Economic Development, Jobs, Transport and Resources

Serviced Supply Chains:

Monitoring & modelling to improve the quality of Australian fresh produce into Asian markets

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AGRICULTURE VICTORIA

Topics…

- Horticultural export challenges
- Serviced Supply Chains project (SSC)
- Postharvest physiology research underpinning SSC
  - Preharvest and fruit quality variation
  - Harvest maturity and eating quality
  - Export simulation
  - Predictive tools
    - Aims & Scope
    - Risk assessment for exporters
    - Modelling of export chains

Australian horticulture - production & exports ($m)

Year Ending June 2016	Wholesale Value ($m)
All Horticultural Products	$11,287.5
All Fruit	$4,410.1
Apples	$490.2
Avocados	$514.5
Bananas	$489.4
Berries - Combined	$776.1
Blueberries	$211.0
Rubus Berries	$149.1
Strawberries	$416.0
Cherries	$130.8
Citrus - Combined	$525.7
Grapefruit	$20.2
Lemons/Limes	$144.9
Mandarins	$211.4
Oranges	$149.2
Custard Apples	$7.5
Kiwifruit	$88.9
Lychees	$27.1
Mangoes	$214.9
Melons - Combined	$163.8
Muskmelons	$59.1
Watermelons	$104.7
Nashi	$13.6

Year Ending June 2016	Wholesale Value ($m)
Passionfruit	$20.1
Papaya/Pawpaw	$33.4
Persimmons	$13.5
Pears	$110.0
Pineapples	$50.7
Summerfruit - Combined	$393.1
Apricots	$39.8
Nectarines/Peaches	$296.8
Plums	$56.4
Table Grapes	$285.8
Processing Fruit Combined*	
Dried Grapes*	
Prunes*	
Other Dried Tree Fruit*	
Canned Fruit*	
Olives*	
Other Fruit	*$61.0*
All Vegetables	**$3,998.7**
Artichokes	$1.1
Asparagus	$77.8
Beans	$76.8
Beetroot	$10.6
Broccoli/Baby Broccoli	$231.7

Year Ending June 2016	Fresh Export Value ($m)
All Horticultural Products	$2,118.7
All Fruit	$936.6
Apples	$12.4
Avocados	$9.2
Bananas	
Berries - Combined	$31.1
Blueberries	$5.2
Rubus Berries	<$0.1
Strawberries	$25.8
Cherries	$76.1
Citrus - Combined	$297.3
Grapefruit	$0.7
Lemons/Limes	$9.6
Mandarins	$84.8
Oranges	$202.1
Custard Apples	$0.4
Kiwifruit	$4.2
Lychees	$5.5
Mangoes	$30.9
Melons - Combined	$31.0
Muskmelons	$24.0
Watermelons	$7.0
Nashi	

Year Ending June 2016	Fresh Export Value ($m)
Passionfruit	
Papaya/Pawpaw	$0.2
Persimmons	$1.0
Pears	$21.7
Pineapples	
Summerfruit - Combined	$48.3
Apricots	$2.5
Nectarines/Peaches	$33.8
Plums	$11.9
Table Grapes	$367.3
Processing Fruit Combined*	
Dried Grapes*	
Prunes*	
Other Dried Tree Fruit*	
Canned Fruit*	
Olives*	
Other Fruit	*<$0.1*
All Vegetables	**$232.1**
Artichokes	<$0.1
Asparagus	$25.1
Beans	$5.8
Beetroot	$0.7
Broccoli/Baby Broccoli	$14.5

Horticulture Innovation Australia

freshlogic

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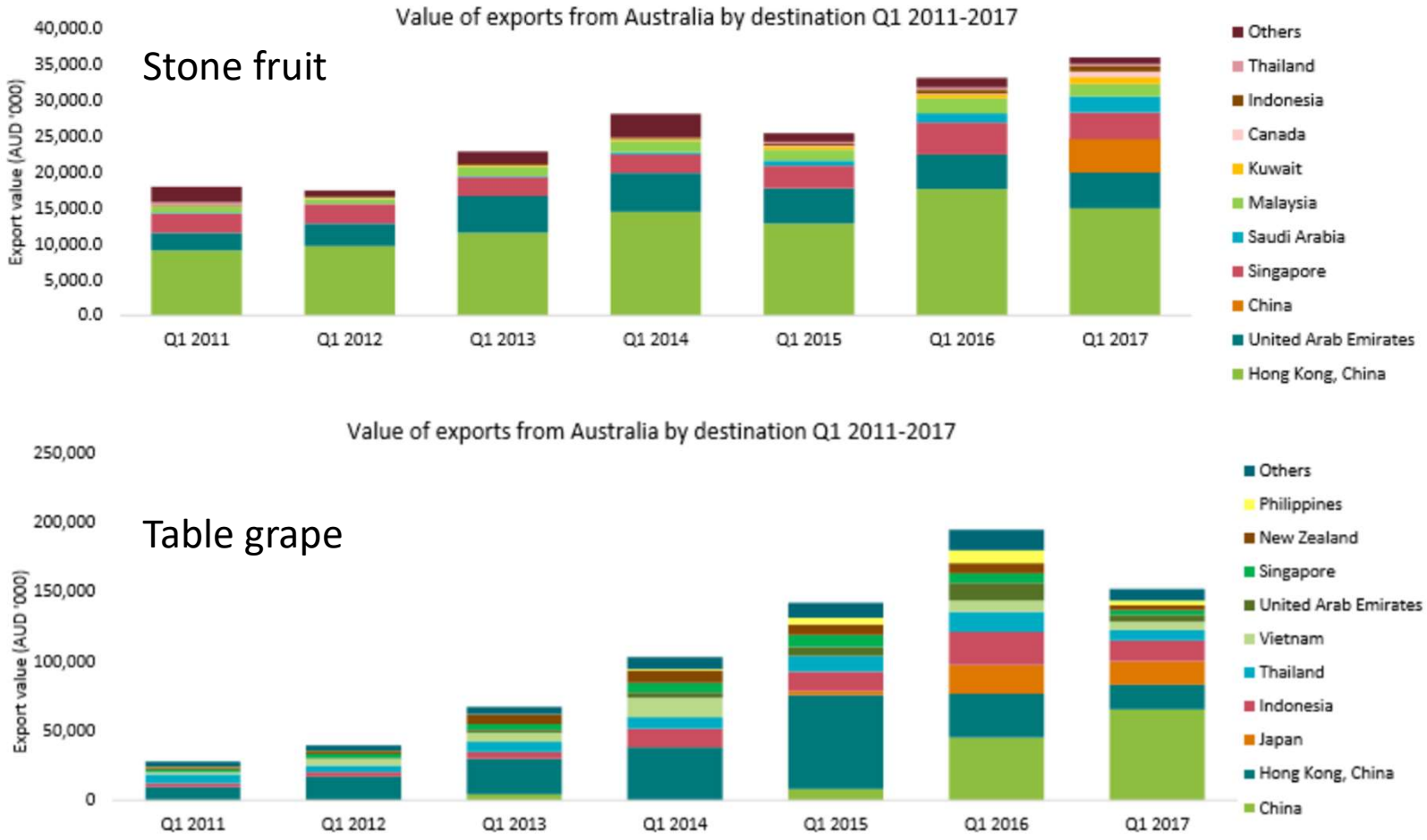
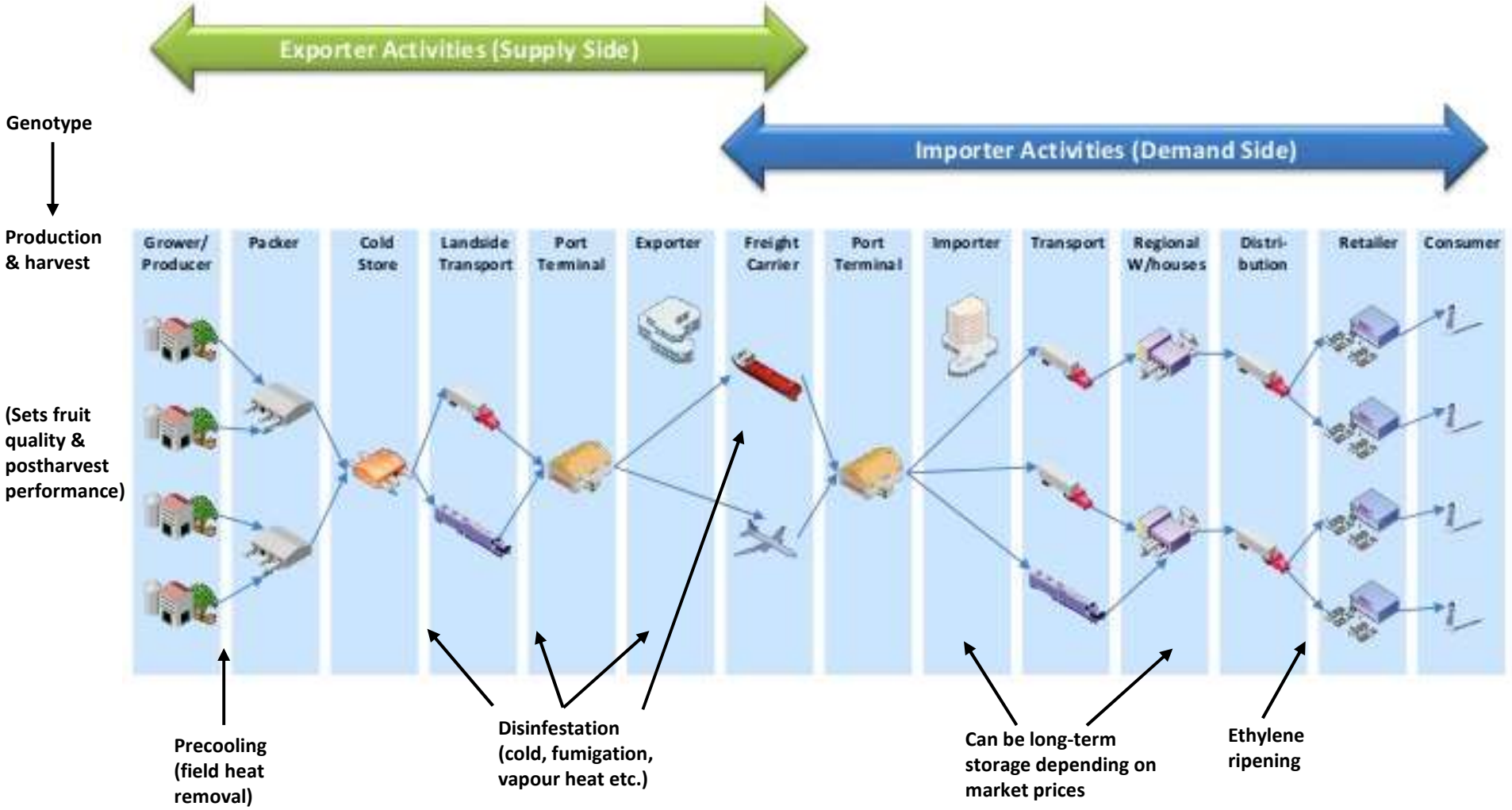
Australian fruit exports (Victoria main producer)

