Australian Government
Department of Agriculture, Fisheries and Forestry

WATER & VINE
Managing the challenge

Australian Government
Grape and Wine Research and Development Corporation

Relationships between yield and water in winegrapes

Yasmin Chalmers, DPI-Mildura

State Government Victoria
Department of Primary Industries

http://waterandvine.gwrdc.com.au

WATER & VINE
Managing the challenge

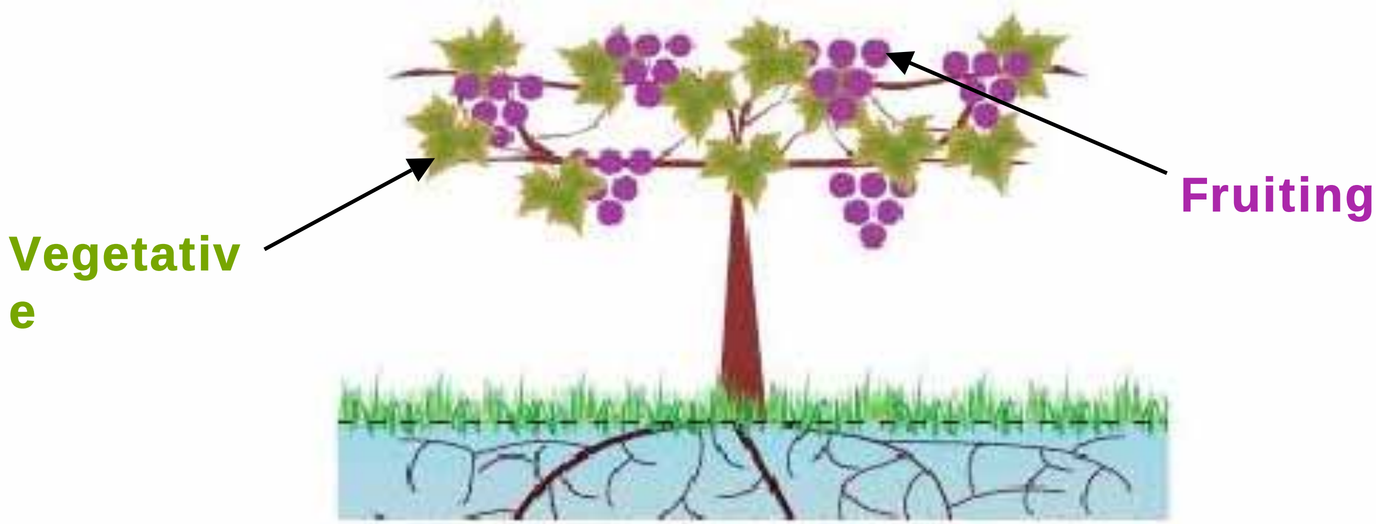
Overview

- Section 1: Components of yield development
- Section 2: Definition of water relations in grapevines
- Section 3: Quantifying water use
- Section 4: Water deficit effects on grapevine physiology
- Section 5: Water deficit effects on grapevine yield
- Section 6: What happens to grapevine yields under limited water?

WATER & VINE
Managing the challenge

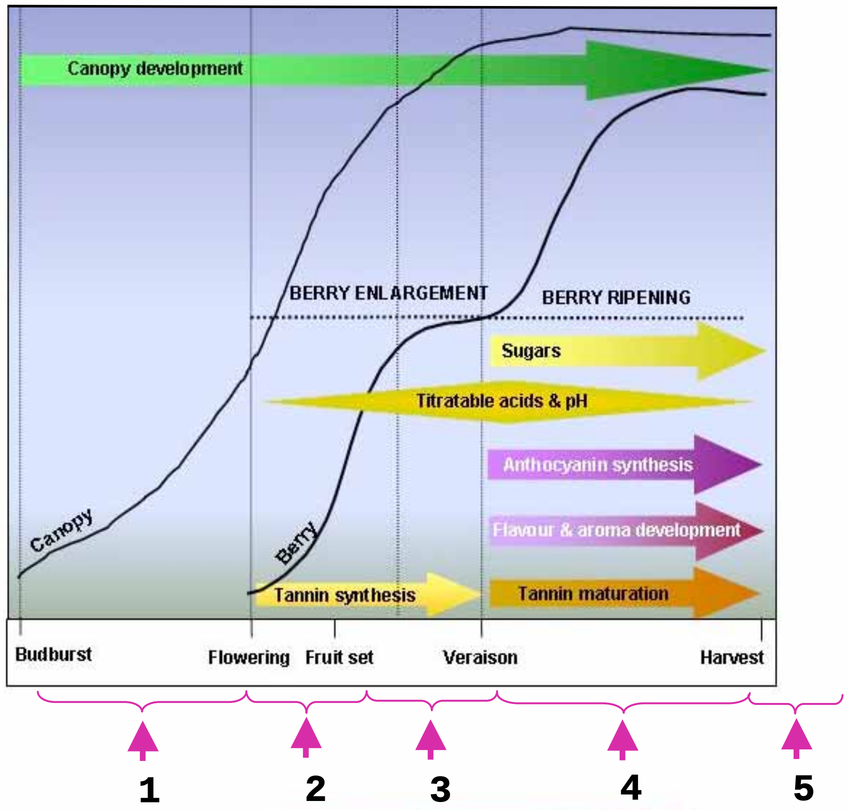
Section 1: Yield Development

Annual growth cycle includes a vegetative and fruiting (reproductive) cycle.



Section 1: Yield Development

There are five stages of development during a grapevine's annual growth cycle.

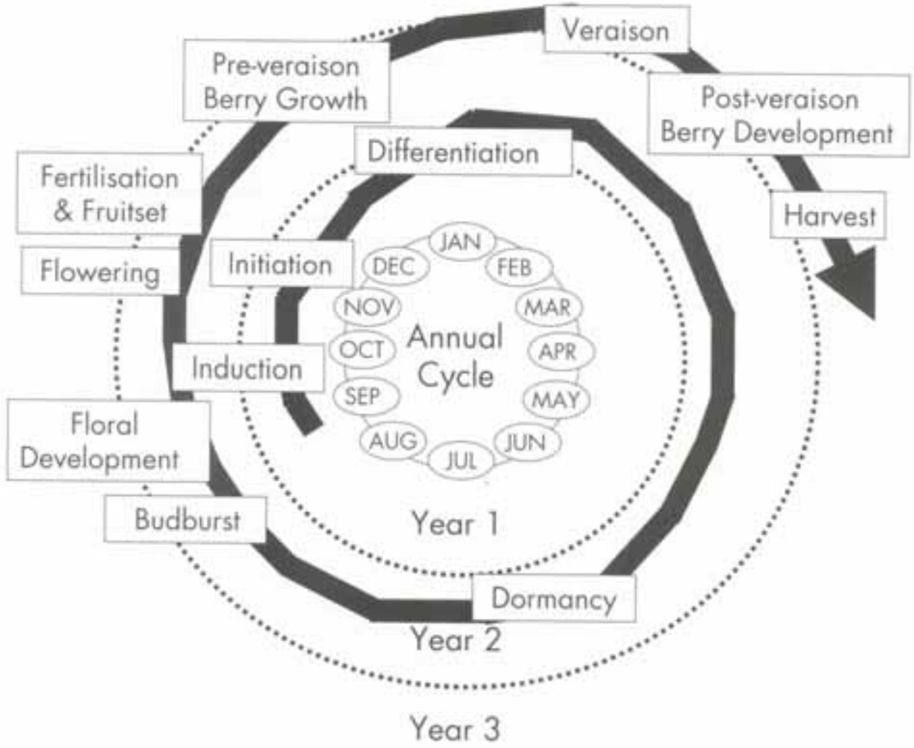


Adapted from Coombe & McCarthy (2000) AJGWR

WATER & VINE
Managing the challenge

Section 1: Yield Development

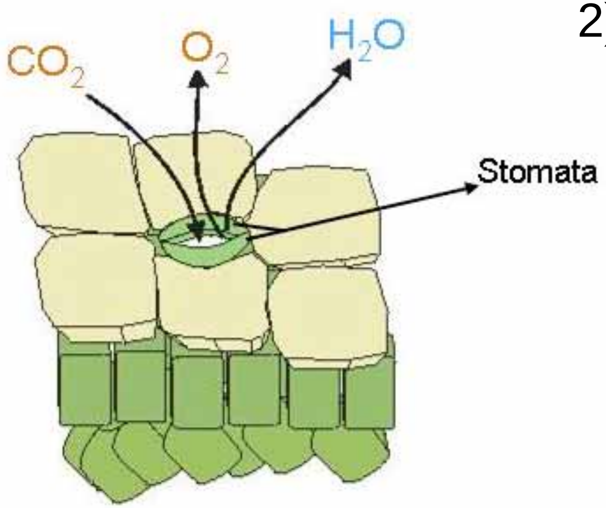
The cycle of yield development for grapevines extends over two growing seasons.



