

# Implications of Research on Wine Grape Irrigation Management

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# Major irrigation management decisions

- When should one initiate irrigations at the beginning of the season?
- How much water should one apply?
- How much water is available for irrigation purposes?
- Could deficit irrigation practices maximize productivity and fruit quality?

# Definitions

- Transpiration – evaporation of water that has passed through a plant
- Evapotranspiration (ET) – the total process of water transfer into the atmosphere from vegetated land surfaces
- Leaf water potential – a measure of the water status of plants (units expressed in bars or megapascals (MPa), 10 bars = 1.0 MPa)

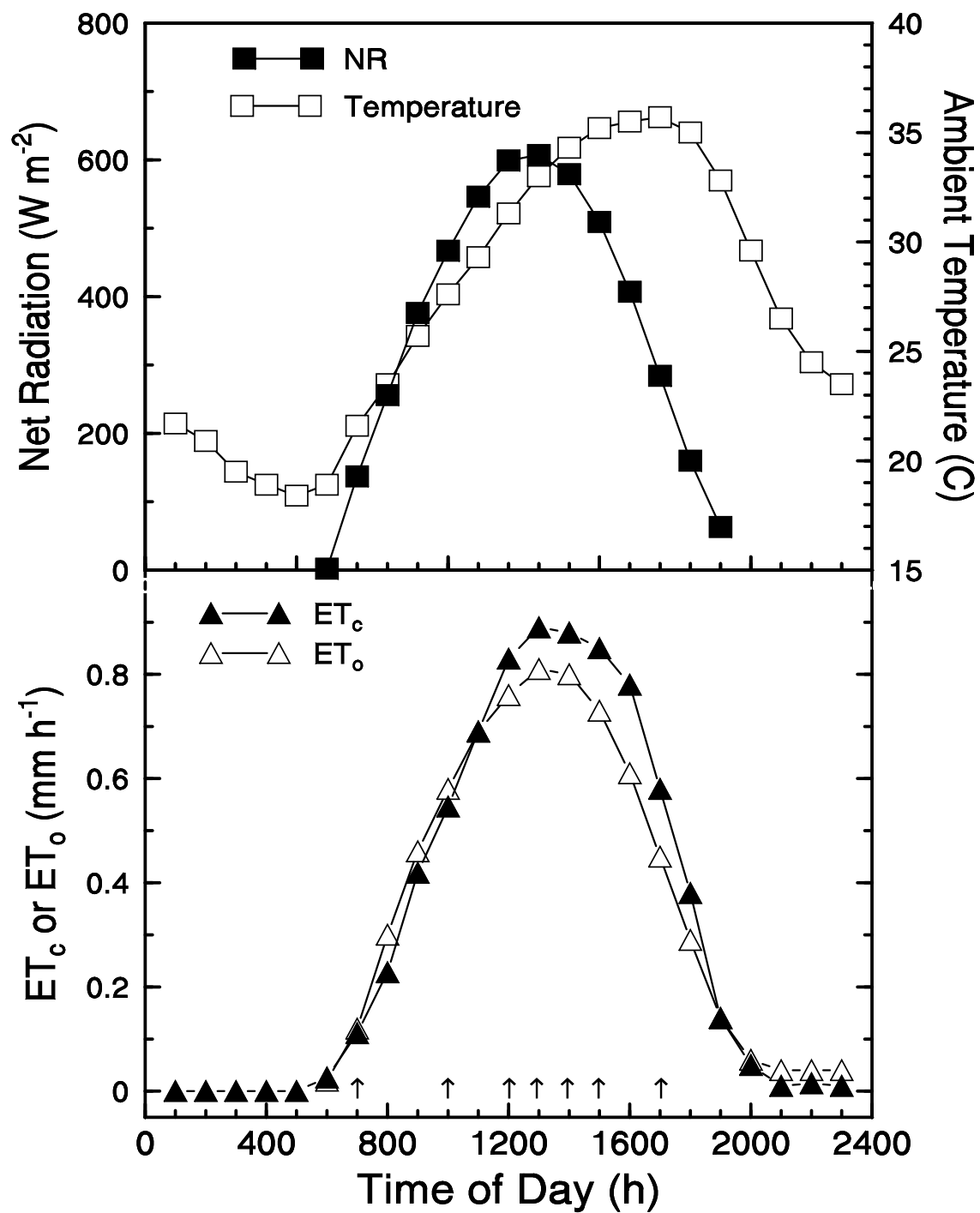
Currently, many individuals and consultants in California are measuring vine water potential with a pressure chamber to aid in irrigation management.

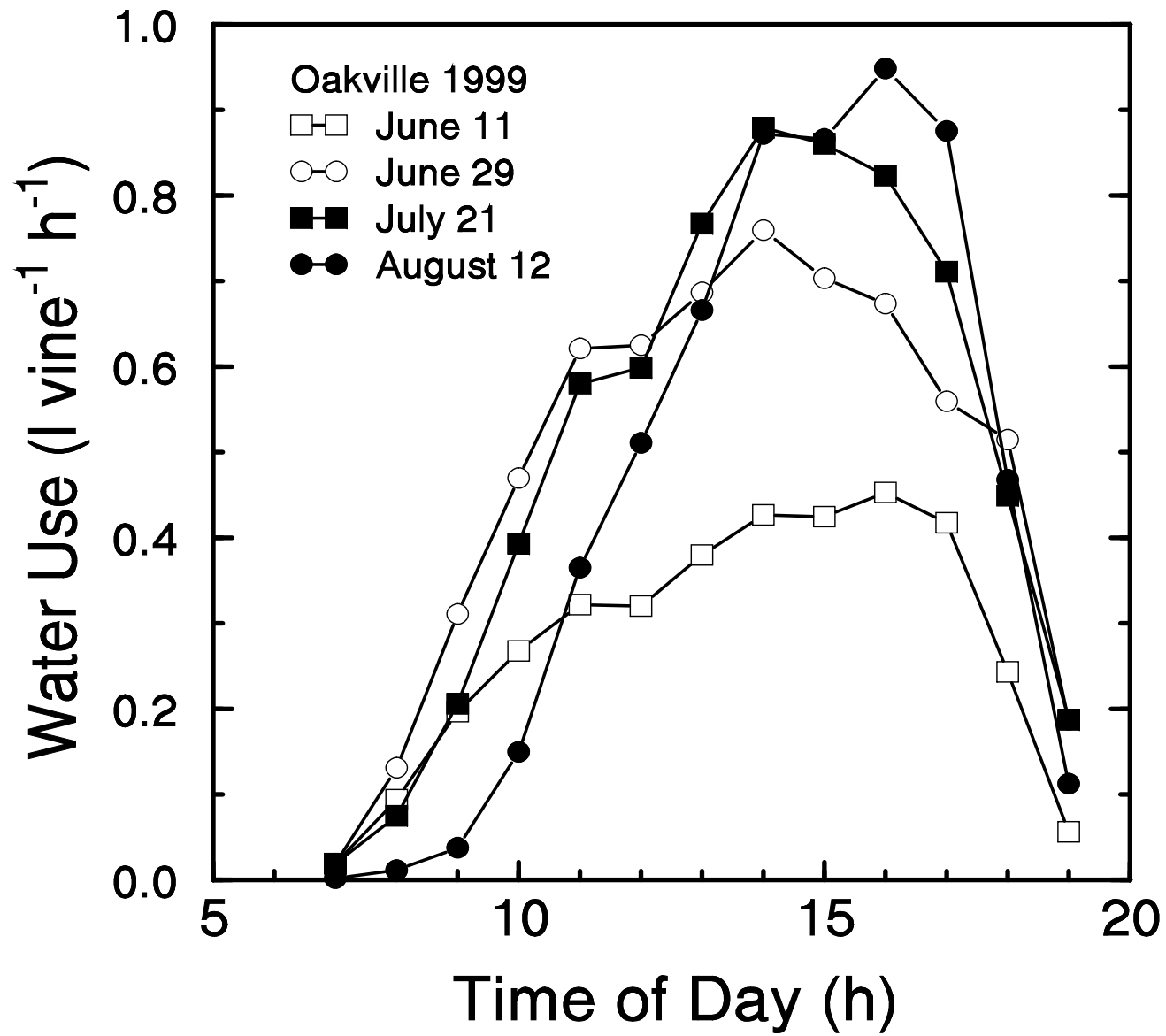
If you plan to use the measurement of vine water status (leaf water potential) to assist in vineyard irrigation management, what factors should you be cognizant of?

