PROJECT NO.: CH-02-201 FINAL

TITLE: Alternative Water Management Strategies for Sweet Cherries

PERSONNEL:
Principal Investigators: Matthew Whiting, Assistant Horticult., WSU-IAREC
Roberto Núñez-Elisea, Horticult., OSU-MCAREC

Cooperators: Jim McFerson, WTFRC, Wenatchee
Horst Caspari, Colorado St. U.
Denny Hayden, Pasco

YR INITIATED: 2002 **CURRENT YR:** 2004 **TERMINATING YR:** 2004

OBJECTIVE:

- Elucidate the effects of season-long deficit irrigation and partial rootzone drying on sweet cherry vegetative growth, fruit quality, and leaf and whole-canopy transpiration and carbon assimilation.

SIGNIFICANT FINDINGS:

- across rootstocks, neither deficit irrigation strategy significantly affected fruit quality compared to the control (*i.e.*, similar quality fruit were grown using less water)
- PRD provided significant vigor control of Mazzard- and Gisela 5-rooted trees, but not for trees on Gisela 6
- Gisela rootstocks are no more/less susceptible to water stress than Mazzard
- irrigation treatment did not affect trunk expansion of any treatment/rootstock combination
- PRD produced better quality fruit compared to DI in 2 of 3 years
- fruit and shoot growth rates were affected inconsistently and only slightly by reduced water input
- components of gas exchange (*i.e.*, net photosynthesis, transpiration, stomatal conductance) were unaffected by irrigation treatment
- DI-treated trees exhibited premature leaf senescence compared to control and PRD which were similar
- shoot leaves senesced prior to spur leaves
- among rootstocks, Gisela 5 trees senesced earliest
- leaf 'greenness' *(i.e.*, SPAD meter readings, related to leaf N) varied seasonally and was highest from control, intermediate for PRD, and lowest for DI
- stem water potential declined throughout the season irrespective of irrigation treatment
- stem water potential was highest in control, and lowest for DI but never varied by more than 0.4 MPa among treatments

- for PRD, alternating between rootzones was necessary every 2 – 3 weeks

METHODS:

The effects of two season-long, reduced-input irrigation strategies (deficit irrigation and partial root zone drying) will be investigated. Experiments will be conducted on mature bearing ‘Bing’ cherry trees at the WSU-Roza experimental orchards, the MCAREC orchards in Hood River, and at grower-collaborator orchards (as identified) in subsequent years.

WSU-ROZA trial:

All treatments will be applied at weekly intervals by under-tree microsprinklers (1/tree).

Control: Water sufficient to replace 100% of that lost by evapotranspiration (Et) will be applied to the entire rootzone. Et is calculated using the Washington Irrigation Scheduling Expert (W.I.S.E.).

Deficit irrigation (DI): Irrigation water will be applied to the entire rootzone but at 50% Et replacement.

Partial root zone drying(PRD): Irrigation water will be applied at 50% Et replacement but only to one half of each tree’s root zone (i.e., alleyway) during each irrigation event. Subsequent irrigation events will alternate between root zone halves.

The following data will be collected from treated and control trees at regular intervals throughout the duration of the experiments:

- trunk-cross sectional area, shoot length, leaf area (spur and shoot), leaf water potential, fruit diameter, soil water content

Total water application will be compared among treatments by timing irrigation events. At harvest, tree yield and fruit quality (weight, size, soluble solids, and firmness), will be determined from each tree.

In addition, gas exchange (transpiration and net photosynthesis) within selected trees will be determined. Trials will be continued in subsequent years to examine carryover effects of reduced water inputs.

RESULTS AND DISCUSSION:

In 2004, soil water content was similar among treatments and high during the preharvest interval (Fig. 1). This is due to several natural rain events that occurred during May and

June. As a result, significant water stress was likely not imposed by either deficit treatment. In fact, mean soil water content during the preharvest interval was

