Project Number: 98-LS-o0

Final Report

Almond Board of California

Measurement of Potential Tree Water Stress Effects on Almond Tree Growth and Yield

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Introduction

The 20-acre Marine Avenue almond planting was established in 1990 to compare the response of 4 almond varieties (Butte, Monterey, Nonpareil, and Carmel) to irrigation by various microirrigation systems (surface drip, subsurface drip, and microsprinklers). A key component of the comparison has been to apply the same amount of water with each of the different microirrigation systems. Thus, what is being compared is the response of the trees to the various microirrigation methods; not differences in the amount of applied water.

Previous years of investigation indicated that there was a yield and tree growth advantage associated with use of microsprinklers. To investigate a possible cause of this difference - differential water stress among trees irrigated with different microirrigation methods - this project was undertaken during the summer of 1998.

Experimental Procedures

To determine if there were different levels of water stress occurring between trees irrigated with different microirrigation systems, we monitored Nonpareil almond trees irrigated with surface drip (18 trees), subsurface drip (12 trees), microsprinklers (18 trees), and microsprinklers 1.2ET (9 trees). The same trees were monitored weekly from July through October for midday leaf stem water potential using a pressure bomb device. Three trees in the same Nonpareil row in each monitored plot were measured (see fig. 1). In addition, a flow meter was installed in each of the lateral lines being monitored and flow meter readings, to determine applied irrigation water, were taken when leaf water potential was measured.

Results

Almond Growth and Yield

Tables 1 and 2 summarize the almond tree growth measured as trunk crossectional area and the yields at the Marine Ave. orchard. Nonpareil, Carmel, and Butte yields indicate that there continues to be an advantage to use of microsprinklers in this orchard. Trunk crossectional area

measurements for all varieties show that the microsprinkler-irrigated trees continue to be larger trees.

The soils at the Marine Ave. orchard are gravely, low water-holding capacity soils which are relatively shallow (3-4 feet to a restricting clay layer). Backhoe investigations and extensive soil moisture monitoring using neutron probes, tensiometers, and gypsum blocks show that by midsummer the active root zone is restricted to the soil volume wetted by the irrigation system. For the microsprinklers, this is a circle, 14 ft. in diameter, centered between trees in the row. For the drip system, this is a wetted "trench", 4-6 ft. wide, along the tree row below the drip lateral line. It is strongly suspected that the different wetted soil volumes associated with the different microirrigation methods is a cause of the differential tree growth and yield. In addition, it is suspected that the different wetted soil volumes affect tree water stress during the growing season.

Irrigation and Leaf Water Potentials

The seasonal water applications for each of the microirrigation systems along with the estimated almond evapotranspiration (ET) is shown in fig. 2. Nearly the same amount of water was applied via the surface drip and the microsprinkler systems. As expected, the 1.2ET microsprinkler treatment applied approximately 20% more water. All three of these microirrigation systems applied less water that the estimated ET demands of the almonds. Soil moisture reserves would make up some of this deficit early in the season. Some deficit irrigation was intentional later in the season to aid in hull split. Irrigations also had to be cut back at the end of the season for harvest.

The subsurface drip irrigated trees received only 70% of the applied water as compared to the surface drip and microsprinkler irrigated trees. Following excavation and lateral line flushing investigations, it was determined that there was root intrusion occurring in the subsurface drip lines. Remedial actions are now being investigated to solve this problem.

Seasonal midday leaf water potential measurement, applied irrigation water, and almond ET for each of the microirrigation treatments are shown in figs. 3 to 6. Fig. 7 shows the seasonal leaf water potentials for each of the microirrigation systems along with the theoretical well-watered condition of the almond trees (labeled CIMIS in fig. 7).

Analyzing figs. 3 to 7, the following observations can be made:

1. All trees monitored experienced water stress during the season with the greatest water stress occurring during August - a period of peak water demand. This, in conjunction with the water application/ET information (fig. 2), indicates that the trees were under-irrigated during this time.
2. Slightly greater water stress was measured in the microsprinkler treatments than in the surface drip irrigated treatment. This is attributed to the less frequent microsprinkler

irrigation as compared to the drip irrigations. During peak water demand periods, the drip irrigated trees received water on nearly a daily basis while the microsprinkler trees were irrigated approximately every 3 days. The microsprinkler trees were monitored just prior to irrigation on two occasions in August (8/5 and 8/19) and the leaf water potential indicated the greatest water stress recorded during the summer's monitoring. Even this level of water stress though would not be considered a severe stress level which would significantly impact yield and growth.