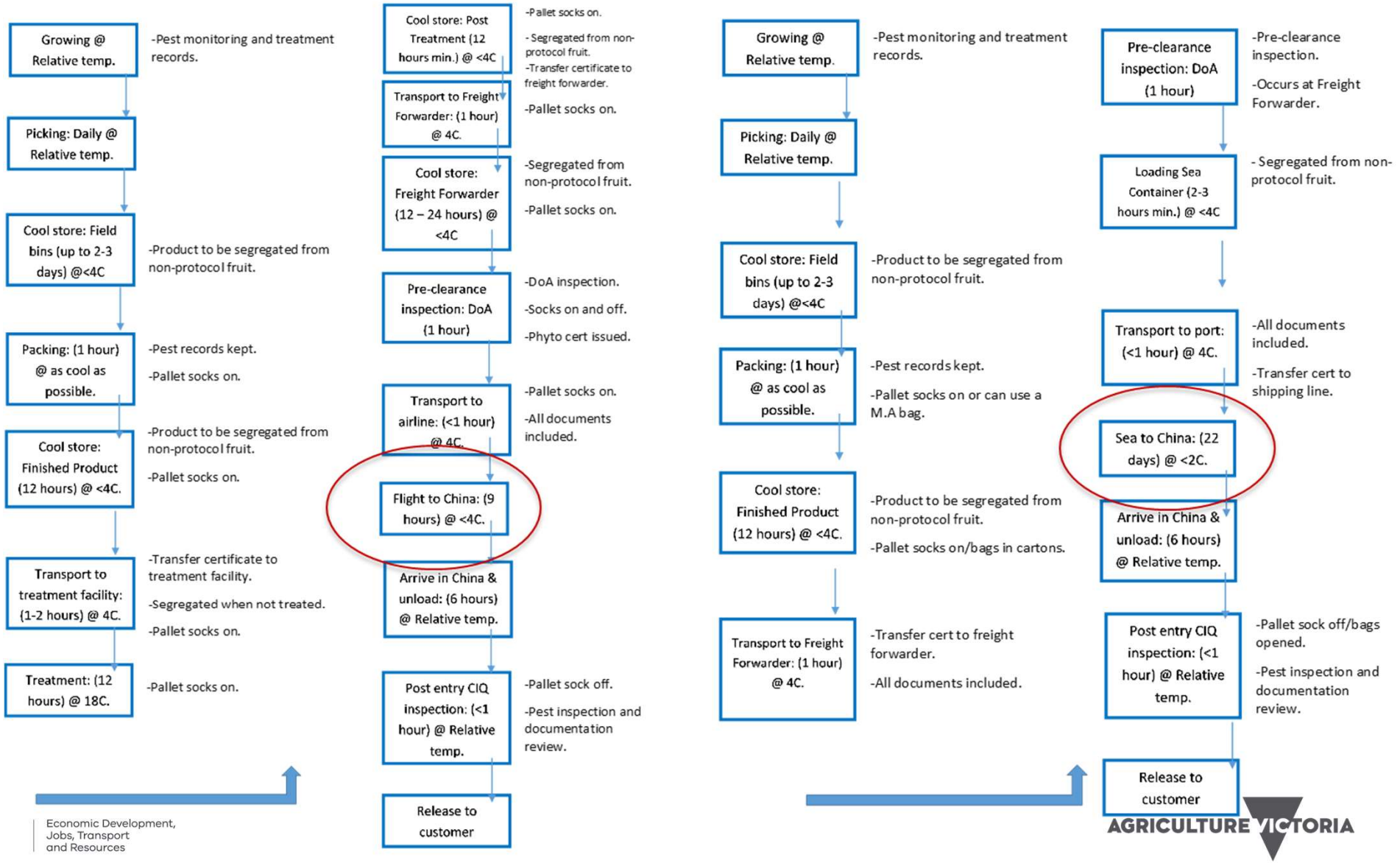


IHS Global Trade Atlas/ Euromonitor International analysis/ HIA

Horticultural/ Fresh produce supply chain



Montague's nectarine export to importer



Fruit maturity vs quality - terminology

- Fruit maturity
  - Physiological development of fruit i.e., immature to fully ripe
  - Measures include ethylene production, decrease in skin chlorophyll-a, change in volatile profile, change in firmness or skin/ flesh colour, fruit size
- Fruit quality
  - Eating quality of fruit i.e., sweetness, texture, acidity, flavour
  - Measures include SSC (soluble solids conc.), TA (acidity), volatiles (flavour and aroma), firmness (ripeness), ratio of SSC to TA
  - Maturity and quality sometimes interchangeable i.e., firmness as a measure of texture, SSC as a measure of sweetness
- Shelf-life
  - Time remaining before fruit is unmarketable or not consumable
  - Can be due to over-ripeness, colour, texture, rot incidence etc.
  - End of shelf-life can be perceived differently by different chain participants e.g., retailer vs consumer

Horticultural supply chain challenges

- Fresh produce are ‘alive’, respire, and use up energy reserves after harvest
  - Quality at harvest can be ‘preserved’ along the chain but not improved
  - Low temperature slows down rate of quality loss
  - Potential shelf life depends on product, and many pre- and post-harvest factors
- Biological variability (fruit are not widgets)
  - Due to fruit position within trees, plots within fields etc.
  - Grading after harvest reduces this to an extent
  - Understanding quality distribution in a shipment is important
- Commercial challenges
  - Will high quality produce result in higher returns in export markets?
  - Does the grower/ exporter/ importer supply what the consumer wants?
  - Lack of knowledge linking new genotypes and postharvest performance

Fruit maturity and quality – Who wants what?

Export chain participant	Fruit maturity and quality requirements	Potential issues
Grower/ Exporter	Harvest maturity to ensure fruit can accommodate handling during export	Harvesting of immature fruit of poor eating quality to reduce risk of losses in export chain
	Timing to maximise market price (particularly early season)	Harvesting too early
	Multiple harvests to ensure fruit is of a minimum maturity/ quality	Harvesting costs
Importer/ Wholesaler	Fruit is sound and 'fresh' on arrival and can accommodate further cool storage and handling	Importer has little knowledge of previous handling
		Poor cool storage & handling practices resulting in loss of shelf life
Retailer	Fruit of good appearance and approaching ripening stage with enough shelf life remaining for retail and consumption	Poor storage and retailing practices
		"Flexible" specifications for minimum eating quality e.g., sweetness
	Consistent visual quality e.g., fruit size, colour, shape etc.	Wastage or discounts along the supply chain
Consumer	Consistent fruit with good eating quality after ripening	Poor eating experience e.g., sour, poor texture
		No return purchases
		Different consumers may have different tastes e.g., sub-acid vs high acid nectarines

Serviced supply chains

Horticulture business opportunity

- ASEAN fruit and vegetable consumption predicted to increase by ~100% between 2007 and 2050[1].
- Significant opportunities for Australian Horticulture, but:
  - ~20% wastage from farm to retailer[2]
  - Competition from other export countries
  - “Clean, green, fresh” can/will be copied
- High quality value chain, consistency, integrity, service is much harder to copy
  - Our unique competitive advantage?

1.https://www.crawfordfund.org/wp-content/uploads/2014/05/penm.pdf
2. Kader 2005

Serviced supply chains

Project Objectives

Increase the value and profitability of Australian horticulture export businesses by improving the "freshness", consistency and reputation of Australia's exports into Asia, and the reputation of our export chains

1. **Monitoring to improve chains**: Demonstrate the benefits of monitoring produce conditions (e.g. temperature) and performance (e.g. colour, firmness) from farm to retail to identify improvement strategies
2. **Predictive tools**: Develop tools to predict out-turn quality and remaining shelf life to allow rapid decision-making that will maximise value and returns
3. **Sustainable Solutions**: Systems and services to assist adoption of monitoring and prediction tools to consistently improve the quality and profitability of exports to Asian customers.

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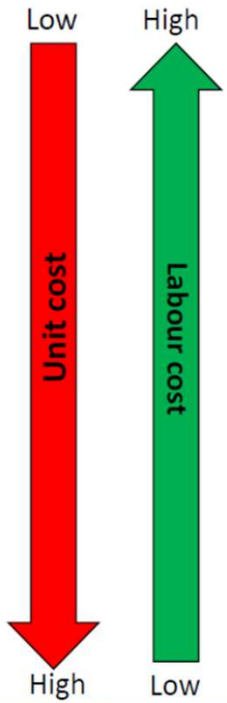
Monitoring to Improve Chains

"We can not improve what we do not know"

- Compare technologies to efficiently monitor and report conditions (e.g. temperature) and product quality from farm to retail
  - Investigate feasibility of monitoring other conditions (maturity, volatiles)
- Demonstrate the above technologies in commercial shipments of co-investing chains
- Compare monitored conditions and product outturn quality
- Recommend where practice change is required
- Train importer chain members in outturn assessment and reporting
- Strengthen trust and transparency in the export chain.

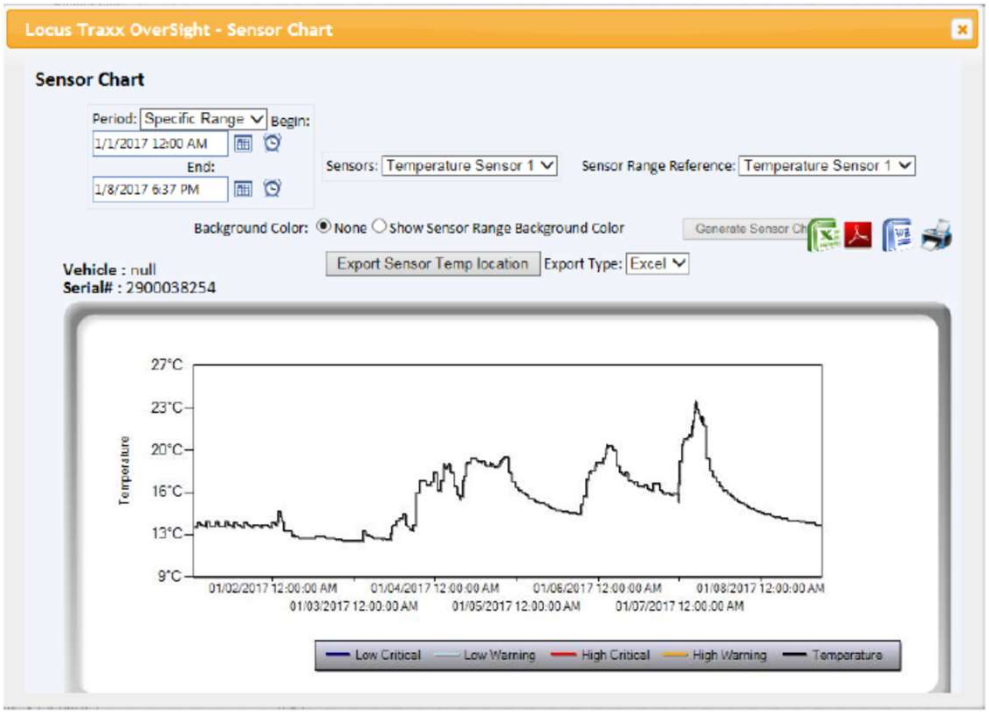
Export temperature monitoring

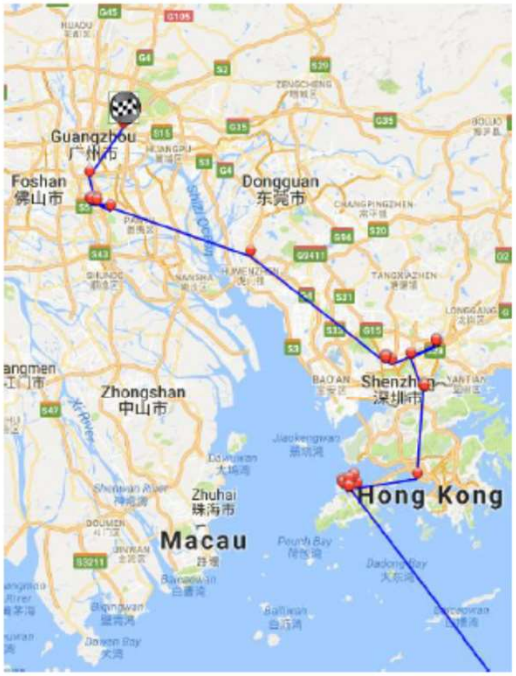
Monitoring system	Advantages	Disadvantages
Time x temperature indicators	Low unit cost. Indirect freshness indicator.	Only receive a colour signal. No digital temperature data. No data over time.
Chart recorder	Temperature can be monitored continuously over time. Low unit cost.	High labour cost in physical retrieval. Low data resolution.
Digital dataloggers	Continuous monitoring. Data analysis. Alert function.	Require physical retrieval and data download. High labour cost.
RFID	Parallel reading of several sensors. Automatic data download. Semi-real time data acquisition.	Data downloaded only when sensors are within close range of a hub.
SIM-based	Continuous and automatic real time temperature and location data acquisition. Low labour cost.	Higher unit cost. Network incompatibility in some countries. Data only downloaded when near mobile towers.