From Krstic et al. (2005), ASVO proceedings, Mildura

Section 2: Water relations in grapevines

- Water loss is controlled by varying the stomatal aperture
- Stomates have a dual role:
  1) Diffuse carbon dioxide (CO_2)
  2) Release oxygen (O_2) and water (H_2O) to the environment

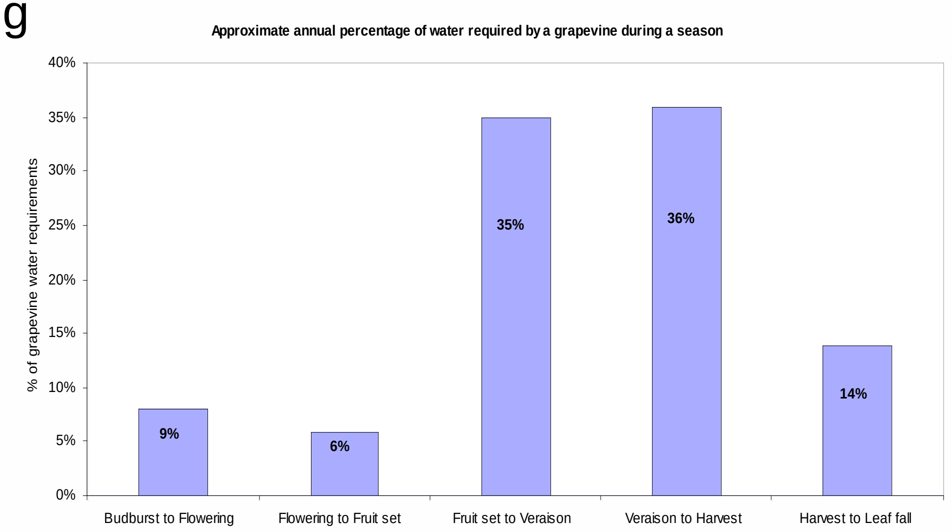


Stomates balance transpiration and prevent excessive water loss, whilst maintaining adequate photosynthesis for healthy growth.

Section 2: Water relations in grapevines

The approximate annual percentage of water required by a grapevine at each growth stage varies depending on:

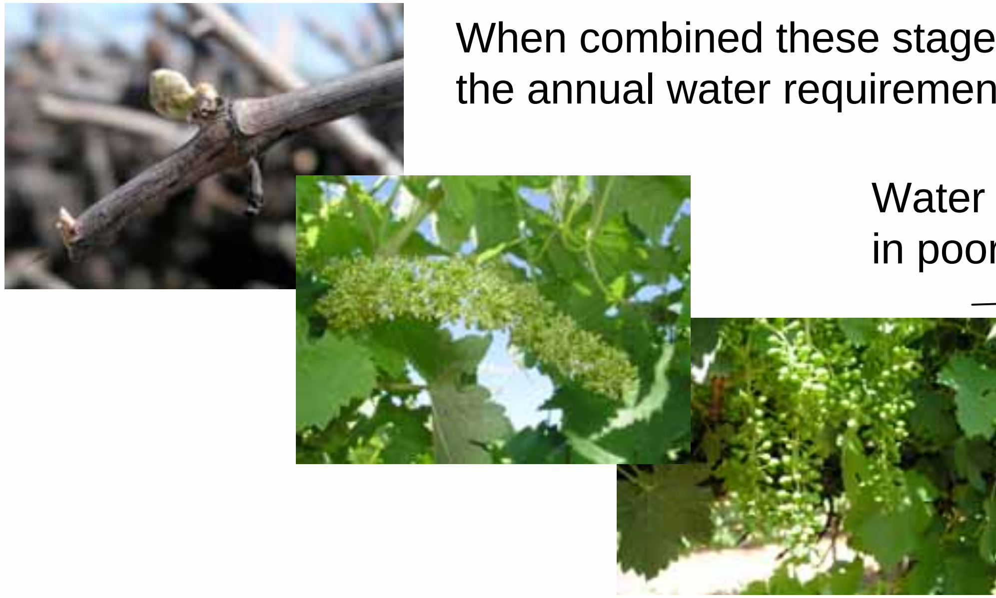
- Variety
- Rootstock
- Climate (rainfall/evaporation)
- Soil type/depth
- Crop load



Section 2: Water relations in grapevines

Early season water use:

Stage 1 (budburst to flowering) and Stage 2 (flowering to fruit-set)



When combined these stages utilize approximately 14% of the annual water requirement

Water stress at flowering may result in poor fruit set or aborted fruit

→ yield reduction

Section 2: Water relations in grapevines

Mid season water use:
Stage 3 (fruit-set to veraison)

This stage utilises approximately 35% of the annual water requirement.

Berry expansion occurs during stage 3.

Deficit irrigation strategies applied during stage 3 will tend to reduce berry size.

Severe water stress can affect bud fruitfulness.

Section 2: Water relations in grapevines

Mid-late season water use:
Stage 4 (veraison to harvest)

This stage utilises approximately 36% of the annual water requirement.

Deficit irrigation can reduce yield and even affect ripening and fruit quality.

Severe deficits will cause leaf defoliation.

Section 2: Water relations in grapevines

Late season water use:
Stage 5 (Harvest to leaf fall)

This stage utilises approximately 14% of the annual water requirement.

Need to maintain healthy leaf function to build up reserves for dormancy and next season.

Water stress may lead to restricted growth symptoms in spring.

Section 3: Quantifying water use

Water-efficient management strategy **+** Well-maintained irrigation system **=** Improved irrigation efficiency

Section 3: Quantifying water use

Using crop coefficients to calculate crop water use

K_c = crop coefficient

K_e = evaporation

K_{cb} = transpiration

ET_o = reference crop evaporation

ET_c = crop water use

Equation 1: $ET_c = K_c \times ET_o$

Equation 2: $ET_c = (K_{cb} \times ET_o) + (K_e \times ET_o)$

Allen et al. (1998), FAO No. 56

WATER & VINE
Managing the challenge

Section 3: Quantifying water use

Using crop coefficients to calculate crop water use

K_e = evaporation
ET_o = reference crop evaporation
EAS = effective area of shade
ECC = effective canopy cover
ET_c = crop water use

Equation 3: $ET_c = (1.1 \times EAS \times ET_o) + (K_e \times ET_o)$

Equation 4: $ET_c = (1.5 \times ECC \times ET_o) + (K_e \times ET_o)$

O'Connell & Goodwin (2007) AJAR, 58.

Section 3: Quantifying water use

Using crop factors to calculate crop water use

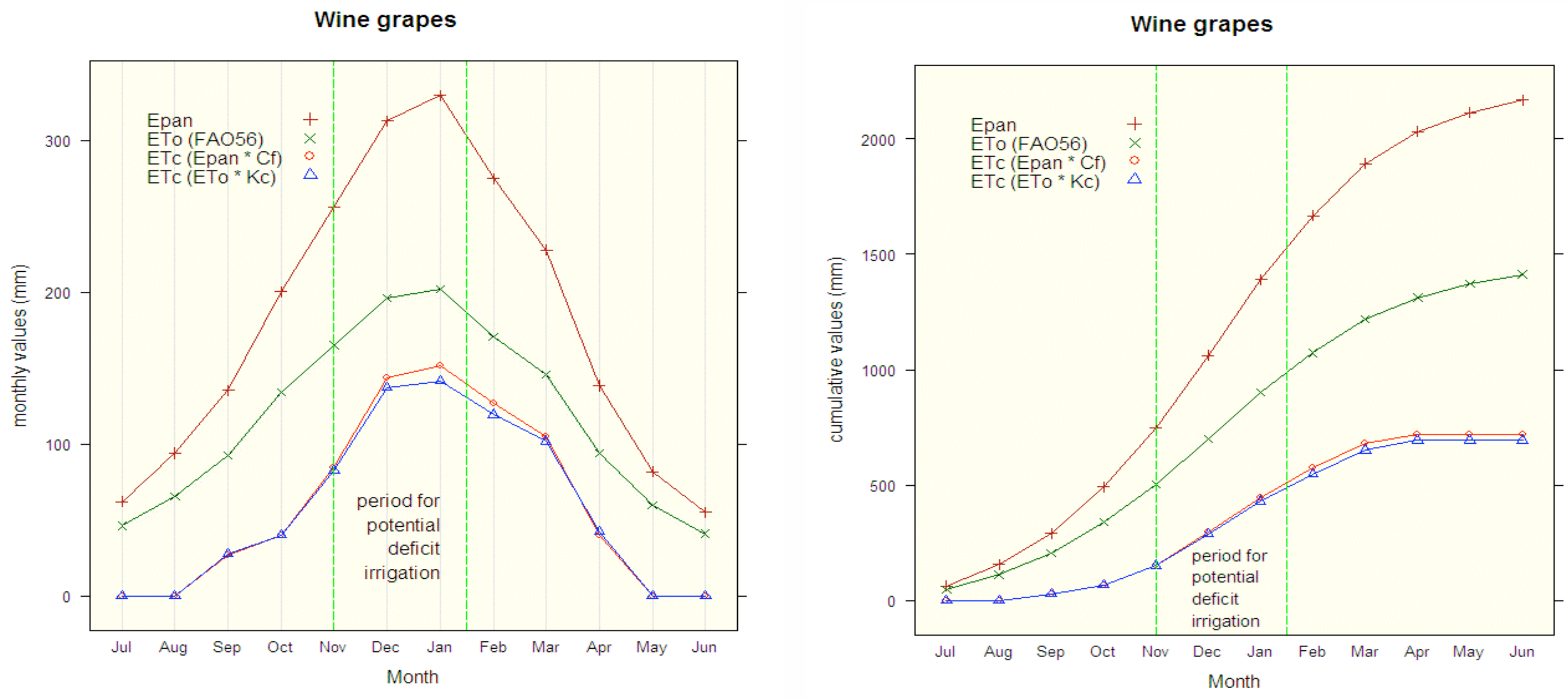
C_f = crop factor
ET_{pan} = evaporation pan
ET_c = crop water use

Equation 5: $ET_c = C_f \times ET_{pan}$

- E_{pan} readings are generally obtained from the Bureau of Meteorology stations.
- Crop factors are provided by industry or obtained from government sources.