What environmental factors affect vine water use on a diurnal basis?

When during the day is vine water use the greatest?

The answers to these questions were determined with a weighing lysimeter and by a model of vine water use.



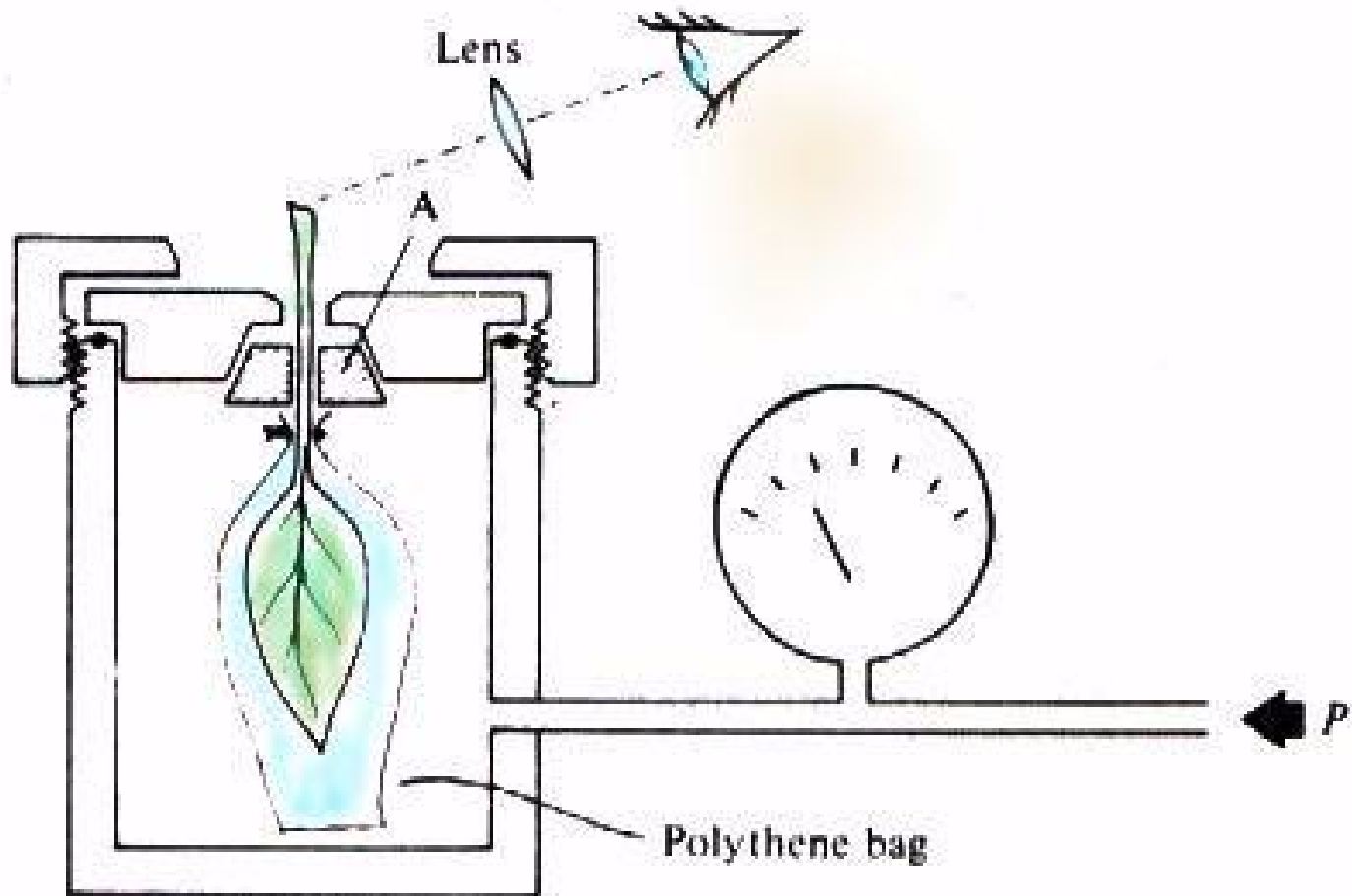


# Ways to measure vine water status with a pressure chamber.

- Pre-dawn leaf water potential - measurements taken prior to sunrise
- Midday leaf water potential - measurements taken when minimum daily would be recorded
- Stem water potential – leaf blade placed in a plastic bag covered with aluminum foil 30 to 60 minutes prior to measurement [assume leaf comes into equilibrium with that of the stem] and measurements taken at daily minimum

# Techniques for the measurement of midday grapevine leaf water potential

- Select a leaf that is exposed to direct sunlight
- Place a plastic bag over the leaf blade (such as a fold-lock sandwich bag)
- Immediately cut the petiole with a sharp razor blade
- As quickly as possible place the bagged leaf into the pressure chamber (~ 10 s after cutting)
- Pressurize at a rate of 0.3 to 0.5 bars per second