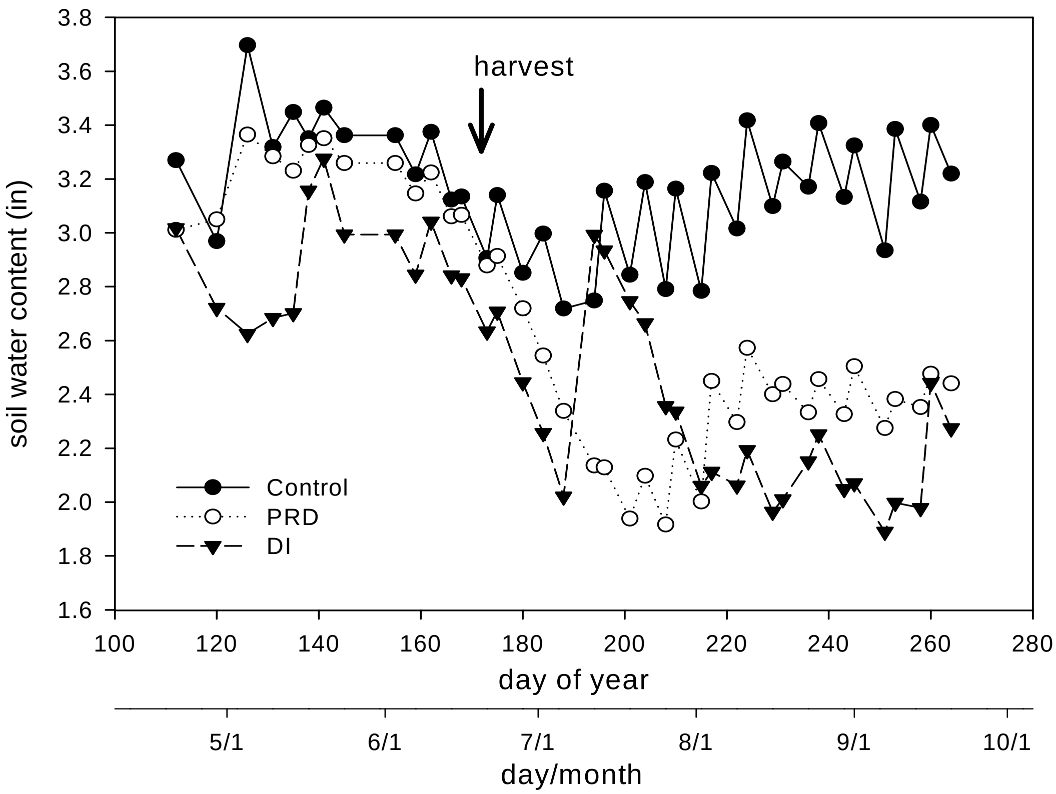

Figure 1. Effect of irrigation regime on the seasonal trend in average soil water content (full profile).

approximately 3.3″, 2.9″, and 3.2″ for control, DI, and PRD, respectively. High water content of spring soils (essentially saturated due to frost-protection with water), low orchard evapotranspiration during April – early June, and the short interval between bloom and harvest each make a deficit situation difficult to impose. Future trials should more aggressively reduce water inputs during the preharvest interval to study the tree's response. Following harvest, during periods of greater evapotranspiration without rain, soil water content of DI and PRD declined rapidly. During the postharvest interval, mean soil water content of control was maintained within ca. 75% of field capacity and was approximately 3.1″. In contrast, mean soil water content of DI and PRD were about 25% lower at 2.3″, during the same period. From early August on, soil water content of the PRD treatment was about 10% higher than that of the DI treatment, despite similar volumes of water applied during the period. This is likely due to greater evaporation from the soil surface of DI – water was applied to twice the surface area for DI compared to PRD. This suggests that the PRD technique may improve water use efficiency compared to DI, though this was not determined explicitly.

Similar to results from previous years, across rootstock, fruit quality was not affected significantly by irrigation treatment (Tables 1 & 2, Figure 2). In 2003, fruit soluble solids were highest from control trees and lowest from DI trees, but all were at commercially acceptable levels. Fruit mass was unaffected by irrigation treatment in every year. However, in 2003, fruit yield per tree was reduced significantly (*ca*. 45%) by deficit irrigation, irrespective of the placement of water. This may have resulted from reduced flower bud induction during 2002 or reduced fruit set or increased fruit drop in 2003. In the case of DI, it is possible that reduced postharvest photosynthetic rates limited carbohydrate availability and reduced flower bud quality in 2002. Similar results were not found in 2004, as yields among treatments were within 3 kg. In 2004 PRD-treated trees yielded slightly (≈10%) firmer fruit than DI and C – this improvement in firmness was not apparent previously. Overall, there has been no consistent effect of irrigation regime on fruit quality; only subtle effects in certain years.

