Turning Water into Oil - Physiology and Efficiency

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The sponsors

- Australian Avocado Growers' Federation
- Horticulture Australia
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The cooperators

- Cooperators:
  - **Alan Blight, Avowest, Carabooda, WA;**
  - **Alan Smerdon, Glasshouse Mountains, Qld**
  - **Bob Paulin, Alec McCarthy, Agriculture Western Australia**
  - **Associate Professor John Kuo, Centre for Microscopy and Micro-analysis, University of Western Australia**
  - **Professor John Pate and David Arthur, Botany Department, University of Western Australia**
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The logos

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Sustainable Solutions for a Growing World

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The worker - Andreas Neuhaus

The issues in this talk

- What information do we have about the efficiency and physiology of irrigation ?
  - **Illustrate this with data from the irrigation research project funded by AAGF and Horticulture Australia**
- Where to from here - towards 2020 vision

The vision for 2020

To double irrigation efficiency in Australia's avocado industry by 2020.

Efficiency - What is it?

How we define it, determines the answers we get

Efficiency in irrigation

$$\text{EFFICIENCY} = \frac{\text{Output}}{\text{Input}}$$

Irrigation efficiency - at the orchard level

If Output is yield

If Input is water added in irrigation

Then Efficiency will be tonnes of fruit per mm water applied

Irrigation efficiency - at the tree level

If Output is kg fruit per tree

If Input is total water received by the tree (rainfall and irrigation)

Then Efficiency will be kg fruit/litre water

Irrigation efficiency - at the economic level

If Output is $ returns for fruit

If Input is $ costs for irrigation

Then Efficiency will be $/$

And we hope the efficiency is > 1 !!

Increase efficiency by either:

- Reducing inputs
  - Outputs may remain unchanged
- Increasing outputs
  - Inputs may remain unchanged

Physiology - what is it?

- Physiology is about how the plant works
- Is physiology linked to efficiency?
- If yes, how might we use this link?

The avocado irrigation project (1998-2001)

Objective: If a limited supply of water is available, how is it best used to maximise yield and quality?

Locate research to be sure of drought!

- Western Australia has long dry summers and sandy soils - low rainfall is a certainty! (unless you are running an irrigation project)
- SE Queensland has a reliably dry springtime - or, for experiments, you can dry the soil by covering it

Research approach

We used glasshouse experiments because they give us good control

Research approach

We used glasshouse experiments because they give us good control

- but do the results mean anything in the field?

Research approach

In our field experiments, we tested the discoveries we had made in the glasshouse

The questions

1. Is reproductive growth more sensitive to water deficit than vegetative growth?
2. What aspect of leaf physiology is most sensitive to water deficit?
3. Does drying half of the root system have a role in increasing irrigation efficiency in avocados?

The questions

1. Is reproductive growth more sensitive to water deficit than vegetative growth?

- Practical aspects:
  - Must water be available at flowering? Assume yes.

The experiments -WA

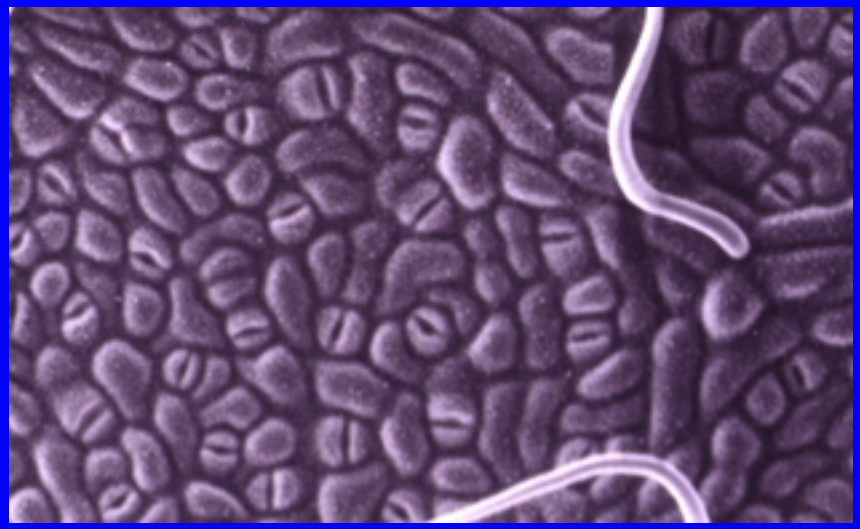
Allow potted plants in the glasshouse to dry (WA and Qld) and measure elongation of young leaves, inflorescence branches and fruit drop

The experiments - Qld

Allow trees in field at Glasshouse Mountains to dry and measure soil water, shoot and fruit growth

The answers - in the field, Qld

Drying the root zone to 50 cm depth at Glasshouse Mtns, closed the stomata 20 days after drying began



The answers - in the field, Qld

Drying the root zone to 50 cm depth at Glasshouse Mtns, closed the stomata after 20 days but did not slow fruit growth up to 30 days after drying began

The answers - glasshouse, WA

- In the glasshouse, mild water stress affected shoot growth before it affected inflorescence growth
- Severe water stress caused flowers to abort

Reproductive growth, WA

Inflorescences, before anthesis, seem to tolerate mild stress.

With too much stress, you lose the lot!

Reproductive growth, Qld

Once set, fruit at Glasshouse Mtns seemed to tough out a dry spell that closed stomata

The questions

2. What aspect of leaf physiology is most sensitive to water deficit?

- Practical aspect:
  - Can a sensitive physiological response be used to schedule irrigation?

Stomata,stomata,stomata

In glasshouse and field experiments in Qld and WA, stomata always responded to water deficits, before growth

Can we use the stomata to manage irrigation and improve efficiency?

