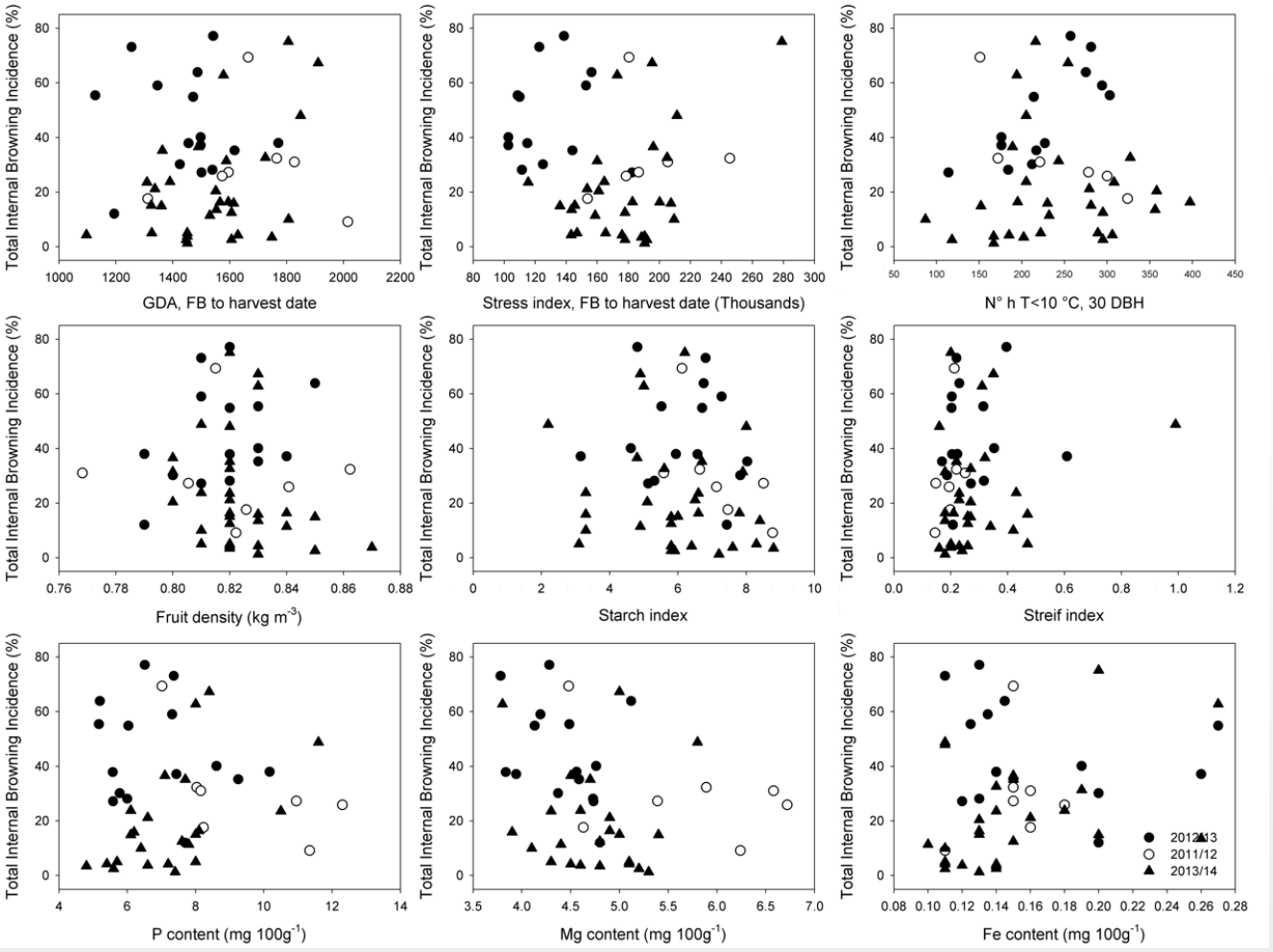


## Great variability between orchards…

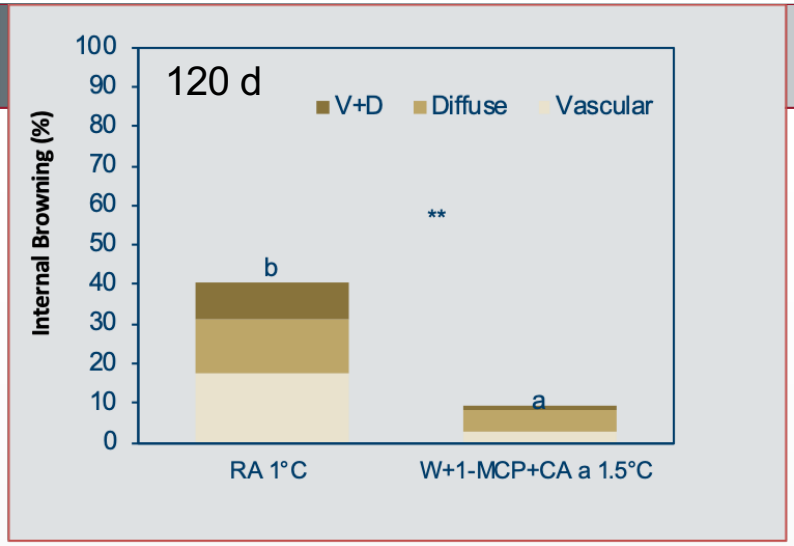


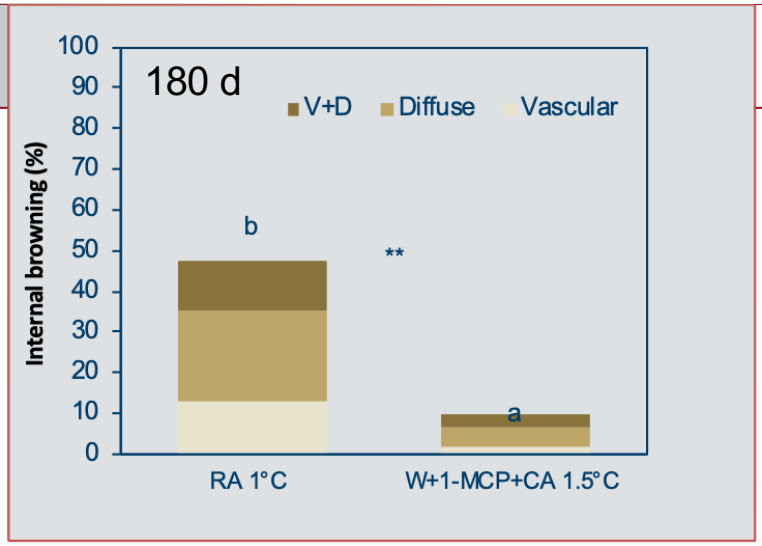

**09.04.14** ⟷ **28.04.14**

**19 d**


Total Internal Browning Incidence (%)
GDA, FB to harvest date
Stress index, FB to harvest date (Thousands)
N° h T<10 °C, 30 DBH
Fruit density (kg m-3)
Starch index
Streif index
P content (mg 100g-1)
Mg content (mg 100g-1)
Fe content (mg 100g-1)
2012/13
2011/12
2013/14