Treatment	Tree yield (kg)	Fruit Mass (g)	Soluble solids (%)	Firmness (g/mm)
2002				
Control	21.5 a	6.3 a	19.8 a	288 a
DI	22.2 a	6.4 a	20.6 a	288 a
PRD	23.1 a	5.8 a	20.7 a	268 a
2003				
Control	31.5 a	6.7 a	25.4 a	327 a
DI	16.8 b	6.8 a	21.1 c	338 a
PRD	18.4 b	7.5 a	22.8 b	328 a
2004				
Control	11.2 a	7.4 a	23.6 a	242 b
DI	13.9 a	7.0 a	24.1 a	239 b
PRD	11.0 a	7.0 a	24.4 a	263 a

Table 1. Effect of deficit irrigation (DI) and partial rootzone drying (PRD) on yield and fruit quality of 8-, 9-, and 10-year-old ‘Bing’ sweet cherry trees. Data is averaged across all rootstocks (Mazzard, Gisela 5 and Gisela 6). Means followed by the same letter within columns and year are not significantly different by LSD ($P < 0.05$).

In 2004, irrigation treatment had subtle effects on yield per row size category (Fig. 2). DI had a slight negative impact on fruit quality of ‘Gisela 5’ and ‘Gisela 6’-rooted trees. On ‘Gisela 5’, DI trees yielded about 8-fold more cull fruit (i.e., smaller than 12-row) and about half the premium size fruit compared to PRD or control. On ‘Gisela 6’, DI trees yielded about 30% (≈ 8.2 lbs) fewer 10.5-row and larger fruit and about 50% fewer (≈ 10.5 lbs) fruit in the 11 and 12-row size category per tree compared to PRD and control. There were no significant effects of irrigation on fruit yield and quality of Mazzard-rooted trees though PRD trees yielded about 40% more fruit in the largest category.

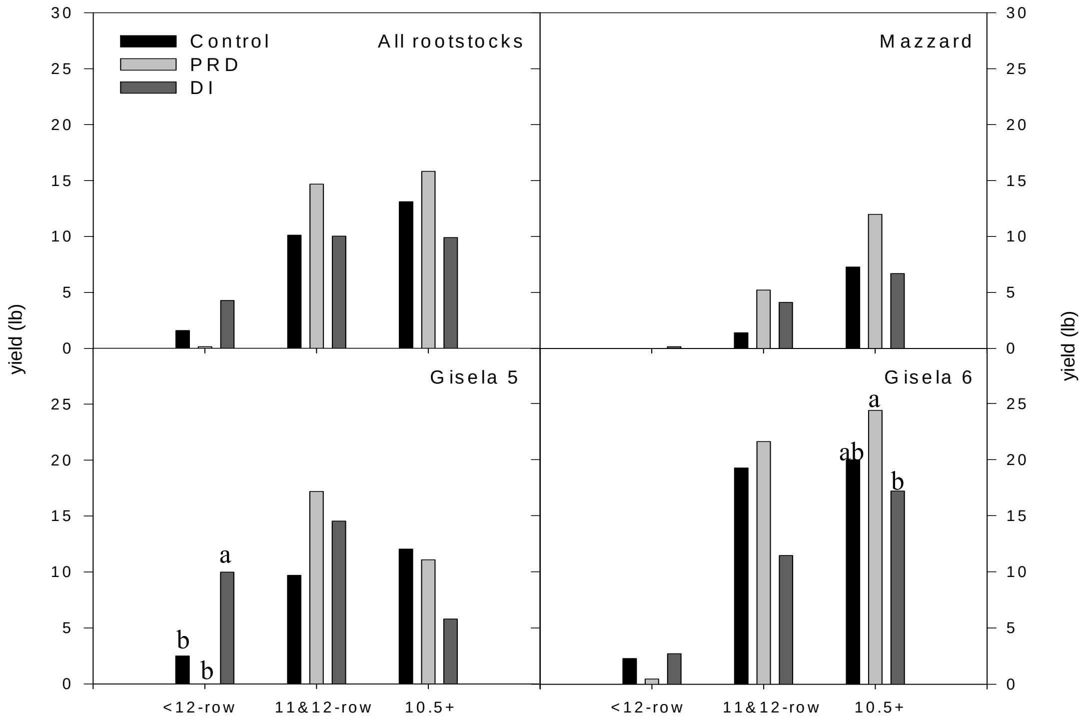

Figure 2. Fruit yield and row size of 10-year-old 'Bing' sweet cherry trees grown on 3 rootstocks (Gisela 5, Gisela 6, and Mazzard) and under 3 irrigation regimes (control, deficit irrigation (DI), and partial rootzone drying (PRD)). Bars with different letters are statistically different ($P < 0.05$).