Suggested winegrape crop factors and coefficients for mature vines in the Sunraysia region. Winegrape average water use based on Mildura BoM weather records (July1970 - June 2007).

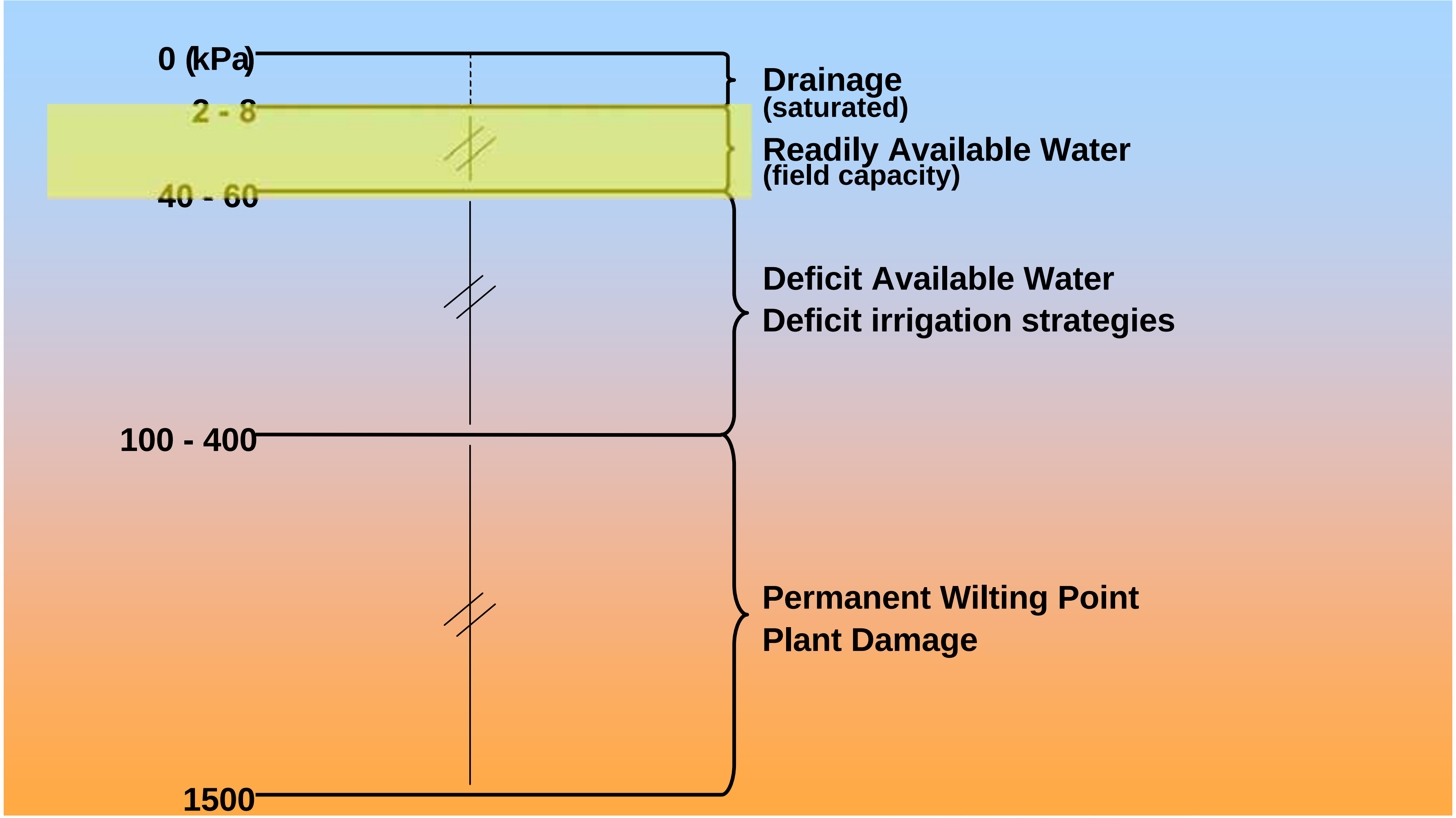
Month	**FAO56**		**Epan**		**ETo (FAO56)**		**ETc (Epan * Cf)**		**ETc (ETo * Kc)**	
	crop factor (Cf)	**crop coefficient (Kc)**	*monthly*	*cumulative*	*monthly*	*cumulative*	*monthly*	*cumulative*	*monthly*	*cumulative*
Jul	0	0	62	62	46	46	0	0	0	0
Aug	0	0	94	156	66	112	0	0	0	0
Sep	0.2	0.3	135	291	93	205	27	27	28	28
Oct	0.2	0.3	200	491	134	339	40	67	40	68
Nov	0.33	0.5	256	747	165	504	84	151	83	151
Dec	0.46	0.7	313	1060	196	700	144	295	137	288
Jan	0.46	0.7	330	1390	202	902	152	447	141	429
Feb	0.46	0.7	275	1665	171	1073	127	574	119	548
Mar	0.46	0.7	228	1893	146	1219	105	679	102	650
Apr	0.29	0.45	139	2032	94	1313	40	719	42	692
May	0	0	82	2114	60	1373	0	719	0	692
Jun	0	0	55	2169	41	1414	0	719	0	692
Total			**2169**		**1414**		**719**		**692**	

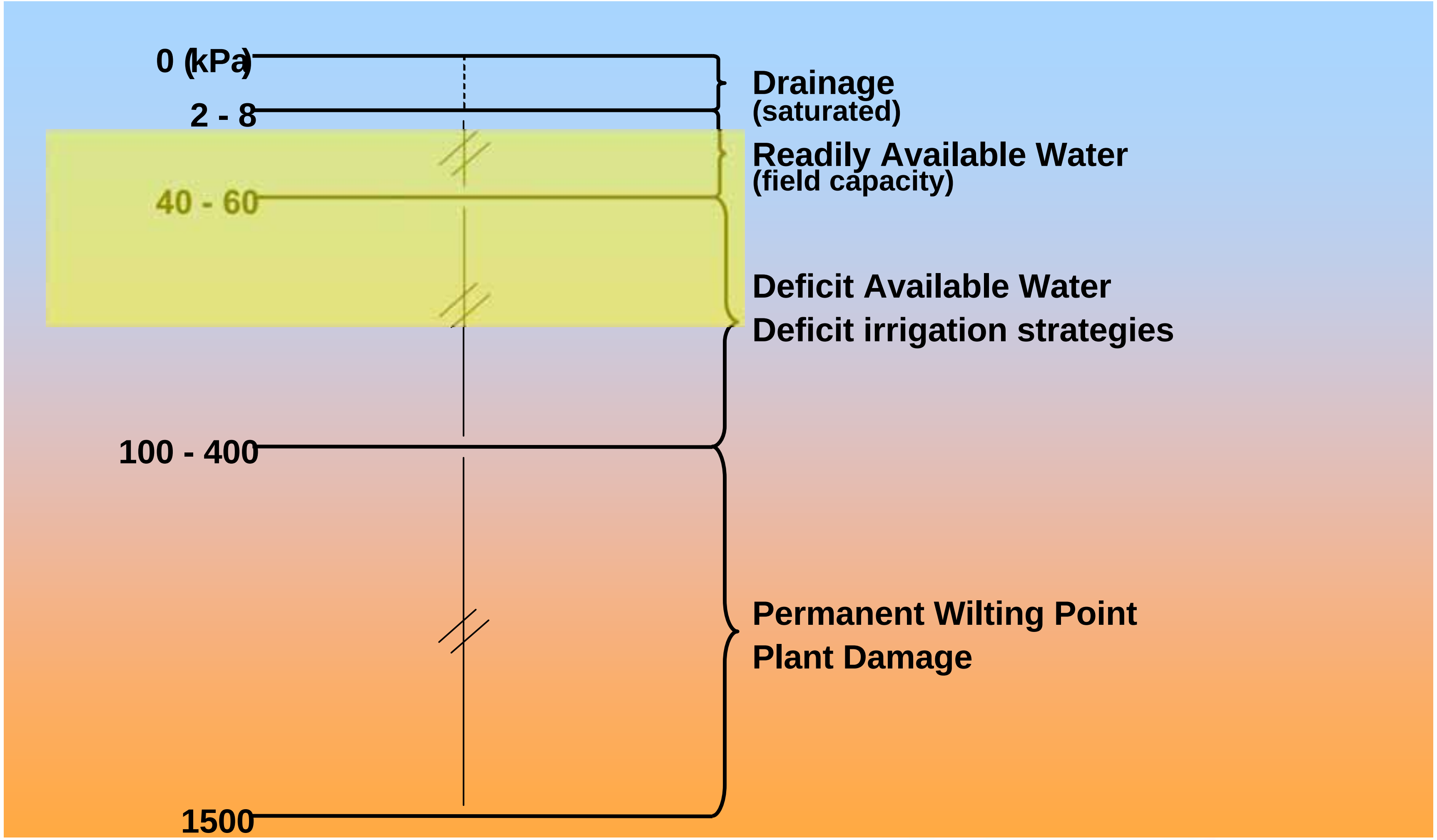


Monthly (left) and cumulative (right) pan evaporation (Epan), reference crop evaporation (ETo) calculated according to Allen et al. (1998) and estimated crop water use ETc.