- Problem with expensive gear needed
- Simple solution for measuring stomata not yet found

Expensive gear to measure stomatal conductance

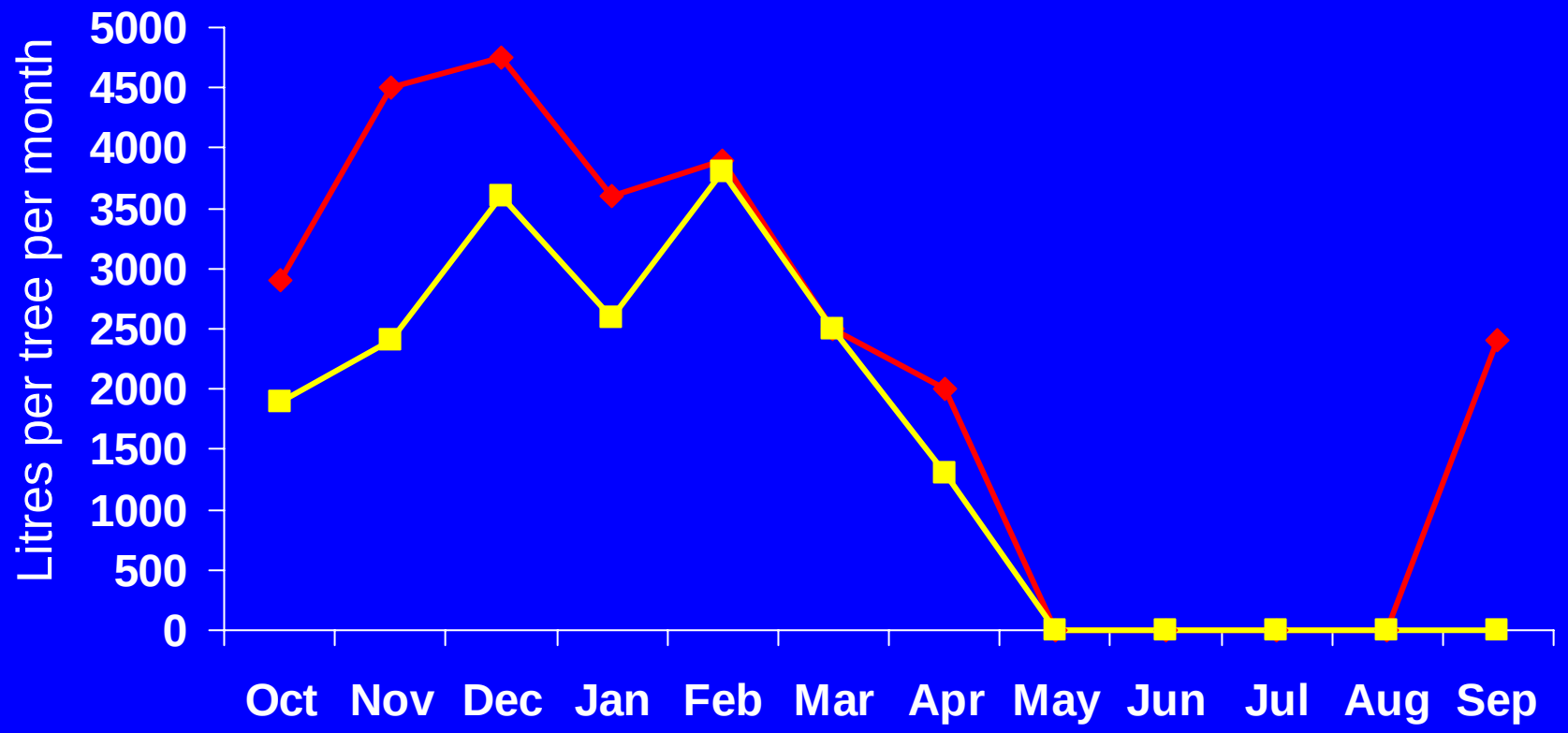
Some avocado, eh?!!