- Locus Traxx (SIM card) loggers

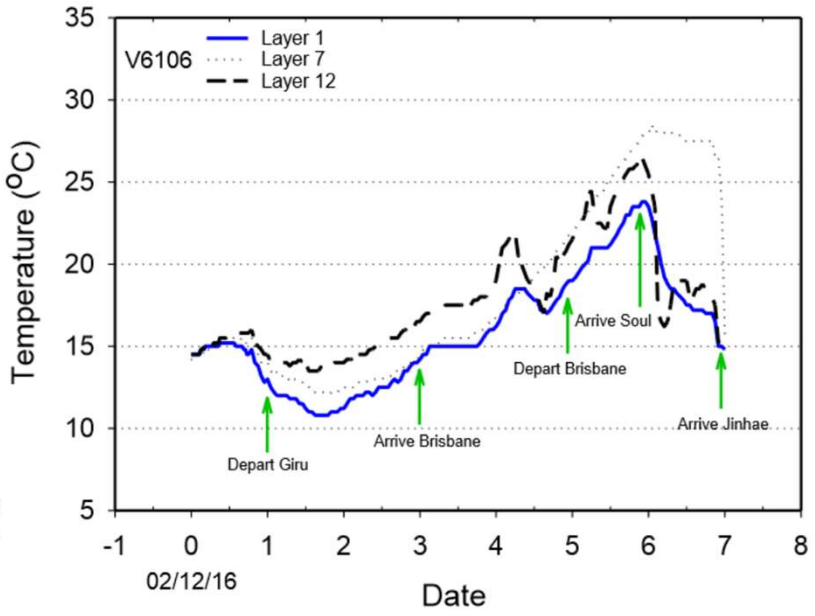
Minimal intervention monitoring

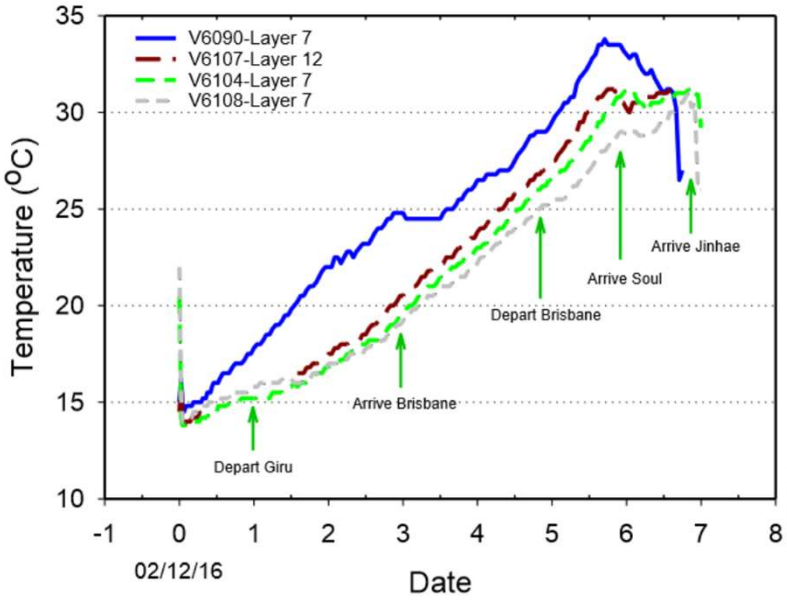




- Xsense (RFID) interface

Air freight monitoring – Nectarine and Mango





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Predictive Tools

- Laboratory trials to determine the impact of e.g. product maturity, air and sea transport time and conditions, and post-shipment handling, on outturn quality.
  - Will determine product responses to expected or preferred shipment conditions
- Predictive tools so the chain can:
  - Estimate the effect of monitored conditions on product quality on arrival
  - Adjust handling conditions in country to prevent further quality loss and maximise quality to the consumer – every time!

http://www.iseesystems.com/store/products/stella-architect.aspx

Predictive tools - Quality

- Will allow horticultural industries to:
  - Anticipate possible quality issues prior to export
    - Sub-optimal harvest maturity, effects of disinfestation protocols
    - Classify fruit batches by risk (e.g., rot risk in table grapes)
  - Vary quality inputs (harvest maturity & variation)
    - Determine effect of maturity/ quality at harvest
    - Maximise product quality into export markets
  - Determine residual shelf life during export
    - Remaining shelf life on arrival at export market until product becomes unsaleable
    - Ideally predict during 'real time' monitoring!
      - Requires real time data transfer and consolidation…
  - Understand $$ benefits of modifying practices to improve quality (Value chain)

Serviced supply chains

Sustainable Solutions

Facilitating long term improvement

- Assess the drivers and impediments to adoption
- Non-confidential case studies demonstrating the business case
  - Benefit cost analysis
- Chain support to implement improvement opportunities
- Training resources etc. to improve individual chain performance
- Workshops and presentations at industry forums
- Train private providers to ensure on-going impact

Serviced supply chains

Current partnerships

R&D co-funders

- Dept. of Agriculture and Fisheries (Qld) – project leader
- Horticulture Innovation Australia (Pool 2 Fund)
- Department of Economic Development, Jobs, Transport & Resources (Victoria)
- University of Southern Queensland

First three industry co-funders

- Manbulloo (mangoes)
- Montague Fresh (summerfruit)
- Glen Grove (citrus, submitted)

In-kind collaborators

- Chinese Academy of Sciences
- University of Queensland

Serviced supply chains

Where to from here?

- Project currently $16 mill total investment over 5 years
- Approach: Demonstrate the benefits using targeted co-investing chains, then “spread the word”
- Work with 5-6 commodity groups to start with
  - Mango, summerfruit and citrus engaged
  - Negotiating with table grapes and vegetables
- Other commodities/chains can co-invest in future years
- Will partner with peak bodies and service providers to increase project impact and benefit.

Postharvest R&D underpinning Serviced Supply Chains

- Snapshot of current applied & strategic research:
  - Preharvest factors & variability
    - Variation in fruit size and sweetness in early season nectarine
  - Harvest maturity and eating quality
    - Use of DA meter (IAD) for non-destructive fruit maturity measurement
    - Relationship between maturity and aroma volatile compounds of peaches and nectarines
  - Cool storage/ Export simulation
    - Export simulation of new white nectarine cultivars
  - Predictive tools
    - Aims & Scope
    - Risk assessment for exporters
    - Modelling of export chains

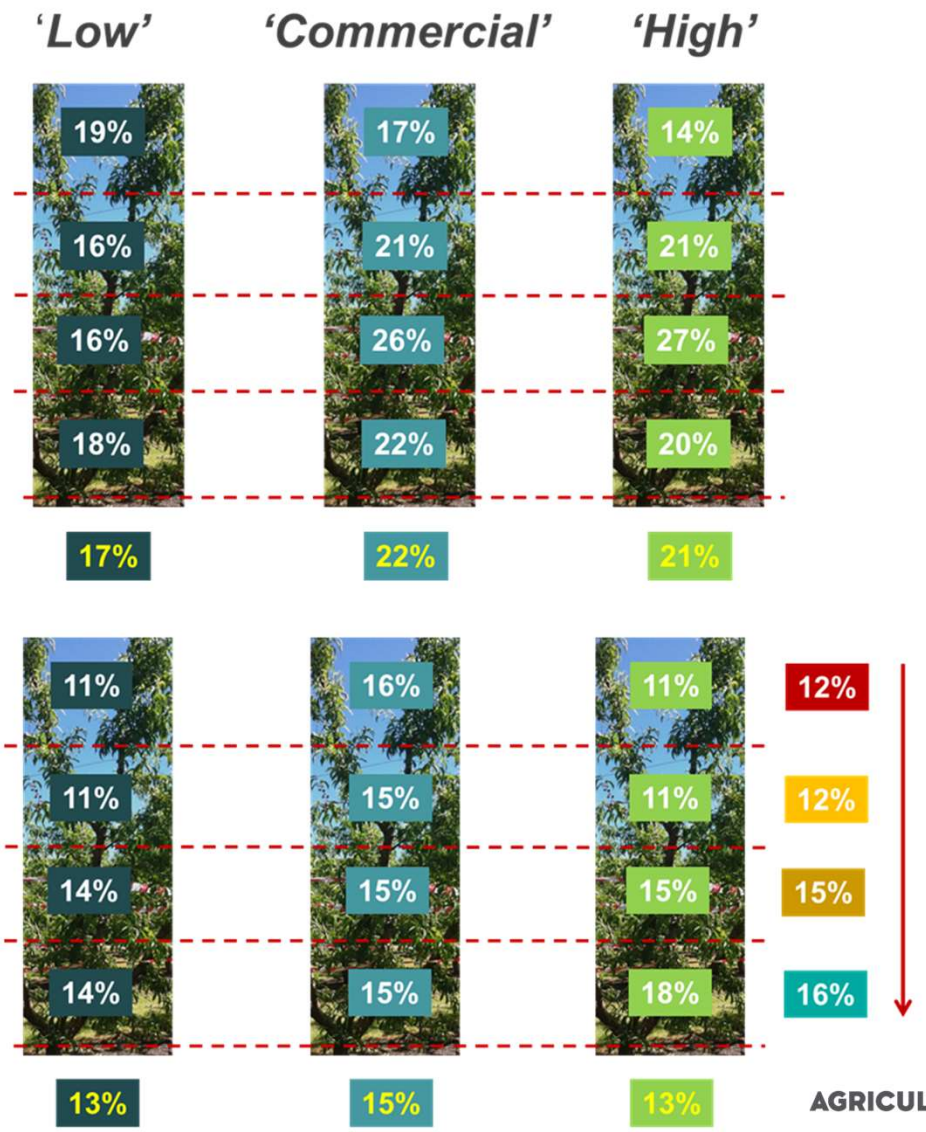
Variation in quality among trees

***Rose Bright* nectarine – 94 DAFB**

Coefficient of variation - CV (%)

Fruit mass

SSC

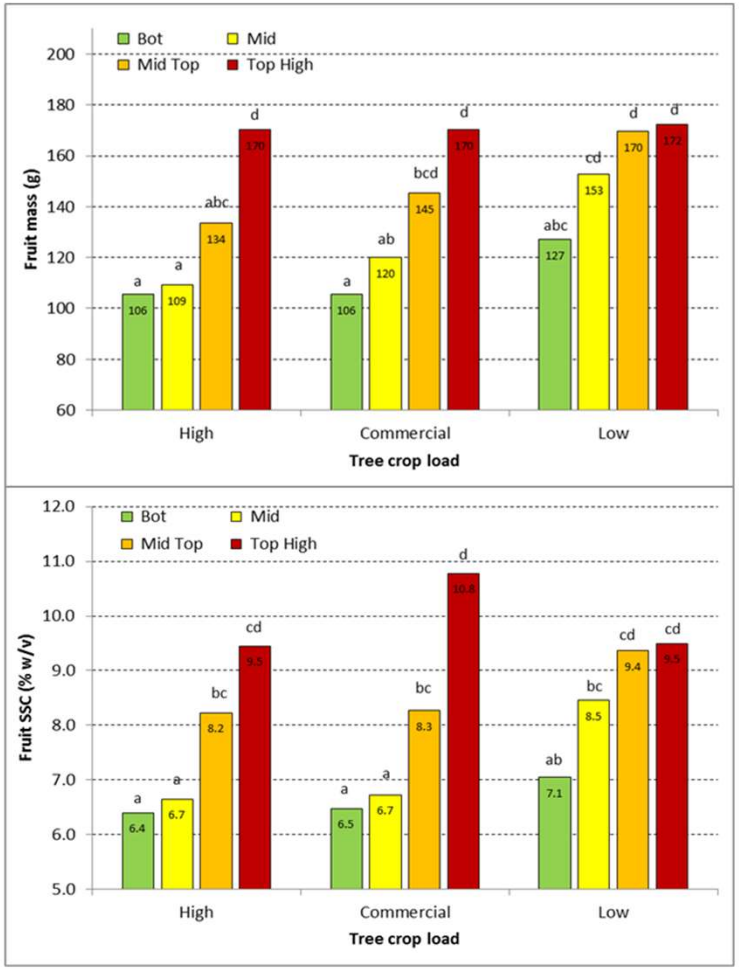


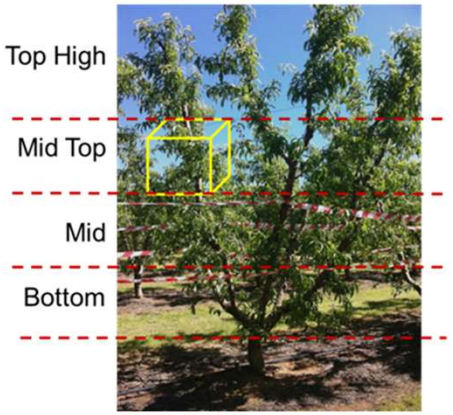
Important physiological, environmental and anatomical factors influencing fruit sink efficiency and variation in summer fruit size and SSC within a tree