3. Water stress occurs even under the frequent irrigation regimes of microirrigation. This is particularly true of microsprinkler irrigated trees where there may be 2-3 days between irrigation during midseason. It is very possible that the soil conditions at the Marine Ave. orchard (shallow soils with low waterholding capacity) contribute to this condition. An orchard with better soil conditions (greater soil moisture reserves) may not exhibit as great a water stress swing between irrigations.

Midday vs. Predawn Leaf Water Potential Measurements

On two dates (8/12/98 and 9/2/98) both predawn and midday stem leaf water potential measurements were collected. Figs. 8-12 shows the predawn vs. midday pressure bomb readings for each of the microirrigation systems separately (figs. 8-11) and for the combined data (fig. 12). For both the surface drip and subsurface drip treatments, there appears to be a more definite relationship between predawn and midday leaf water potentials than there is for the microsprinkler irrigated trees. Predawn leaf water potential reflects the water stress the tree is under after it has had a chance to recover during the night. Midday leaf water potential reflects the water stress the tree experiences during its peak water demand period (midday).

The lack of a more definite relationship between predawn and midday leaf water potential in the microsprinkler treatments may be due to the fact that on the two dates that the readings were taken, the microsprinkler trees had been well-watered and were under minimal stress. Additional measurements gathered when the microsprinkler irrigated trees were under greater water stress would be useful and will be pursued next summer.

The combined data from all the microirrigation systems (fig. 12) provides a relatively good relationship between predawn and midday leaf water potential measurements.

Table 1. Mean almond tree trunk crossectional area (square inches) by irrigation treatment and almond variety for 1994 - 1997. Statistical comparison of mean trunk diameters done by variety and by year. Numbers followed by the same letter are not significantly different at the 5% level.

1994

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	17.7 *b*	22.2 *b*	20.3 *c*	21.2 *a*
Microsprinklers	19.2 *a*	24.3 *a*	24.3 *a*	21.7 *a*
Subsurface drip	17.1 *b*	22.2 *b*	21.3 *b*	21.4 *a*

1995

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	23.0 *b*	33.8 *b*	29.8 *b*	28.7 *b*
Microsprinklers	26.0 *a*	37.5 *a*	31.8 *a*	35.6 *a*
Subsurface drip	24.4 *b*	35.3 *b*	29.8 *b*	29.4 *b*

1996

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	30.9 *b*	44.6 *b*	40.0 *b*	36.2 *b*
Microsprinklers	35.6 *a*	52.9 *a*	43.4 *a*	48.9 *a*
Subsurface drip	30.4 *b*	46.7 *b*	38.1 *b*	36.7 *b*

1997

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	35.9 *a*	52.0 *b*	47.2 *b*	41.6 *b*
Microsprinklers	38.2 *a*	55.9 *a*	49.7 *a*	53.4 *a*
Subsurface drip	36.7 *a*	48.4 *c*	45.8 *b*	39.7 *b*

1998

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	39.6 *a*	56.4a	52.6 *b*	46.9 *a*
Microsprinklers	45.2 *b*	65.0 *b*	55.2 *b*	60.5 *b*
Subsurface drip	39.9 *a*	55.8 *a*	49.4 *a*	46.0 *a*

Table 2. Almond dry nut yields (lbs/acre) by almond variety and irrigation treatment. Statistical comparison of yield was done by variety and by year. Numbers followed by the same letter are not significantly different at the 5% level.

Almond Yield (lbs/acre)

1994

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip		1047 *b*	1053 *c*	
Microsprinklers		1543 *a*	1532 *a*	
Subsurface drip		1235 *b*	1234 *b*	

1995

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	752 *a*	745 *a*	920 *a*	1293 *a*
Microsprinklers	715 *a*	726 *a*	983 *a*	1332 *a*
Subsurface drip	873 *a*	701 *a*	639 *b*	1241 *a*

1996

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	1777 *a*	1924 *a*	2362 *a*	2492 *a b*
Microsprinklers	1748 *a*	2276 *b*	2708 *a*	2884 *a*
Subsurface drip	1673 *a*	1845 *a*	2350 *a*	2231 *a b*

1997

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	2002 *a*	2468 *a*	1991 *a*	1948 *a b*
Microsprinklers	1888 *a*	2513 *a*	2179 *a*	2252 *a*
Subsurface drip	1829 *a*	2422 *a*	1846 *a*	1714 *b*

1998

Irrigation Treatment	Almond Variety			
	Carmel	Butte	Nonpareil	Monterey
Surface drip	1726 *a*	2822 *a*	2419 *ab*	2244 *a*
Microsprinklers	1891 *a*	2984 *a*	2736 *b*	2270 *a*
Subsurface drip	1601 *a*	2768 *a*	2339 *a*	1958 *a*

Fig. 1

Nickel's Soils Laboratory - [illegible]rine Ave. Orchard
Irrigation System Layout - 1996