The fancy gadget

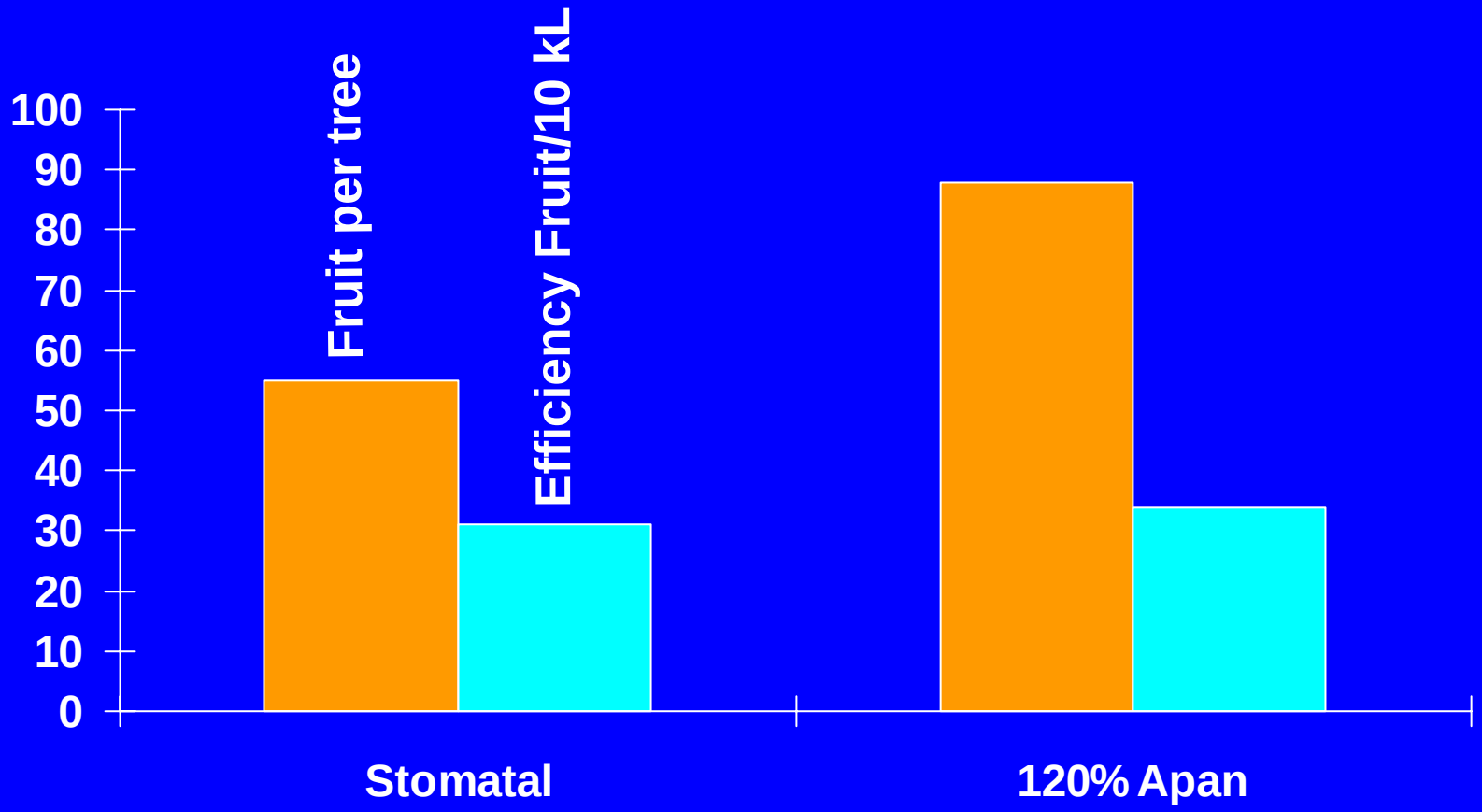
The experiment - field, WA

Schedule irrigation in summer when stomata close to 25% of their open position

The stomatal method received 1/3rd less water (L/tree) than the 120% A_{pan}



In WA, 1/3rd less water reduced yield but had almost no effect on efficiency



The questions

3. Does drying half of the root system have a role in increasing irrigation efficiency in avocados?

Why consider this question?

- How does a plant ‘know’ when the soil is getting dry?
- When water is in short supply, is it just the shortage of water that induces the response, or is it some other factor generated within the plant itself (e.g., a translocatable compound)?

Can the effect of water deficit be separated from other plant factors?

Experiments with partially dry (split) root systems say: ‘yes’.

What practical use?

If we have limited water supplies

- Partial root drying offers considerable savings in water (at least 30 to 40%)
- Partial root drying may allow us to reduce water application, without the yield/quality penalties of the whole root system being dry

Partially dry root systems

- NOT reduced deficit irrigation (RDI)
- May be used as a strategy in viticulture to manage canopy growth

The experiments - glasshouse, WA

- Potted plants
- Split the root systems and allow them to ‘settle down’ for a few months
- Apply three treatments:
  - Wet/wet, - Wet/dry, - Dry/dry

The experiments - field, WA

- Three treatments:

Wet	Wet
Wet	Dry
Dry	Dry

Measurements - glasshouse, WA

For the first four weeks:

Soil water content
Leaf water status
Leaf physiology and growth

At seven weeks:

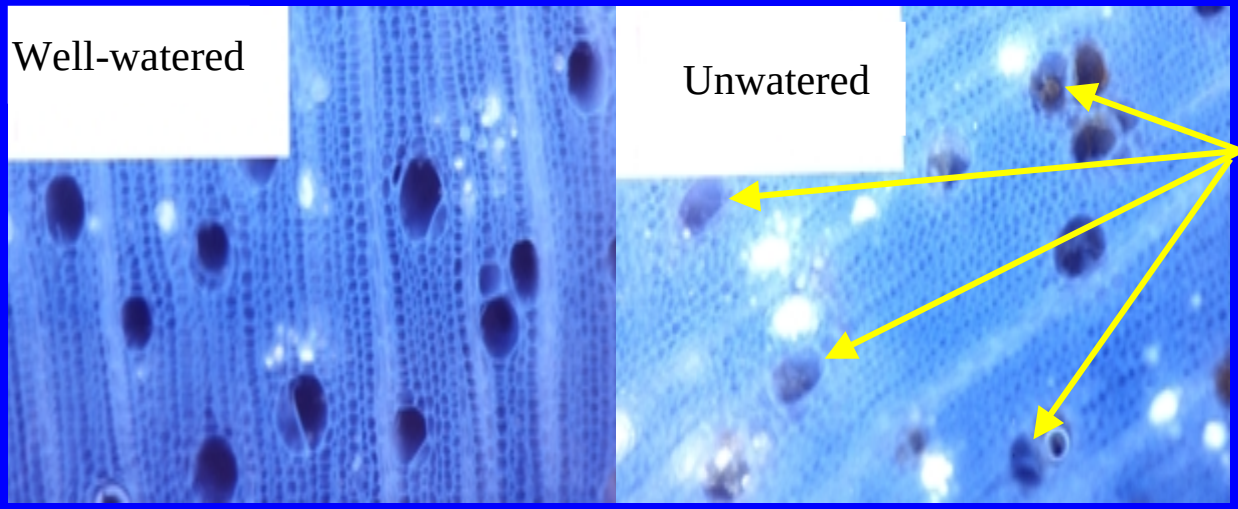
Tyloses (microscopic, gummy blockages) in the stems (destructive sampling)