Main physiological or environmental factor	Specific factor	Comments in relation to fruit quality and variability	Degree of evidence in scientific literature
Carbohydrate availability to fruit	Solar radiation intensity and duration	-Tree training has important influence -Generally increases with tree height	*****
	Leaf-to-fruit ratio	-Determines level of fruit competition and type of fruit growth (source or sink limited) in conjunction with CHO availability -Effect on fruit competition and quality of different ratios relative to carbohydrate supply not clearly defined	****
	Fruiting branch autonomy	-Autonomy of scaffold limbs established -Autonomy of fruiting branches dependent on level of competition within other sections of tree but degree of autonomy not clear	***
	Fruit proximity to source	-Very important at tree 'compartment' level but importance within fruiting branch not clearly established -Likely to be influenced by tree crop load and fruit sink size	***
Fruit exposure to solar radiation	Micro environment - Temperature	-Critical role in influencing fruit physiology (respiration) and growth -Effect on SSC of relative differences in accumulated temperature or average maximum temperature not established -High temperature effects not fully determined eg. fruit stress, skin speckling, rate of maturation	**
Fruit development	Fruit development stage	-More developmentally-advanced fruit potentially at an advantage in terms of growth and quality	****
	Physiological maturity within a stage	-Relatively greater physiological maturity within a stage correlated with higher fruit SSC and mass -Relationship between rate of maturation and rate of sugar accumulation not clearly established	***
Fruit flesh anatomy	Cell size distribution	-May be linked to cell 'development' thus influencing CHO utilisation within fruit -May also be associated with SSC variation within individual fruit -Larger cells may also contain higher ploidy number and thus stronger sinks for CHO	*
	Cell number	-Sets potential dry matter (DM) accumulation and fruit size -Measure of 'sink strength' -In very large fruit competition between cells may reduce rate of increase in fruit size	***

Lopresti J, I. Goodwin, B. McGlasson, P. Holford & J. Golding (2014). Variability in Size and Soluble Solids Concentration in Peaches and Nectarines. Horticultural Reviews, 42:253-311.

Effect of preharvest factors on nectarine quality





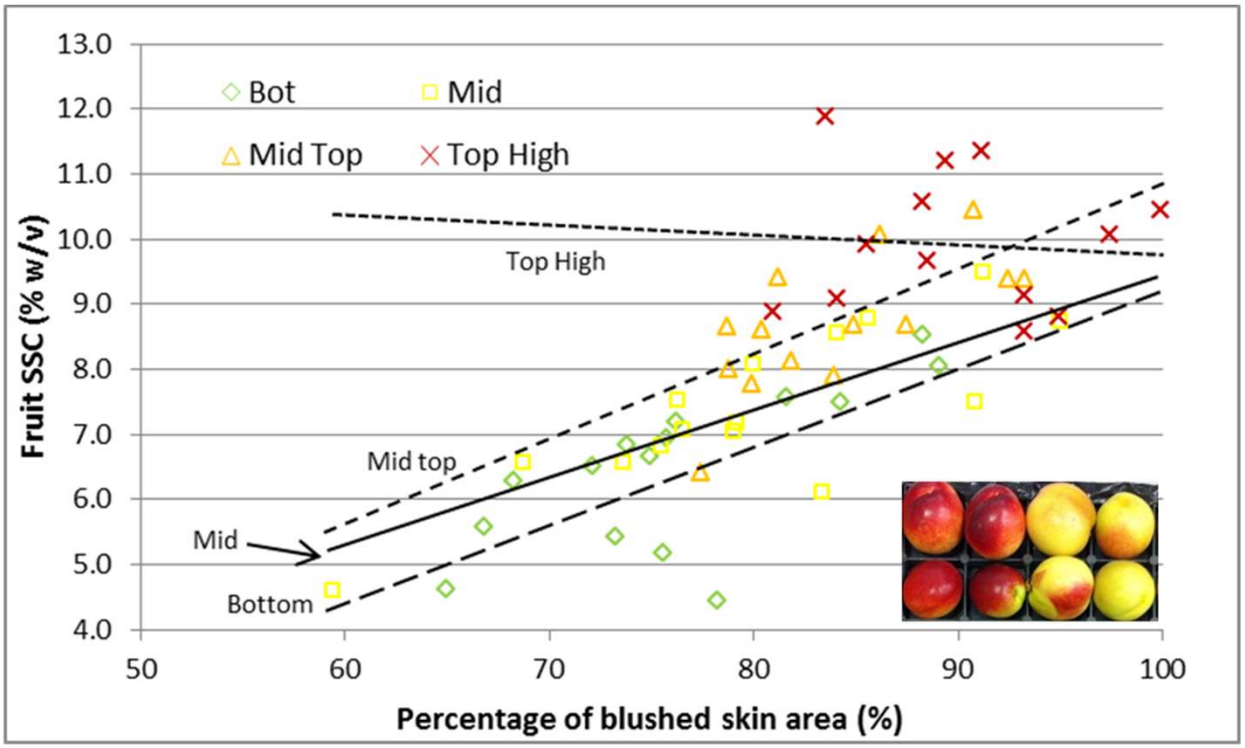
All fruit at 'climacteric' maturity based on I_{AD} value

2 branches per compartment (n=6-8 fruit)

All fruit harvested within a compartment

Effect of fruit height and tree crop load on fruit mass & SSC in 'Rose Bright' nectarine at 94 DAFB. Means adjusted for differences in fruit yield between tree heights. Means based on 30-40 fruit per height and crop load combination

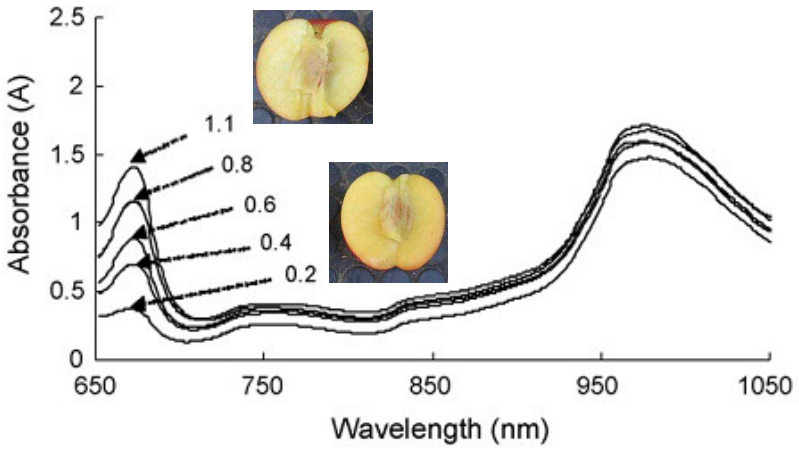
Sweetness and fruit skin blush



- Strong relationship between SSC and blush within a tree height
- Relationship not as strong in Top High position
  - Fruit exposure to sunlight marginally less important
- Light exposure in bottom of tree marginally less effect on SSC

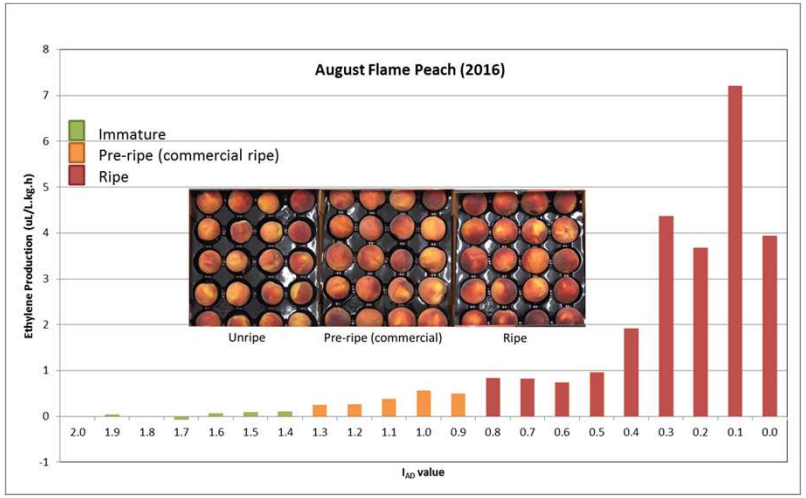
Harvest maturity & eating quality

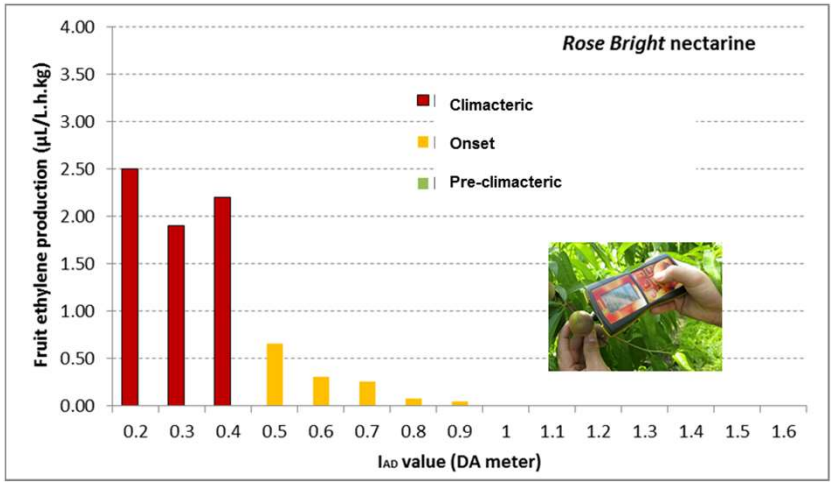
- Various technologies available
  - Non-destructive based on vis-NIR
- Index of Absorbance (DA meter)
  - Measures chlorophyll-a below skin (670 to 720 nm band)
  - Index of fruit physiological maturity
  - Positive results for stone fruit, pome fruit and some pear varieties
- Felix NIR meter
  - Measures sugars and dry matter
  - Provides full absorbance spectrum
  - Requires calibration model to account temperature, orchard variation…