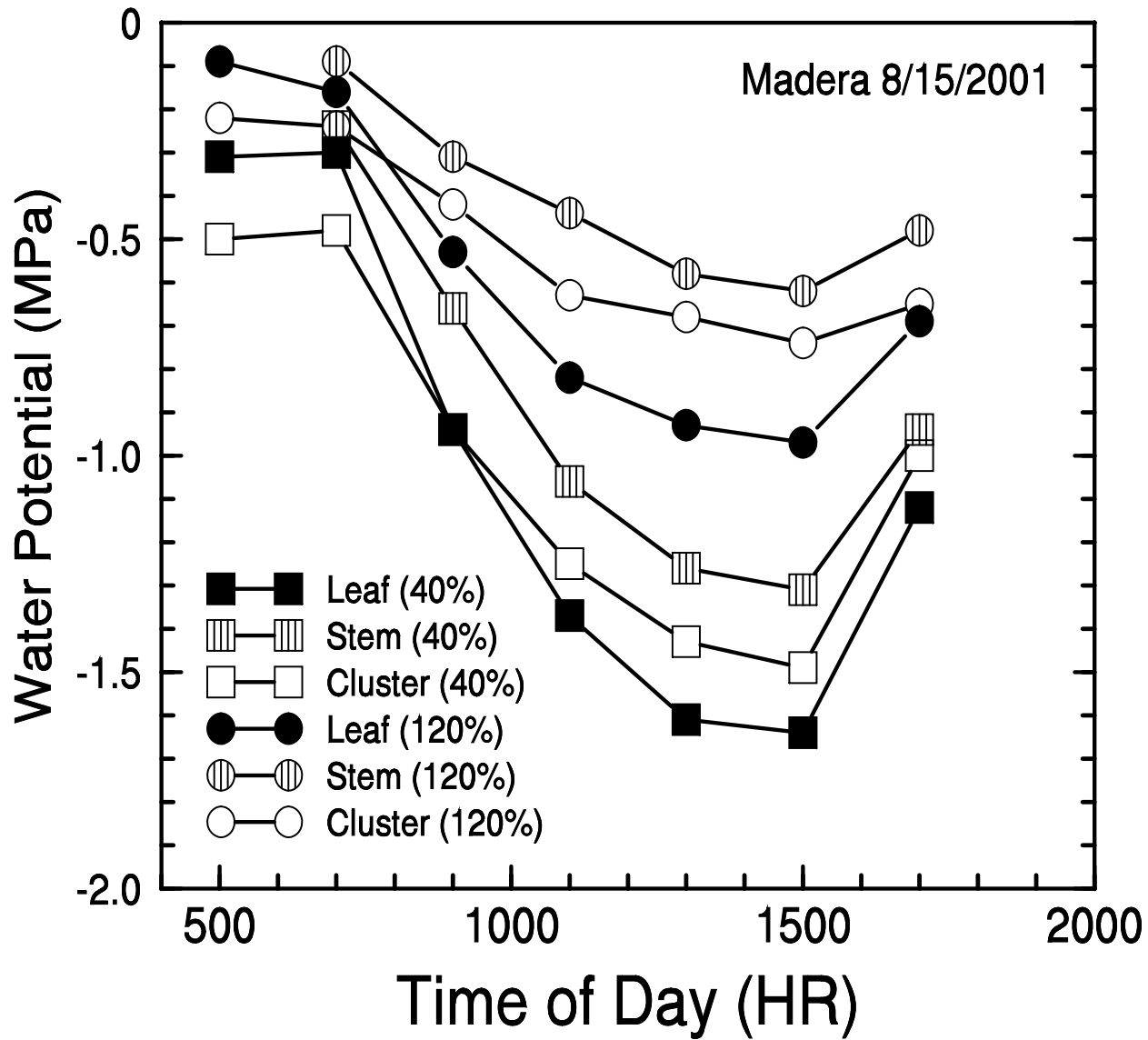


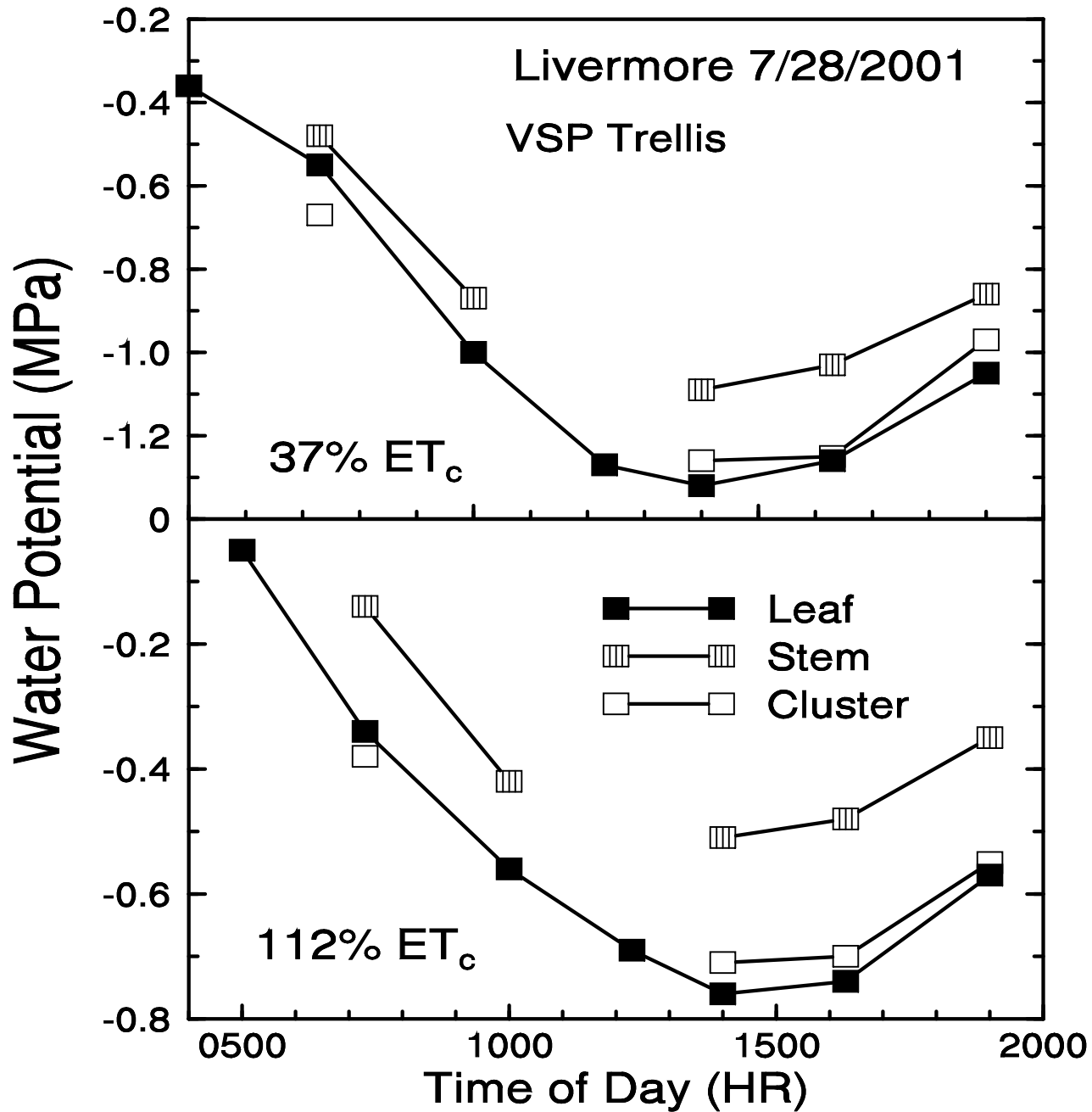
Effects of different practices (covering or not covering blades with a plastic bag) on leaf water potential of Merlot.