The answers - glasshouse, WA

For the first four weeks of the experiment:

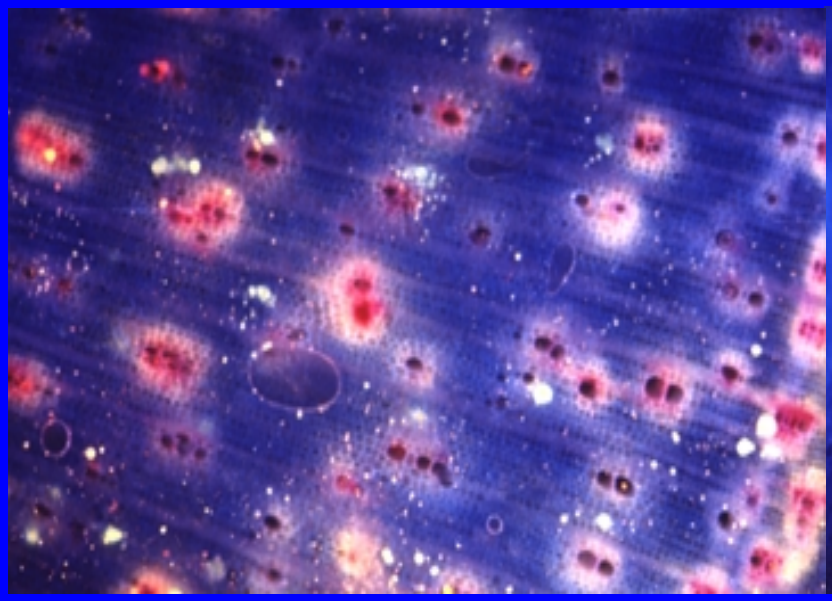
- wet/dry treatment = wet/wet,
- even though:
  - the soil on the dry side became as dry as in the dry/dry treatment
  - Water use of the wet/dry was about half that of the wet/wet

Tyloses blocked the xylem mainly in the dry/dry treatment

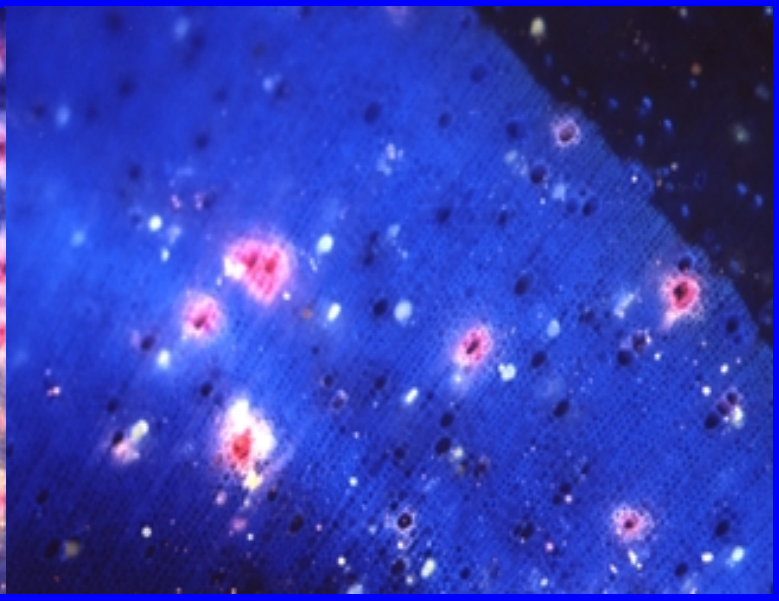


Wet and the dry side of wet/dry treatment Looked exactly the same as the wet/wet treatment

