UC DAVIS VITICULTURE AND ENOLOGY




TRELLIS SYSTEM EVALUATION FOR MECHANIZATION

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Outline

- Our estimate at current mechanization levels
- Labor operations costs associated with mechanizing cultural practices
- What can we currently?
- Mechanization experiment
- Where are we heading?

What is driving mechanization in vineyards?

- **Mechanization**
  - Timeliness of cultural practices
  - Willing labor force
  - Cost of labor ($15/h)
  - Quality of life/socioeconomic factors
  - Proximity to population centers
  - Land availability and cost
  - Foreign competition

Estimated percentage of acres for grape commodities for mechanical cultural practices

	Wine	Raisin	Table
Dormant season			
Pre-prune	65	5	30
Box-hedge	12	None*	None
Canopy Mgt			
Leaf removal	45	None	10
Shoot thinning	7	None	None
Hedging	100	100	100
Shoot positioning	2	None	None
Cluster removal	7	None	None
Harvesting	91	35	None

Labor operations cost for California Sprawl for Cabernet Sauvignon (2012)

Table 5. Labor cost comparison for conventional and mechanical canopy management of 'Cabernet Sauvignon' grapevine in Fresno, CA.

	Cost calculations		
Mangement method[z]	($/h)	(h/acre)[y]	($/acre)[y]
HP			
HP labor	8.50	28.4	241.40
HP follow-up	8.50	7.3	62.05
Benefit rate	33%		100.14
Total			403.59
MP+HT			
Mechanical pruning labor	12.00	1.85	22.20
Manual follow-up labor	8.50	1.20	10.20
Crop estimation labor	12.00	0.34	4.08
Hand shoot thinning labor	8.50	8.43	71.66
Equipment maintenance labor	12.00	0.24	2.88
Benefit rate	33%		36.64
Pruning fuel	1.85 h/acre × 1 gal/h × $4.00/gal		7.40
Total			153.42
MP+MT			
Mechanical pruning labor	12.00	1.85	22.20
Manual follow-up labor	8.50	1.20	10.20
Mechanical crop estimation labor	12.00	0.34	4.08
Mechanical crop thinning labor	12.00	0.9	10.80
Equipment maintenance labor	12.00	0.48	5.76
Benefit rate	33%		17.50
Pruning fuel	1.85 h/acre × 1 gal/h × $4.00/gal		7.40
Thinning fuel	0.9 h/acre × 1 gal/h × $4.00/gal		3.60
Total			81.54

[z]HP = hand pruned to 36–40 buds, MP+HT = mechanically prepruned to an 8-inch (20.4 cm) bearing surface, hand shoot thinning conducted at Eichhorn-Lorenz scale (Coombe, 1995) stage 17 to retain similar number of shoots as HP, MP+MT = mechanically box-pruned to a 4-inch (10.2 cm) bearing surface, mechanical shoot

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Mechanical cultural practices and trellis type adaptability

	California sprawl	VSP	Quadrilateral	Single high wire	Head-trained
Pre-pruning	+++	++++	++	++++	-
Final pruning	++	++	+	++++	-
Shoot thinning	++	++	+	++++	-
Leaf removal	++	++++	++	++++	++
Berry/cluster thinning	++	++	+	++++	-
Trunk suckering	++	+	++	++++	-
Harvest	+++	++++	++	++++	-

Cultural practices that are conducted mechanically

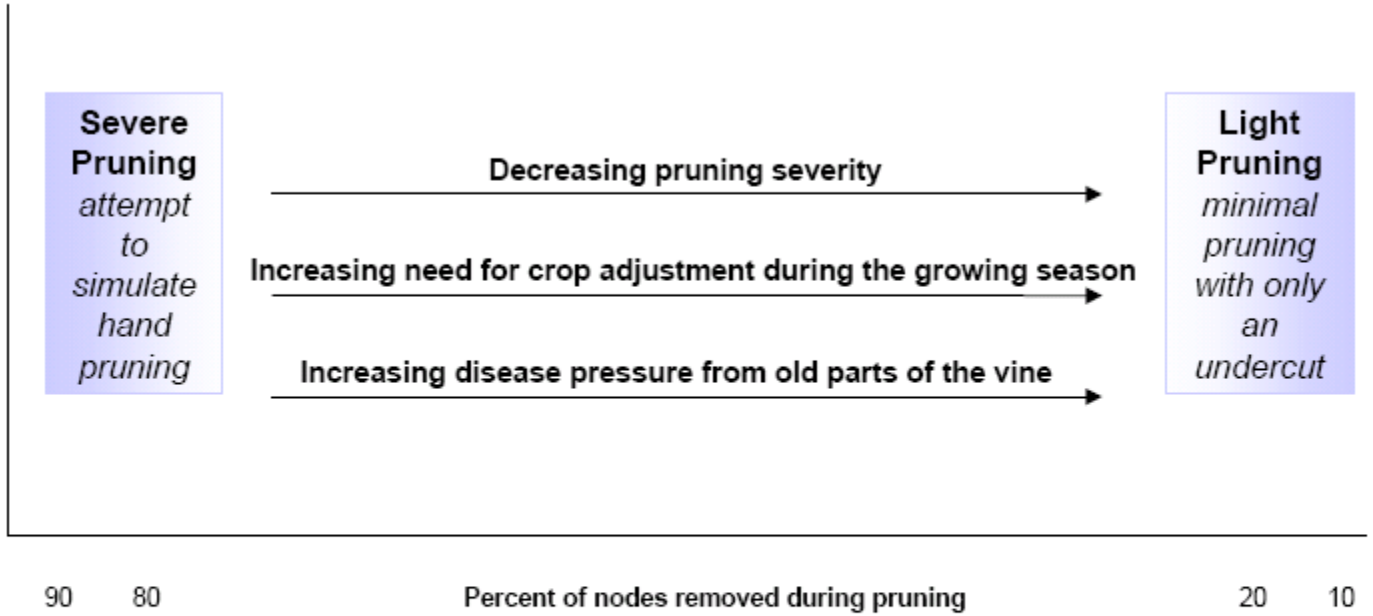
- Dormant pruning
  - Pre-pruning
  - Final pruning
- Suckering
- Shoot removal
- Leaf removal
- Berry/cluster thinning
- Shoot combing
- Hedging/caning
- Harvest **
  - Yield monitoring

Dormant pruning

- When?
  - Depends on where you are
  - Dormant season
  - Incidence of rain
- Severity
  - Defines bearing surface
  - Capacity
- Costs:
  - Spur: $0.29/vine
  - Cane w/ tying: $0.48/vine
  - Mechanical w/ hand follow up: $ 0.36/vine:
  - Box-prune single-high wire: $0.07/vine

Types of equipment available

- **Pre-pr**
  - **Vari**
  - **Vari**
  - **May**
  - **Mos**
  - **Hav**
- **Comb**
  - **Mul**
  - **May**
  - **May**



prawl

Figure 1. Mechanical pruning can be practiced with a wide range of pruning severities, which influence the need for crop adjustment during the growing season and the potential for disease pressure.

Parts c

Shoot thinning

- When?
- During dormant pruning*
- Trunk suckering
  - 1” – 3” shoot length
- Cordon
  - 8” – 12” shoot length
- In FROST PRONE AREAS WAIT TILL ALL DANGER OF FROST HAS PASSED!

- Reduces shoot density, but impact on canopy density is often temporary if irrigation is unchecked
- Efficient method of crop thinning
- Assists in the establishment of spur positions
- Reduces pruning costs next season
- Cost per acre - $80 – $300/acre

Trunk suckering

Canopy shoot thinning application – Manual/Mechanical

How do you set up a mechanical shoot thinner?