Treatment	40% ET <sub>c</sub>	120% ET <sub>c</sub>
	----- MPa -----	
Covered before excision	-1.33	-0.93
Covered after excision	-1.45	-1.04
Not covered	-1.52	-1.21

When during the day will one measure the lowest values of leaf water potential?

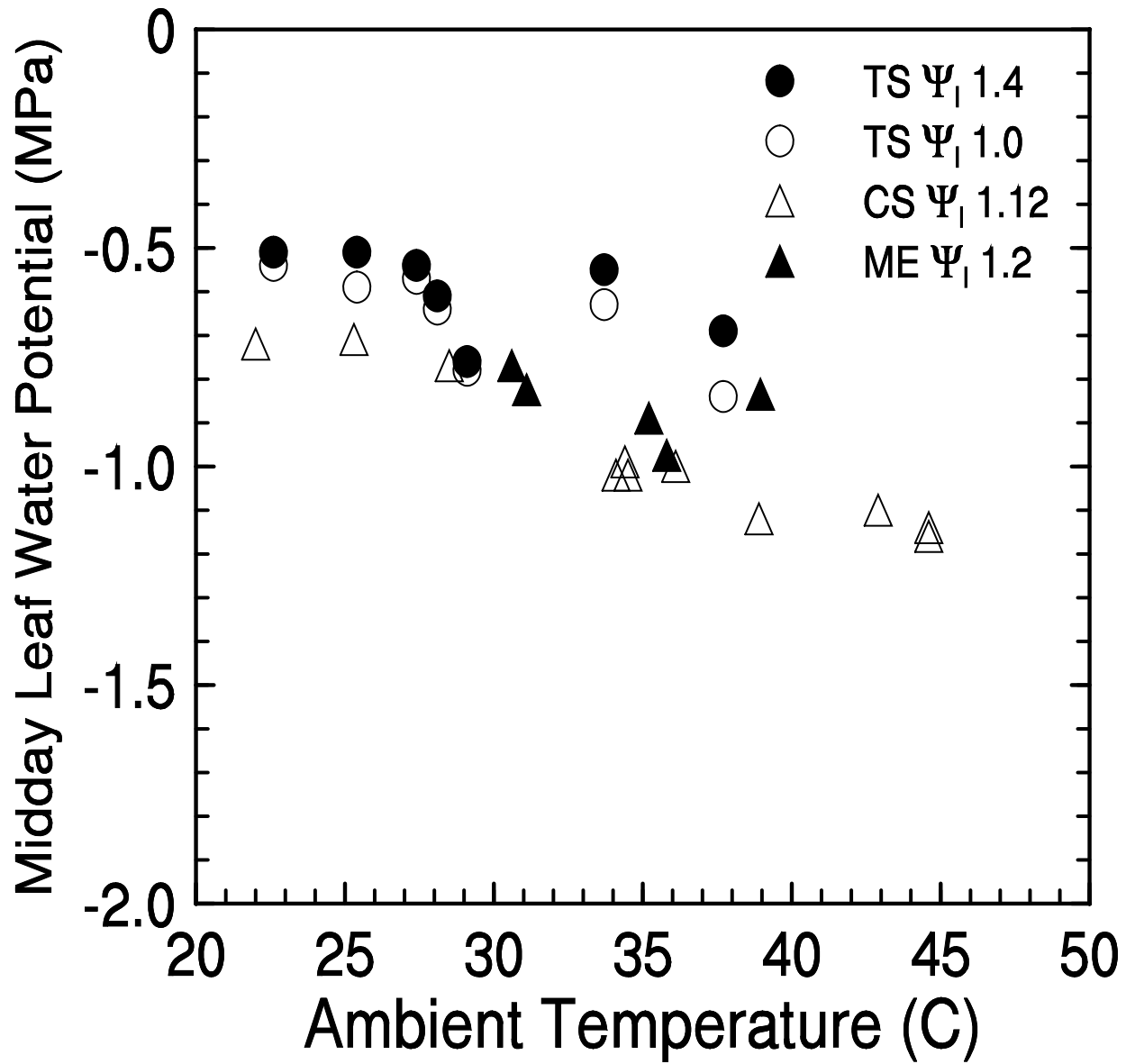
When is the vine most stressed for water during the day?