These blockages reduced water flow in the stems



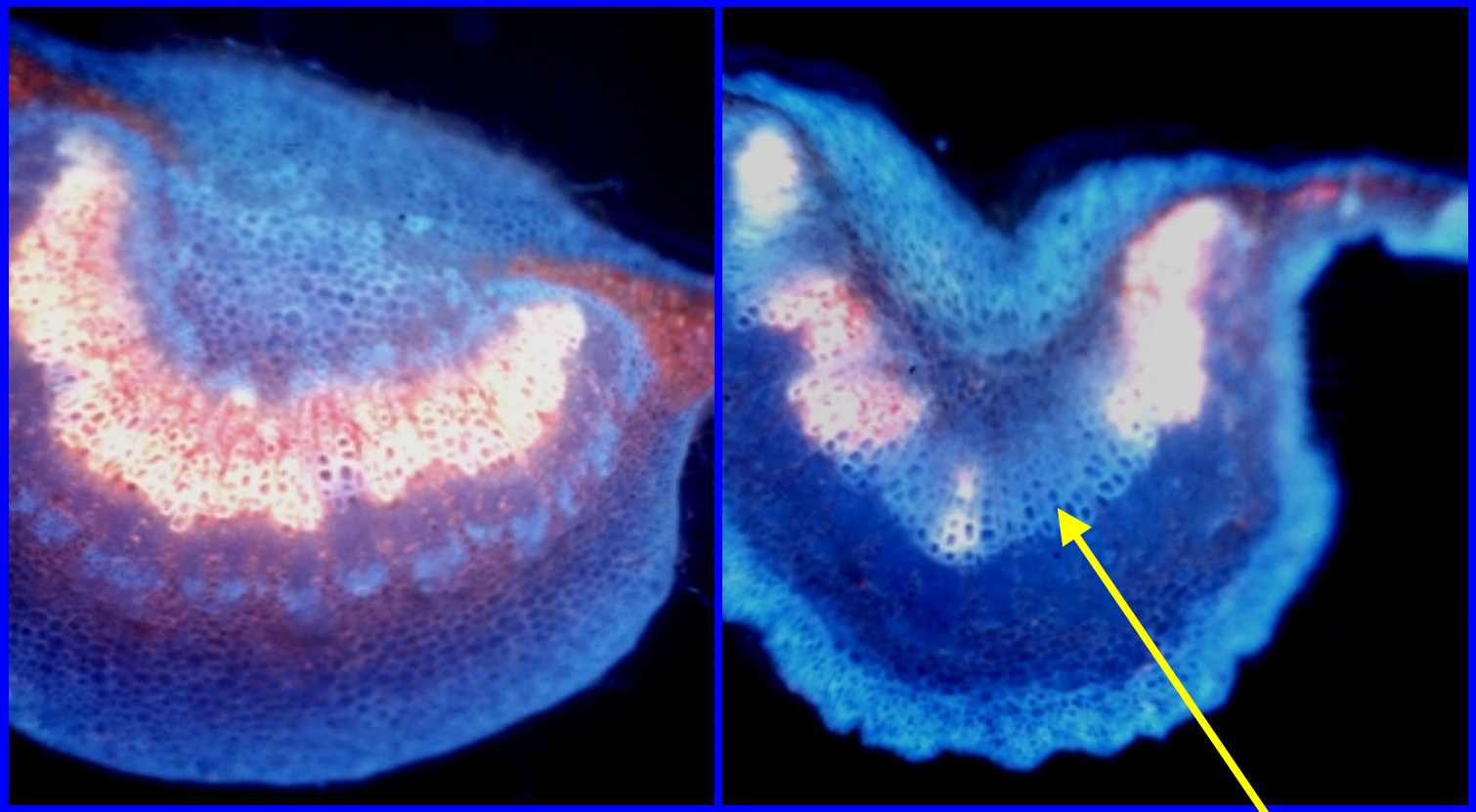
Wet/wet



Dry/dry

The water contained a flourescent dye
Lots of red means water can flow through the vessels

The same applies to the petioles of the leaves



Wet/wet

Dry/dry

Water not flowing through here

The answers - field, WA

The field experiment gave us the opportunity to see whether the exciting glasshouse results could be repeated and whether there was any effect on yield.

The answers - field, WA

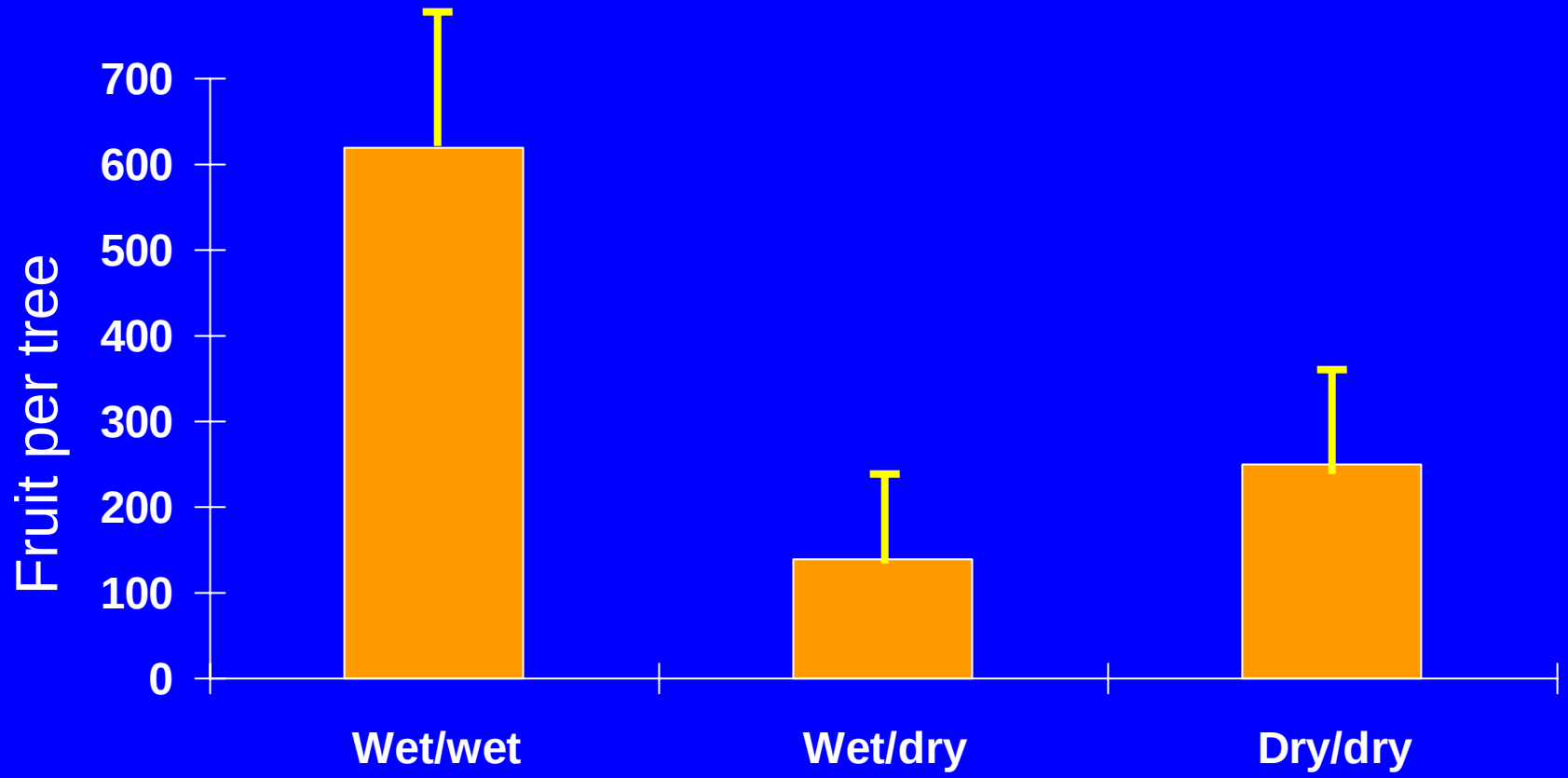
The physiological results observed in the glasshouse experiment were repeated in the field!