Interestingly, in 2003 there were significant interactions between rootstock and irrigation regime that did not manifest in 2002 or 2004. Mazzard-rooted trees subjected to deficit irrigation exhibited reductions in yield *and* fruit quality. In 2003 and compared to the control, Mazzard trees subjected to DI had 60% lower yields and PRD had 66% lower yields. In addition, compared to the control trees, DI and PRD produced only about one-quarter and one-third the yield of premium quality fruit, respectively. In contrast, Gisela 5 and 6-rooted trees subjected to deficit irrigation exhibited yield reductions but improved fruit quality compared to the control. In 2003, DI reduced yield by 42% and PRD reduced yield by 31%, compared to the control. However, the yield of premium quality fruit from DI was over 5-fold greater and 8-fold greater from PRD and both deficit treatments nearly eliminated the production of cull fruit (*i.e.*, smaller than 12-row). This response was not seen in 2004.

SPAD meter readings are interpreted as a general indication of leaf health because they are related to leaf nitrogen/chlorophyll content. In 2003/4 we found that leaf SPAD meter readings varied seasonally, increasing from shortly after bloom, peaking near day 170 (19 June), and declining thereafter at a fairly steady rate. On all but one sample date (4 June) control was significantly higher than DI. Early in the season, DI and PRD were similar and generally lower than the control. Later in the season, DI SPAD meter readings were significantly lower than PRD indicating a higher degree of stress in DI trees. In addition, the late-season decline in readings from control and PRD leaves appear to be occurring at a lower rate compared to DI. However, the physiological significance of different SPAD meter readings was not apparent.