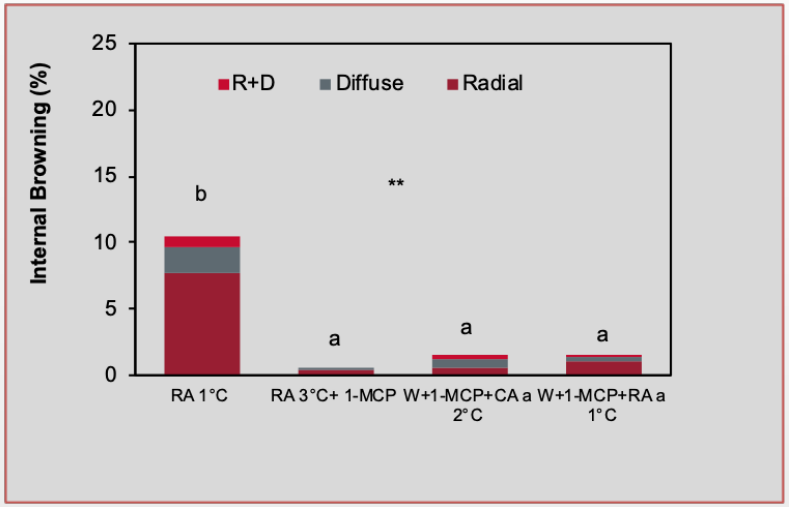
Year 2

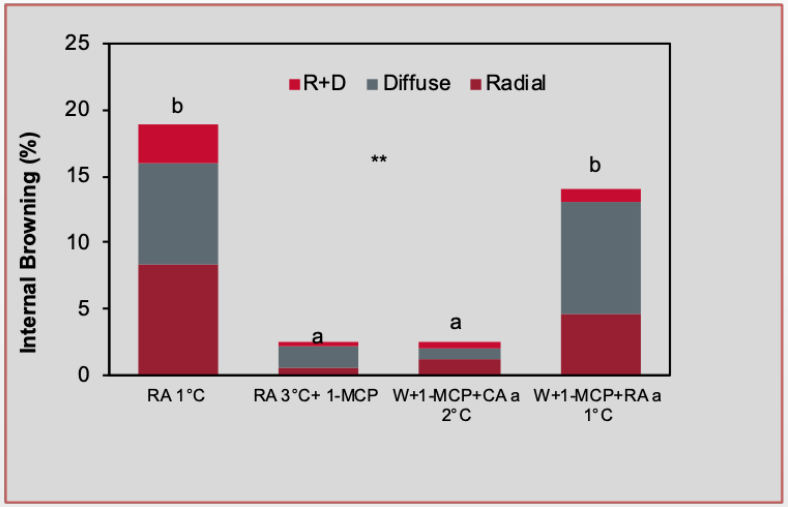


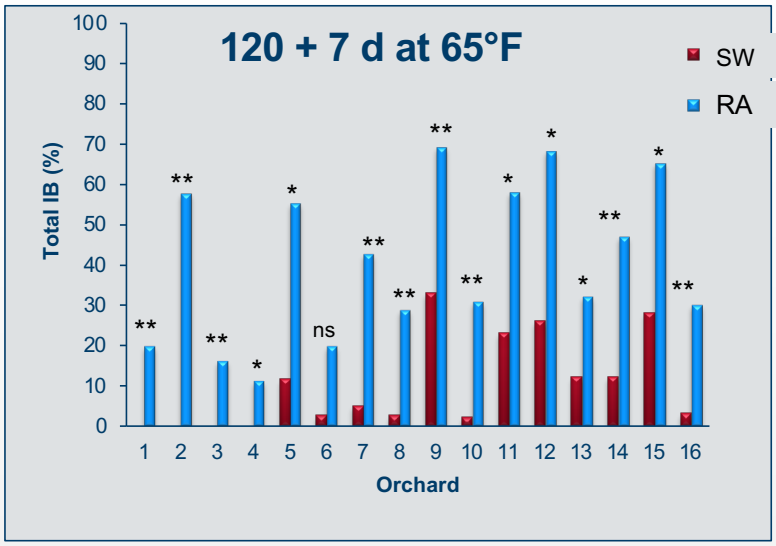



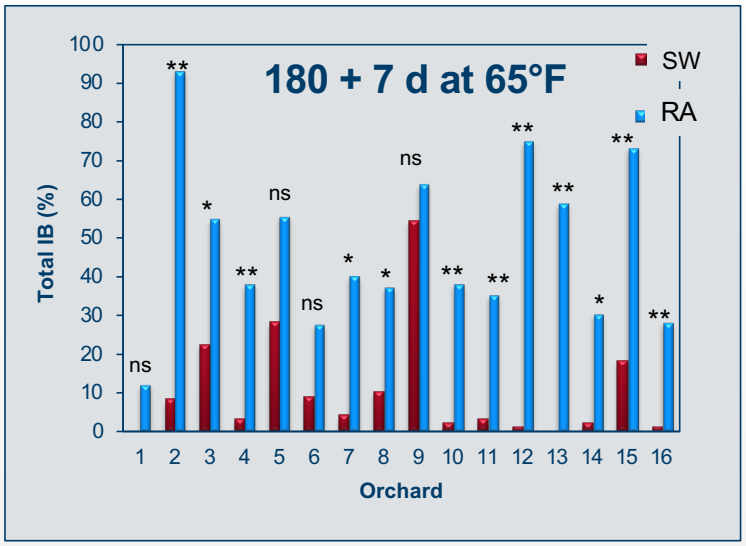

**WC**: Stepwise-cooling (4°, 3° until 1.5 °C)+1-MCP (1000 ppb) & CA ($O_2$ 2.0%, $CO_2$ <0,8 %)

Year 3



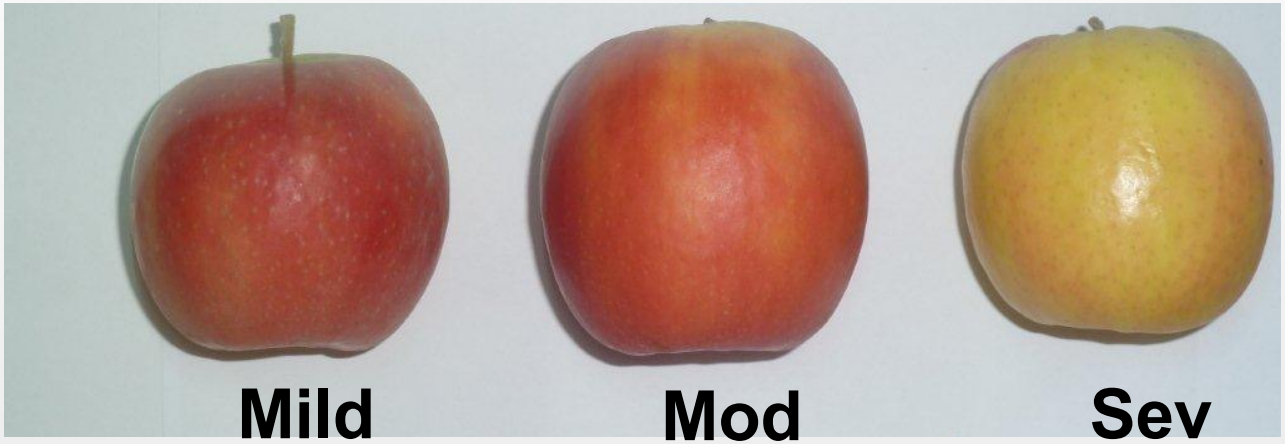

120 + 7 d at 65°F
SW
RA
Total IB (%)
Orchard
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
** ** ** * * ns ** ** ** ** * * ** * ** *


180 + 7 d at 65°F
SW
RA
Total IB (%)
Orchard
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
ns ** * ** ns ns * * ns ** ** ** ** * ** **

* P ≤ 0.05
** P ≤ 0.01
n.s.

1-MCP/CA is a ‘must’ when storing at temperatures above 2C to keep fruit quality and fast ripening

Greasiness



# Final Remarks

- Higher storage temperatures (> 2.5 °C) and conditioning significantly reduced IB (vascular and diffuse) on Cripps Pink apples. Nonetheless, this was not true for highly susceptible batches of fruit, revealing its multi-factorial origin.

- Higher storage temperatures increased fruit greasiness and yellow background color, both of which downgrade Pink Lady quality. Therefore, they must consider 1-MCP applications and/or CA regimes in order to maintain fruit quality on long-term storage (6 m).

# Acknowledgements

Fruit companies in Chile & WA
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Corfo (Production Development Corporation)-Chile

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