Section 4: Water deficit effects on grapevine physiology

- When soil water is limiting vines close their stomates to minimise transpiration and water loss.
- A decrease in photosynthesis can also occur that leads to a decrease in carbohydrate production.
- When carbohydrate production is limited vines prioritise its use (partioning rules).
- Fruit growth > Root growth > Shoot Growth


0 (kPa)
2 - 8
40 - 60
100 - 400
1500
Drainage
(saturated)
Readily Available Water
(field capacity)
Deficit Available Water
Deficit irrigation strategies
Permanent Wilting Point
Plant Damage



0 (kPa)
2 - 8
40 - 60
100 - 400
1500
Drainage
(saturated)
Readily Available Water
(field capacity)
Deficit Available Water
Deficit irrigation strategies
Permanent Wilting Point
Plant Damage

Section 4: Water deficit effects on grapevine physiology

- Different grapevine cultivars have evolved various strategies to deal with water deficit.

  Isohydric (pessimist) – conserves available resources by early stomatal closure and subsequent reduced gas exchange.

  Anisohydric (optimist) – maintains a higher rate of gas exchange for immediate gain at the expense of stored soil water.

- Rootstock genotypes may vary in sensitivity to soil moisture levels and subsequent hormonal production

Schultz (2003) Plant, Cell & Environment, 26.
Soar et al., (2006) AJGWR, 12

Section 5: Water deficit effects on grapevine yield

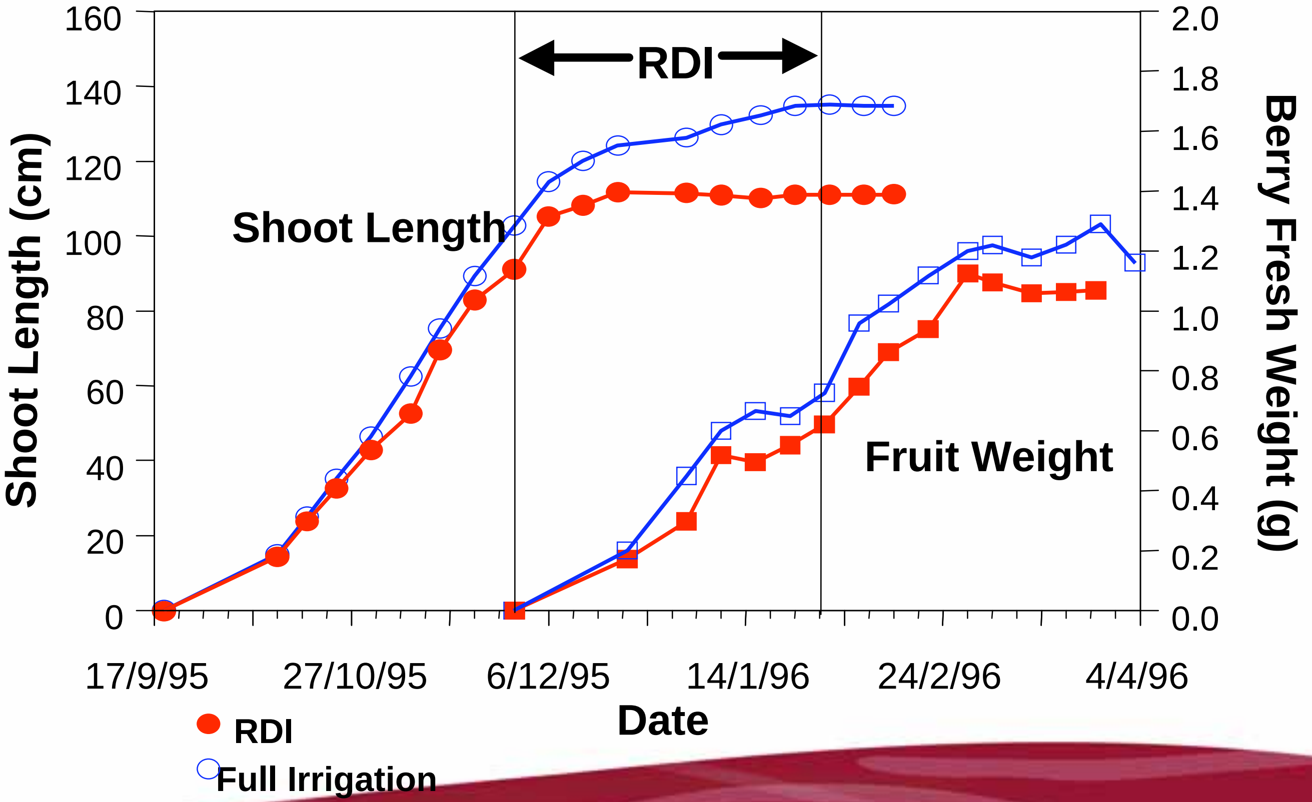
The effect of water deficit on yield differs depending on the stage of growth that the water deficit was applied.

The deficit irrigation strategy used to apply the water deficit may also influence yield levels i.e.

- Regulated Deficit Irrigation (RDI)
- Partial Rootzone Drying (PRD)
- Sustained Deficit Irrigation (SDI)

WATER & VINE
Managing the challenge

RDI requires a controlled application of irrigation water at less than the crop water use applied at a specific vine growth stage (temporal deficit).



http://waterandvine.gwrdc.com.au

Graph courtesy Ian Goodwin, DPI-Tatura

PRD involves applying alternate irrigations to each side of the grapevine to create discrete wet and dry zones around the root system (spatial deficit)

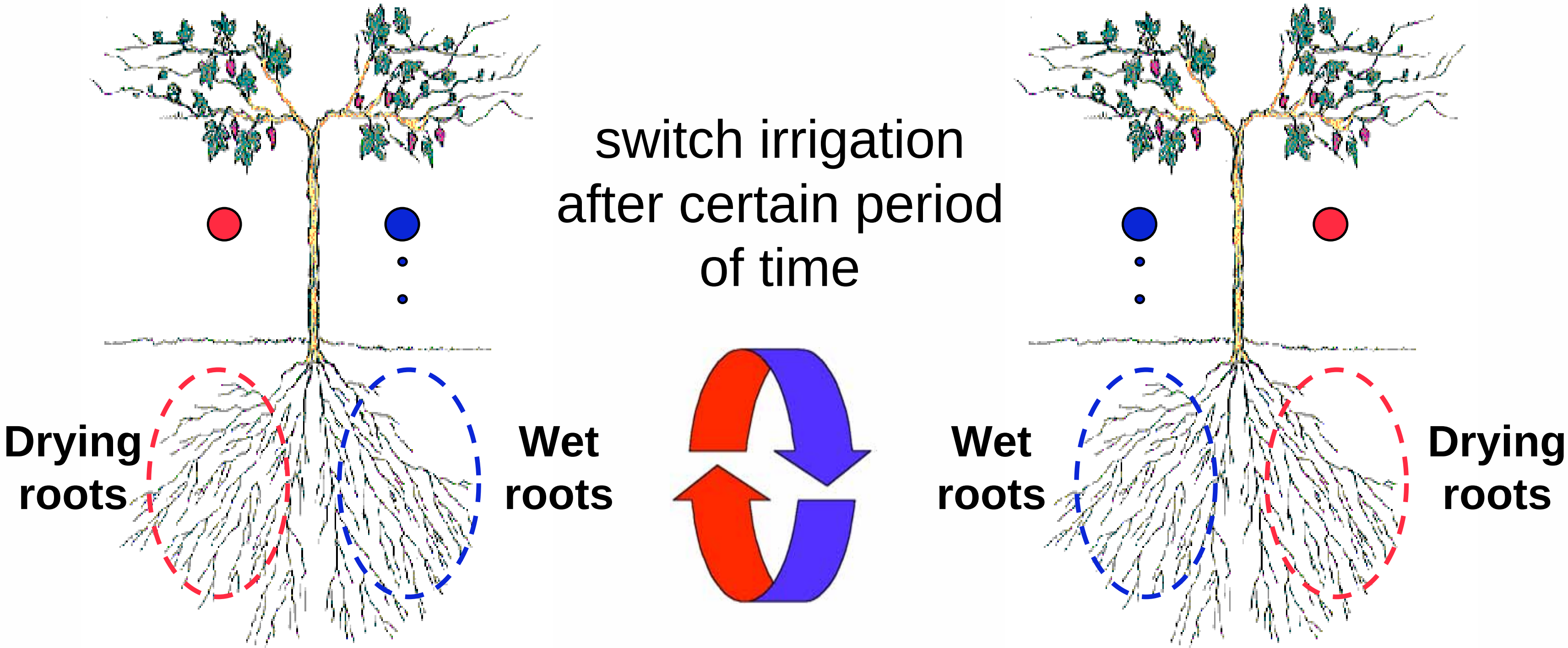


Diagram courtesy Peter Dry, University Adelaide

SDI creates a soil water deficit by applying less water than the optimum required at each irrigation event for the entire season