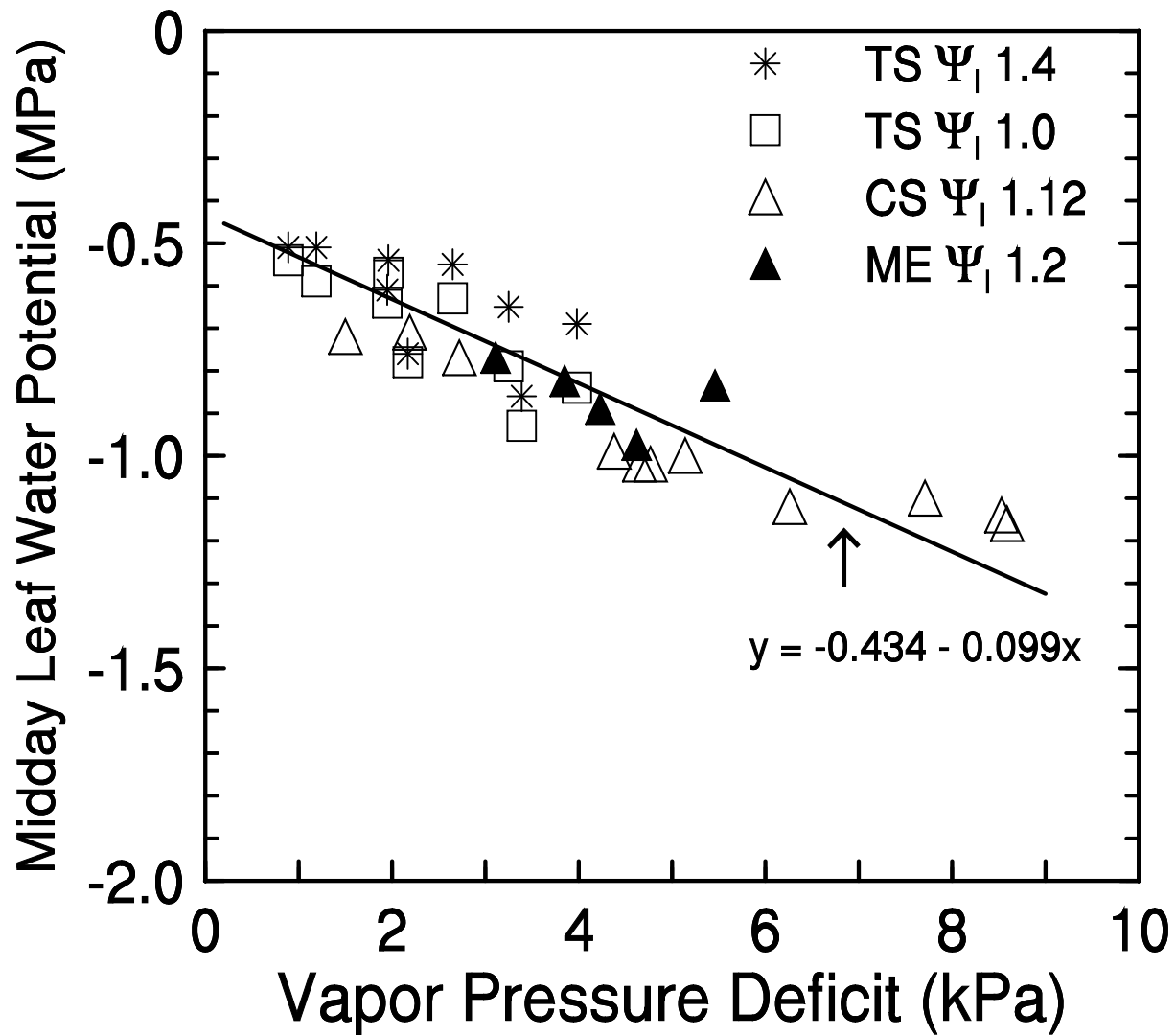




Based upon the results I obtained in 2001 and 2002, I feel leaf water potential could be measured over a two hour time period (i.e. 12:30 to 2:30 pm or 1:00 to 3:00 pm) with little variation in the results. On a north/south row, the daily minimum may not be measured until 3:30 to 4:00 pm in the afternoon.

What other factors might affect the values of leaf water potential you measure in your vineyard?





Midday leaf water potential of grapevines not stressed for water is affected by ambient temperature and vapor pressure deficit (VPD) at the time the measurements are made. Midday leaf water potential of water stressed grapevines is much less responsive to temperature and VPD.

# How can monitoring vine water status assist in vineyard irrigation management?

- It can be used to determine when the first irrigation of the season should be applied.
- It can be used to determine the interval between irrigations, once initiated
- It will not tell you the water requirements of your vines (how much water to apply)

These Merlot vines had been irrigated several times prior to when this image was taken on May 24, 2002.



These Merlot vines had not been irrigated prior to the date this image was taken, May 24 2002.



Midday leaf water potential of the vines that had been irrigated from the beginning of the season was -0.6 MPa on May 24, 2002. Midday leaf water potential for the vines that had not been irrigated was -0.8 MPa on May 24, 2002.

The effect of not irrigating early in the growing season on canopy size (% shaded area measured beneath the vine at solar noon)

Calendar Date	Simpson Vineyard	Experimental Vineyard
	% Shaded Area	
May 3	11.8	10.9
May 24	25.7	21.9
June 6	47.8	38.0
June 21	38.5	41.3

Once you've decided to start irrigating, how can you determine the quantity of water to apply?

# Factors affecting vine or vineyard water use.

- Evaporative demand
- Seasonal growth of vine
- Ultimate canopy size (trellis type)
- Spacing between vines
- Row spacing
- Amount of water in the soil profile

The following equation can be used to calculate vine water requirements:

$$ET_c = ET_o \times K_c$$

where  $ET_c$  = vineyard evapotranspiration,  $ET_o$  = reference evapotranspiration and  $K_c$  = crop coefficient. The above equation will give water requirements in inches (one acre inch = ~ 27,500 gallons per acre)

# Evaporative Demand

- It is a function of net radiation, vapor pressure deficit and wind.
- Reference evapotranspiration ( $ET_0$ ) is used as a measure of evaporative demand.
- $ET_0$  can be obtained from a CIMIS weather station or by other means.

# Reference ET ( $ET_0$ )

- The amount of water transpired per unit time by a short green crop, completely shading the ground, of uniform height and never short of water (it is a useful standard of reference for different climatic regions or seasons).  $ET_0$  cannot exceed free water evaporation under the same weather conditions.