- **Consider:**
  - Target shoot density:
    - Count shoots
    - Non-count shoots
  - Cordon brush
  - Rotary paddles
    - 2 to 12 paddles
  - Tractor ground speed
    - 1 to 1.2 miles/h

Effects of shoot density on berry chemistry of Syrah/1103P

Table 6 Effects of mechanical canopy management and timing and severity of regulated deficit irrigation (RDI) on average berry skin phenolics, anthocyanins, and tannins of Syrah/1103P grapevines during harvest at 23 Brix in 2009 and 2010 (n = 48).

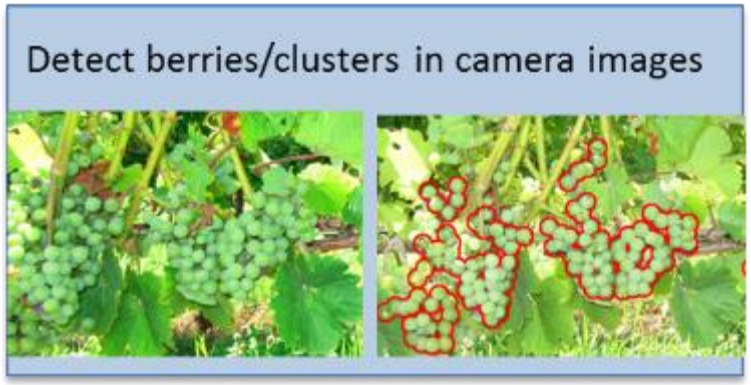
	2009			2010		
	Total phenolics ($\mu g \cdot g^{-1}$)	Anthocyanins ($\mu g \cdot g^{-1}$)	Tannins ($\mu g \cdot g^{-1}$)	Total phenolics ($\mu g \cdot g^{-1}$)	Anthocyanins ($\mu g \cdot g^{-1}$)	Tannins ($\mu g \cdot g^{-1}$)
Canopy						
Hand pruned (HP)	875.9 b[a,b]	496.2 c	417.3 b	685.9 c	527.9	355.3
Crop load low CLL)	973.1 a	560.4 b	463.5 a	795.7 a	552.4	351.9
Crop load mid (CLM)	980.2 a	607.2 a	468.3 a	832.1 a	545.5	400.1
Crop load high (CLH)	954.2 ab	604.2 ab	462.5 a	724.9 b	542.2	363.9
Pr > F	0.0289	0.0471	0.0426	0.0421	0.0501	0.2081
RDI						
Control (RDIC)	909.3 b	365.0 b	398.1	699.7 c	525.1 b	295.3 c
Early (RDIE)	1092.9 a	466.4 a	542.0	826.5 a	570.9 a	408.9 a
Late (RDIL)	864.7 b	268.8 c	449.2	750.9 b	530.8 b	398.4 b
Pr > F	0.0353	0.0356	0.1096	0.0324	0.0120	0.0024
Interaction[c]	0.9921	0.8825	0.8710	0.9096	0.5849	0.9837

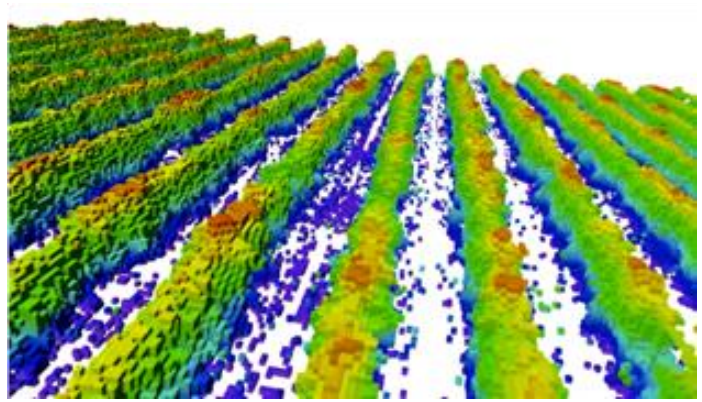
[a]Significance for main and subplot and interaction according to type III tests of fixed effects.
[b]Means separated by a letter are significantly different according to Tukey's HSD test at *Pr > F* 0.05.
[c]Interaction of canopy management x RDI.

Berry/Cluster thinning

- Pre-bloom thinning
- Post fruit set-thinning
  - Rule of thumb for post fruit-set cluster thinning
  - If shoot is < 12” long remove all clusters
  - If shoot 12” – 24 “ long retain one cluster
  - If shoot > 24” long retain 2 clusters
- We are seeing most beneficial responses if applied
  - Berries b-b size
  - Post veraison applications – self gratifying

Variable mechanical cluster thinning





Leaf Removal

- Severity
  - Both sides of the canopy
  - Shade side of the canopy
    - East side if rows N-S *
    - North side if rows E-W
  - Cost
    - $80 to $250/acre depending on
    - Trellis type
    - Hand vs. Machine
    - Timing
    - Canopy density

Types of equipment available

- Suck and cut type leaf removal implements
  - Mostly adapted to VSP trellis
  - Damage to flower cluster and clusters
  - Did not work well in sprawling canopies
- Air-blast type leaf removal implements
  - Mostly adapted to VSP trellis
  - Did not work as well in sprawling canopies
  - Little to no damage to flower cluster and clusters
- Roll-over type leaf removal implements
  - Adapted to VSP, sprawling and split canopy systems
  - Selective
  - Little to no damage to flower cluster and clusters

Leaf removal

Some economic data on mechanical leaf removal

Table 6 Effects of mechanical leaf removal and fractions of crop evapotranspiration application on labor operations cost of canopy management and cost of producing total skin anthocyanins per hectare in northern San Joaquin Valley of California (n = 4).

	Pruning cost ($/ha)	Leaf removal cost ($/ha)	Irrigation applied (ML/ha)	Irrigation water cost ($/ha)	TSA production[a] (g/ha)	TSA unit cost ($/g)
2013						
Control + SDI	748	0	2.37	950	1,086 c[b]	1.56 a
Control + RDI	748	0	2.03	827	1,718 b	0.92 bc
Prebloom + SDI	748	30	2.37	950	1,976 a	0.87 c
Prebloom + RDI	748	30	2.03	827	1,958 a	0.82 c
Post fruit-set + SDI	748	30	2.37	950	1,589 b	1.09 b
Post fruit-set + RDI	748	30	2.03	827	1,799 ab	0.89 c
Pr > F	–	–	–	–	0.0001	0.0001
2014						
Control + SDI	748	0	3.08	1,235	1,079 c	1.84 a
Control + RDI	748	0	2.60	1,029	1,261 b	1.41 b
Prebloom + SDI	748	30	3.08	1,235	1,657 a	1.21 c
Prebloom + RDI	748	30	2.60	1,029	1,552 a	1.16 c
Post fruit-set + SDI	748	30	3.08	1,235	1,062 c	1.90 a
Post fruit-set + RDI	748	30	2.60	1,029	1,181 b	1.53 b
Pr > F	–	–	–	–	0.0001	0.0001

[a]TSA: total skin anthocyanin (g) produced per hectare.
[b]Columns followed by a different letter are significantly different according to Tukey's HSD test at *Pr > F* 0.05.