B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M
Surface Drip 1	Double Micro-Sprinklers 2	Netafim Sub-drip Single-line 2' from Tree 3	Micro-Sprinklers 4	Geoflow Sub-drip Double-line 4' from Tree 5	Double-line Surface Drip 6	Surface Drip 7	Double Micro-Sprinklers 1.5X 8	Netafim Sub-drip Double-line 4' from Tree 9
Double Micro-Sprinklers 1.5X 10	Netafim Sub-drip Single-line 2' from Tree 11	Double-line Surface Drip 12	Geoflow Sub-drip Double-line 4' from Tree 13	Surface Drip 14	Double Micro-Sprinklers 15	Netafim Sub-drip Double-line 4' from Tree 16	Double-line Surface Drip 17	Micro-Sprinklers 18

B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M	B N C B N M
Netafim Sub-drip Double-line 4' from Tree 19	Double Micro-Sprinklers 20	Surface Drip 21	Netafim Sub-drip Single-line 2' from Tree 22	Micro-Sprinklers 23	Double-line Surface Drip 24	Micro-Sprinklers 25	Geoflow Sub-drip Double-line 4' from Tree 26	Double-line Surface Drip 27
Netafim Sub-drip Double-line 4' from Tree 28	Double-line Surface Drip 29	Double Micro-Sprinklers 1.5X 30	Surface Drip 31	Micro-Sprinklers 32	Netafim Sub-drip Single-line 2' from Tree 33	Geoflow Sub-drip Double-line 4' from Tree 34	Micro-Sprinklers 35	Surface Drip 36

B = Butte C= Carmel
N = Nonpareil M = Monterey

Tree Spacing = 16' x 22'
124 Trees / acre

Total area = 21.7 acres
Block = 11 trees long (180') by six trees wide (132')