# CIMIS Weather Stations in California

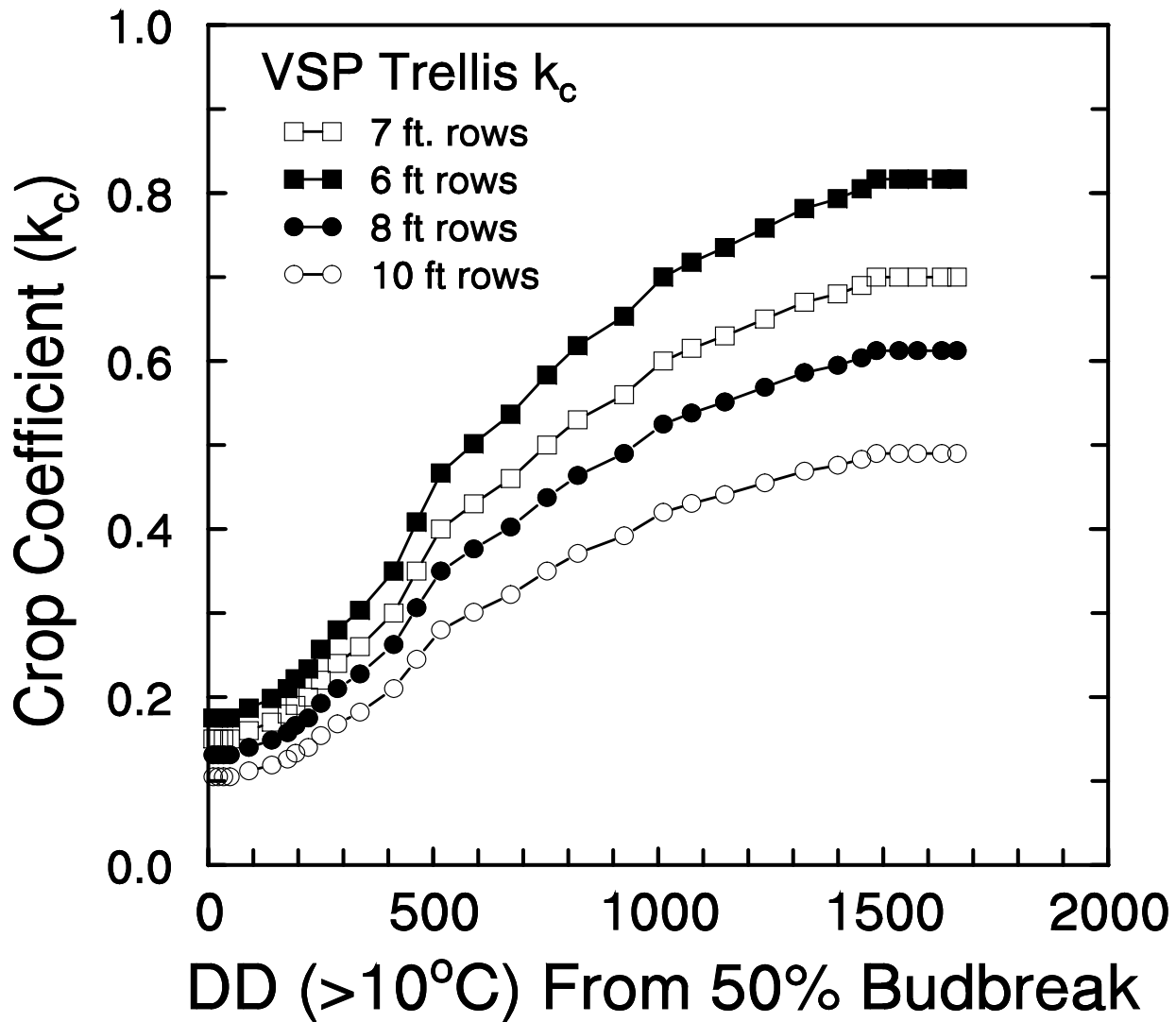


# Crop Coefficient ( $K_c$ )

- The fraction of water used by a specific crop compared to that of  $ET_o$  at a given location
- $K_c = ET_c / ET_o$
- The  $K_c$  depends upon stage of crop development, degree of cover, crop height and canopy resistance.

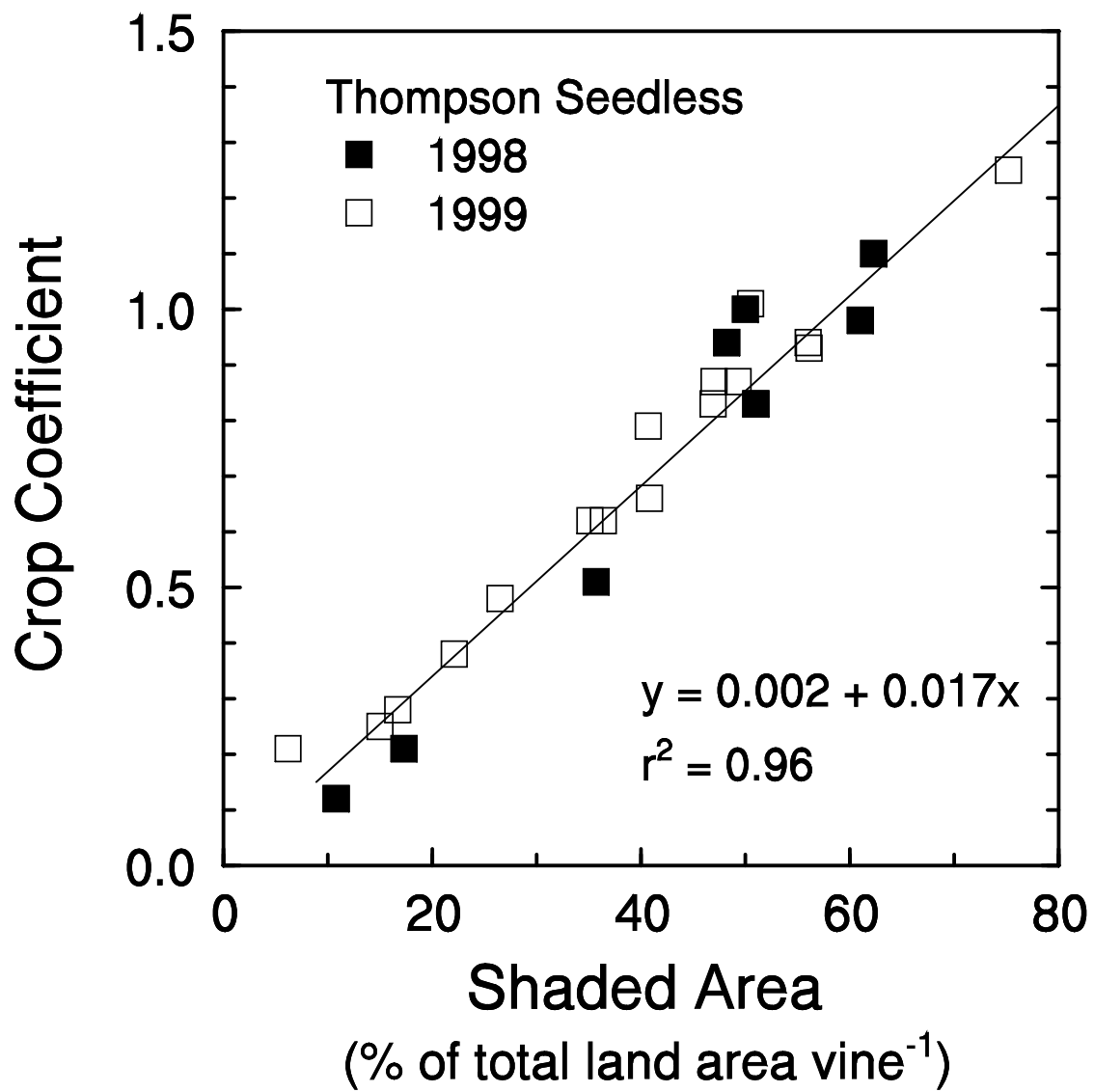
Reliable crop coefficients should take the following into account:

- Seasonal growth of the grapevines
- Canopy size, which is a function of trellis
- Row spacing



## Where does one obtain $K_c$ values for different vineyard situations?

- There are several UC publications that have published  $K_c$  values (however, I've found them not to be appropriate for coastal vineyards).
- I've published  $K_c$  values in various proceedings.
- I've developed a procedure to estimate  $K_c$  values



## Methods to estimate seasonal vineyard crop coefficients: use of the shaded area technique

- Measure the amount of shade cast on the ground beneath the vine at solar noon (from 1230 to 1330 hours). This can be accomplished using a tape measure, a board with small squares drawn over its surface or a digital camera.

## Methods to estimate seasonal vineyard crop coefficients: use of the shaded area technique

- The percent shaded area is the amount of shade measured with one of the three previously listed techniques, divided by the total area allocated per vine in the vineyard. This value is then multiplied by 100.

## Methods to estimate seasonal vineyard crop coefficients: use of the shaded area technique

- The percent shaded area is then multiplied by 0.017 (the slope of the  $K_c$  as a function of Thompson Seedless shaded area) to give you an estimated  $K_c$ .