Cabernet Sauvignon/140-Ruggeri

Irrigation Volume (ML/ha)	100%	70%	52%	43%
2003/2004	6.0	4.2	3.1	2.6
2004/2005	6.6	4.6	3.4	2.8
2005/2006	7.5	5.3	3.9	3.2
Dripper flow rate (L/h)	2.3	1.6	1.2	1.2
Dripper spacing (m)	0.5	0.5	0.5	0.6

Shiraz/140-Ruggeri

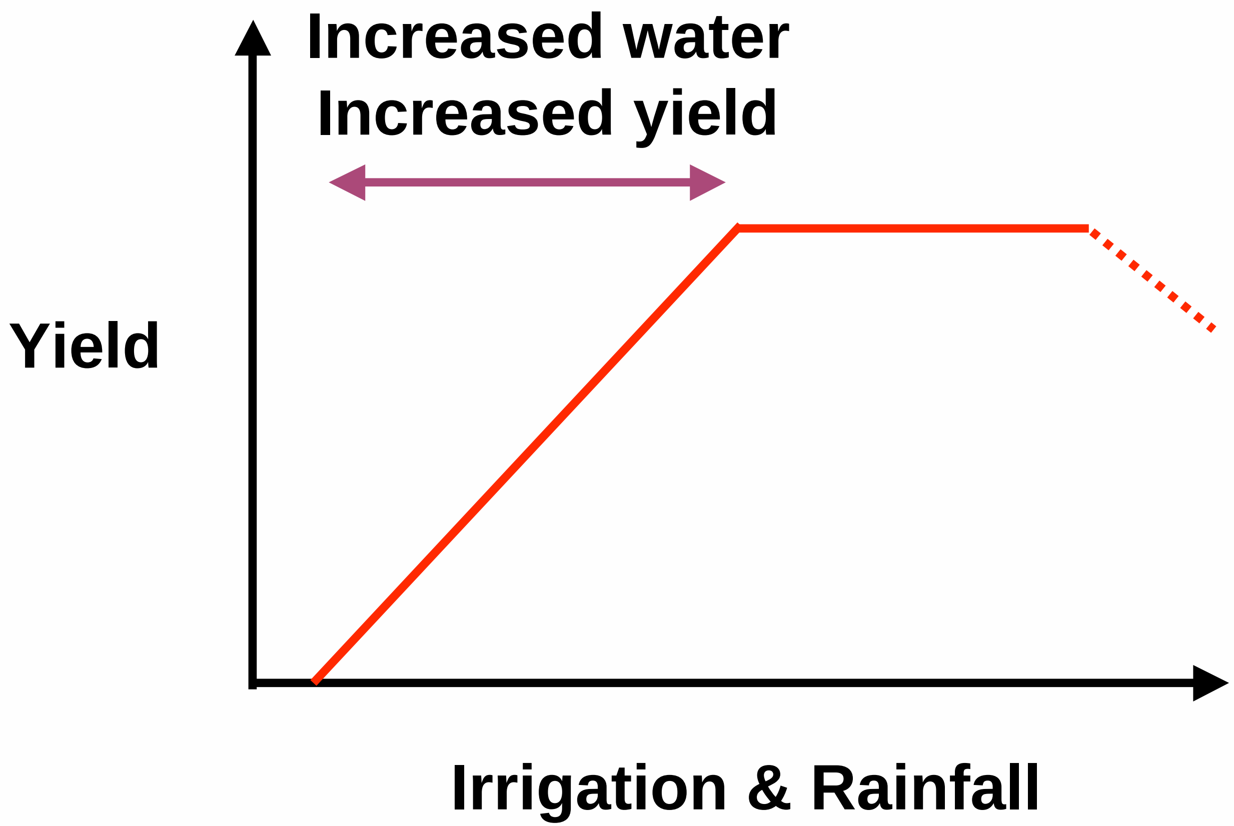
Irrigation Volume (ML/ha)	100%	65%	45%	34%
2003/2004	3.4	2.2	1.5	1.2
2004/2005	5.7	3.7	2.6	1.9
2005/2006	5.9	3.8	2.6	2.0
Dripper flow rate (L/h)	3.5	2.3	1.6	1.2
Dripper spacing (m)	0.5	0.5	0.5	0.5