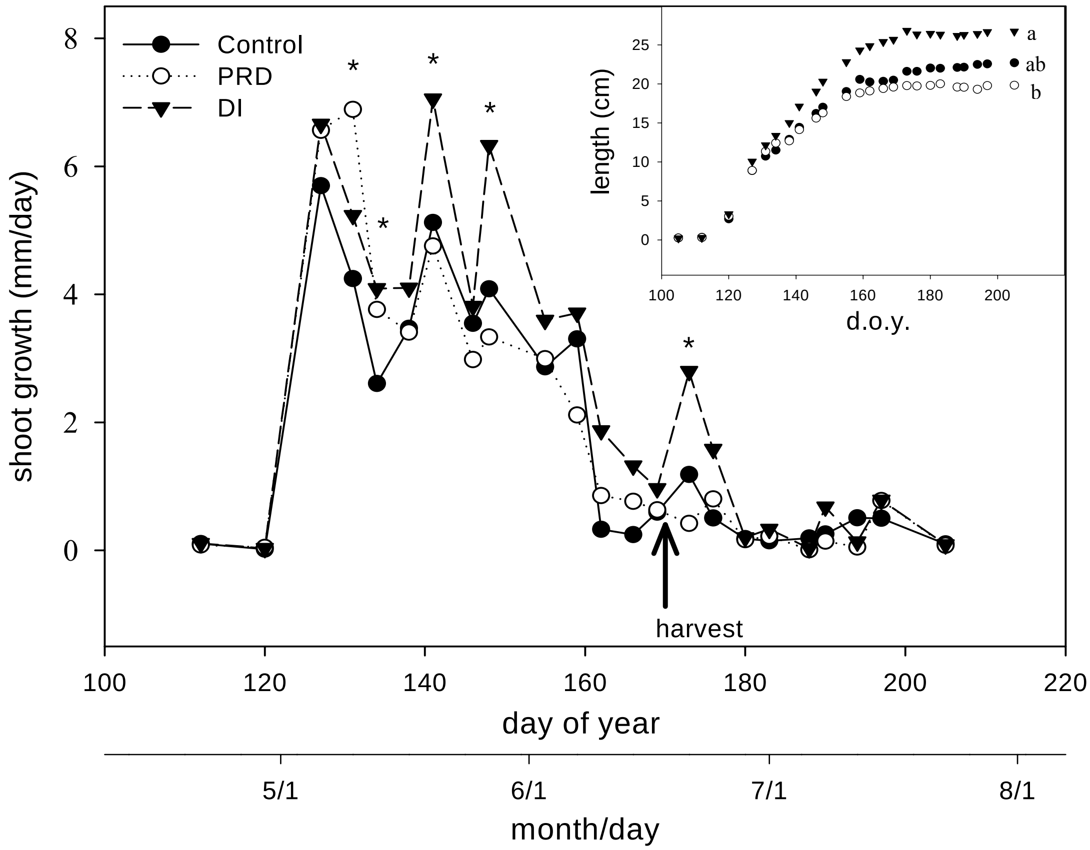

Figure 3. Seasonal trend of expansion rate of shoots and shoot length (inset) within 'Bing' sweet cherry trees subjected to deficit irrigation (DI) and partial rootzone drying (PRD). Asterisks indicate significance ($P < 0.05$).

In 2004, vegetative vigor was significantly higher for DI trees on several sample dates (Fig 3). These higher growth rates resulted in significantly longer shoots compared to PRD, which were the least vigorous (Fig 3 inset). It is not clear why DI exhibited higher growth rates. It is possible that these trees had fewer shoots per tree and therefore reduced whole-canopy sink activity. In addition, high growth rates of DI appear to be related to an increase in soil water content (Fig 1) though this is not consistent. To be sure, the tree's growth response to changes in soil water content remains obscure. However, over the course of this trial, there has been no consistent effect of irrigation regime on vigor and any differences among treatments have been subtle (i.e., not horticulturally significant). Therefore, we have not documented any vigor control using deficit irrigation strategies. This may be due to our inability to induce marked differences in soil water content among treatments during the earliest and most rapid period of shoot growth. This rapid shoot growth has consistently occurred during May - shoot growth rates decline in June and approach zero by the beginning of July (Fig. 3). Interestingly, the decline in shoot expansion rates coincides approximately with a period of increasing fruit expansion rates (stage III), irrespective of rootstock. This confirms earlier reports from our lab that the preharvest period is one of rapid growth and therefore intense competition for growth resources.