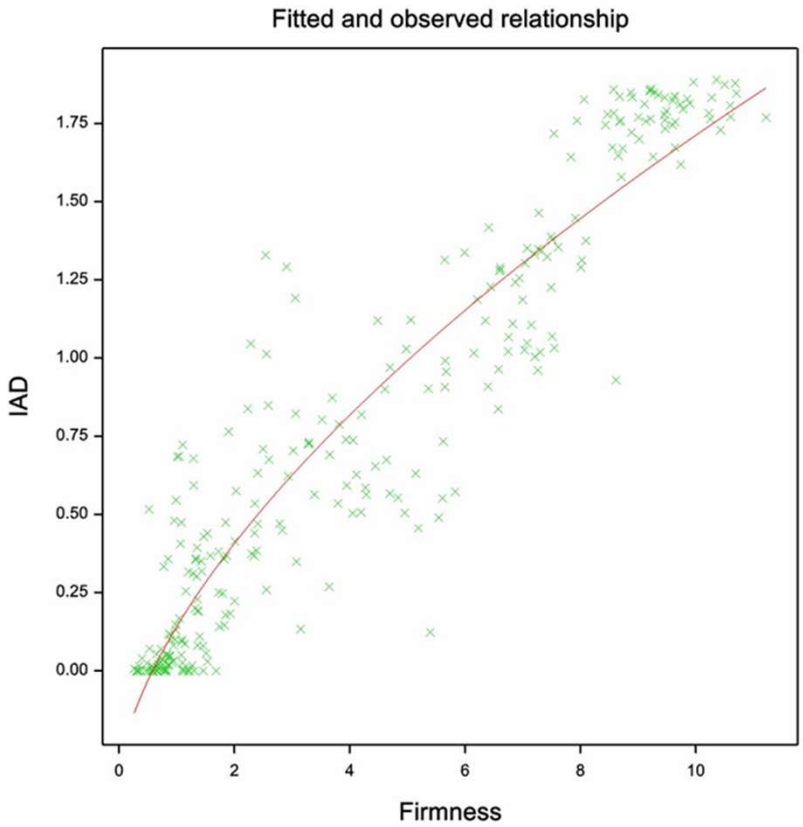
I_{AD} index and fruit ripening

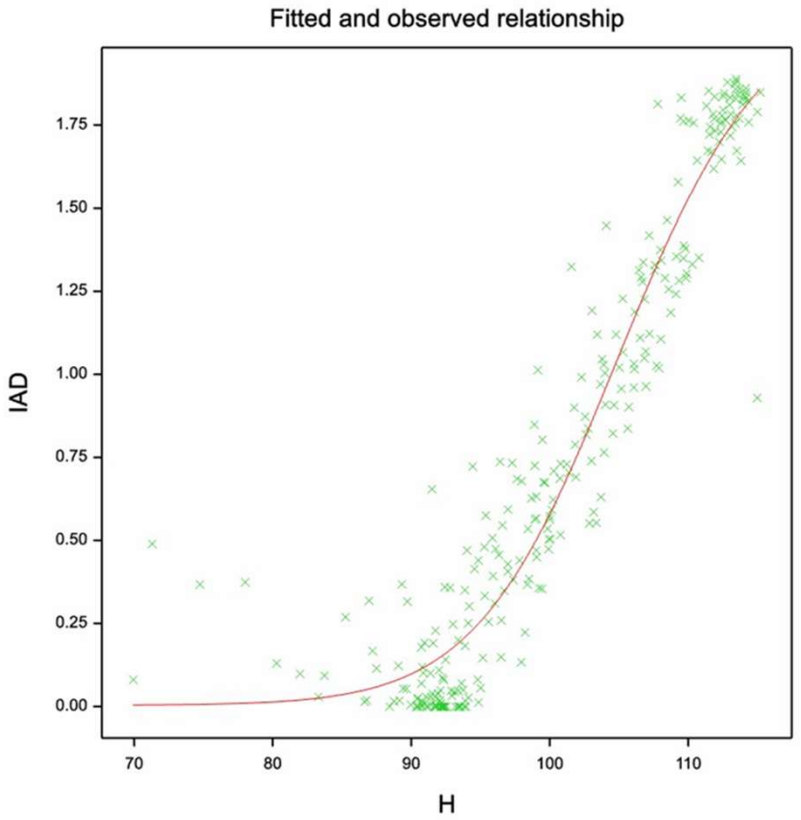
- I_{AD} related to time course of ethylene production during fruit ripening
- I_{AD} classes are cultivar specific and generally consistent among seasons





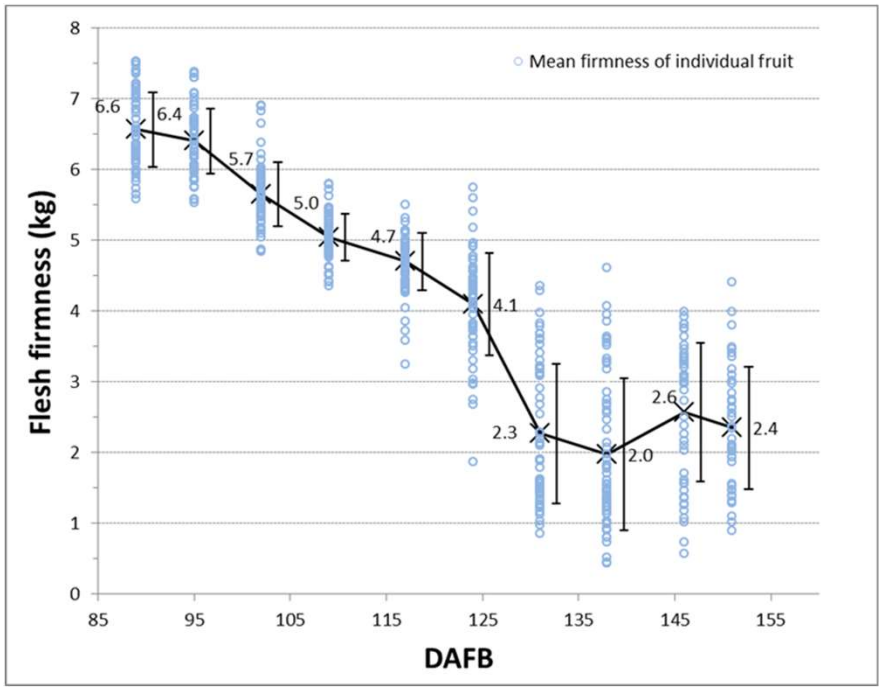
Good correlation with classical measures of maturity (Williams pear: r^2>0.85)

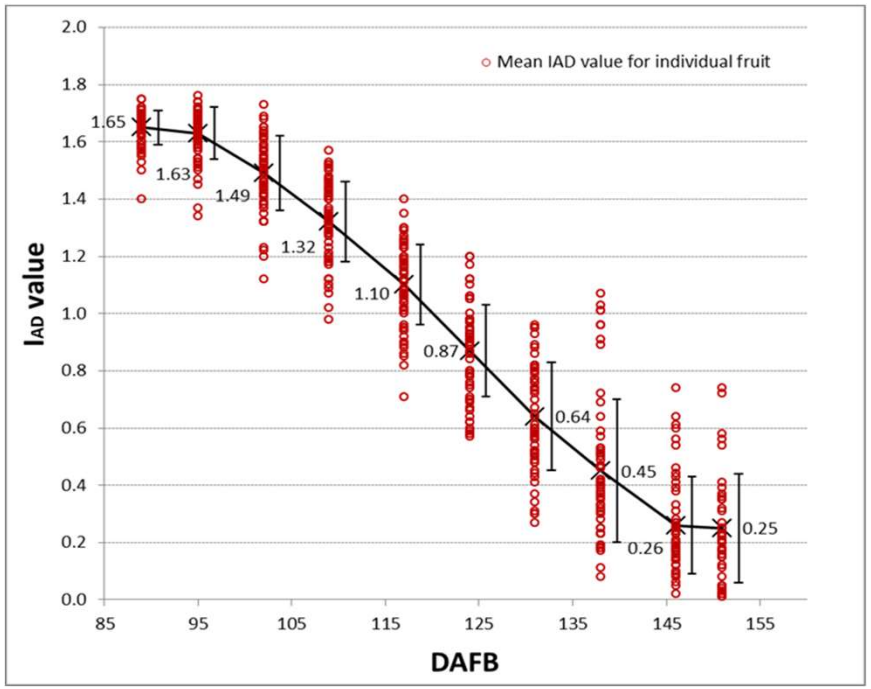




Effegi penetrometer flesh firmness and skin hue angle H (green to yellow colour)

Good correlation with classical measures of maturity (Blush pear variety ‘Lanya’)

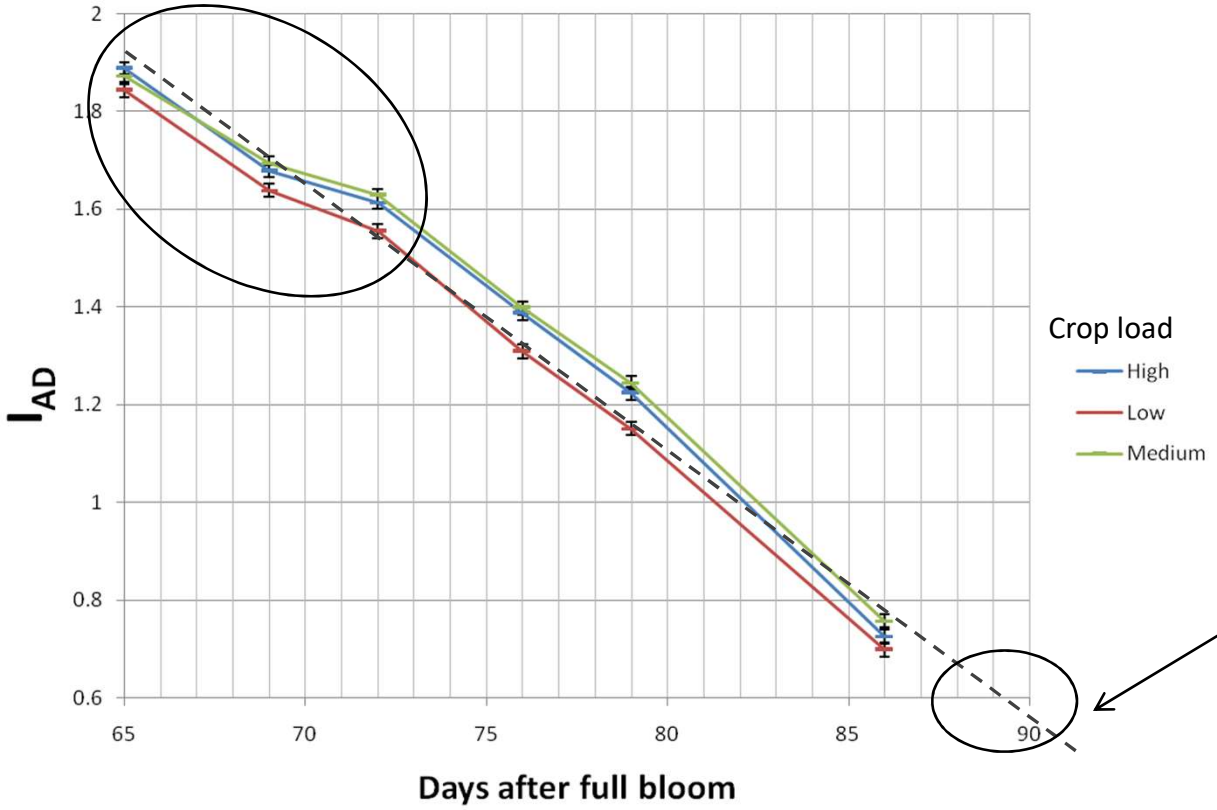




Mean and range of flesh firmness and IAD in ‘Lanya’ pears measured at each of ten harvests (n = 40 - 60 fruit). Each error bar represents the standard deviation.