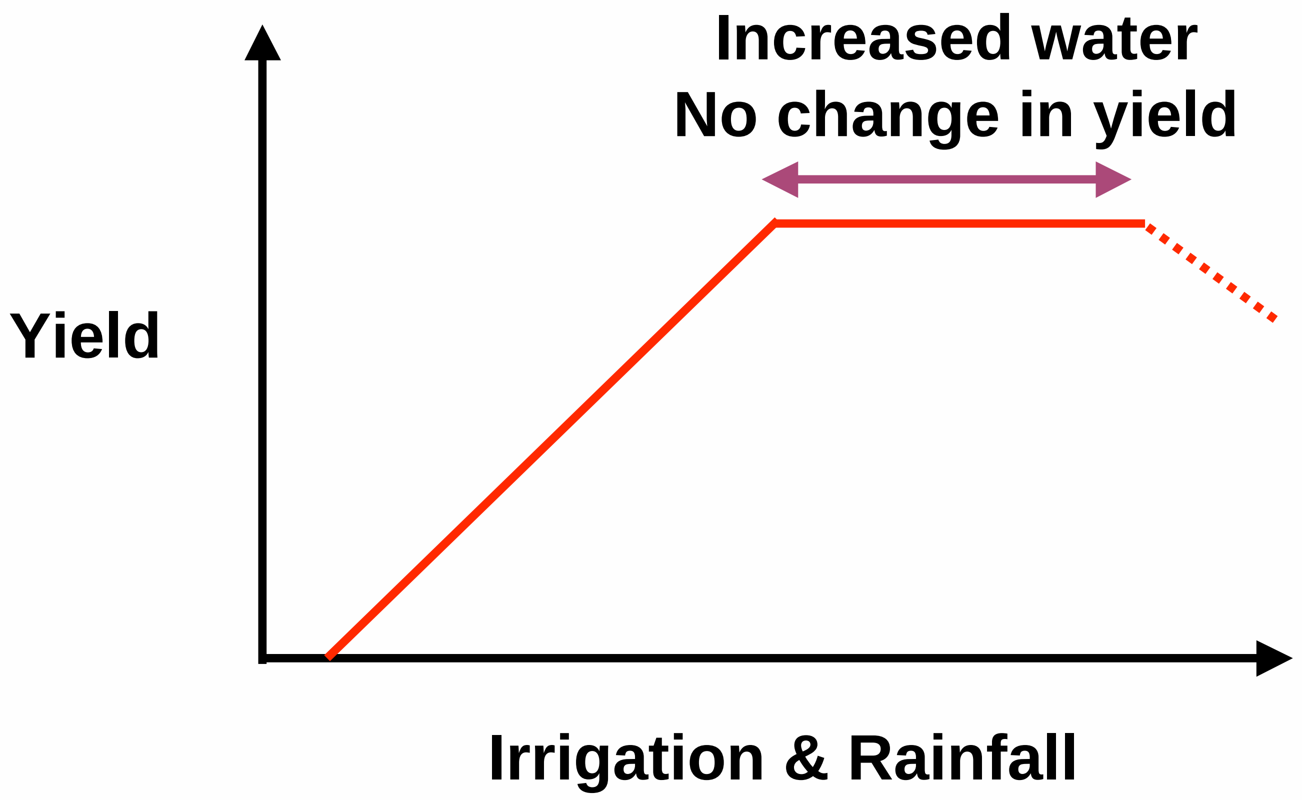
Data from Chalmers (2007) PhD thesis

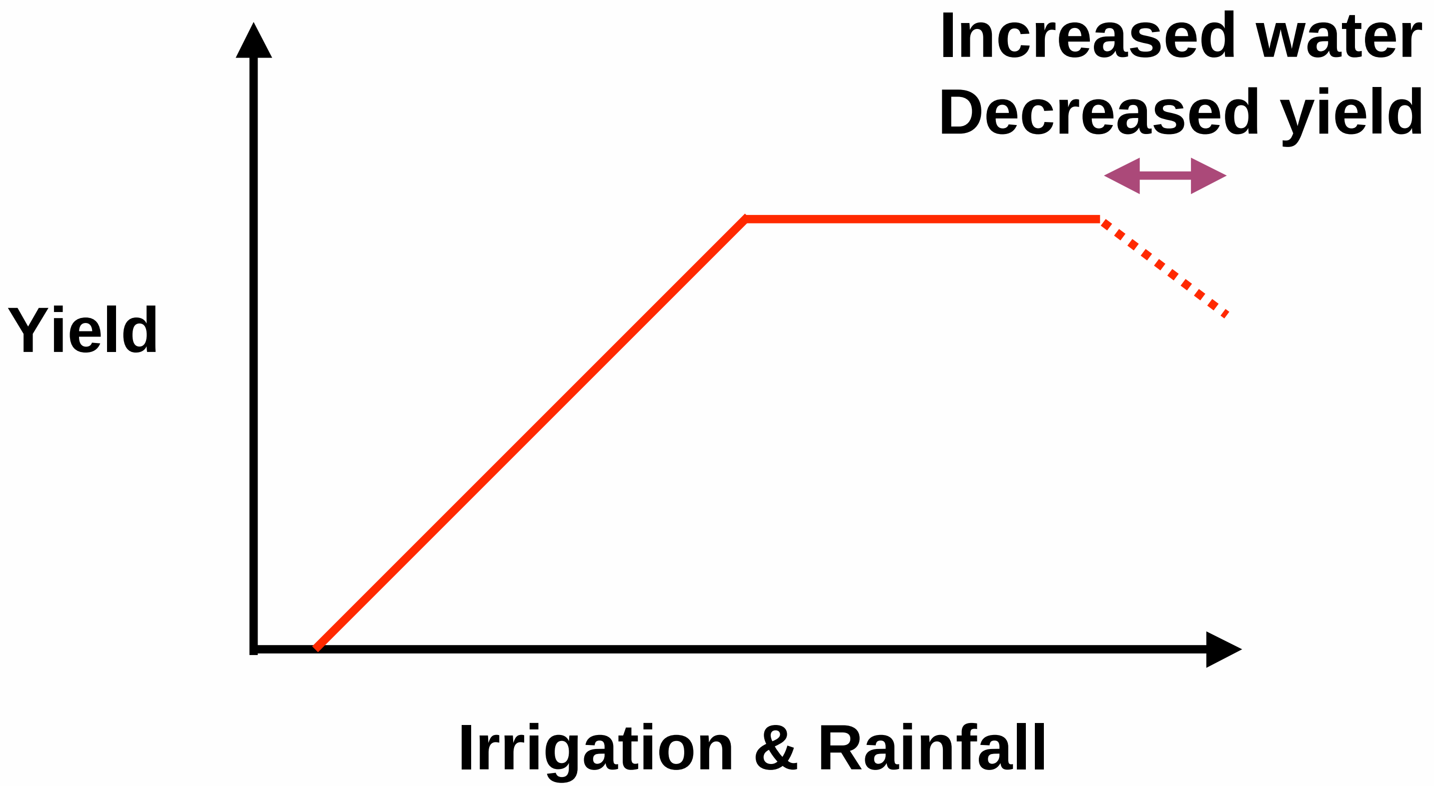
Section 6: What happens to grapevine yields under limited water?

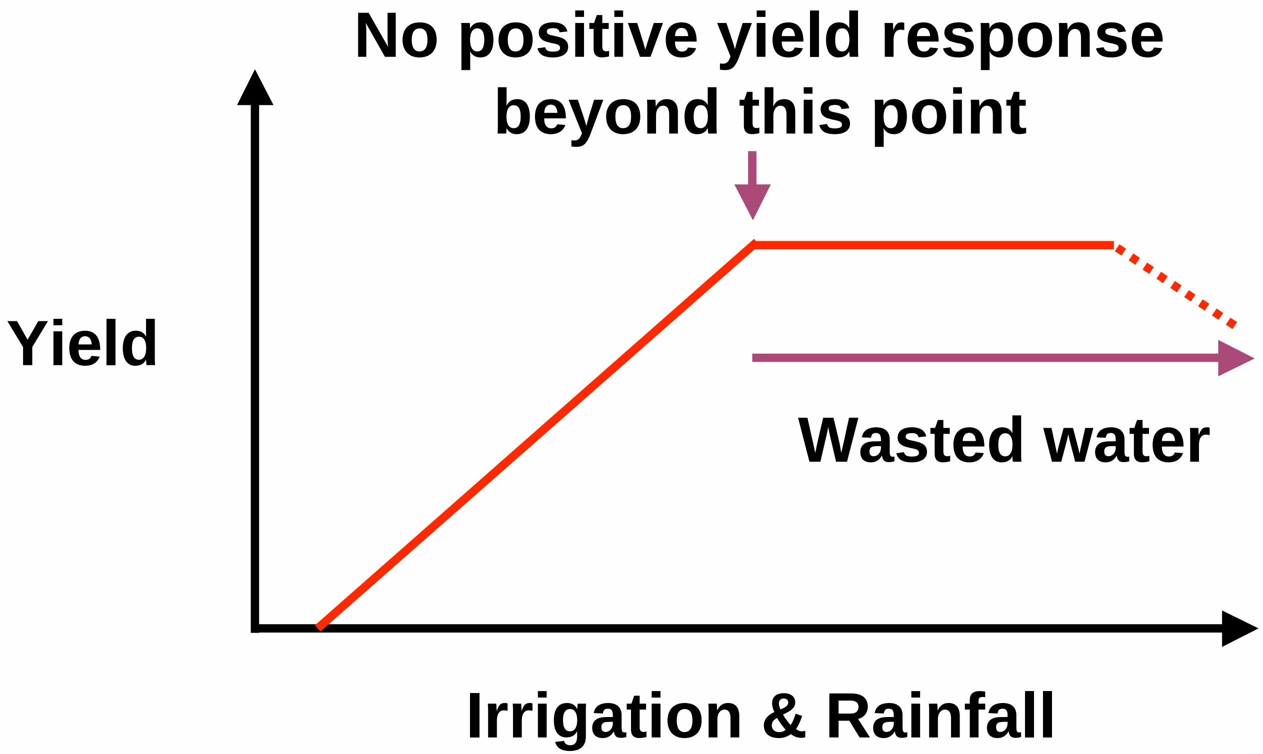
- The effect of irrigation on yield is not a linear relationship.
- Theoretically there is an irrigation threshold that maximizes yield & productivity.

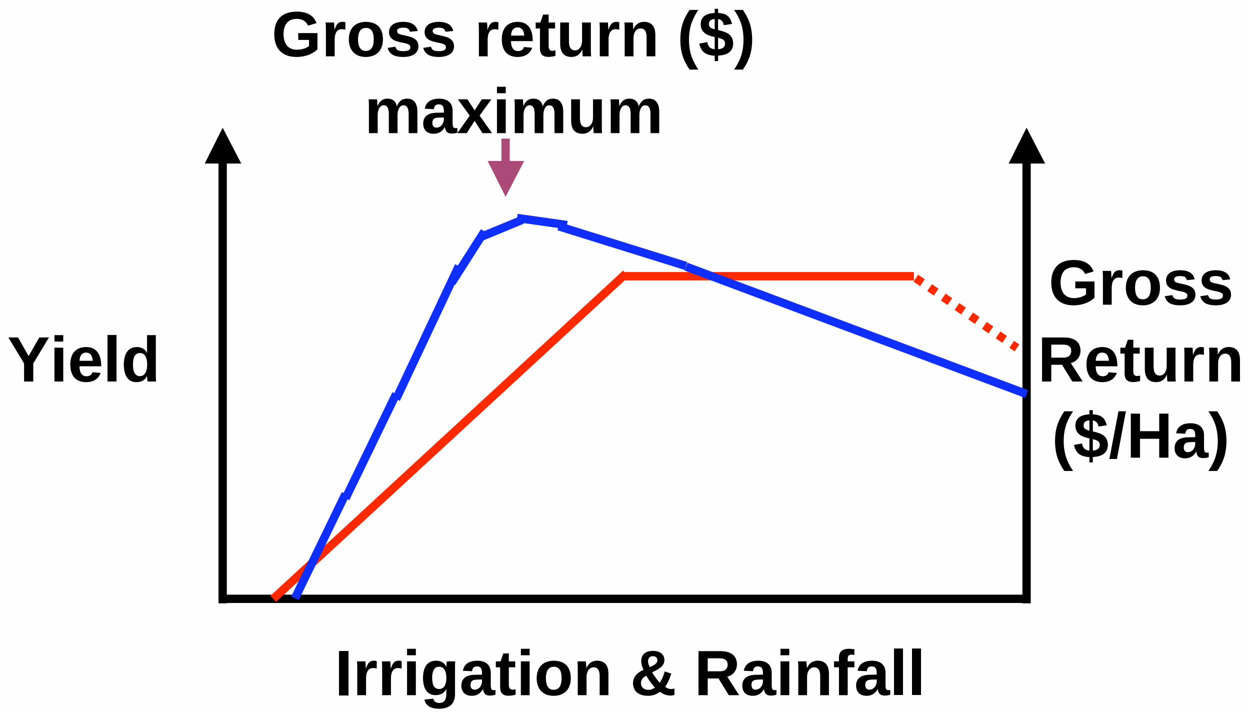
- Show 2007/08 regional max. & min. temperatures plus effective rainfall.
- Effective rainfall is ≥5mm rain in 24 hours.
- Regional case studies showing yield vs water use data.