The answers - field, WA

Things look promising for the wet/dry treatment

- except:

Most of the fruit fell off!!



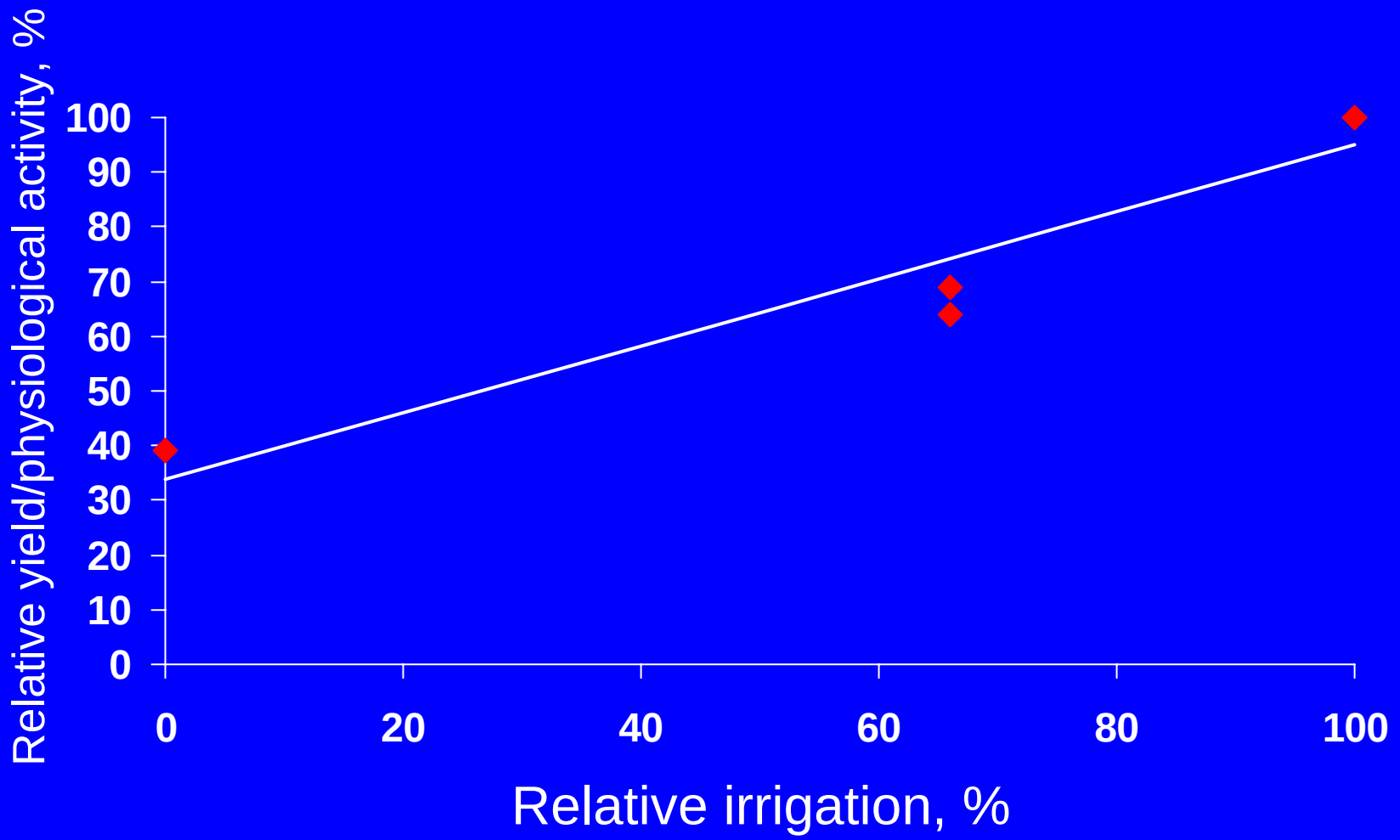
Is this the end of the story?

- Flowering of the wet/dry trees in the following season (2000) was similar to the wet/wet
- The dry/dry trees flowered prolifically but had defoliated and were not expected to retain many fruit
- The harvest in September 2001 will tell

Towards a conclusion

Let's put the field experiments in WA into perspective and see whether partial root system drying is worth pursuing