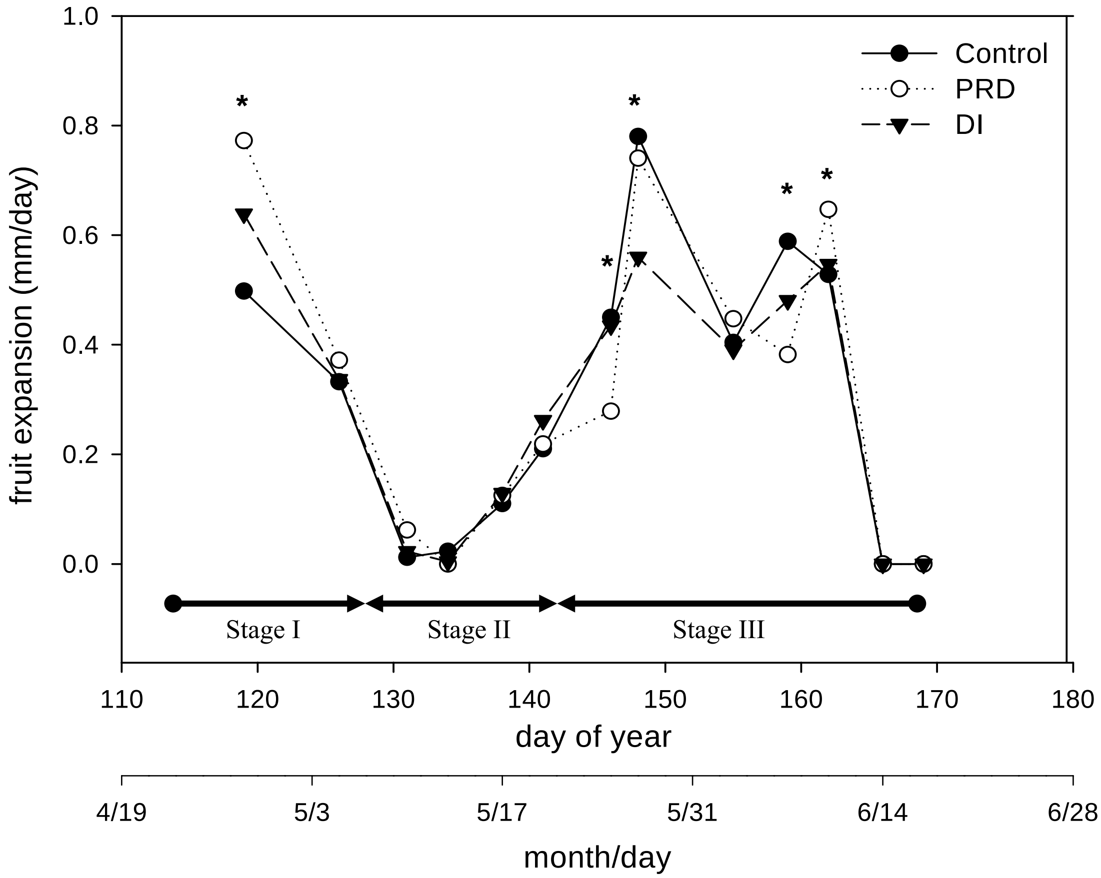

Figure 4. Effect of irrigation regime on the seasonal trend of expansion rate of 'Bing' sweet cherry fruit equatorial diameter. Asterisks indicate significance ($P < 0.05$).

Rates of fruit expansion across all rootstocks were similar (Fig 4). Seasonally, distinct phases of fruit ontogeny were apparent with high rates of expansion during both stage I and III and very little increase in diameter during pit hardening (stage II). Irrigation regime did not affect the transition among, or duration of the distinct growth stages. Differences in daily expansion rate of fruit were evident during stage I and III but not stage II. A similar trend occurred in 2003. We documented no consistent effect of irrigation treatment on fruit expansion despite differences, albeit slight, in soil water content. Therefore, at harvest, fruit size and weight were similar among treatments (Table 1). This may be related again to the lack of a significant drawdown in soil water content during the preharvest interval. It is likely that, the slight reduction in soil water content from deficit irrigation during the preharvest interval, was not sufficient to induce a significant stress response in the trees.

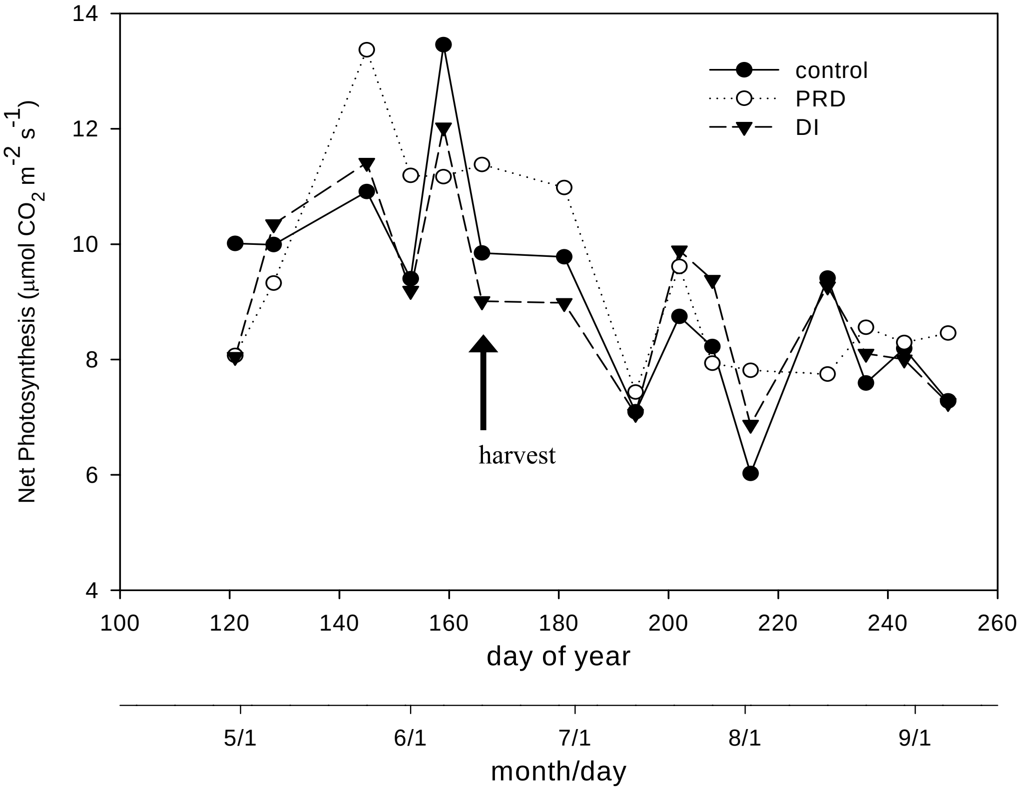

Figure 5. Effect of irrigation treatment on the seasonal trend of leaf net photosynthesis. Measurements were taken on well-sunlit 'Bing'/Mazzard leaves within 1 h of solar noon at 1000 µmols·m^{-2}·s^{-1} PAR.