Increased water
Increased yield
Yield
Irrigation & Rainfall


Increased water
No change in yield
Yield
Irrigation & Rainfall


Increased water
Decreased yield
Yield
Irrigation & Rainfall


No positive yield response beyond this point
Yield
Wasted water
Irrigation & Rainfall

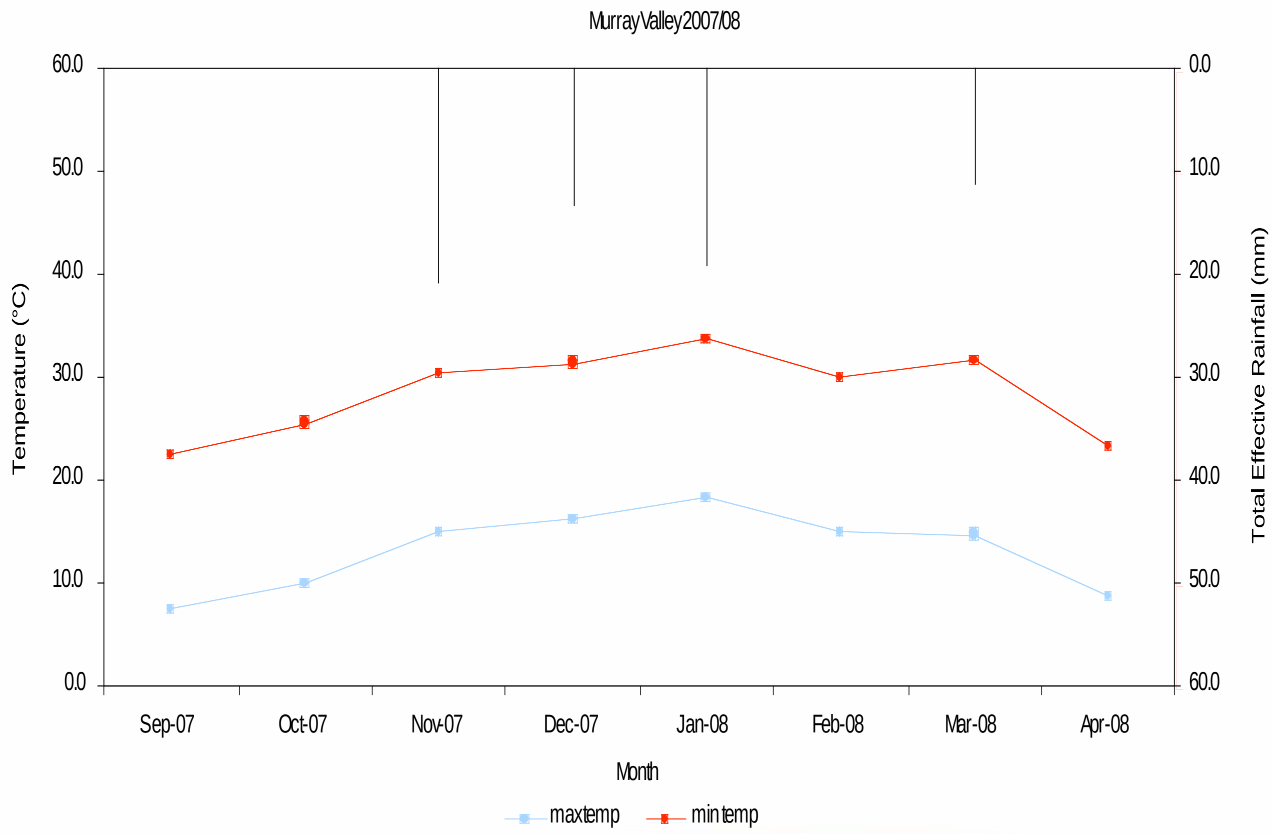


Quality of horticultural produce is critical

WATER & VINE
Managing the challenge

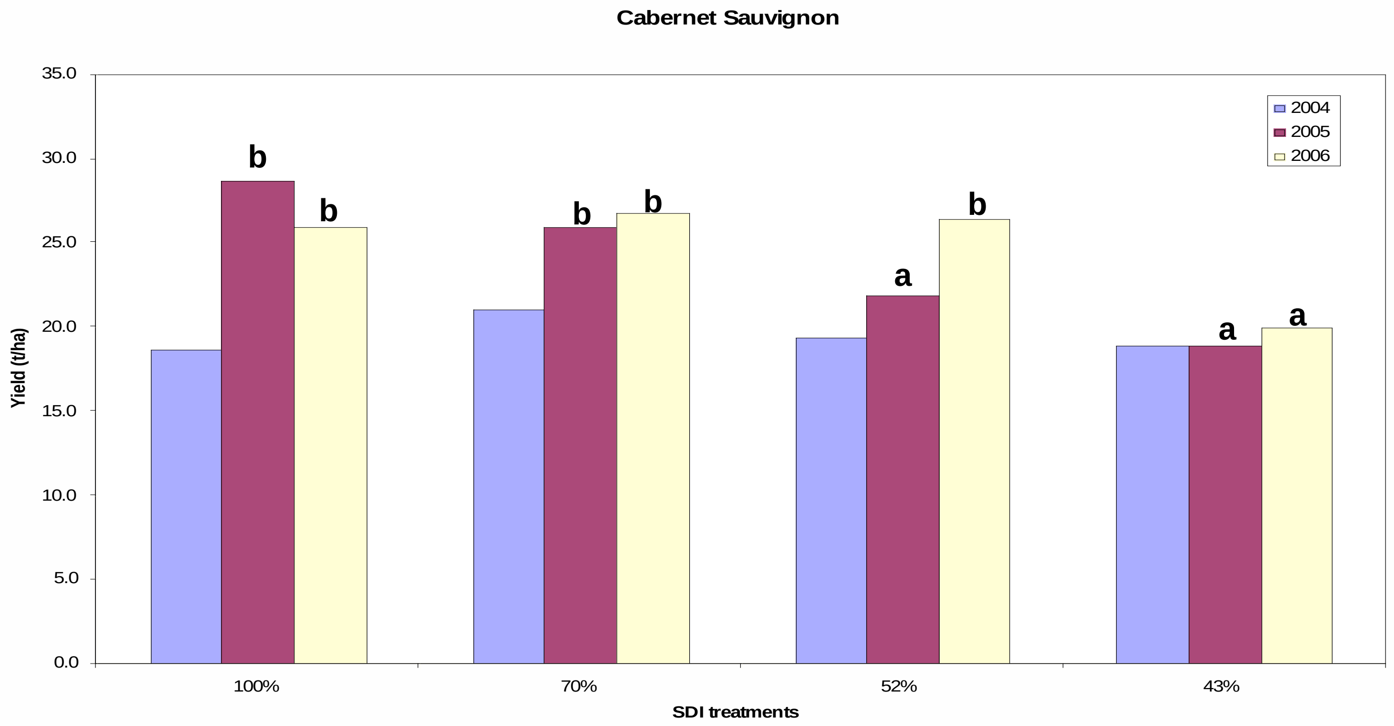
Section 6: Regional weather data

Average monthly maximum and minimum temperatures and total effective rainfall for the Murray Valley from September to April 2007/08



http://waterandvine.gwrdc.com.au

Section 6: Regional yield and water data

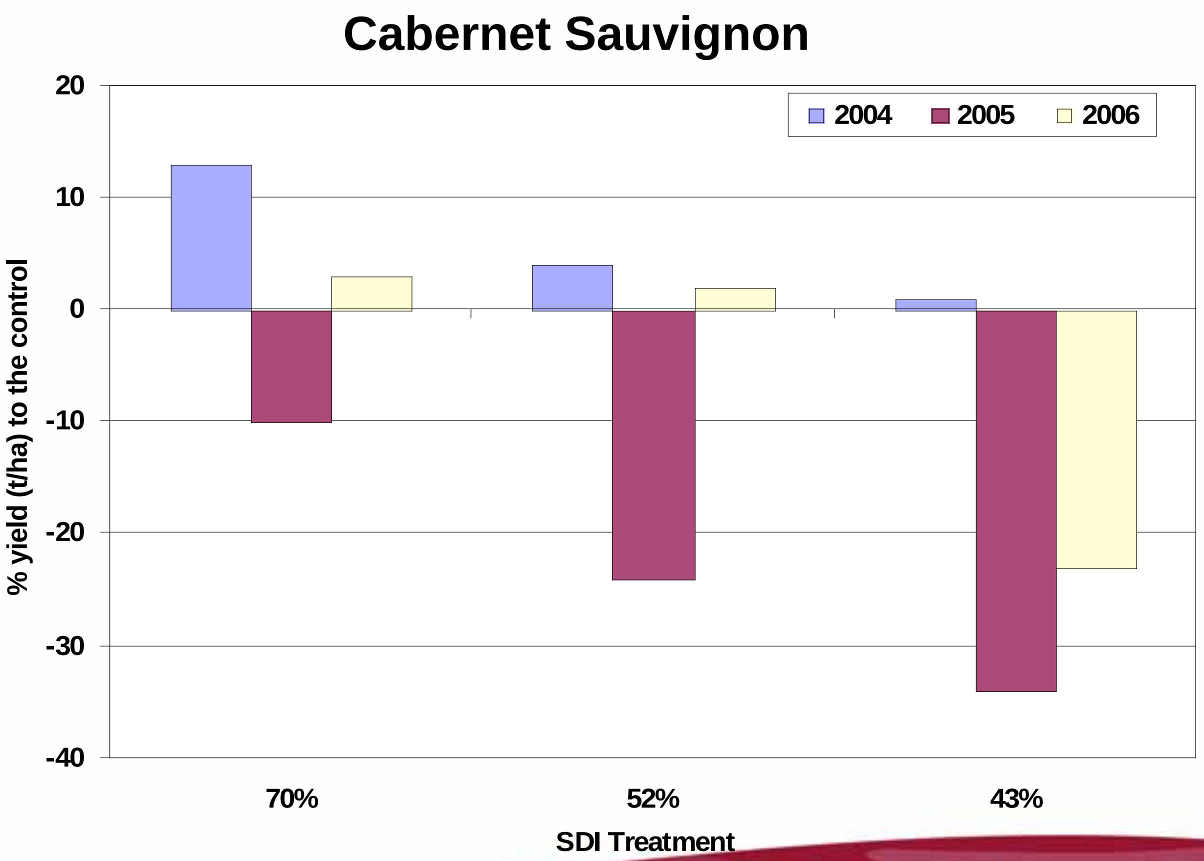


Treatments within a season followed by the same letter are not significantly different at $P<0.05$.

