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FACULTY OF VETERINARY & AGRICULTURAL SCIENCES

Crossing the Threshold: Adaptation Tipping Points for Australian Fruit Trees

Dr Rebecca Darbyshire

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Acknowledgements

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Australian Government Department of Agriculture and Water Resources

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Lenswood Cooperative; Paul James
Fruit Growers Victoria
Donnybrook Orchard Improvement Group
Walnuts Australia

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Tim Reid
Nick Owens

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Background

Continued warming is likely

"Adaptation has the potential to **reduce adverse impacts** of climate change and to **enhance beneficial impacts**, but will incur costs and will not prevent all damages."

(IPCC, 2014)

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Background

- Decisions made now will last into new climates
- Adaptive flexibility is constricted
  - E.g. changing cultivars requires substantial investment and can lock in a decadal scale commitment.
- Compounding this vulnerability, knowledge gaps in temperature-physiology relationships
  - No mechanistic model

(Atkinson et al., 2013; Campoy et al., 2011; Luedeling, 2012; Darbyshire et al., 2014)

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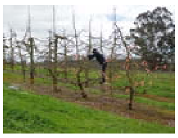
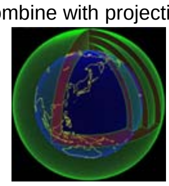
Approach

Collect observations



Understand relationships

Combine with projections



When

Where

How

(http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/nwp-top.htm)

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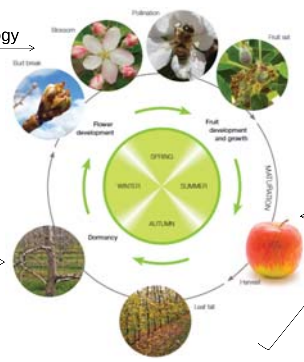
Approach

Flowering Phenology

Winter Chill



Sunburn

Potential Yield

http://www.piccc.org.au/resource/fruit-tree-cycle

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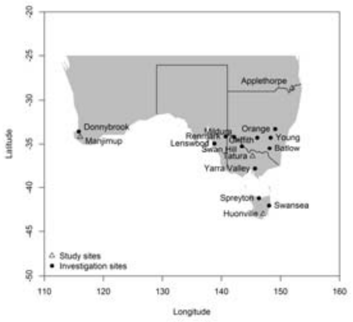
Approach



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Climate Projection Approach

"One of the challenges associated with developing climate projections is how to deal with the requirements of end-users—particularly those faced with making immediate decisions about coping with future impacts."

"… we are not concerned so much with being proved "right" or "wrong" with regard to climate change projections … as [we are] with providing expert advice that is both transparent, and can be can be acted on now"

(Smith and Chandler, 2010)

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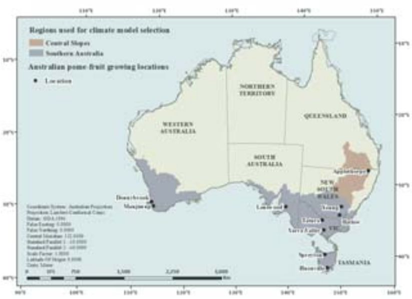
Climate Projection Approach

CSIRO Australian Climate Futures approach



(Webb et al., 2016)

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Climate Projection Approach

GCM 'uncertainty' + emission 'uncertainty' + natural variability
= future climate estimate

Aimed to capture the range of likely futures with minimal set projections

Created 'best' and 'worse' case scenarios. The **RANGE** across these are interpreted as the range of likely future scenarios

Climate Projection Approach

Historical (1981-2010): baseline

2030: Short-term

2050: Strategic

2090: Long-term

Winter Chill

Winter Chill

‘Winter chill’ required to break winter dormancy

Insufficient winter chill = poor flowering and potentially poor yield

Measured in chill portions (CP) – Dynamic model

(Erez et al., 1990)

Winter Chill

1. Crop and cultivar specific projections

2. Estimating cultivar chilling requirements

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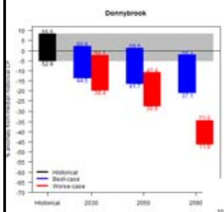
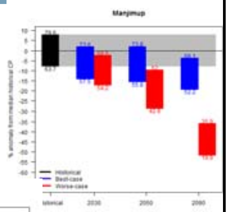
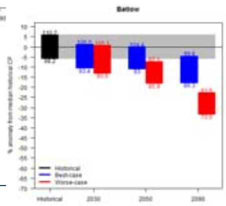
Winter Chill Projections



So What?