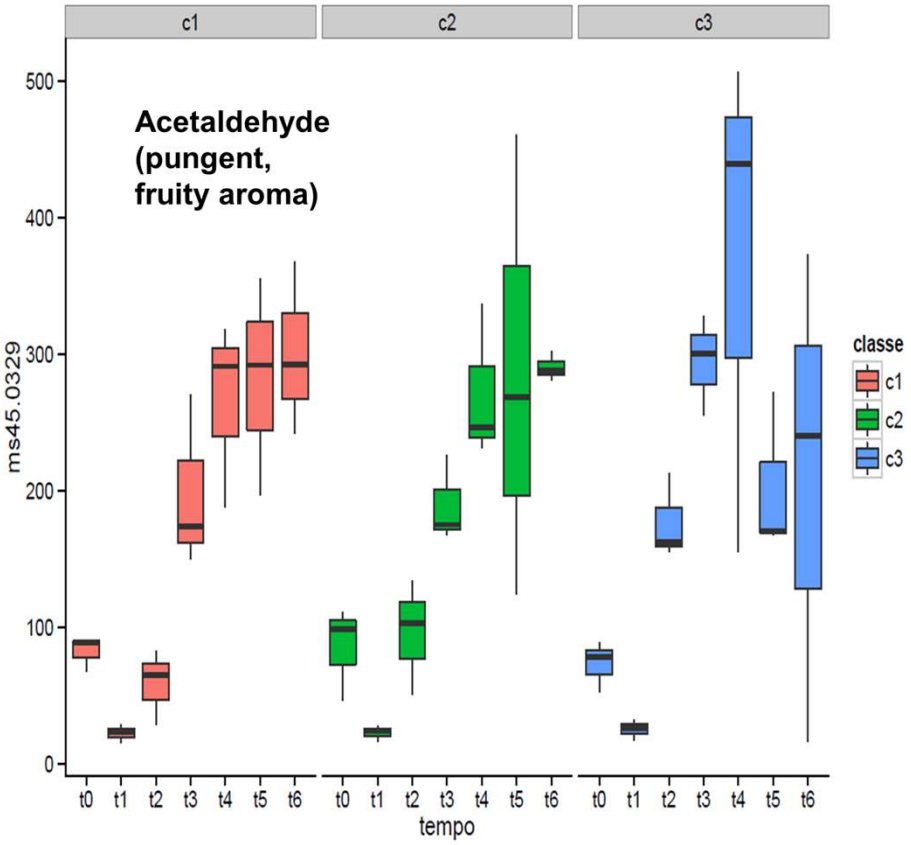
I_{AD} index and harvest prediction

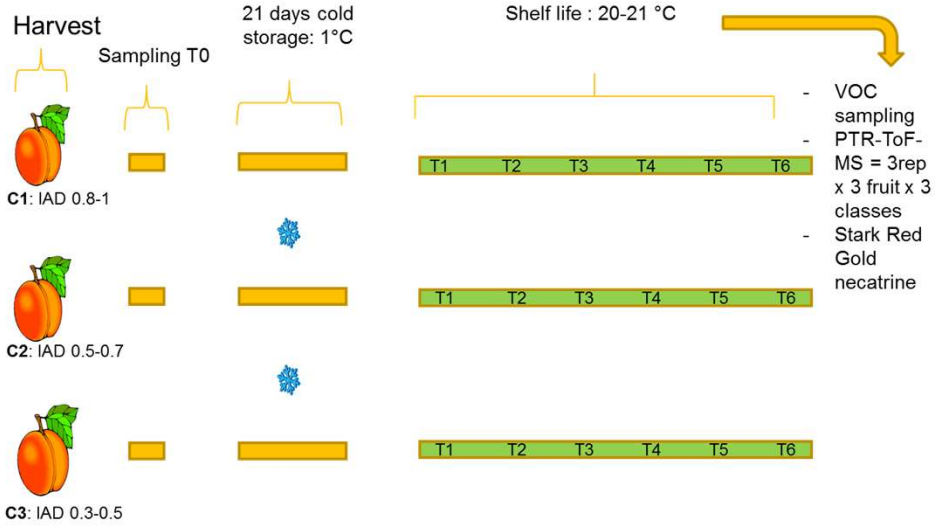
- Early measurement of fruit maturity may enable prediction of harvest date/ window

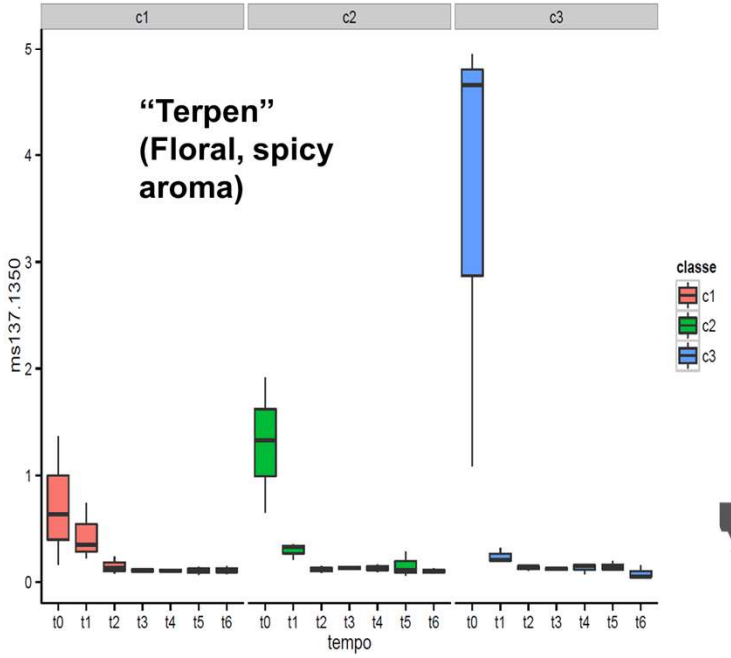


Predicted harvest window for commercial maturity cv. Rose Bright

Fruit maturity and volatiles (aroma)







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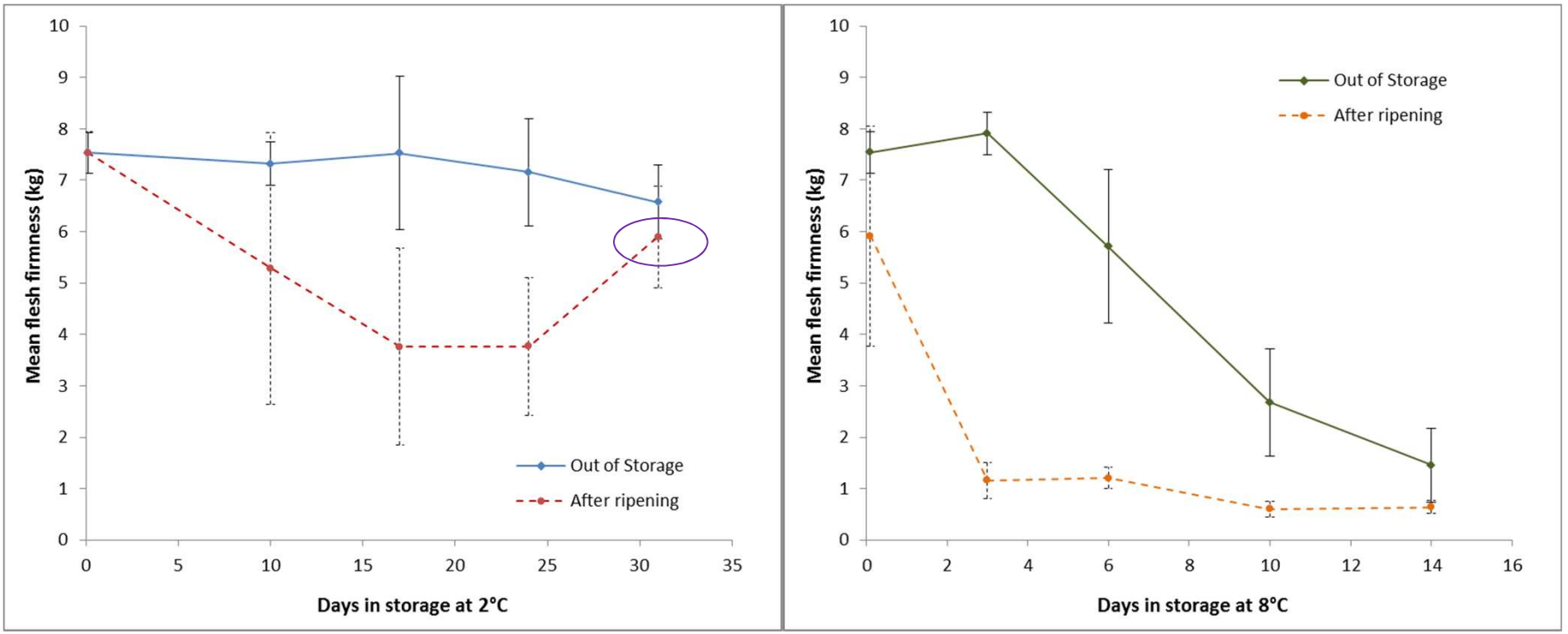
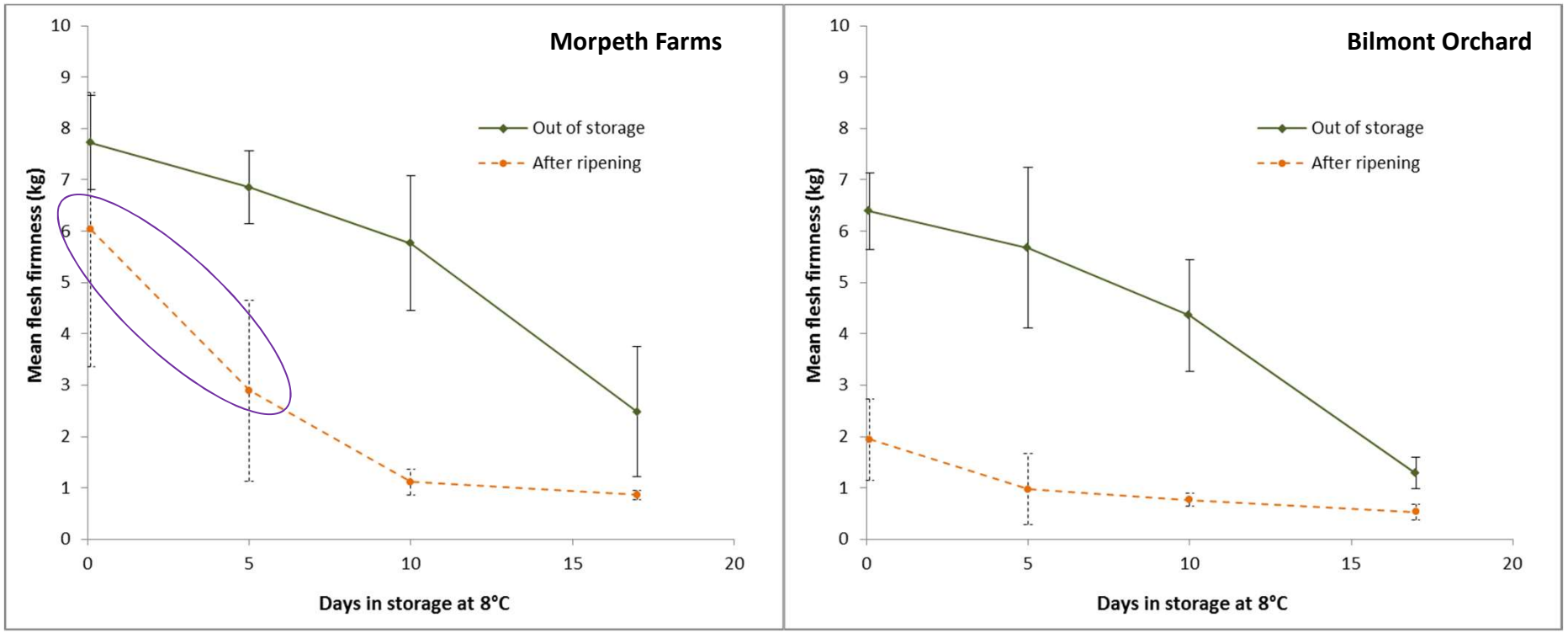
Nectarine export simulation - Sea and Air freight

- Postharvest behaviour of new cultivars largely unknown
- Growers & exporters want to understand risk in exporting



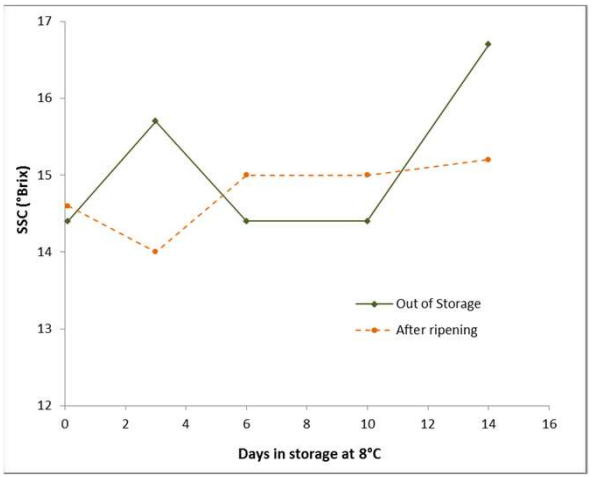
Change in *Majestic Pearl* flesh firmness during storage at 2°C and 8°C; N = 10 fruit per assessment; Error bars are standard deviations.