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Cook et al. 2015

Leaf removal

Pre-bloom

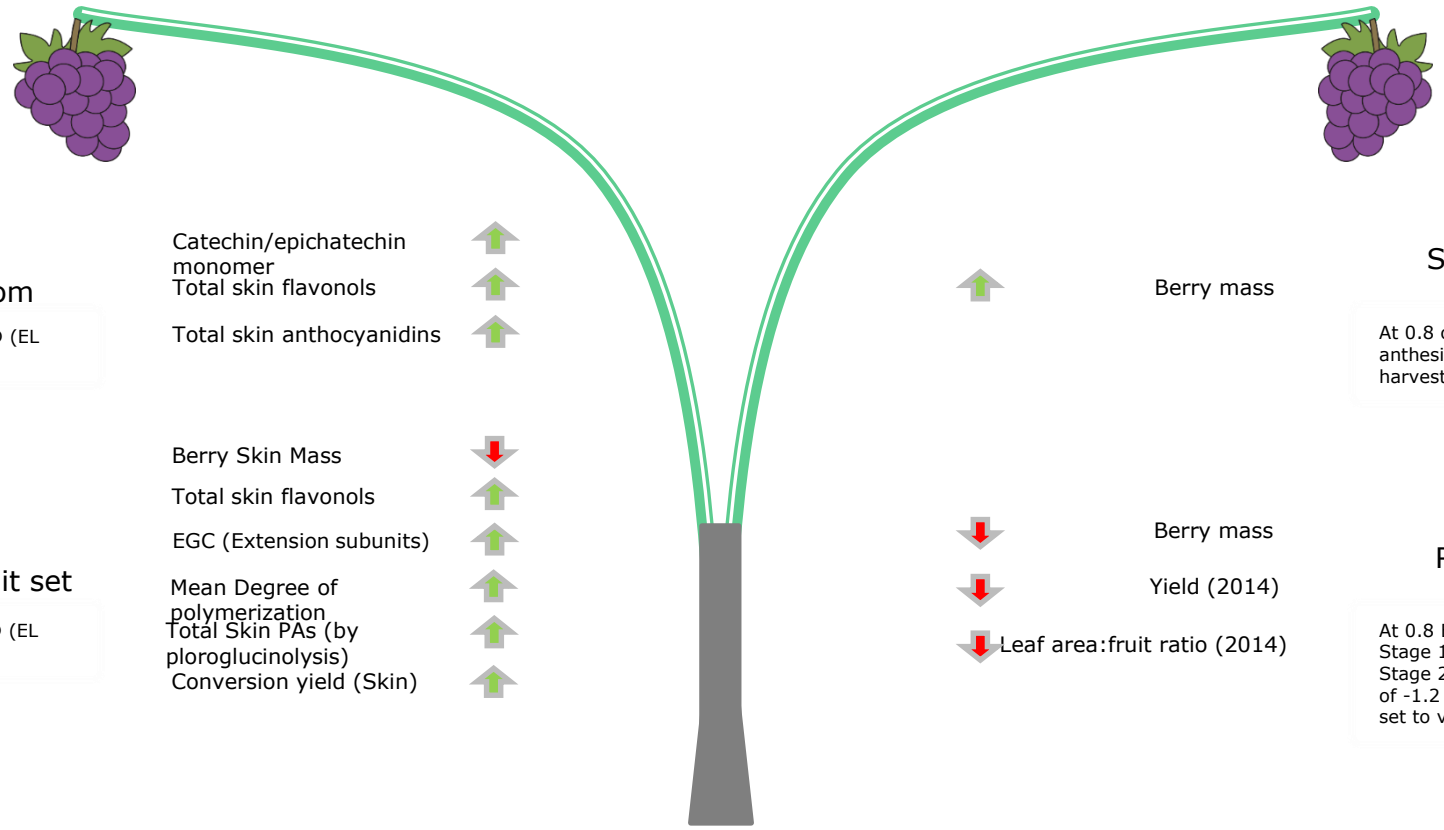
At 200 GDD (EL stage 17)

- Catechin/epichatechin monomer ↑
- Total skin flavonols ↑
- Total skin anthocyanidins ↑

Post-fruit set

At 644 GDD (EL stage 19)

- Berry Skin Mass ↓
- Total skin flavonols ↑
- EGC (Extension subunits) ↑
- Mean Degree of polymerization ↑
- Total Skin PAs (by ploroglucinolysis) ↑
- Conversion yield (Skin) ↑



Water deficits

Sustained Deficit Irrigation

At 0.8 of estimated ET_c from anthesis (EL-Stage 19) until harvest (EL-Stage 38)

- Berry mass ↑

Regulated Deficit Irrigation

At 0.8 ET_c from anthesis (EL-Stage 19) to fruit set (EL-Stage 28) with a Y_l threshold of -1.2 MPa, 0.5 ET_c from fruit set to veraison (EL-Stage 35)

- Berry mass ↓
- Yield (2014) ↓
- Leaf area:fruit ratio (2014) ↓

EVALUATION OF TRELLIS SYSTEMS AND APPLIED WATER AMOUNTS ON ZINFANDEL IN WARM CLIMATE

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Background

- Zinfandel
  - Still economically important
  - Propensity to develop tight clusters
  - Propensity for summer rots, cracking
  - Commercial clones have trouble developing cultivar characteristics
- Viticulture in the warm climate
  - High evaporative demand
    - Cons: Irrigation is needed
    - Pros: Ability to manipulate rate of shoot growth through irrigation schedules
  - Mutual shading
    - Greater vigor when sunlight and irrigation are not limiting
  - Degradation of flavonoids
    - Higher temperatures and heat spikes in our region

Objectives

- **Trellis systems and applied water amounts**
  - Canopy architecture
  - Components of yield
  - Leaf area to fruit ratio
  - Berry composition
  - Flavonoid composition
  - Water footprint

Experiment set-up

- **Trellis systems**
  - MP: Mechanically box-pruned to 4” hedge SHW
  - HP: Spur-pruned to 22 positions of CA Sprawl
  - CP: Split-canopy, cane pruned to 6, eight-bud canes
- **Applied water amounts**
  - Sustained deficit: -12 bars from fruit-set to leaf fall
  - Regulated deficit: Alternate:
    - -12 bars Budbreak-Fruit set
    - -14 bars Fruit set – Veraison
    - -12 bars Veraison-Leaf fall

MP: Box-pruned system

- Box-pruned to 4” hedge
- ~ 55 buds/m
- No further management

HP: Spur-pruned

- Spur-pruned
  - 22, two bud spurs
- No further manipulation

CP: Cane-pruned split canopy

- Cane-pruned
  - 6, eight bud canes
  - Canopy split by 12” cross arm
  - No further manipulation