## Example:

- 1.) Vine and row spacing = 6 x 8 ft. (48 ft<sup>2</sup>)
- 2.) Measured shaded area = 12 ft<sup>2</sup>
- 3.) % shaded area =  $12/48 = 0.25 \times 100 = 25$
- 4.) % shaded area x 0.017 =  $K_c$   
 $25 \times 0.017 = 0.425$
- 5.) Assume  $ET_o = 1.2$  inches (~17,500 gal/acre inch)
- 6.)  $ET_o \times K_c = ET_c$
- 7.)  $1.2 \times 0.425 = 0.612$  inches = 16,830 gal/acre
- 8.)  $16,830 \text{ gal}/907 \text{ vines acre}^{-1} = 18.6 \text{ gal/vine}$

# “Irrigation of winegrapes in California”

Practical Winery and Vineyard  
November/December 2001

Larry E. Williams

“The  $k_c$  value relates to ET of a disease-free, crop grown under large fields under optimum soil water and fertility conditions and achieving full production potential under the given growing environment”

Doorenbos and Pruitt, 1977

# Sustained Deficit Irrigation (SuDI)

- The practice of purposely creating water deficits beginning with the first irrigation and irrigating such throughout the remainder of the growing season. SuDI is based upon knowing what full ET for the vineyard is and then irrigating at a particular fraction of full ET – Larry E. Williams

# Experimental sites and materials

- Gonzales – Chardonnay on 5C, 110R and Freedom, VSP, vine x row = 6 x 8 ft
- Edna Valley – Chardonnay on 5C, 110R and Freedom, VSP, vine x row = 6 x 10 ft
- Paso Robles – Cabernet Sauvignon on 5C, 110R, Freedom, 140Ru, and 1103P, VSP vine x row = 6 x 10 ft

The effect of year, location and applied water amounts on berry weight of Chardonnay (Gonzales and Edna Valley) and Cabernet Sauvignon (Paso Robles).

Site	Year	-----Irrigation Treatment-----				
		0.25	0.5	0.75	1.0	1.25
		-----Berry weight (g/100 berries)-----				
Gonzales	1998	112	126	129	131	133
	1999	116	133	144	146	148
	2000	114	140	159	155	162
		LSD <sub>0.05</sub> 1998 = 5, 1999 = 6, 2000 = 5				
Edna V.	1998	151	157	163	167	168
	1999	151	169	187	190	193
	2000	146	156	178	180	183
		LSD <sub>0.05</sub> 1998 = 5, 1999 = 8, 2000 = 5				
Paso R.	1998	85	96	103	105	105
	1999	83	95	106	111	116
	2000	101	116	128	132	132
		LSD <sub>0.05</sub> 1998 = 5, 1999 = 4, 2000 = 5				

The effect of year, location and applied water amounts on soluble solids of Chardonnay (Gonzales and Edna Valley) and Cabernet Sauvignon (Paso Robles).

Site	Year	-----Irrigation Treatment-----				
		0.25	0.5	0.75	1.0	1.25
		-----Soluble Solids (°Brix )-----				
Gonzales	1998	23.4	22.8	23.4	22.4	21.6
	1999	21.4	21.0	20.5	20.4	20.0
	2000	23.0	21.6	21.2	20.8	20.6
		LSD <sub>0.05</sub> 1998 = 0.6, 1999 = 0.6, 2000 = 0.4				
Edna V.	1998	22.5	22.3	22.2	22.1	21.9
	1999	23.5	22.4	21.8	21.8	21.6
	2000	24.6	23.8	23.3	23.1	23.2
		LSD <sub>0.05</sub> 1998 = 0.6, 1999 = 0.4, 2000 = 0.3				
Paso R.	1998	22.2	21.6	22.2	21.6	21.8
	1999	23.8	23.3	22.9	22.6	22.5
	2000	22.5	22.2	21.9	21.4	21.5
		LSD <sub>0.05</sub> 1998 = 0.3, 1999 = 0.3, 2000 = 0.3				

The effect of year, location and applied water amounts on pH of Chardonnay (Gonzales and Edna Valley) and Cabernet Sauvignon (Paso Robles).

Site	Year	-----Irrigation Treatment-----				
		0.25	0.5	0.75	1.0	1.25
		----- pH -----				
Gonzales	1998	3.27	3.27	3.29	3.27	3.27
	1999	3.30	3.26	3.25	3.26	3.24
	2000	3.48	3.40	3.39	3.40	3.36
		LSD <sub>0.05</sub> 1998 = ns, 1999 = 0.02, 2000 = 0.05				
Edna V.	1998	3.29	3.34	3.40	3.41	3.41
	1999	3.42	3.38	3.40	3.38	3.40
	2000	3.56	3.59	3.59	3.61	3.65
		LSD <sub>0.05</sub> 1998 = 0.11, 1999 = 0.03, 2000 = ns				
Paso R.	1998	3.46	3.48	3.53	3.51	3.54
	1999	3.59	3.53	3.47	3.43	3.42
	2000	3.42	3.54	3.58	3.54	3.55
		LSD <sub>0.05</sub> 1998 = ns, 1999 = 0.03, 2000 = ns				

The effect of year, location and applied water amounts on titratable acidity of Chardonnay (Gonzales and Edna Valley) and Cabernet Sauvignon (Paso Robles).

Site	Year	-----Irrigation Treatment-----				
		0.25	0.5	0.75	1.0	1.25
		-----Titratable Acidity (g L <sup>-1</sup> ) -----				
Gonzales	1998	9.1	10.0	10.2	10.3	10.7
	1999	10.7	11.2	11.6	11.6	12.2
	2000	6.6	7.5	8.0	7.7	8.0
		LSD <sub>0.05</sub> 1998 = 0.3, 1999 = 0.3, 2000 = 0.4				
Edna V.	1998	8.0	8.0	8.1	8.3	8.3
	1999	7.8	8.5	8.9	9.2	9.1
	2000	5.4	5.2	5.4	5.5	5.7
		LSD <sub>0.05</sub> 1998 = ns, 1999 = 0.4, 2000 = 0.4				
Paso R.	1998	7.3	7.3	6.7	7.4	7.0
	1999	6.2	6.8	7.3	7.9	8.1
	2000	5.9	6.3	6.1	6.6	6.6
		LSD <sub>0.05</sub> 1998 = 0.3, 1999 = 0.3, 2000 = 0.5				

The effect of year, location and applied water amounts on yield of Chardonnay (Gonzales and Edna Valley) and Cabernet Sauvignon (Paso Robles).