White Knight nectarine – Air freight simulation

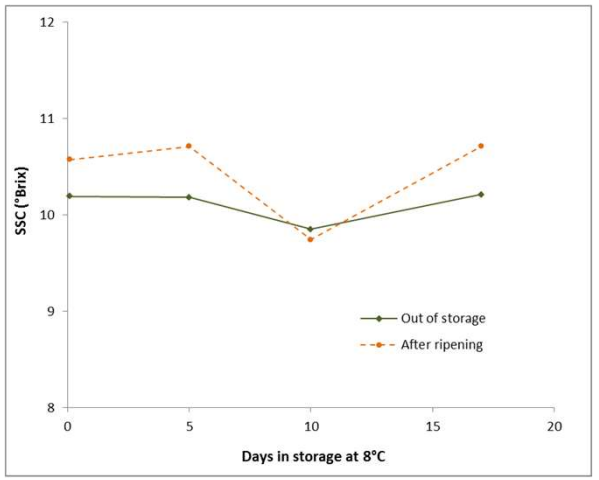


Change in *White Knight* flesh firmness during storage at 8°C;
N = 10 fruit per assessment; Error bars are standard deviations.

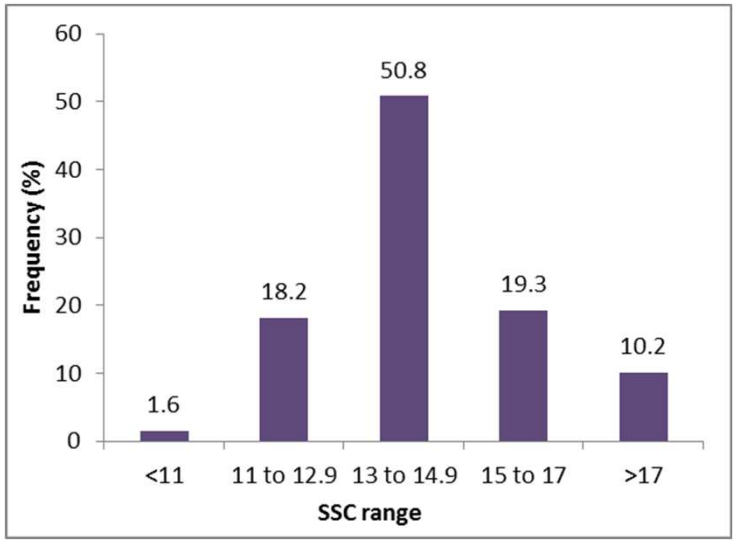
SSC distribution after grading in export nectarines

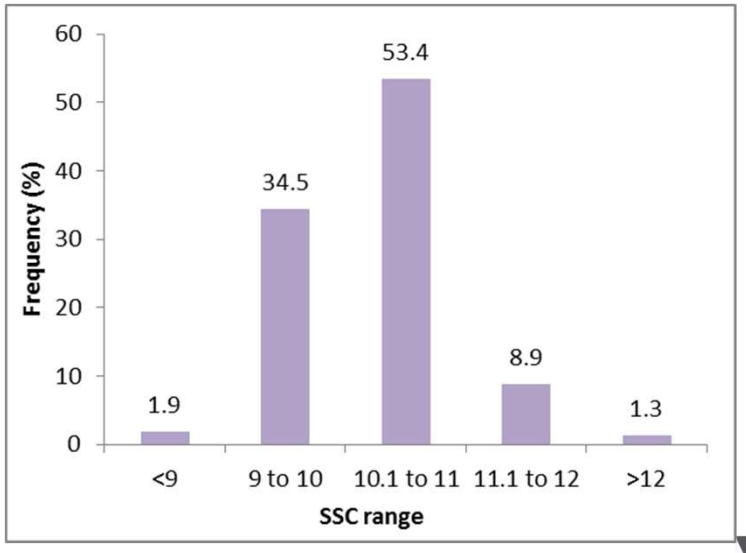


Majestic Pearl (mid-season)

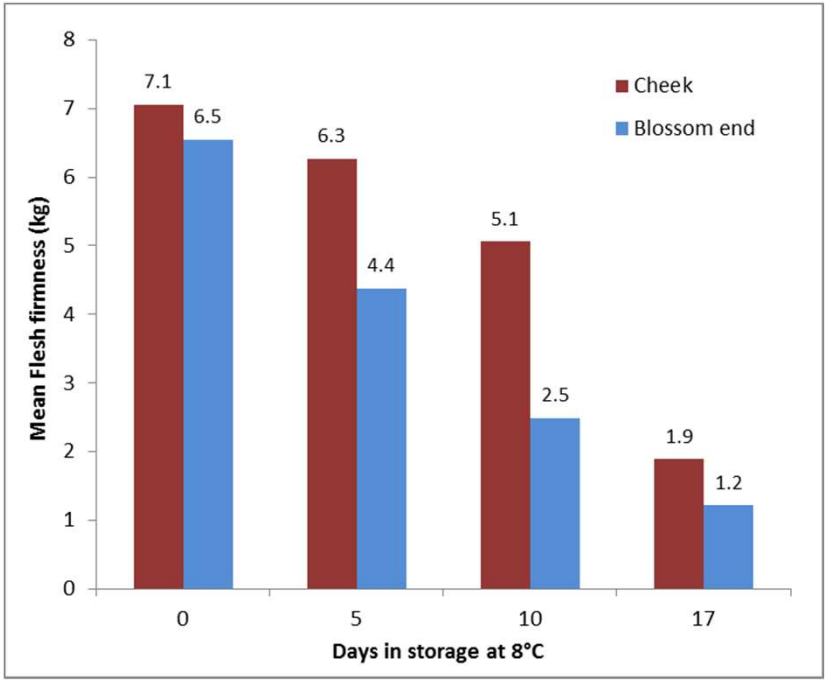


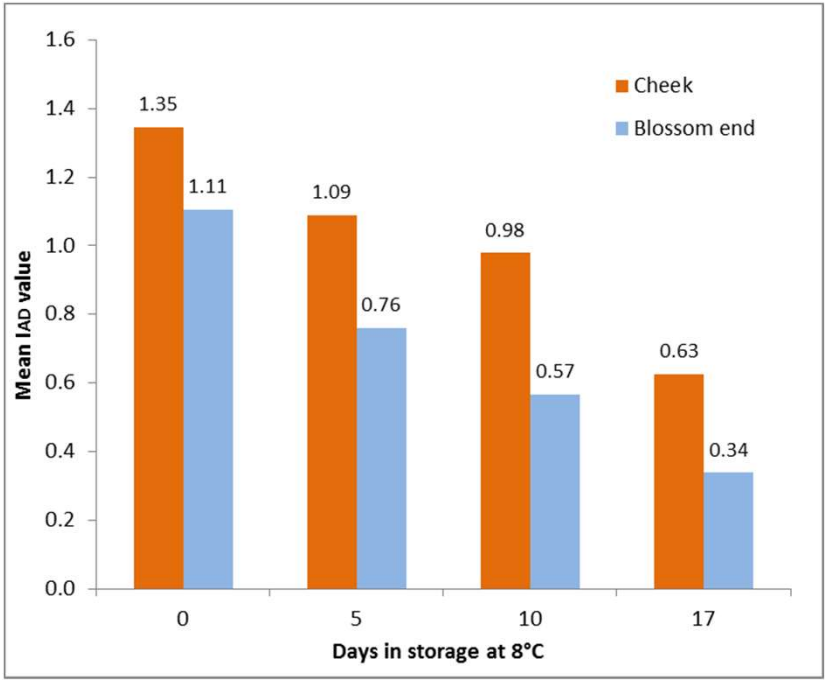
White knight (early-season)





White Knight – *Unsuitable for export?*





Comparison of *White Knight* cheek and blossom end flesh firmness, and IAD, after removal from storage at 8°C; N = 10 fruit per assessment; Means calculated across two orchards.

<u>Blossom end = Bottom of fruit</u>

Predictive tools & scope

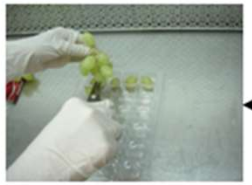
- What is achievable?
  - Timeframe
    - 4 years to develop tools and validate!
  - Practical
    - Predictive tools must be practical & useful for industry
    - What do horticultural industries want?
      - 'Quick' answers to current quality problems
      - Understanding of how their product 'holds up' during export
  - Type of tools/ Outputs
    - Risk assessment at harvest (e.g., rot risk in table grapes) – STOP/ GO
    - Guidelines for fumigation to minimise quality loss, or ethylene dose to ensure fruit ripening – MODEL MODULES
    - Export chain model – BY COMMODITY (INPUT/ OUTPUT)
      - Average quality of a batch at points in chain
      - Residual shelf life
      - Likely risk of physiological disorders in a batch

Rot risk assessment at harvest - Grapes

Developing a simple method for detecting potential rot infections in fruit batches at harvest and cold storage

Step 1: Fumigation with sulphur dioxide to eliminate external infections

- two sets of bunches (5-10/block) are picked along a vine row from an area of 0.1-0.3 ha or 120-430 vines.
- bunches are trimmed as per commercial practices and placed inside bunch bags and liners in plastic boxes.
- one set of bunches is treated with sulphur dioxide (e.g. SO_2-generating pads) to eliminate external infections.

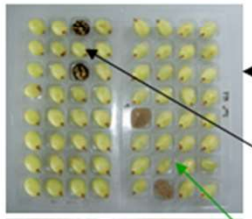


Step 2: Remove all berries from each bunch

- on a laminar flow cabinet or clean bench, clip all berries (with pedicel attached) from each bunch
- place berries singly in compartments of plastic trays and label tray with block

Step 3: Incubate berries to speed up development of external and internal (latent) infections.

- place trays with berries inside plastic bags to increase humidity.
- incubate trays at room temperature (18-22°C) for 7-10 days.



Step 4: Determine the levels of rot infections

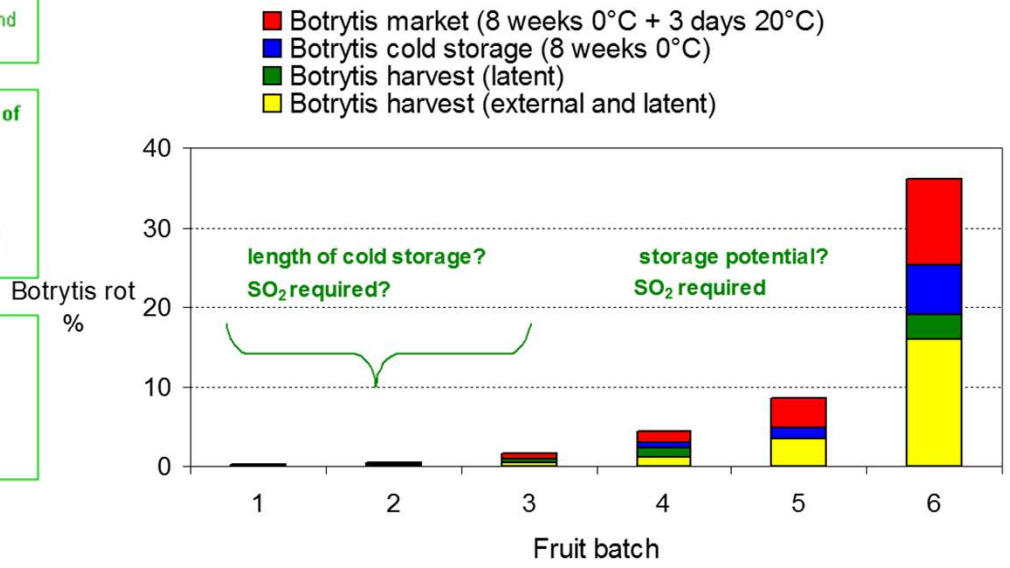
- count the number of berries infected with Botrytis and other rot infections per bunch.
- calculate the percentage of berries with Botrytis and other rots in a sample of bunches (e.g. 5/block).