In 2004 we documented the seasonal trend in leaf net photosynthesis (NCER)(Fig. 5) and midday stem water potential (Ψ_s)(Fig. 6) of Mazzard-rooted trees. There was no consistent effect of irrigation regime on NCER, though differences existed on certain sample dates. The preharvest mean NCER was 10.6, 10.7, and 10.0 µmol·m^{-2}·s^{-1} for control, PRD, and DI, respectively. This is not surprising considering the similarities in soil water content and Ψ_s among treatments and confirms the lack of apparent physiological stress in deficit-irrigated treatments. Postharvest mean NCER declined about 20% irrespective of treatment to ca. 8.1, 8.5, and 8.3 µmol·m^{-2}·s^{-1} for control, PRD, and DI, respectively. This suggests that trees were still not experiencing significant physiological stress during this period, despite lower soil water content of deficit-treated trees (Fig. 1). Therefore, soil water content may not be a reliable tool for assessing physiological stress of sweet cherry trees. Moreover, Ψ_s was often unrelated to NCER and soil water content, though they followed similar seasonal trends. However, Ψ_s of deficit treatments did not differ significantly from the control in this trial. Moderate water stress is suggested to require a reduction of about 1.2 – 1.4 MPa compared to a non-stressed control – in our trial Ψ_s differentials between control and deficit treatment did not exceed ca. 0.4 MPa at any point. Preharvest mean Ψ_s was -0.58, -0.62, and -0.65 for control, PRD, and DI, respectively. Mean Ψ_s declined after harvest, during the period of greater evapotranspiration and declining soil water content, to ca. -0.91, -1.04, and -1.09 for control, PRD, and DI, respectively.