+ Tree monitored for Leaf Water Potential

Fig. 2

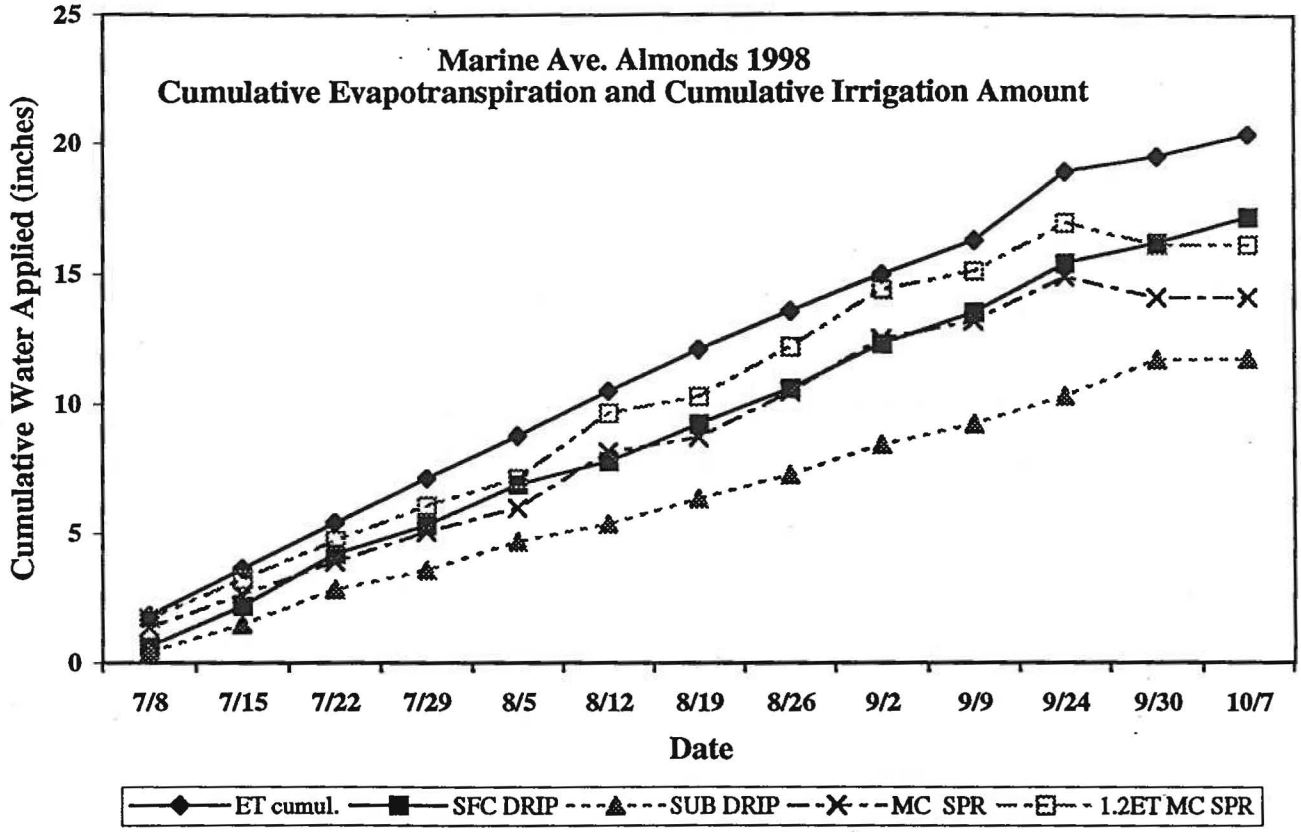

Marine Ave. Almonds 1998
Cumulative Evapotranspiration and Cumulative Irrigation Amount
Cumulative Water Applied (inches)
25
20
15
10
5
0
7/8
7/15
7/22
7/29
8/5
8/12
8/19
8/26
9/2
9/9
9/24
9/30
10/7
Date
ET cumul.
SFC DRIP
SUB DRIP
MC SPR
1.2ET MC SPR