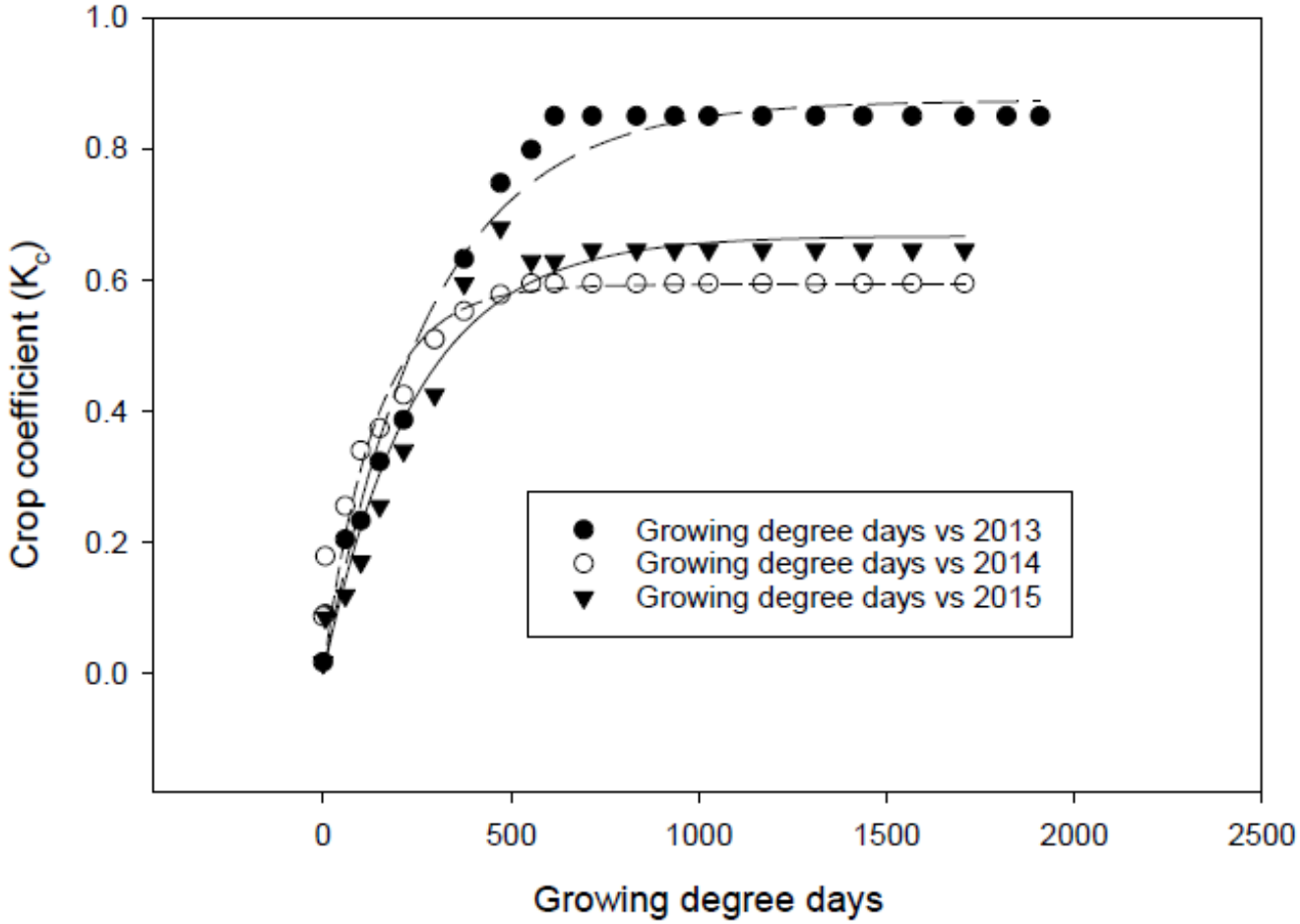
Applied water

- **Sustained deficit**
  - 80% of ET crop
  - Bloom to leaf fall
  - Target LWP -12 bars

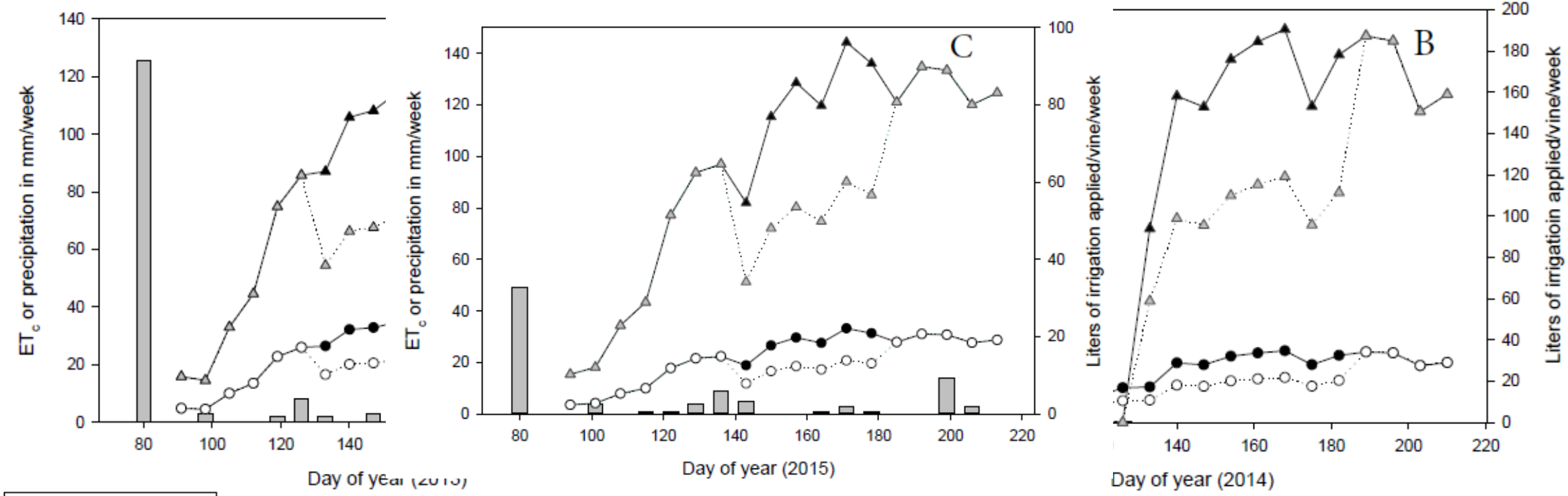
- **Regulated deficit**
  - 80% off ET crop
  - Bloom to fruit set
    - LWP -12 bars
  - 50% of ET crop
  - Fruit set to veraison
    - LWP -14 bars
  - 80% of ET crop
  - Veraison to leaf fall
    - LWP -12 bars