(Darbyshire et al., 2016)

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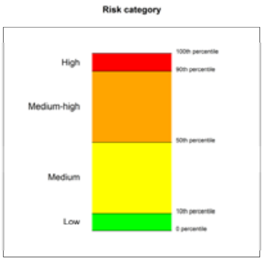
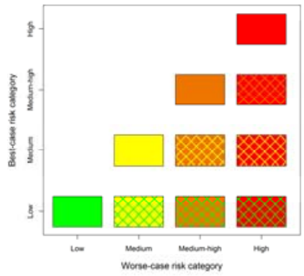
Winter Chill Projections





(Darbyshire et al., 2016)

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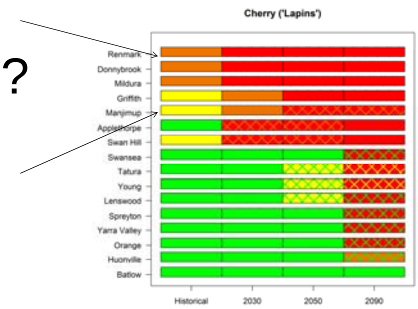
Winter Chill Projections

?



CR = 66CP

(Darbyshire et al., 2016)

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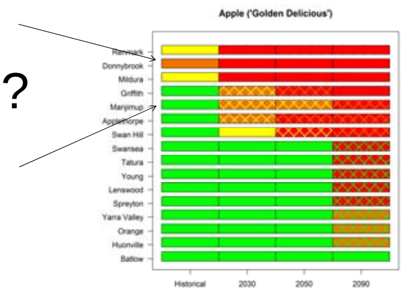
Winter Chill Projections

?



CR = 61CP

(Darbyshire et al., 2016)

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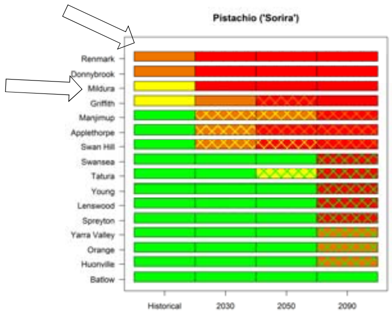
Winter Chill Projections



CR = 62CP

Industry advice:
apply winter oil
if by 15th August
CP<57

(Darbyshire et al., 2016)

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Winter Chill Projections

- Representing climate projection uncertainty via a colour-and-hash system
  - easy to interpret view of the range of uncertainty
  - Incorporate own risk appetite
  - Incremental strategies, ongoing efficacy?
- Results interpreted for adaptation strategies for 2030, 2050 and 2090 time horizons.
  - Differs by crop and site
  - No single national or commodity strategy
  - WA sites likely to dip below thresholds first

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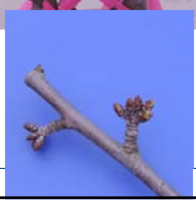
Chilling Requirements

What are the chilling requirements for important Australian species?



Cripps Pink
Lapins

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Two Seasons (QLD)

Cultivar	Year	Dynamic (CP)
Cripps Pink	2014	72.9
	2015	73.8
mean±sd		**73.3±0.6**

BUT 73.3CP only achieved in Applethorpe 56% of years (1968-2015)

{73.3CP: Manjimup 65/100 years; Donnybrook 5/100 years}

(Parkes et al, in prep)

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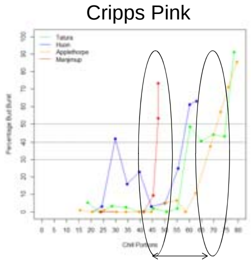
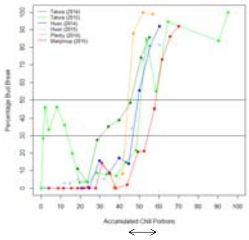
Cross-site evaluation

Cripps Pink



~25 CP

Lapins



~20 CP

(Measham et al., in prep)

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Chilling Requirements

- Results incongruent with physiology assumptions
- Start of chill period?
- Measure of chill (chill portions)?
- Methodology?
- Metabolic and genetic markers?
- In field heat confounding?
- Local acclimatisation may buffer previous chill results for WA