Fig. 3

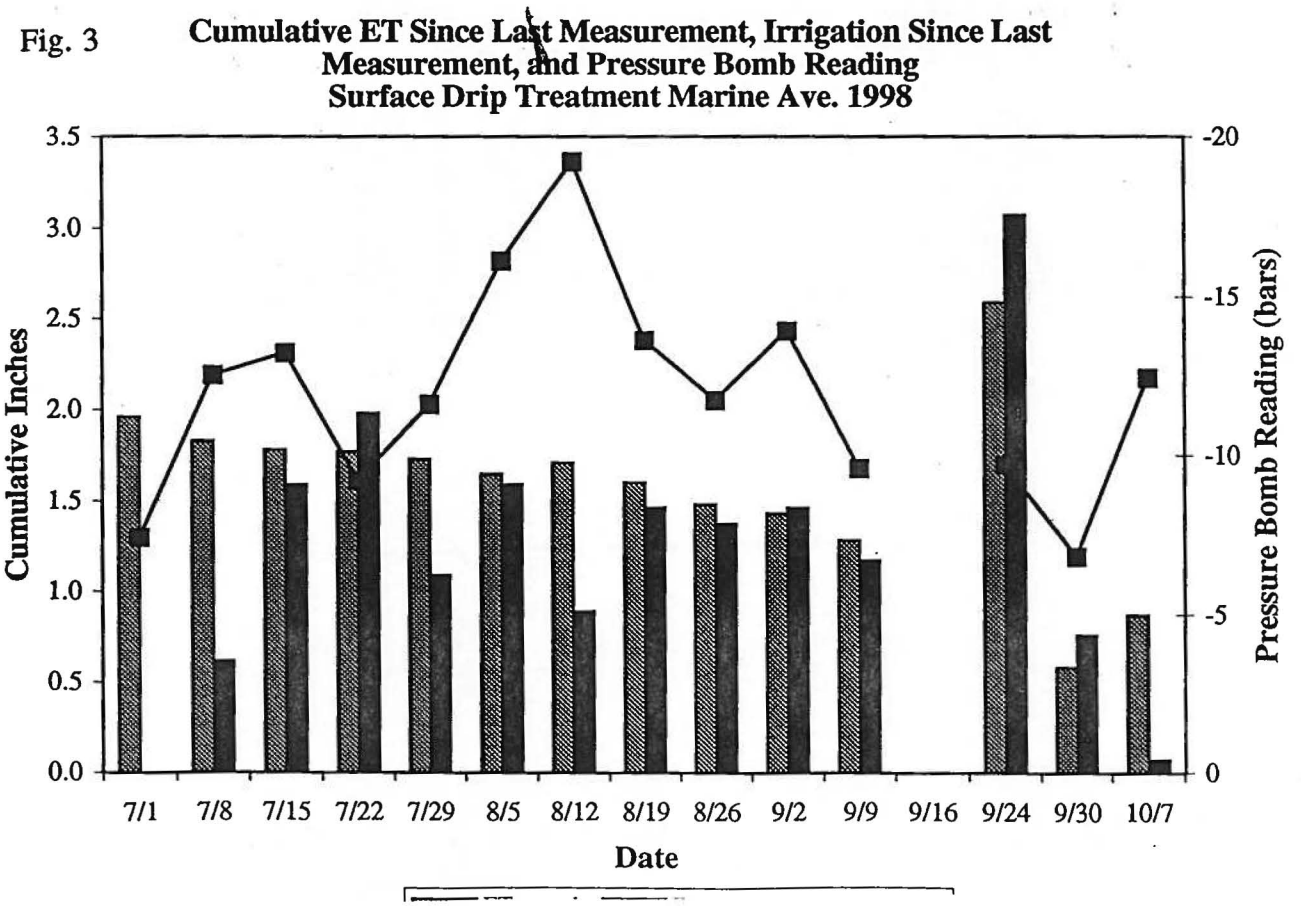

Cumulative ET Since Last Measurement, Irrigation Since Last Measurement, and Pressure Bomb Reading
Surface Drip Treatment Marine Ave. 1998
Cumulative Inches
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-20
-15
-10
-5
0
Pressure Bomb Reading (bars)
7/1
7/8
7/15
7/22
7/29
8/5
8/12
8/19
8/26
9/2
9/9
9/16
9/24
9/30
10/7
Date

Fig. 4 **Cumulative ET Since Last Measurement, Irrigation Since Last Measurement, and Pressure Bomb Reading Sub-Surface Drip Treatment Marine Ave. 1998**

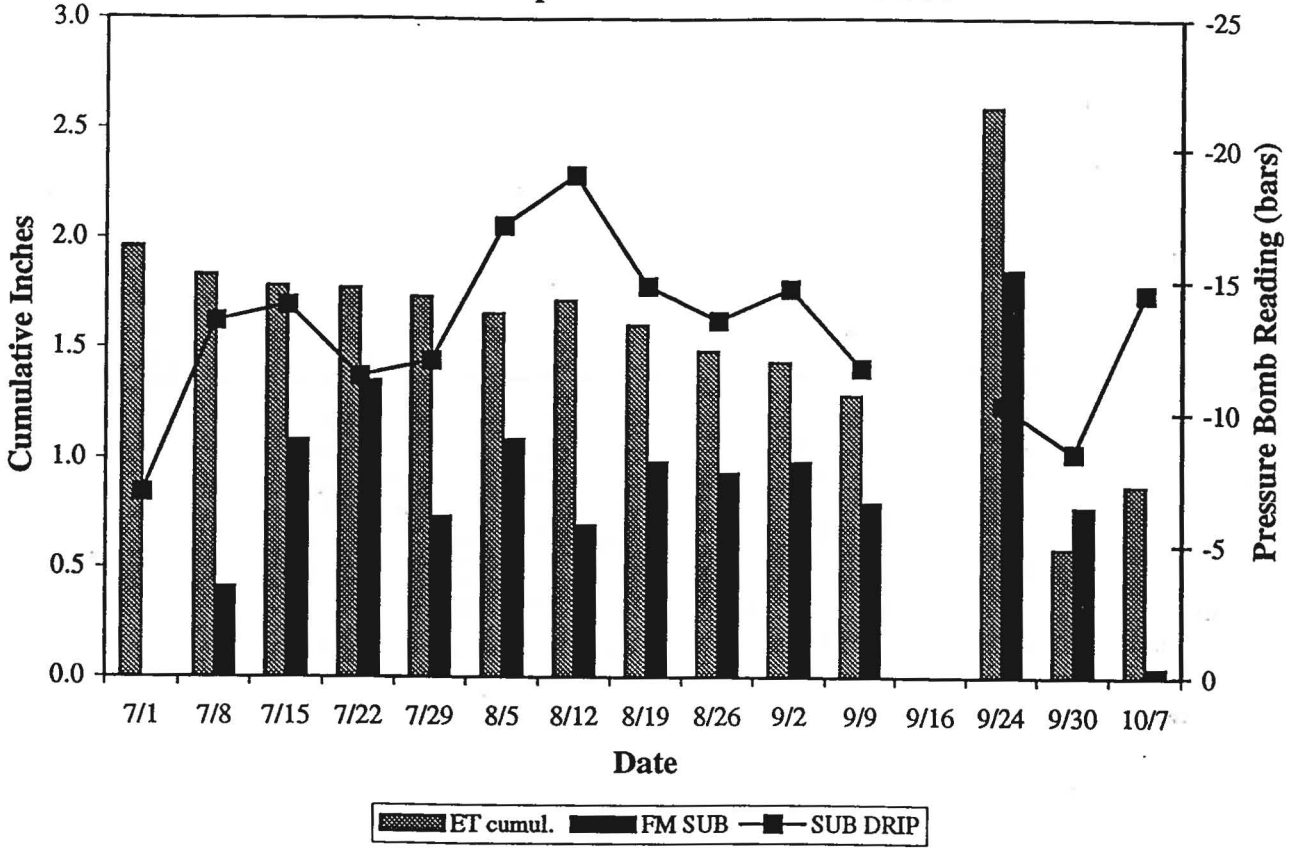


Fig. 5 **Cumulative ET Since Last Measurement, Irrigation Since Last Measurement, and Pressure Bomb Reading Microsprinkler Treatment, Marine Ave. 1998**