RESULTS

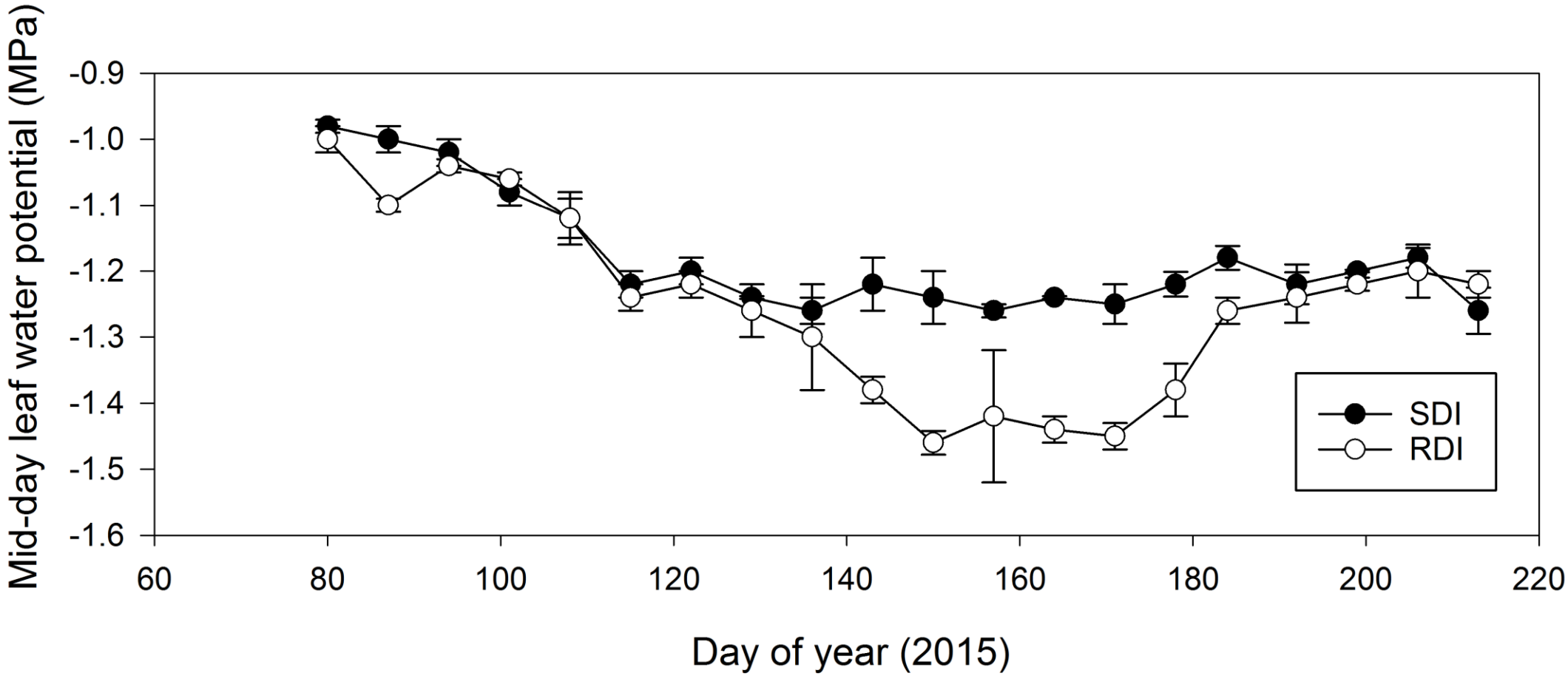
Crop coefficient 2013-2015



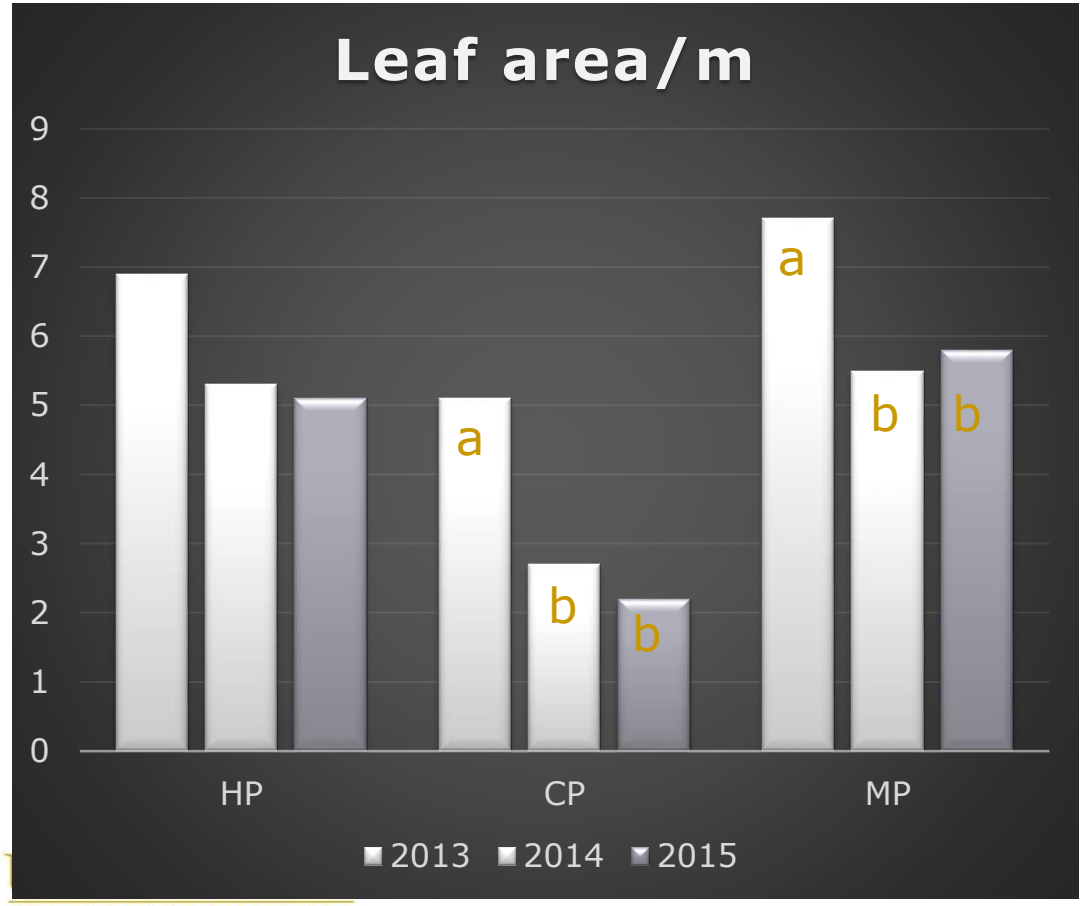
Precipitation, crop evapotranspiration, applied water amounts