Site	Year	-----Irrigation Treatment-----				
		0.25	0.5	0.75	1.0	1.25
		-----Yield (kg 3 <sup>-1</sup> vines) -----				
Gonzales	1998	13.4	17.6	17.7	19.3	21.7
	1999	----	----	----	----	----
	2000	12.0	15.2	17.4	17.0	19.5
		LSD <sub>0.05</sub> 1998 = 4.9, 1999 = --, 2000 = 2.0				
Edna V.	1998	25.0	24.7	23.3	25.1	26.2
	1999	16.9	16.3	16.8	19.2	17.9
	2000	24.1	23.6	26.1	25.8	27.4
		LSD <sub>0.05</sub> 1998 = 1.5, 1999 = ns, 2000 = 3.0				
Paso R.	1998	21.5	22.0	22.9	25.1	27.0
	1999	9.0	11.2	14.4	16.3	18.6
	2000	13.4	17.1	22.2	26.6	29.6
		LSD <sub>0.05</sub> 1998 = 1.6, 1999 = 3.4, 2000 = 3.0				

The effect of irrigation amount and canopy management (defoliation in fruiting zone) on anthocyanins of Merlot grown in Madera County

Canopy Man.	--- Irrigation Treatment			Ave. Eff. C.M.
	0.4	0.8	1.2	
	----- (mg cm <sup>-2</sup> skin) -----			
Control	0.723	0.631	0.563	0.639
Set	0.776	0.618	0.584	0.660
Veraison	<u>0.755</u>	<u>0.691</u>	<u>0.656</u>	0.701
Ave. Eff. Irrig.	0.751	0.647	0.601	
<u>LSD<sub>0.05</sub> Irr. = 0.054 CM = ns Interaction = ns</u>				

The effects of irrigation amounts on titratable acidity, pH and color intensity of wine made from Cabernet Sauvignon grapes.

Irrigation Treatment	TA (g L <sup>-1</sup> )	pH	Color Intensity
0.0	5.9	3.83	7.59
0.25	5.4	4.05	8.18
0.5	5.4	4.12	7.52
0.75	5.4	4.16	6.89
1.0	---	4.24	6.33

# Irrigation Management Strategies

- Sustained Deficit Irrigation
- Partial Rootzone Drying
- Regulated Deficit Irrigation
- Allowable depletion of soil water content
- Use of Pre-established values of vine water status

# Partial Rootzone Drying (PRD)

- An irrigation regime whereby vines are watered on one side of the vine (receiving 50%, the water of the control treatment (full ET)) during a two week period and then irrigating the next two weeks on the other side of the vine. During the two week period roots on the other side of the vine would experience water deficits – [Brian Loveys](#)

# Regulated Deficit Irrigation (RDI)

- The practice of purposely creating water deficits during specific times of the season primarily to save water while minimizing or eliminating negative impacts on yield or crop revenue –

David Goldhamer

# Paso Robles Irrigation Strategies

- SuDI – Sustained Deficit Irrigation
- PRD – Partial Rootzone Drying: (sides alternated every 2 weeks)
- RDI – S to V: deficit irrigation at fraction of  $ET_c$  from set to veraison, then  $1.12 ET_c$  from veraison to harvest.
- RDI – V to H: irrigation at  $1.12 ET_c$  from set to veraison and then deficit irrigation at fraction of  $ET_c$  from veraison to harvest.
- Dry Down: water applied every two weeks (approximately 24 gallons per vine)

The effect of irrigation management strategy and irrigation amount on vine water status of Cabernet Sauvignon grown near Paso Robles on August 21, 2002. Measurements were taken between 1400 and 1530 hours.

Irrig. Strategy	Time	-----Irrigation Amount -----				
		0.375	0.56	0.75	1.12	DryDwn
-----Midday leaf water potential (MPa) -----						
SuDI	S - H	-1.31 fg	-1.23 e	-1.12 d	-0.95 a	-1.36 g
PRD	S - H	-1.31 fg	-1.20 e	-1.13 d	--	--
RDI	S - V	-1.04 c	-1.02 bc	-0.96 ab	--	--
RDI	V - H	-1.29 f	-1.21 e	-1.13 d	--	--

Means followed by a different letter are significantly different at the 0.05 level.

The effect of irrigation management strategy and irrigation amount on berry weight and soluble solids of Cabernet Sauvignon grown near Paso Robles during 2002, the first year of the study.

Irrig. Strategy	Time	-----Irrigation Amount -----				
		0.375	0.56	0.75	1.12	Dry Dwn
		-----Berry weight (g 150 <sup>-1</sup> berries) -----				
SuDI	S - H	118	135	156	156	116
PRD	S - H	120	132	150	--	--
RDI	S - V	123	137	157	--	--
RDI	V - H	140	151	155	--	--
		----- Soluble Solids (°Brix) -----				
SuDI	S - H	24.3	24.0	23.1	23.5	23.4
PRD	S - H	23.8	23.7	24.1	--	--
RDI	S - V	23.2	22.9	23.3	--	--
RDI	V - H	24.0	24.1	23.5	--	--

The effect of irrigation management strategy and irrigation amount on yield of Cabernet Sauvignon grown near Paso Robles during 2002, the first year of the study.

<b>Irrig. Strategy</b>	<b>Time</b>	<b>-----Irrigation Amount -----</b>				
		<b>0.375</b>	<b>0.56</b>	<b>0.75</b>	<b>1.12</b>	<b>DryDwn</b>
		<b>-----Yield (lbs 4<sup>-1</sup> vines) -----</b>				
<b>SuDI</b>	<b>S - H</b>	<b>84.5</b>	<b>77.4</b>	<b>98.8</b>	<b>97.0</b>	<b>77.2</b>
<b>PRD</b>	<b>S - H</b>	<b>72.2</b>	<b>77.0</b>	<b>82.5</b>	<b>--</b>	<b>--</b>
<b>RDI</b>	<b>S - V</b>	<b>82.5</b>	<b>90.9</b>	<b>85.6</b>	<b>--</b>	<b>--</b>
<b>RDI</b>	<b>V - H</b>	<b>81.4</b>	<b>80.5</b>	<b>86.2</b>	<b>--</b>	<b>--</b>

Phenolics and anthocyanins of Cabernet franc due to different irrigation treatments (Data of Matthews and Anderson, 1989)

Irrigation Treatment	Juice	Skin	
	Phenolics (mg L <sup>-1</sup> )	Phenolics (mg cm <sup>-2</sup> )	Anthos
Control	149	0.46	0.51
Early Def.	194	0.56	0.61
Late Def.	202	0.52	0.59
Full Def	198	0.57	0.65

Control = grower practice; Early deficit = no water until veraison; Late deficit = no water after veraison; Full deficit = no applied water

## Conclusions:

- One can use several techniques to determine when to start irrigating and/or intervals between irrigation events.
- Deficit irrigation can increase soluble solids in the fruit. Its effect on TA and pH is less clear (it depends upon whether the measurements are made on berries or wine).
- Deficit irrigation's effect on yield is dependent upon timing of deficit, year, and location.
- Is there a superior irrigation management strategy? Further research is necessary.