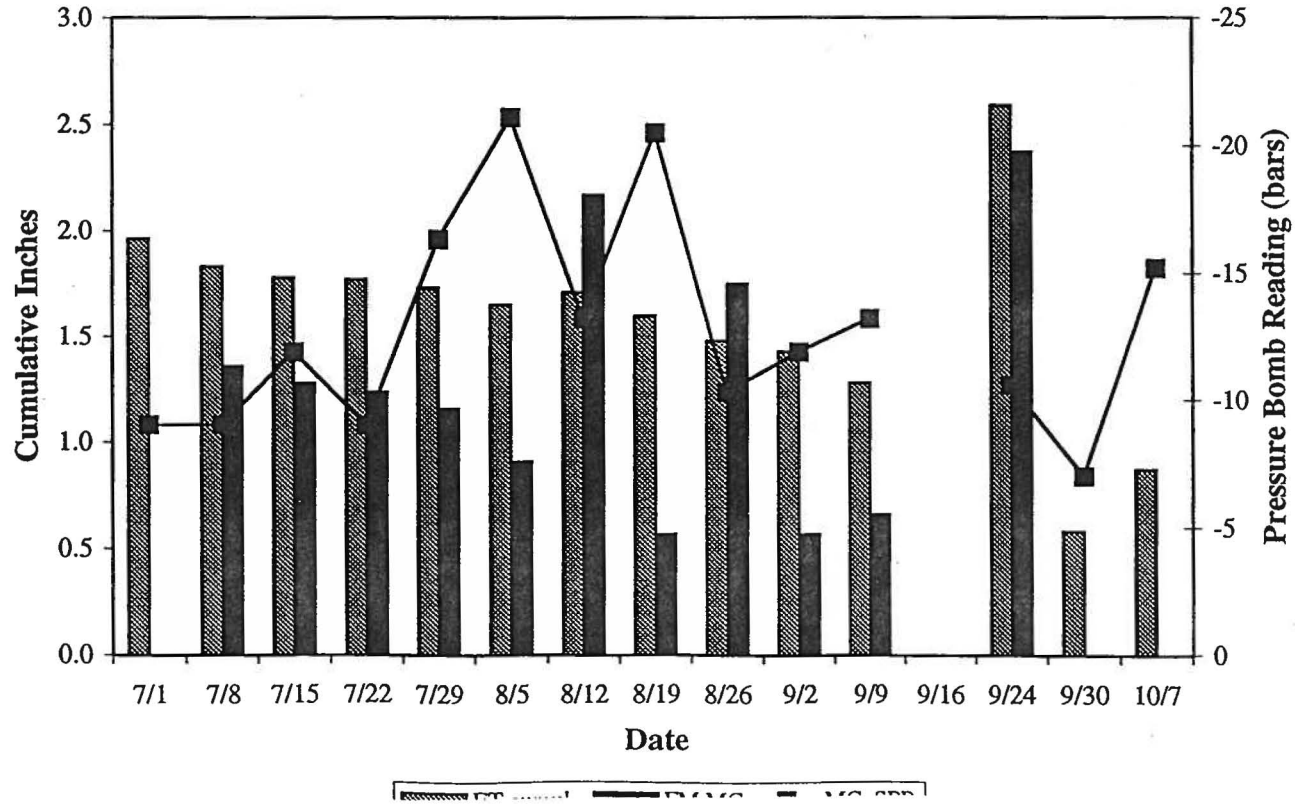


Fig. 6 **Cumulative ET Since Last Measurement, Irrigation Since Last Measurement, and Pressure Bomb Reading 1.2ET Microsprinkler Treatment, Marine Ave. 1998**