Berries infected with Aspergillus rot

Berries infected with *Botrytis cinerea*

The berry incubation method requires further validation before it can be used commercially.

- Assesses latent infection in berries at harvest
- Botrytis incidence at harvest correlated with Botrytis bunch rot in cool storage



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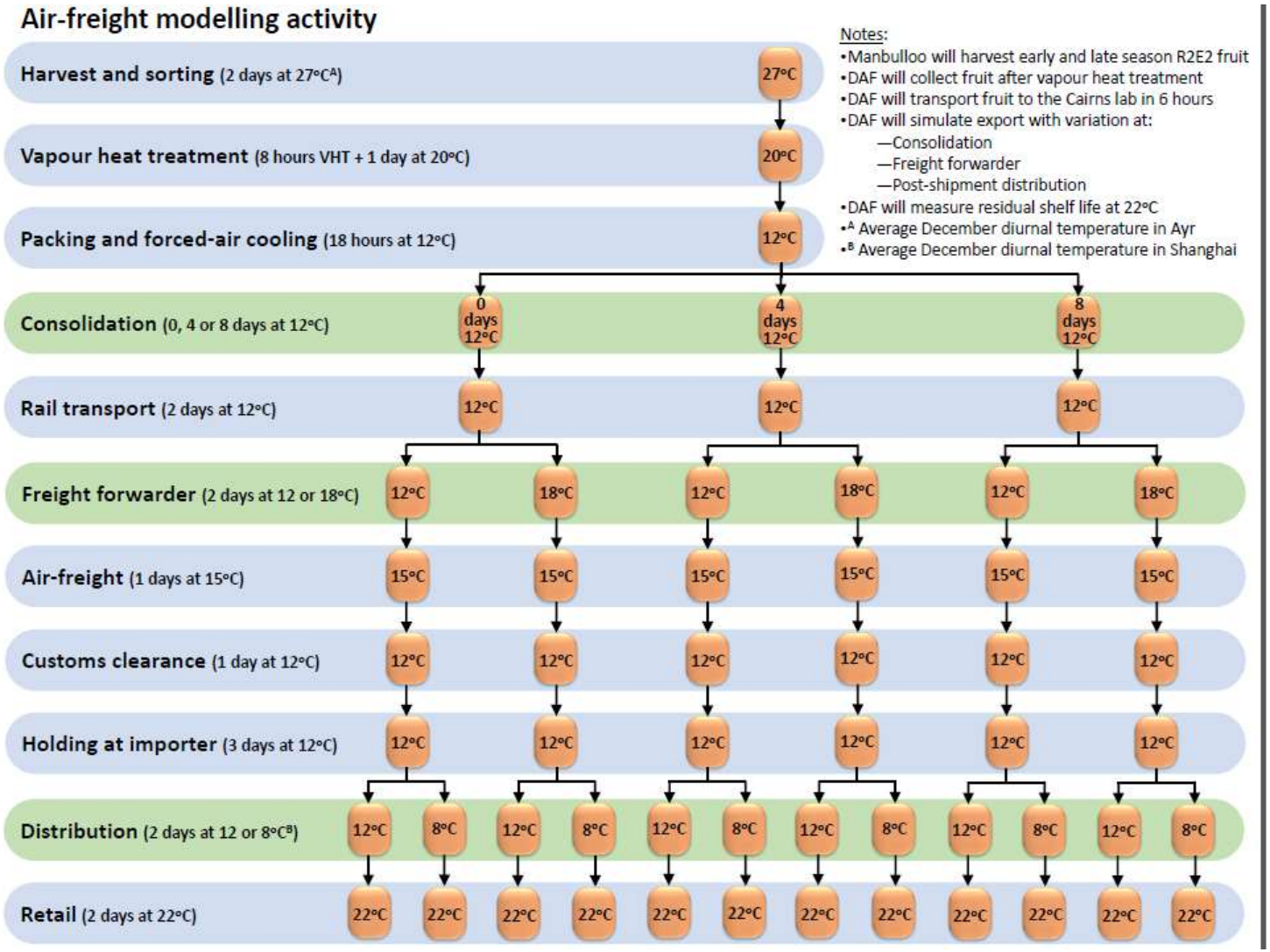
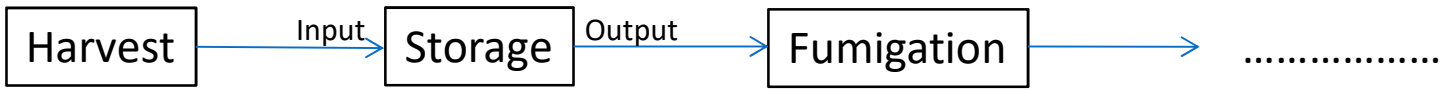
Export chain model - A module approach?

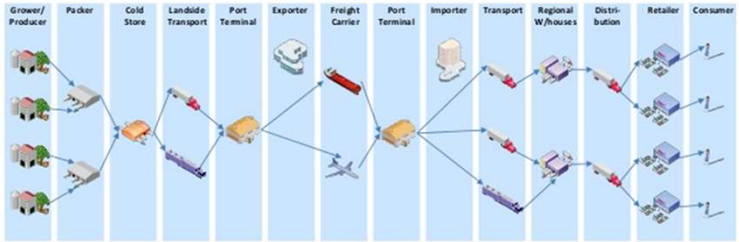


Modules within an export chain model

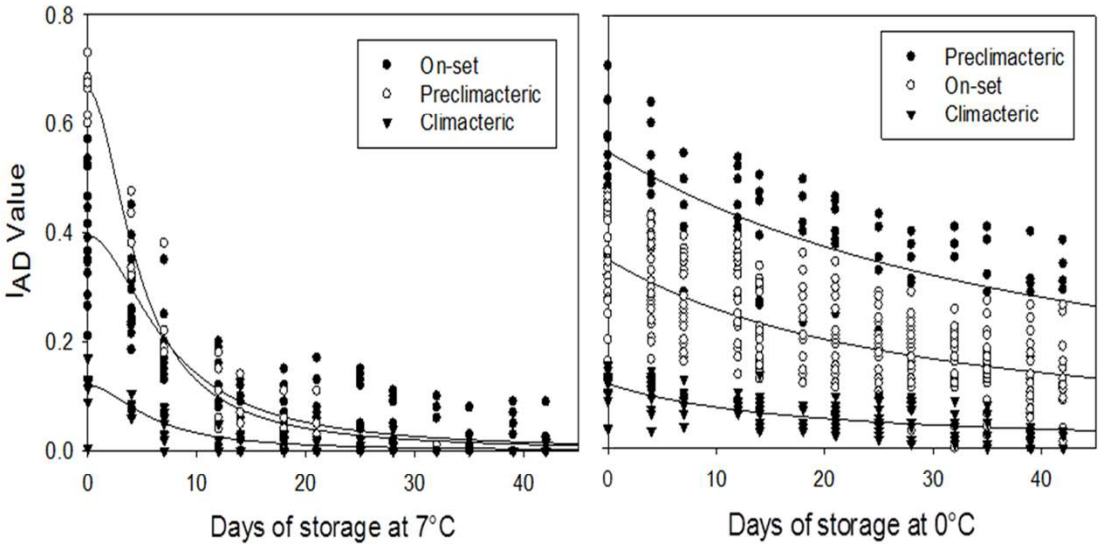
- Module approach enables:
  - Answers to specific industry questions
    - Export performance of cultivars (temp x time models)
    - Effect of postharvest processes on quality
      - Fumigation, ripening etc.
    - Modules can be linked together to predict quality changes at key points in the export chain
  - A module may contain a risk assessment (stop/go) or empirical data (regression model)

- 'Initial conditions' are critical for effective prediction
  - Harvest maturity e.g., firmness, IAD
  - Harvest quality e.g., SSC
  - Biological variation e.g., Standard deviation, type of distribution

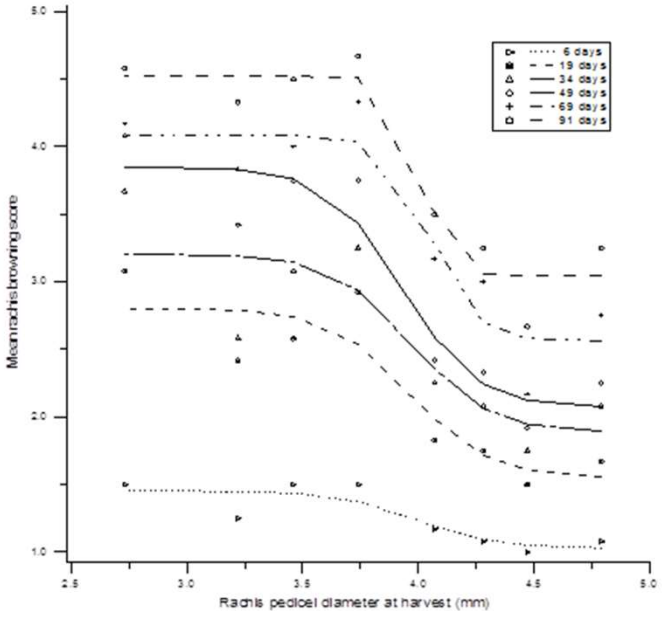




Examples of regression models within modules



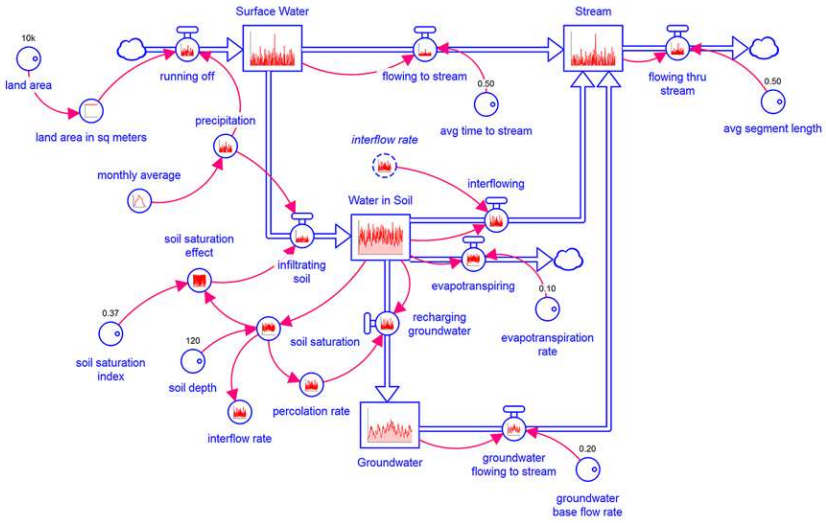
Relationship between nectarine maturity, storage temperature and days in storage



Logistic model fitted to pedicel diameter at harvest and storage period at 0°C to explain rate of rachis browning (r^2=91%, P<0.001, n=48). Each data point represents the mean score of 8 bunches from each of 6 vineyards.

Model platform and user-interface

- Need a relatively simple and ‘intuitive’ user interface
- Web based
  - Password entry
  - User able to upload data
- Stella interface a likely candidate – dynamic simulation



Serviced supply chains

- Ambitious multi-commodity, multi-stakeholder project to ensure Australian horticulture remains competitive in export markets

- Hort Production Sciences well positioned to conduct strategic and applied R&D required to meet project objectives
  - Minimal intervention export monitoring
  - Novel technologies for fruit quality measurement and monitoring
  - Export simulation (Cultivar x Maturity x Temperature x Time)
  - Predictive tools

- Support of major hort industry players critical for success