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Flowering Phenology

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Flowering Phenology

Timing of flowering is dependent on temperature conditions (winter & spring)

Climate change could lead to:
- cross pollination mis-match
- frost risk +/-

1. How to represent flowering phenology?
2. How will climate change modify flowering phenology?

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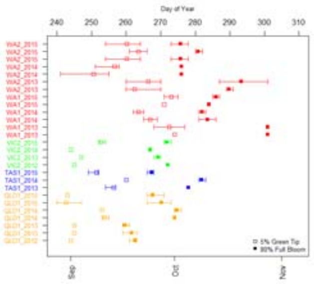
Flowering Phenology

Cripps Pink



Different timing:
- between sites
- between seasons

WA = later & more variable flowering (between trees)

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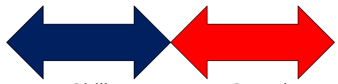
Represent Flowering Phenology

Sequential model = common approach



Flowering

Chill

Growth

Warming has opposite influence on each phase

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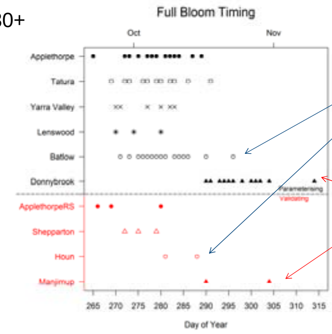
Represent Flowering Phenology

30+



Cold winter

Warm winter

2nd warmest spring, flowering last

(Darbyshire et al., 2016b)

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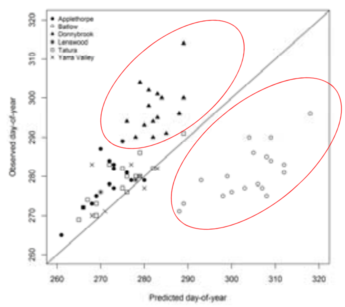
Represent Flowering Phenology

Sequential Model

RMSE=14.7days
(RMSE$_{ave}$=9.6days)



Predicating:
1. cold site later than observed
2. warm site earlier than observed

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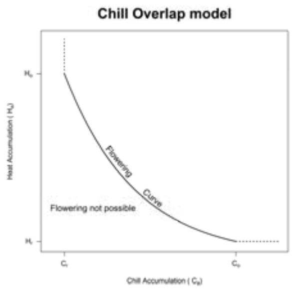
Represent Flowering Phenology



Minimum chill requirement

‘over-chill’ reduces heat requirement to minimum heat requirement

i.e. dynamic heat requirement

(Pope et al., 2014; Darbyshire et al., 2016b)

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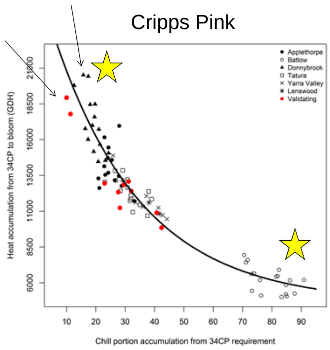
Represent Flowering Phenology

Cripps Pink



RMSE=6-7days

Important that models are stable across current climates for projections

Fits with grower observations

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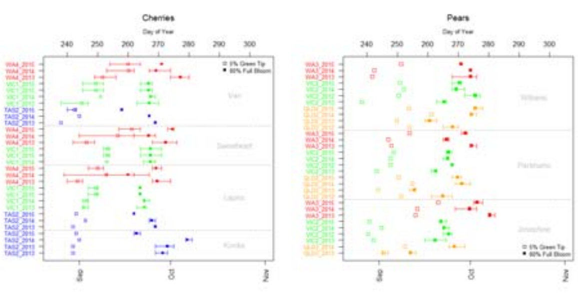
Represent Flowering Phenology



Some evidence of similar flowering behaviour across other fruit but not always…

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Represent Flowering Phenology

- Different Australian growing districts demonstrate different flowering timing and between tree variability.
  - Manjimup, WA demonstrated later and more variable flowering than the other sites.
- The sequential flowering phenology model was unable to adequately represent Cripps Pink flowering
  - misrepresentative if used for projection analyses.
- The chill overlap model represented Cripps Pink flowering phenology well across the range of Australia’s tree growing districts.
  - More appropriate for projection analyses