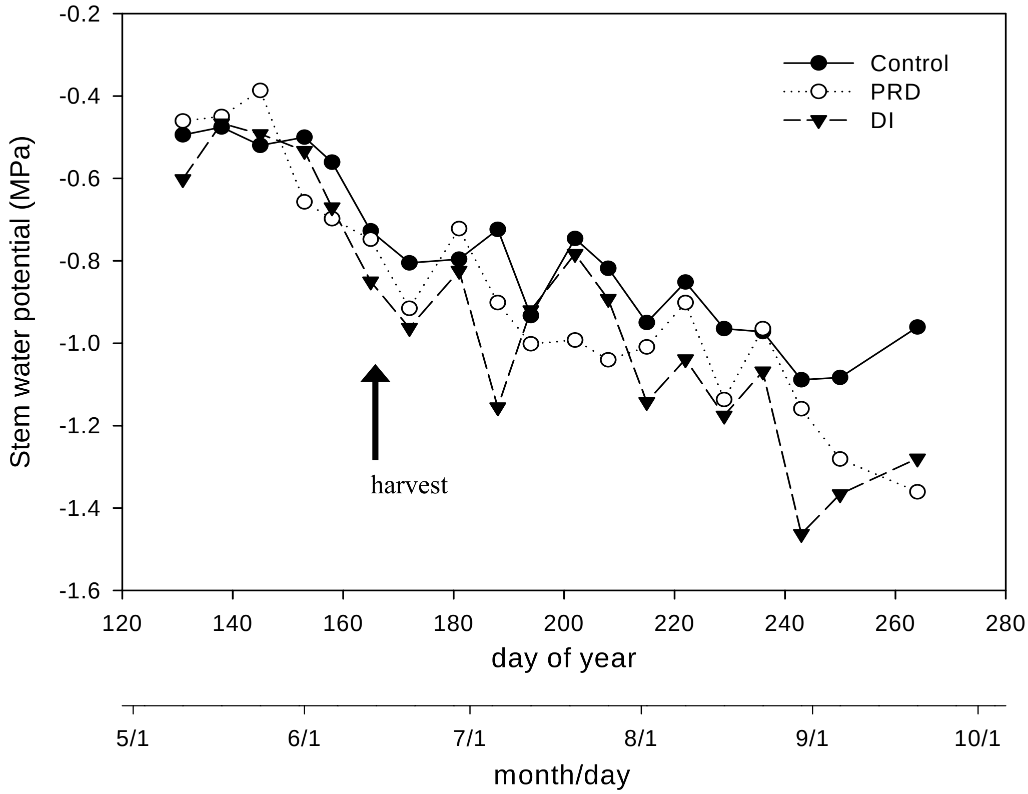

Figure 6. Effect of irrigation treatment on the seasonal trend of midday stem water potential. Measurements were taken on well-sunlit 'Bing'/Mazzard leaves within 1 h of solar noon.

Conclusion Between 2002 and 2004, entire rows of 'Bing' sweet cherry trees grafted on Mazzard, 'Gisela 6', and 'Gisela 5' rootstocks were subjected to season-long irrigation treatments that varied in the volume (by ca. 2-fold) and placement of water applied. We have studied the trees' horticultural and physiological response to these treatments and found no consistent, significant effect of any irrigation treatment. Therefore, we conclude that water resources may be conserved in most commercial orchards without affecting negatively fruit yield or quality. Moreover, sweet cherry trees appear to be physiologically resilient and not particularly susceptible to low soil water content (at least within the range we imposed). Future research should impose a more severe depletion of soil water in order to illicit a physiological response necessary to identify thresholds.

BUDGET

Project: Alternative water management strategies
P.I.: Whiting
Project duration: 2002-2004
Current year: 2004
Project total: $41,920
Current year request: n/a

Year	2002	2003	2004
Total	$20,000	$10,960	**$10,960**
Current year breakdown			
Item			
Salaries			
Benefits (30%)			
Wages[1]	6,000	6,000	6,000
Benefits (16%)	960	960	960
Equipment	10,040		
Supplies[2]	1,500	2,500	2,500
Travel[3]	1,500	1,500	1,500
Miscellaneous			
Total	$20,000	$10,960	$10,960

1 Time slip wages for data collection and fruit quality/laboratory analyses.
2 Whole-canopy chamber and laboratory supplies.
3 Travel to plots and transport of shared equipment between MCAREC and IAREC.

Table 1. Effect of rootstock and irrigation regime on yield and quality from 10-year-old 'Bing' sweet cherry trees grown on 3 rootstocks. Data followed by different letters within a column and analysis are different (P > 0.05).

Rootstock	Irrigation	Weight (g)		Brix		Firmness		% < 12-row		% 11 & 12-row		% > 11-row		Yield (kg)	
Gi5		6.8	a	24.1	a	233	a	13	a	46	a	40	a	12.5	b
Gi6		7.4	a	23.2	a	230	a	5	a	40	a	55	a	18.0	a
Mazzard		7.2	a	24.8	a	281	b	2	a	32	a	67	a	5.6	c
lsd		0.8		1.9		16		12		25		27		4.1	
	Control	7.4	a	23.6	a	242	b	5	ab	36	a	59	a	11.2	a
	PRD	7.0	a	24.1	a	239	b	0	b	40	a	60	a	13.9	a
	RDI	7.0	a	24.4	a	263	a	14	a	42	a	44	a	11.0	a
	lsd	0.8		1.9		16		12		25		27		4.1	
Gi5	Control	7.6	a	22.9	ab	211	e	11	ab	41	a	49	ab	11.0	cd
Gi5	PRD	6.7	ab	25.6	a	234	cde	0	b	49	a	51	ab	12.8	bc
Gi5	RDI	6.0	b	23.9	ab	253	c	29	a	50	a	21	b	13.8	bc
Gi6	Control	7.0	ab	23.7	ab	216	e	5	b	47	a	48	ab	18.8	ab
Gi6	PRD	7.5	a	21.5	b	224	de	1	b	39	a	60	ab	21.1	a
Gi6	RDI	7.7	a	24.5	ab	250	cd	9	ab	36	a	56	ab	14.2	abc
Mazzard	Control	7.5	a	24.1	ab	300	a	0	b	21	a	79	a	3.9	d
Mazzard	PRD	6.8	ab	25.4	a	259	bc	0	b	33	a	67	ab	7.8	cd
Mazzard	RDI	7.2	ab	24.9	a	285	ab	5	b	42	a	53	ab	5.0	d