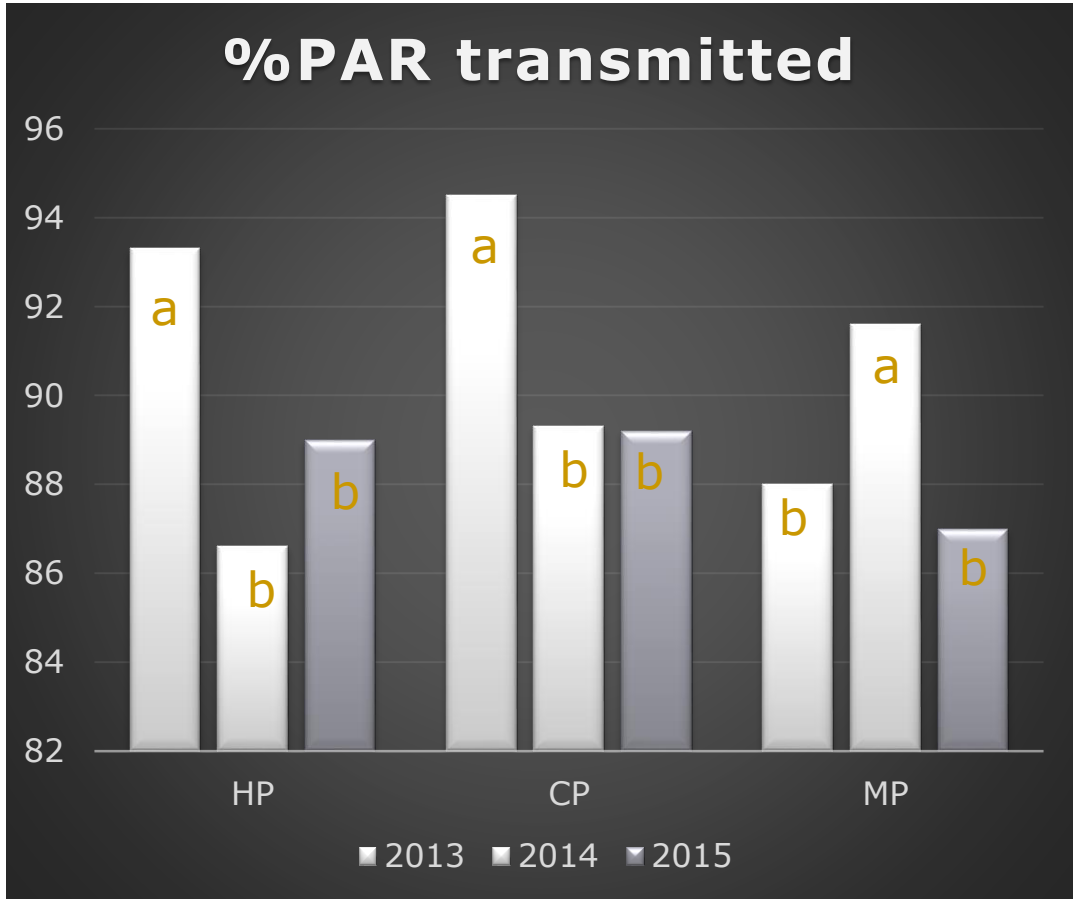


Plant response to applied water

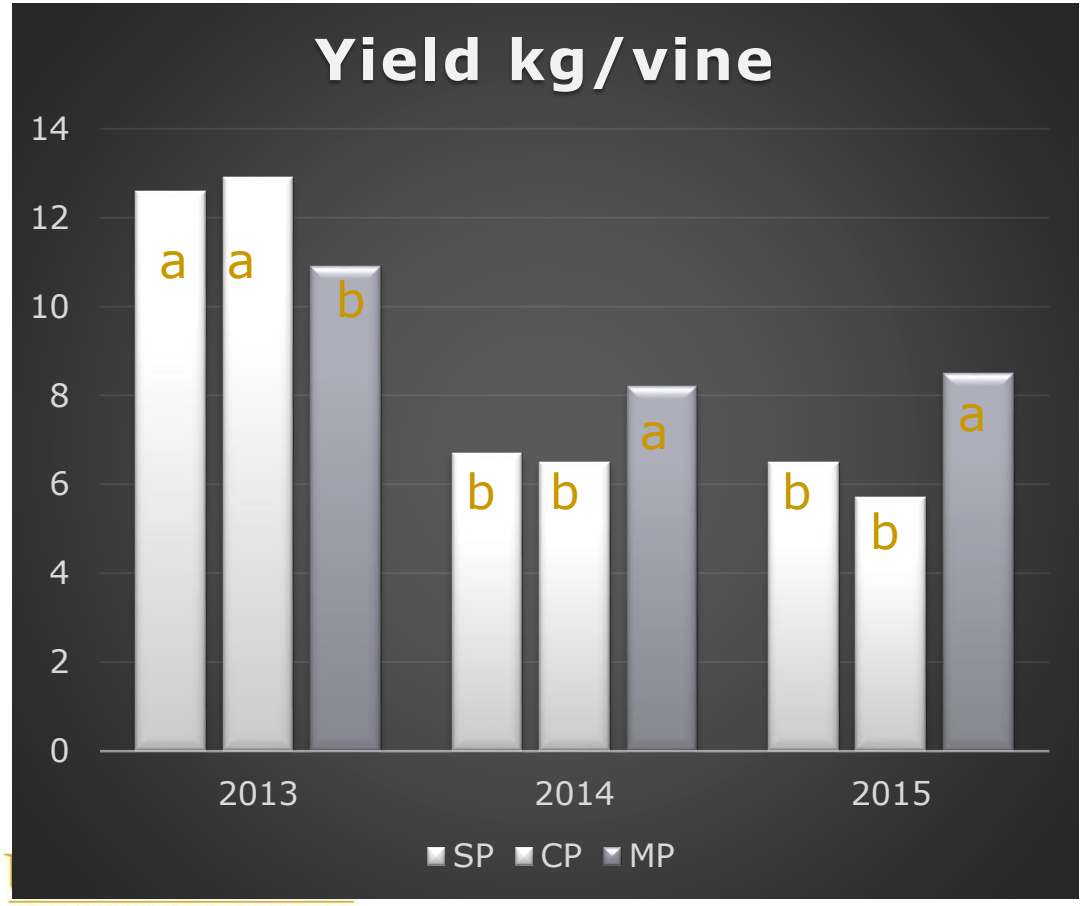


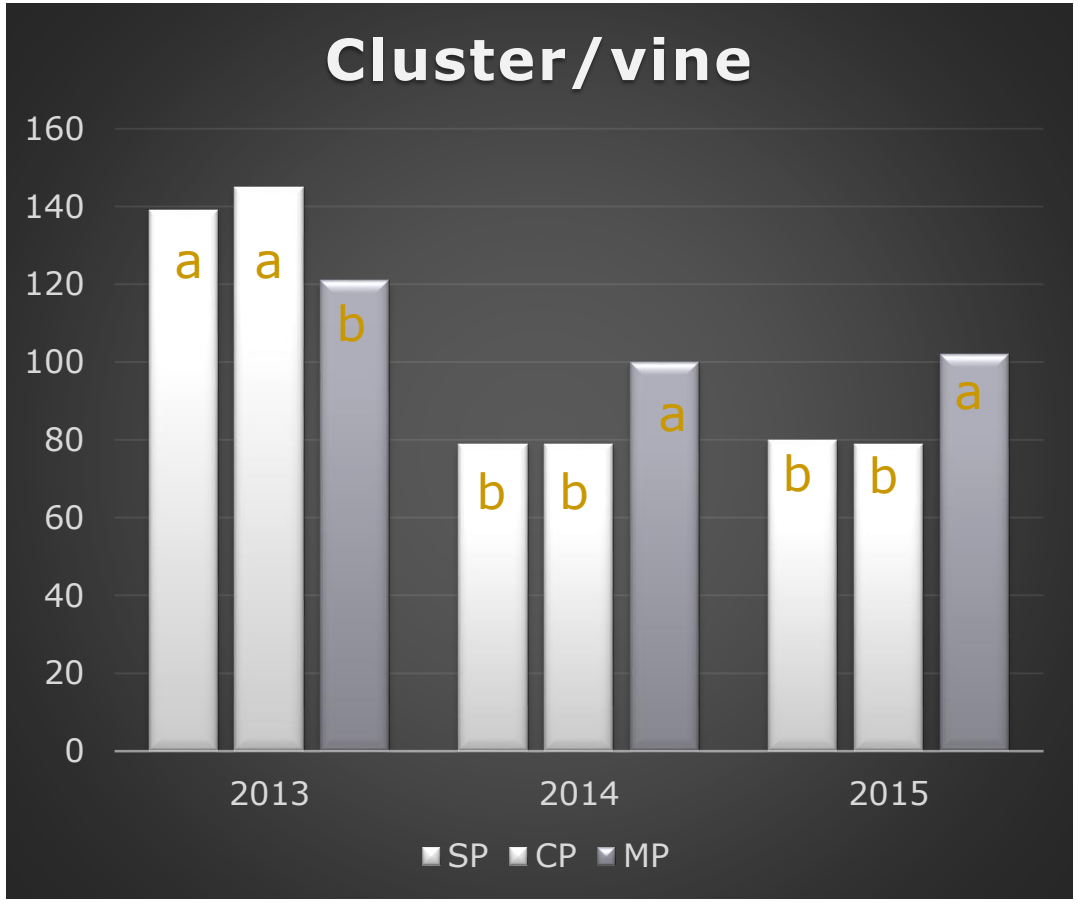
Canopy architecture and microclimate



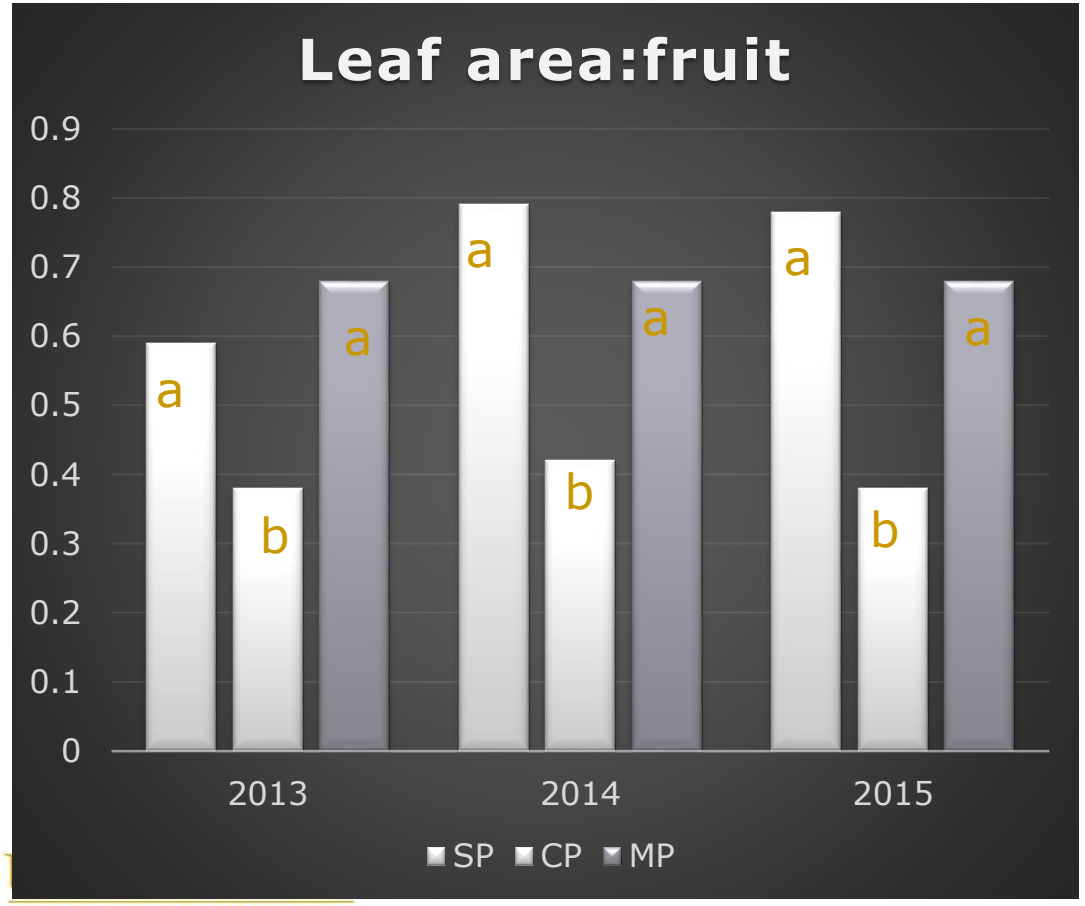


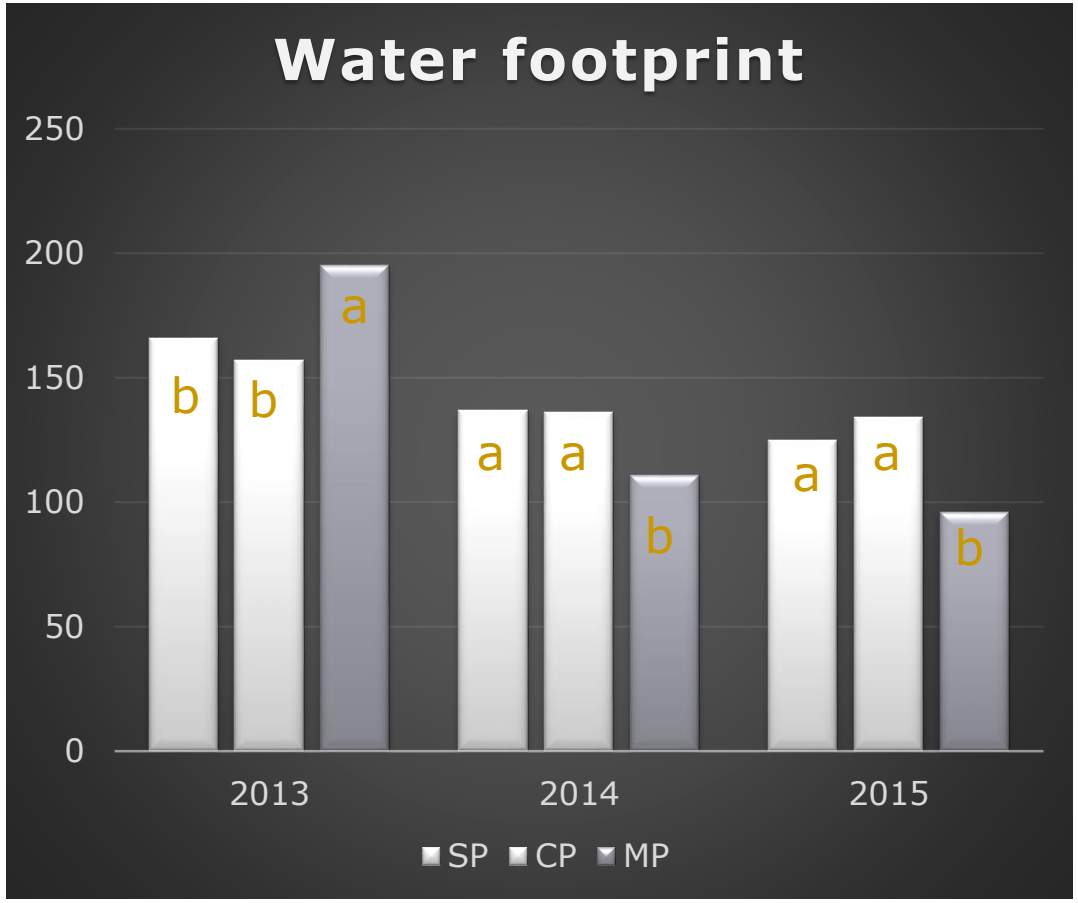
Components of yield





Leaf area to fruit ratio and water footprint





Berry composition at harvest

	Brix	Juice pH[w]	TA (g/L)[v]
Production system		**2013**	
SP	19.1 b[a]	3.48 b	6.63 a
CP	19.7 ab	3.53 a	5.65 b
MP	20.1 a	3.52 ab	6.24 ab
Pr>F	0.0121	0.0188	0.0161
Applied water[y]			
SDI	19.6	3.44 b	6.55 a
RDI	19.7	3.57 a	5.80 b
Pr>F	0.6772	<0.0001	0.0087
Production system × irrigation (*Pr>F*)	0.3170	0.6362	0.0253
Production system		**2014**	
SP	20.5	3.69	5.95
CP	20.1	3.68	6.05
MP	19.8	3.66	6.05
Pr>F	0.2855	0.7540	0.9238
Applied water			
SDI	19.9	3.61 b	6.25 a
RDI	20.3	3.74 a	5.75 b
Pr>F	0.2445	<0.0001	0.0360
Productionsystem × irrigation (*Pr>F*)	0.7858	0.8950	0.1477
Production system		**2015**	
SP	20.0	3.71	5.98
CP	20.6	3.69	6.02
MP	19.9	3.66	6.03
Pr>F	0.8523	0.2149	0.1259
Applied water			
SDI	20.2	3.69	6.31 a
RDI	20.0	3.70	5.88 b
Pr>F	0.5468	0.5412	0.0215
Production system × irrigation (*Pr>F*)	0.3645	0.2657	0.2147