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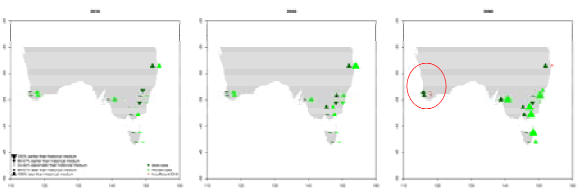
Flowering Phenology Projections



Limited change

Limited change to delay (-Batlow)

Mostly delay (-Batlow)

Many Nth Hemisphere studies = advancement

(Darbyshire and Goodwin, under review)

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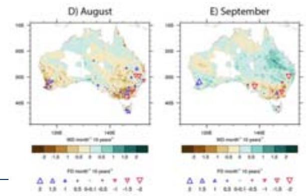
Flowering Phenology Projections

- Likely delay in flowering may reduce frost risk
  - Assuming current frost windows & incidence. Historically this has been changing (Dittus, 2014)



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Flowering Phenology Projections

- Cross pollination de-synchronisation
  - Parameterisation of chill overlap of other cultivars
  - Requires data from wide range of climates (rare in Aus)

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Extreme Heat Damage

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Extreme Heat Damage

1. How to estimate extreme heat damage?
2. What is the advantage of installing netting?

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Extreme Heat Damage

GV: 30-70% cull (Feb 2009)
Damage ~ FST; light

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Benefit of Netting?

A netted ‘Royal Gala’ apple orchard in Shepparton

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Estimate extreme heat damage

Thermocouples to measure FST

Weather stations to measure AT

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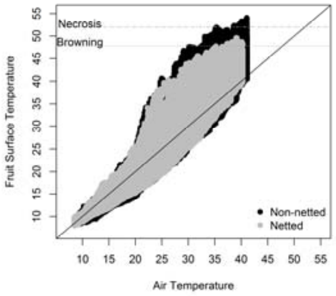
Estimate extreme heat damage



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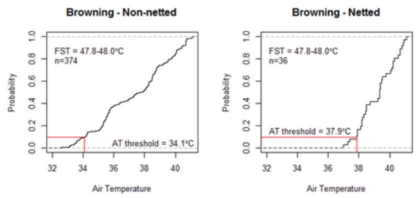
Estimate AT for Browning



Conservative AT threshold for potential damage

(Darbyshire et al., 2015)

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Browning risk (non-netted)

Results = Median (10^{th},90^{th})

Location	Historical	2030	2050	2090
Spreyton	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.3)
Huonville	0.0 (0.0 to 2.0)	1.0 (0.0 to 2.7)	1.0 (0.0 to 2.9)	1.5 (0.0 to 3.2)
Yarra Valley	2.0 (0.0 to 7.7)	4.3 (0.6 to 9.2)	4.6 (0.6 to 9.5)	5.6 (1.3 to 10.5)
Lenswood	3.0 (1.0 to 7.0)	4.5 (1.6 to 9.4)	5.1 (1.8 to 10.2)	6.0 (2.8 to 10.7)
Applethorpe	0.0 (0.0 to 2.0)	0.3 (0.0 to 4.6)	1.0 (0.0 to 5.9)	3.0 (0.0 to 9.7)
Batlow	1.0 (0.0 to 4.0)	2.9 (0.0 to 7.7)	4.1 (0.0 to 9.5)	5.5 (0.3 to 12.6)
Manjimup	2.5 (0.0 to 5.0)	3.9 (0.1 to 7.2)	4.5 (1.1 to 7.7)	6.1 (2.1 to 9.5)
Tatura	6.0 (1.0 to 13.0)	9.4 (3.3 to 16.3)	10.4 (4.5 to 17.7)	13.0 (6.5 to 21.0)
Donnybrook	7.0 (3.0 to 11.0)	8.9 (3.2 to 13.9)	10.3 (4.1 to 15.4)	12.8 (7.1 to 18.4)
Young	9.0 (1.2 to 16.0)	13.3 (2.6 to 20.2)	15.4 (3.8 to 22.7)	17.8 (5.8 to 24.9)

≤ 1.6 days	1.7 to 3.1 days	3.2 to 6.2 days	6.3 to 9.3 days	9.4 to 15.5 days	≥ 15.6 days
≤ 5.0 %	5.1 to 10.0 %	10.1 to 20.0 %	20.1 to 30.0 %	30.1 to 50.0 %	≥ 50.1 %

(Webb et al., 2016)

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(Webb et al., 2016)

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Decision to install nets – what's your risk appetite?