For traditional irrigation, less water reduces physiological activity and yield



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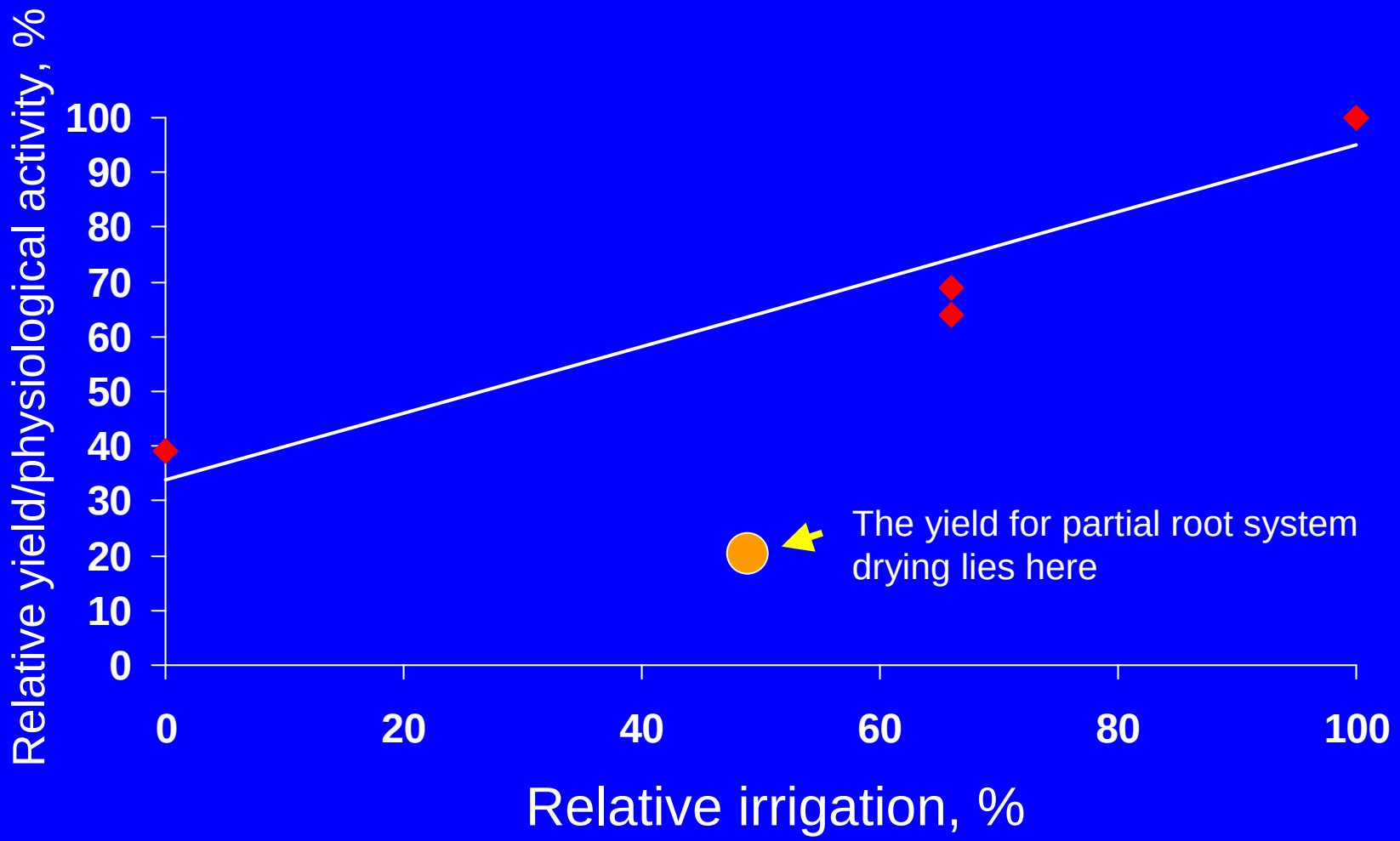
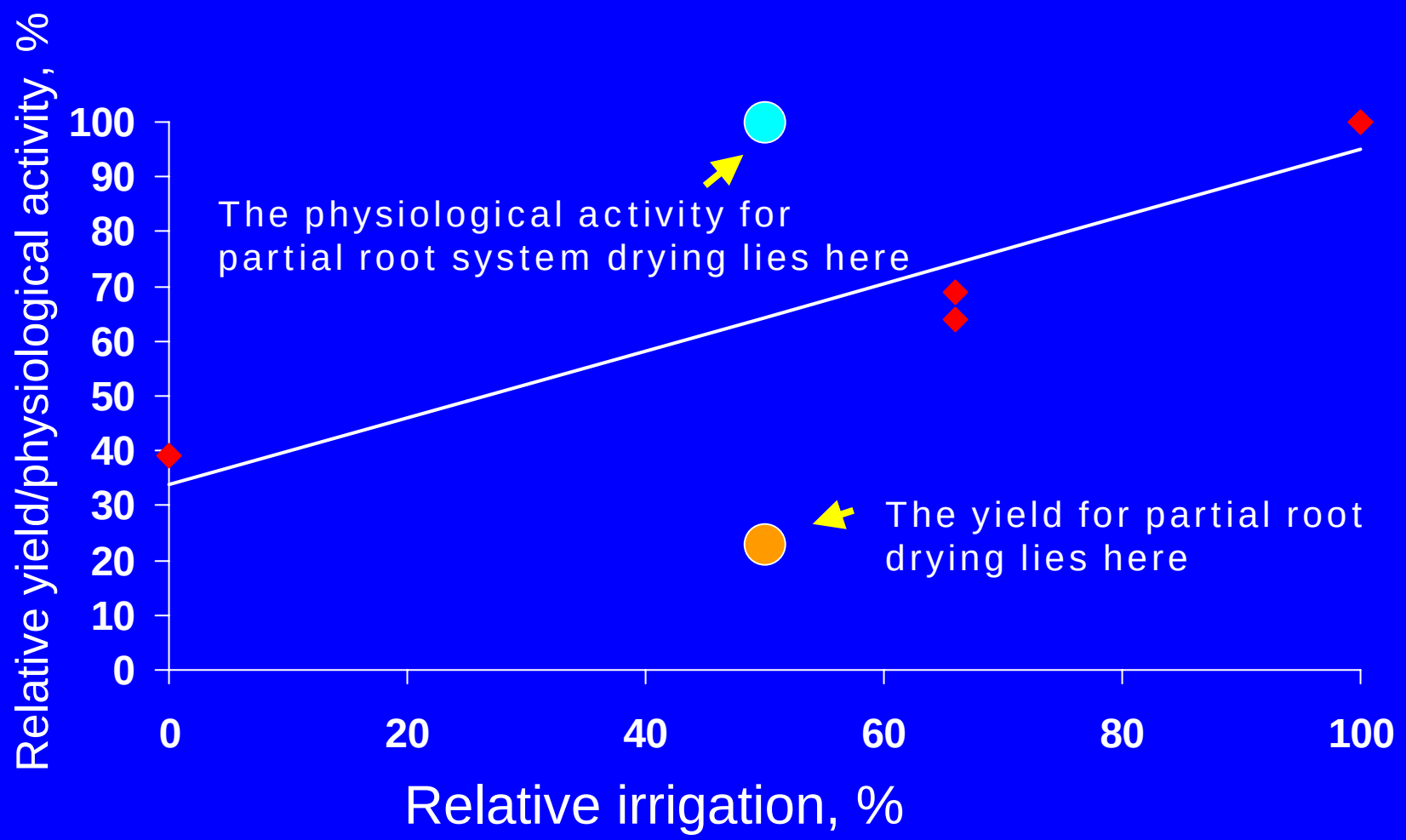