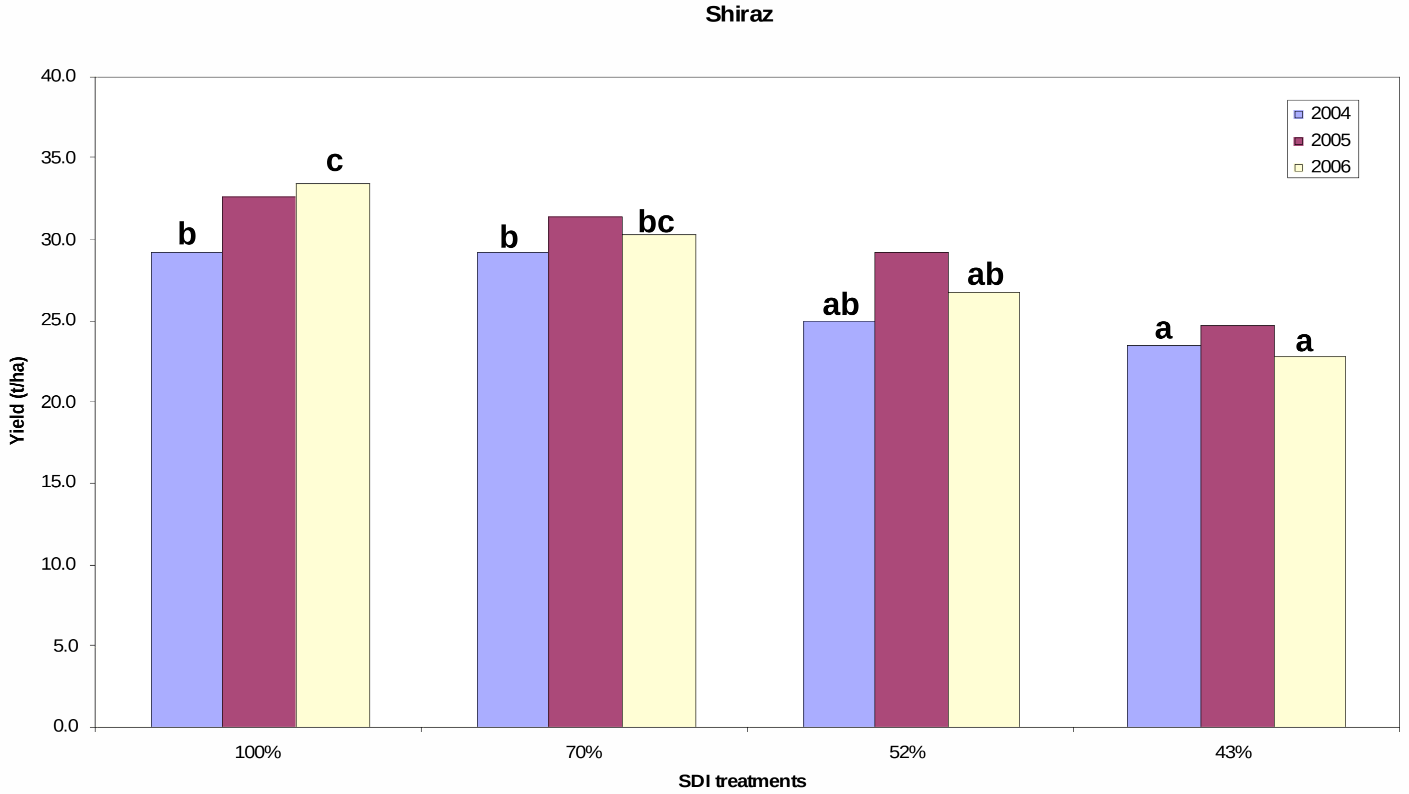
Data from Chalmers (2007) PhD thesis

WATER & VINE
Managing the challenge

Section 6: Regional yield and water data



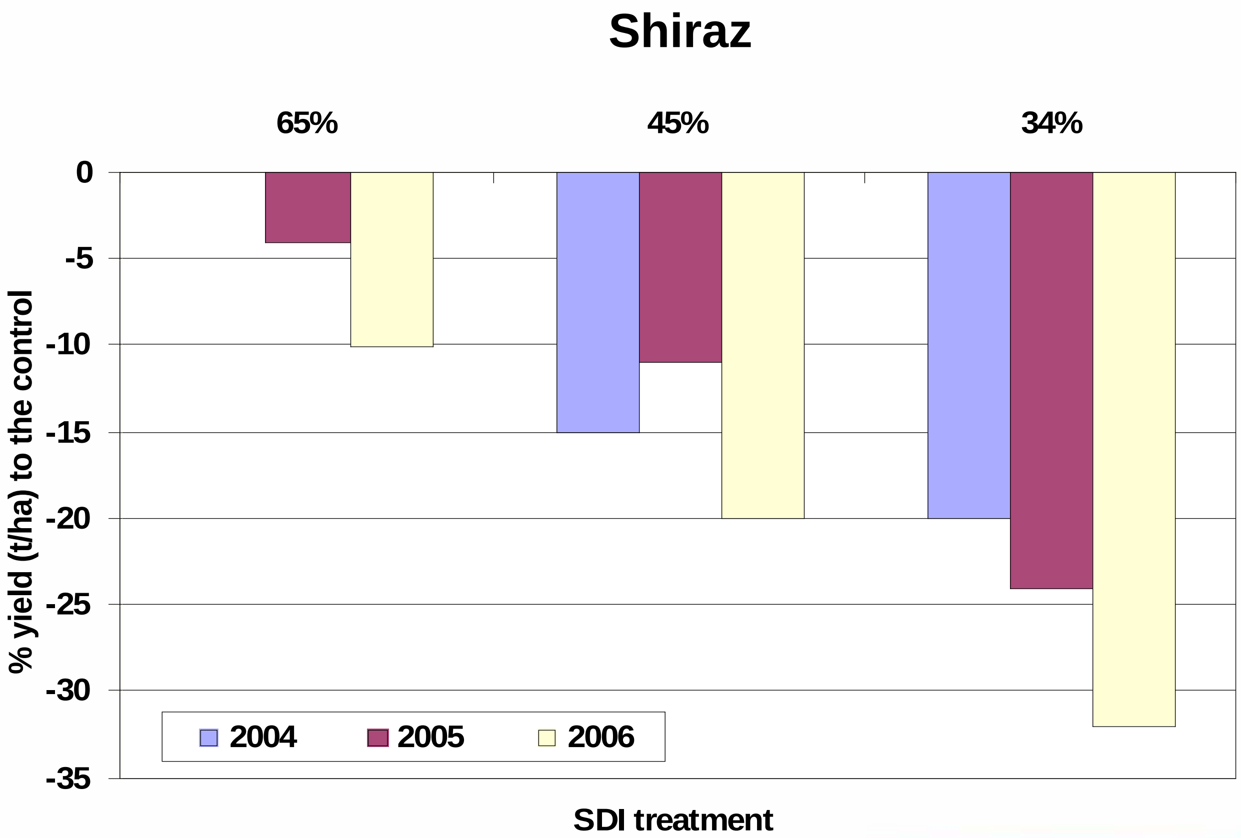
Section 6: Regional yield and water data



Treatments within a season followed by the same letter are not significantly different at $P<0.05$.

Data from Chalmers (2007) PhD thesis

Section 6: Regional yield and water data



Section 6: Regional yield and water data

Below is a table that could be used by a regional representative to fill in for the respective varieties.

Region name	**2006/07**		**2007/08**	
Variety	**Irrigation volume (ML/ha)**	**Yield (t/ha)**	**Irrigation volume (ML/ha)**	**Yield (t/ha)**
Shiraz	3.9	9.0	6.4	16.5
Cabernet Sauvignon				
Merlot				
Chardonnay				

Summary

- Government and the winegrape industry have accepted that severe shortages of water for irrigation will continue.
- Irrigation is now a substantial cost and in some regions will limit wine production.
- Limited scientific knowledge on the relationship between yield and water, particularly in white wine grapes i.e. Chardonnay.
- Knowledge gap as to the implications on productivity of applying a sustained or strategic water deficit.
- Impact of reduced water allocations on salinity and drought induced erosion problems.

WATER & VINE
Managing the challenge

Useful websites

- www.vic.dpi.gov.au Agriculture & food-horticulture-wine & grapes-information
- www.pir.sa.gov.au Wine-viticulture-irrigation-developing a water budget
- www.riverlink.gov.au/waterlink/w_factsheets.html

Acknowledgements

- GWRDC
- Yasmin Chalmers, DPI-Mildura
- Karl Sommer, DPI-Mildura
- Regional representatives who have contributed to the module

Australian Government
Department of Agriculture, Fisheries and Forestry

WATER & VINE
Managing the challenge

Australian Government
Grape and Wine Research and Development Corporation

These updates are supported by the Australian Government through the Irrigation Industries Workshop Program in partnership with the Grape and Wine Research and Development Corporation.