Decision not to install nets (X) or to install nets (✓)

	Risk-sensitive		
Location	2030	2050	2090
Spreyton	X	X	X
Huonville	X	X	X
Yarra Valley	✓	✓	✓
Lenswood	✓	✓	✓
Applethorpe	X	X	✓
Batlow	✓	✓	✓
Manjimup	✓	✓	✓
Tatura	✓	✓	✓
Donnybrook	✓	✓	✓
Young	✓	✓	✓

a risk-sensitive case: *maximum* browning-risk > 6 days

a risk-tolerant case: *median* browning-risk > 6 days

(Webb et al., 2016)

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Extreme Heat

- AT thresholds browning for Royal Gala apple were 37.9ºC and 34.1ºC for netted and non-netted fruit.
- Projected 50% decrease in potential browning damage days with netting at warm sites (Donnybrook, Tatura and Young).
- Manjimup 2030 ~ Tatura now (import practices)
- Other areas show no benefit of netting out to 2090 (Spreyton, Huonville).
- Dependent on grower risk appetite, the timing and location of the decision to install netting will differ.

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Potential Yield

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Can the model MaluSim be used to predict fruit yield in Australian conditions?

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MaluSim

'Big leaf' carbon partitioning model

Mostly used for thinning management

(Lakso et al., 1994)

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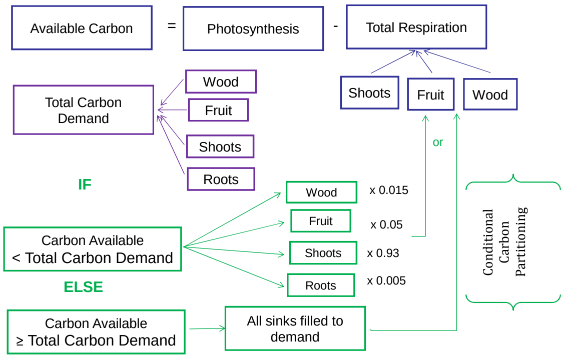
Simplified Model Structure



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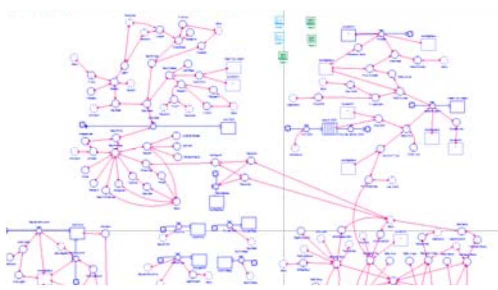

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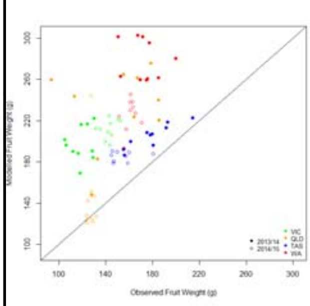
Model Evaluation



Site	RMSE (g)
VIC	75
QLD	71
TAS	31
WA	90
All	70

Structural
Light interception
FGR
Higher temperature effect

Application
Parameterisations
Potential vs field yield
Data collection

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Can MaluSim be applied here?

- No. But maybe…
- Poor model performance combination of
  - model structural components (photosynthesis)
  - appropriate application of the model
- Simplification for thinning advice?
- Other yield models?

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Communication

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Project Communication

PICCC: 732
HIN: 222(chill) 198(calculator) regional (111) factsheet(64)

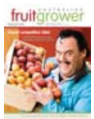
13 scientific papers

ELSEVIER

1 encyclopedia chapter

5 technical reports

15 science & industry conference presentations



24 industry articles

11 media items

http://www.piccc.org.au/research/project/440; http://www.hin.com.au/projects/winter-chill-and-fruit-trees

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Conclusions

- Adaptation options vary by crop, location and grower risk appetite
- Advancements in understanding physiology critical for adaptation assessments
- Coordinated and meaningful interaction internationally, domestically, industry and growers = better results and better outcomes and **enjoyable**!

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