For partial root system drying, the physiological activity is high, but the yield is low



Traditional vs partially dry root system

In traditional irrigation systems, physiological activity and yield are linked -

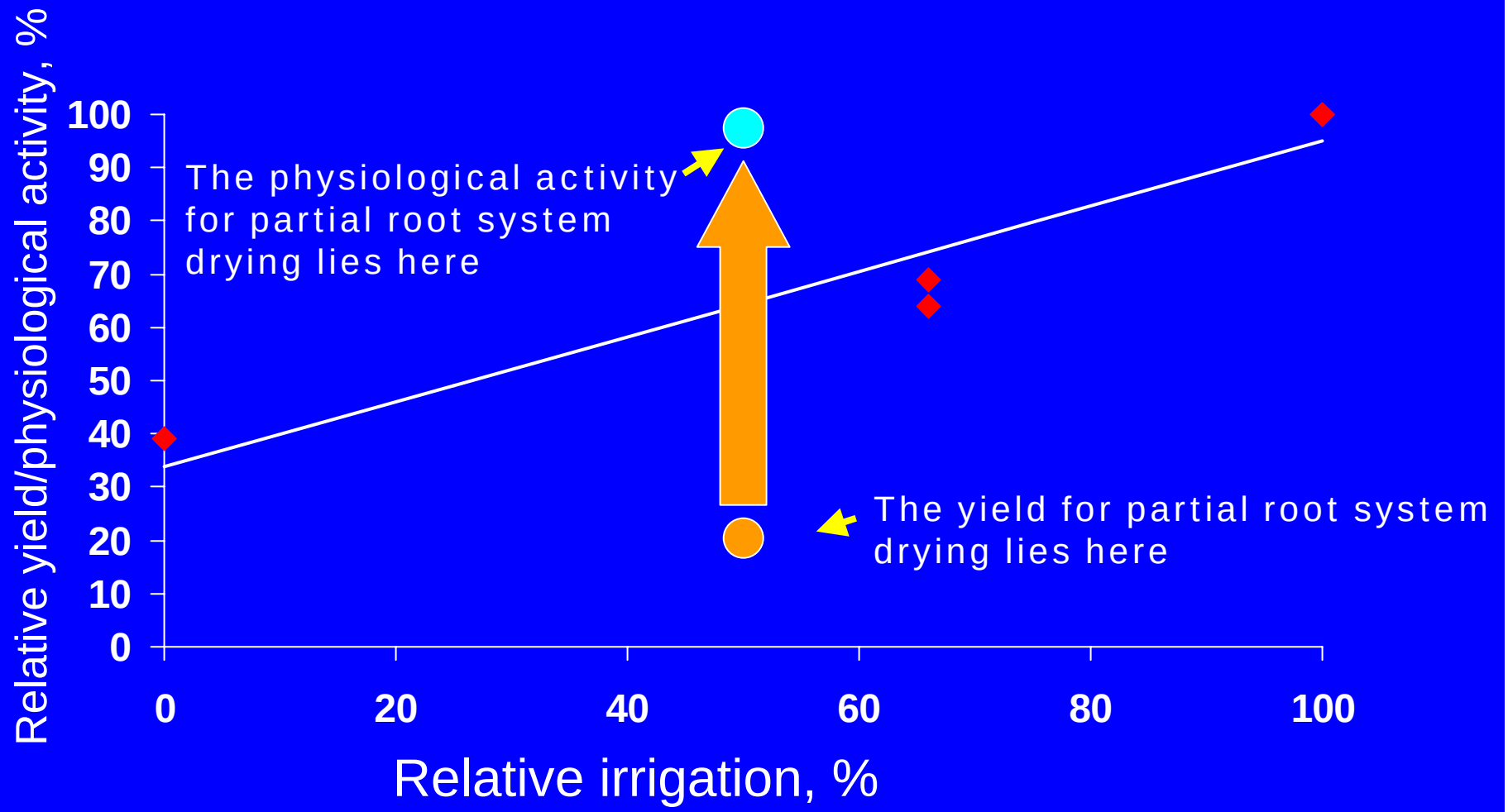
reducing our chances of increasing irrigation efficiency through plant water use

Traditional irrigation vs partially dry root systems

With partially dry root systems, physiological activity is not depressed -

increasing our chances of increasing irrigation efficiency

The challenge for 2020 is to match the yield with the physiological activity



The vision for 2020

To double irrigation efficiency in Australia's avocado industry by 2020.

Where to for 2020 vision?

Improve irrigation efficiency by:

- Developing irrigation strategies that include partially dry root systems because, they offer considerable potential for low water inputs

Where to for 2020 vision?

- Improve irrigation efficiency by:
  - Increasing outputs by adopting improved management practices

Thank you for listening

Please come visit WA, there's more to see than avocados!