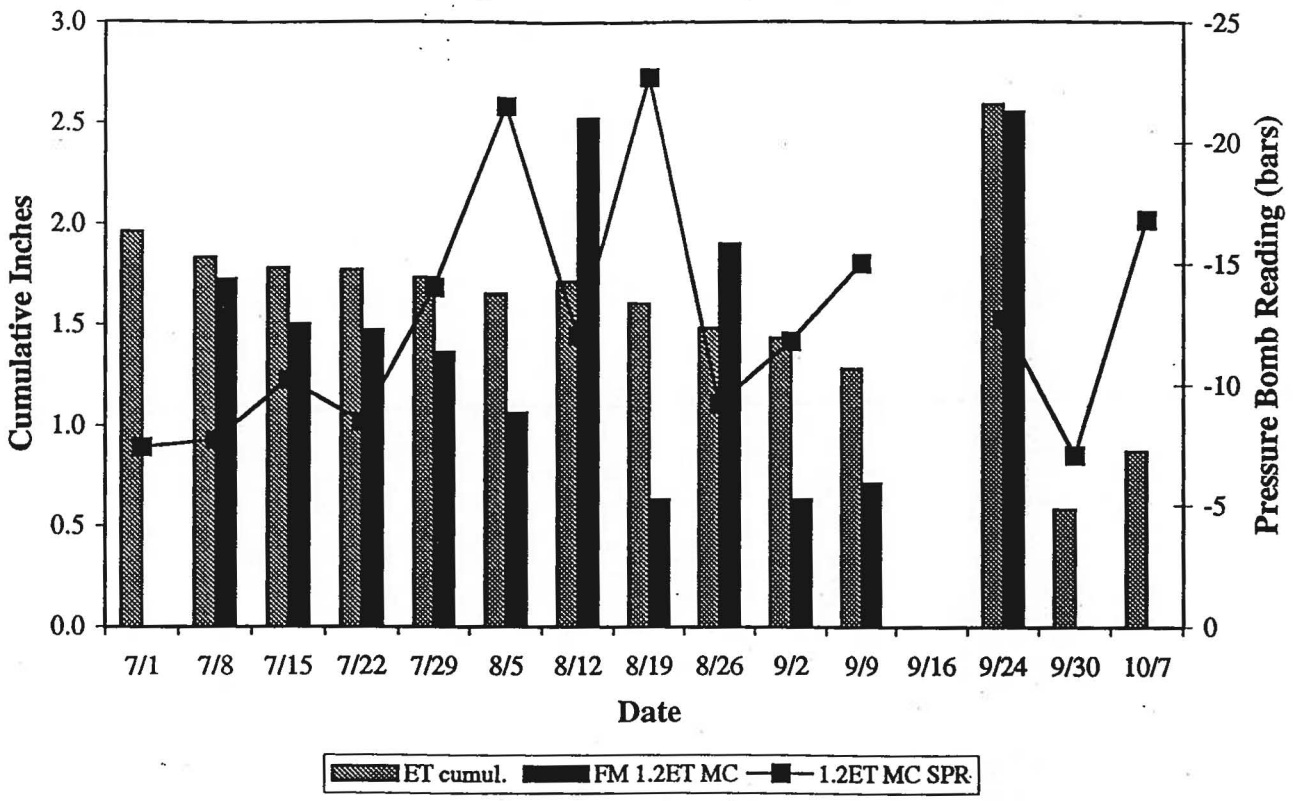


Fig. 7. Seasonal leaf water potential measurements and minimal stress conditions (CIMIS) for Marine Avenue almonds - 1998.