	Di-hydroxylated		Tri-hydroxylated			3-Acetyl-glucosides				3-Coumaryl-glucosides		Total anthocyanins
	cy-3-g[a]	po-3-g	dp-3-g	pe-3-g	mv-3-g	cy-3-ga	po-3-ga	pe-3-ga	mv-3-ga	pe-3-gc	mv-3-gc	
Production system						**2013**						
SP	7.7	47.8	31.7 a[b]	62.0 a	823.8	7.8	35.5 b	131.9	45.3 a	33.3 a	801.6 a	2025.6 a
CP	5.0	41.9	13.2 b	35.6 b	678.1	6.4	85.5 a	103.6	30.7 b	20.7 b	533.1 b	1553.8 ab
MP	5.4	33.5	10.3 b	31.0 b	611.4	6.4	80.8 a	87.3	23.4 c	13.0 c	382.3 c	1283.8 b
Pr>F	0.1012	0.0954	0.0011	0.0107	0.2663	0.5537	0.0282	0.1344	0.0320	0.0088	0.0087	0.0510
Water application												
SDI	6.8	46.3	19.8	47.5 a	779.0	7.2	71.1	100.5	32.5	19.5	558.0	1688.2
RDI	5.1	36.4	17.5	38.9 b	636.9	6.6	62.9	115.2	33.5	25.4	594.3	1572.8
Pr>F	0.0612	0.1145	0.1790	0.0037	0.1542	0.4803	0.6253	0.6307	0.9561	0.7294	0.7317	0.4407
Production system × irrigation (*Pr>F*)	0.7038	0.6312	0.5158	0.5560	0.7400	0.5833	0.7401	0.8349	0.7023	0.7119	0.4167	0.7179
Productions system						**2014**						
SP	7.3 ab	45.2 b	37.6 b	68.2 b	612.2 b	4.8 b	27.7 ab	70.8 b	19.5 b	18.9 b	236.9 b	1148.4 b
CP	6.4 b	41.3 b	37.3 b	66.7 b	574.4 b	4.1 b	24.6 b	46.2 c	18.9 b	19.9 b	237.3 b	1122.3 b
MP	9.1 a	57.8 a	54.5 a	95.0 a	745.3 a	6.5 a	31.5 a	99.3 a	26.5 a	39.1 a	326.9 a	1529.9 a
Pr>F	0.0253	0.0176	0.0236	0.0461	0.0334	0.0096	0.0449	0.0053	0.0438	0.0004	0.0419	0.0038
Water application												
SDI	7.9	49.2	41.0	73.0	593.1 b	4.6 b	26.8	71.8 b	19.9	24.7	253.9	1192.1
RDI	7.3	46.9	45.3	80.2	694.7 a	5.6 a	28.4	85.7 a	23.3	27.2	280.1	1341.4
Pr>F	0.8828	0.9624	0.1453	0.1594	0.0328	0.0379	0.6164	0.0443	0.1035	0.3678	0.1878	0.1582
Production system × irrigation (*Pr>F*)	0.8025	0.8921	0.7853	0.7689	0.7707	0.3206	0.4256	0.3195	0.4265	0.8930	0.5017	0.8461
Productions system						**2015**						
SP	8.1 ab	47.5 b	38.5 b	68.2 b	579.4 b	5.1 b	25.8 b	70.8 b	21.0 b	19.9 b	244.9 b	1129.2 b
CP	7.3 b	43.1 b	35.3 b	66.7 b	575.1 b	3.8 b	23.7 b	46.2 c	19.1 b	20.7 b	221.3 b	1062.3 b
MP	9.8 a	59.1 a	56.1 a	95.0 a	781.3 a	6.7 a	31.3 a	99.3 a	25.7 a	37.1 a	331.8 a	1533.2 a
Pr>F	0.0513	0.0101	0.0316	0.0122	0.0034	0.0061	0.0037	0.0366	0.0310	0.0001	0.0419	0.0001
Water application												
SDI	8.1	47.5	39.1	69.0	589.2 b	4.6 b	24.7	72.4 b	25.4	27.1	247.1	1154.2
RDI	7.4	48.3	42.7	77.1	678.7 a	5.6 a	29.1	87.7 a	27.7	28.6	260.8	1293.7
Pr>F	0.5523	0.2654	0.5514	0.2348	0.0248	0.0379	0.1462	0.0319	0.3124	0.4755	0.5349	0.0621
Production system × irrigation (*Pr>F*)	0.2514	0.5121	0.5631	0.8151	0.1507	0.3206	0.5246	0.1358	0.6531	0.3961	0.7127	0.5412
Year (*Pr>F*)	0.0325	0.0643	<0.0001	<0.0001	0.8134	0.0861	0.0025	0.0312	0.0020	0.2084	<0.0001	0.0206
Year × production(*Pr>F*)	0.5213	0.2536	0.0134	0.0435	0.1982	0.6160	0.2061	0.1207	0.0121	0.0307	0.0099	0.0444
Year × irrigation (*Pr>F*)	0.2141	0.1434	0.2646	0.1312	0.1318	0.2523	0.2459	0.9457	0.7375	0.9908	0.9440	0.6855
Year × production× irrigation (*Pr>F*)	0.9602	0.9274	0.8081	0.9311	0.9986	0.6288	0.3765	0.9677	0.7976	0.8875	0.7995	0.9176

	Flavan-3-ols		Total flavonols	Total tannins
	(+)-catechin	(-)-epicatechin		
Production system			**2013**	
SP	39.2 a	56.2 a[x]	91.3 a	48 a
CP	21.5 b	40.6 ab	69.3 b	32 b
MP	19.5 b	29.8 b	64.9 b	27 b
Pr>F	0.0036	0.0464	0.0031	<0.0001
Water application[y]				
SDI	21.9	43.5	74.5	59
RDI	31.7	41.5	76.1	65
Pr>F	0.1106	0.5373	0.8829	0.6316
Production system × irrigation (*Pr>F*)	0.7816	0.6131	0.7927	0.8373
Production system			**2014**	
SP	31.9 b	82.9	37.5 b	40 a
CP	27.7 b	79.6	33.8 b	31 b
MP	38.2 a	107.9	52.4 a	43 a
Pr>F	0.0033	0.1714	0.0003	0.0284
Water application				
SDI	27.3 b	87.6	38.6	35 b
RDI	37.9 a	92.7	43.9	42 a
Pr>F	<0.0001	0.7044	0.1568	0.0525
Production system × irrigation (*Pr>F*)	0.0532	0.6980	0.2111	0.8871
Production system			**2015**	
SP	32.1 b	84.1	39.1 b	39 b
CP	30.6 b	77.4	34.3 b	33 b
MP	40.2 a	101.2	55.1 a	45 a
Pr>F	0.0001	0.2531	0.0001	0.0001
Water application				
SDI	29.4 b	88.6	37.5	38 b
RDI	35.8 a	91.4	44.1	42 a
Pr>F	0.0001	0.2547	0.9874	0.0351
Production system × irrigation	0.2569	0.4231	0.2641	0.1123
Year (*Pr>F*)	0.0572	<0.0001	0.0006	<0.0001
Year × production (*Pr>F*)	0.0160	0.1738	0.2982	<0.0001
Year × irrigation (*Pr>F*)	0.9395	0.4527	0.7855	0.7205
Year × production × irrigation (*Pr>F*)	0.7148	0.7354	0.6814	0.9614

Discussion

- Weather and irrigation
  - Precipitation regime compared to 10-yr average
  - 2013: 87%
  - 2014: 30%
  - 2015: 23%
- Affect on estimated crop coefficient
  - 2013: 0.85
  - 2014: 0.60
  - 2015: 0.64
- Affect on estimated crop evapotranspiration
  - Likewise crop evapotranspiration declined

Discussion

- **Exposed leaf area**
  - More stable with MP
  - Large variation and decline with CP, possibly due to multiple years of drought
- **Leaf area to fruit ratio**
  - More stable with MP
  - Only treatment approaching optimum leaf area to fruit ratio

Discussion

- **Components of yield**
  - Cluster numbers decline through the experiment
    - SP
    - CP
      - Possibly due to drought carry over effect
  - Yield per vine
    - Yield per vine declined through the experiment
      - MP most stable yielding, least decline over years due to buffering capacity
  - Water footprint
    - Good reflection of the environment x treatment interaction
    - As drought intensified, SP and CP water footprint increased due to lower yield
    - MP water foot print decreased to similar yield with a normal rain year (2013)

Berry composition and flavonoids

- Brix, pH, TA
  - Some statistical differences, but are they viticulturally significant?
- Flavonoids by class
  - Anthocyanins
    - Degradation over years, almost halved for SP
    - MP most stable and greatest in year 2 and 3
  - Flavonols
    - Anthocyanin homologues
    - MP most stable and greatest in year 2 and 3
  - Tannins
    - Reflected similar results to anthocyanins and flavonols

Conclusions

- Water availability conditioned the effectiveness of the different production systems.
- As long as these were plentiful, SP and CP grapevines had the greatest yields and concentration of phenolic compounds.
- When there were fewer precipitation events, as we can expect in the future, MP grapevines had clusters of a similar size as the SP and CP systems that led to higher yields.
- Overall plant fitness (greater leaf area and yield) was frequently associated to improved berry skin composition, rather than lower yields or water stress.
- The results of this study provided evidence that MP can be used to achieve higher yields and improved berry composition under low water resources, but also to achieve more consistent yields and berry composition regardless of water availability.

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QUESTIONS?