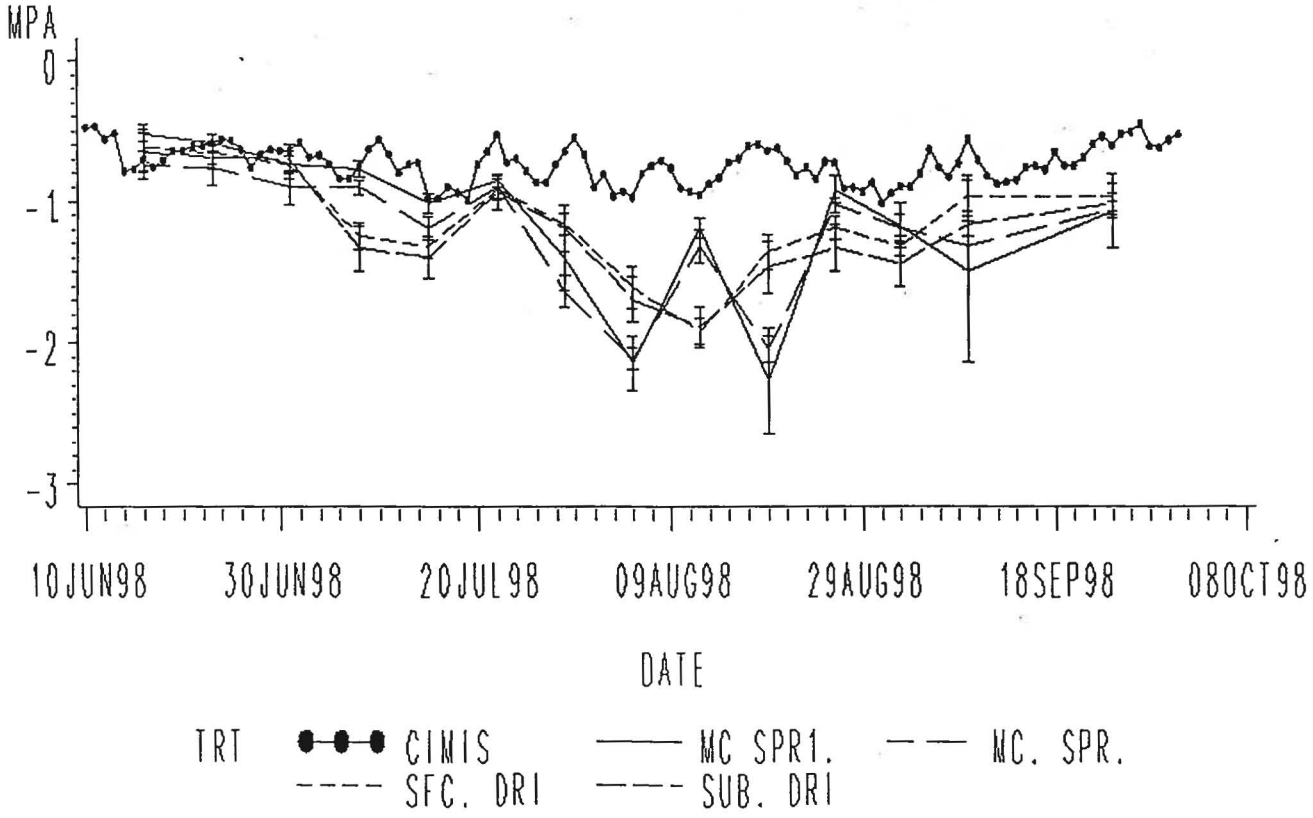


Fig. 8 **Midday vs. Predawn Leaf Pressure Bomb Measurements**
Marine Ave. Surface Drip Almonds 1998

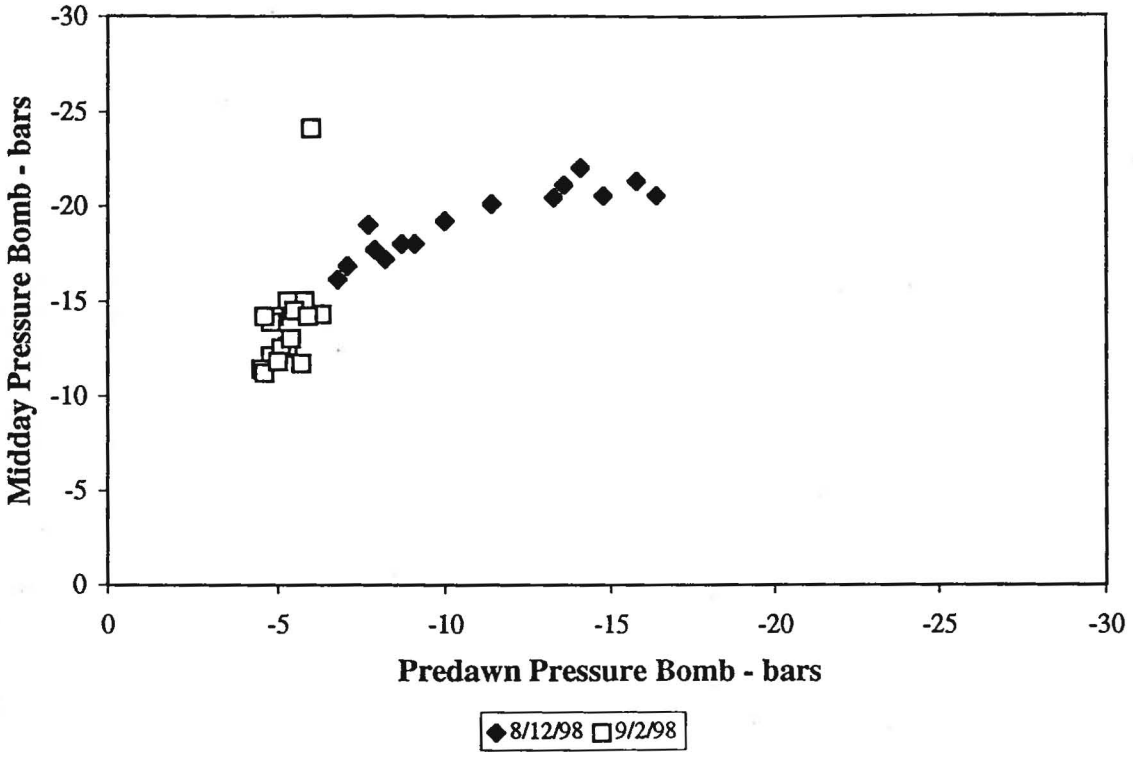


Fig. 9 **Midday vs. Predawn Leaf Pressure Bomb Measurements**
Marine Ave. Sub-Surface Drip Almonds 1998

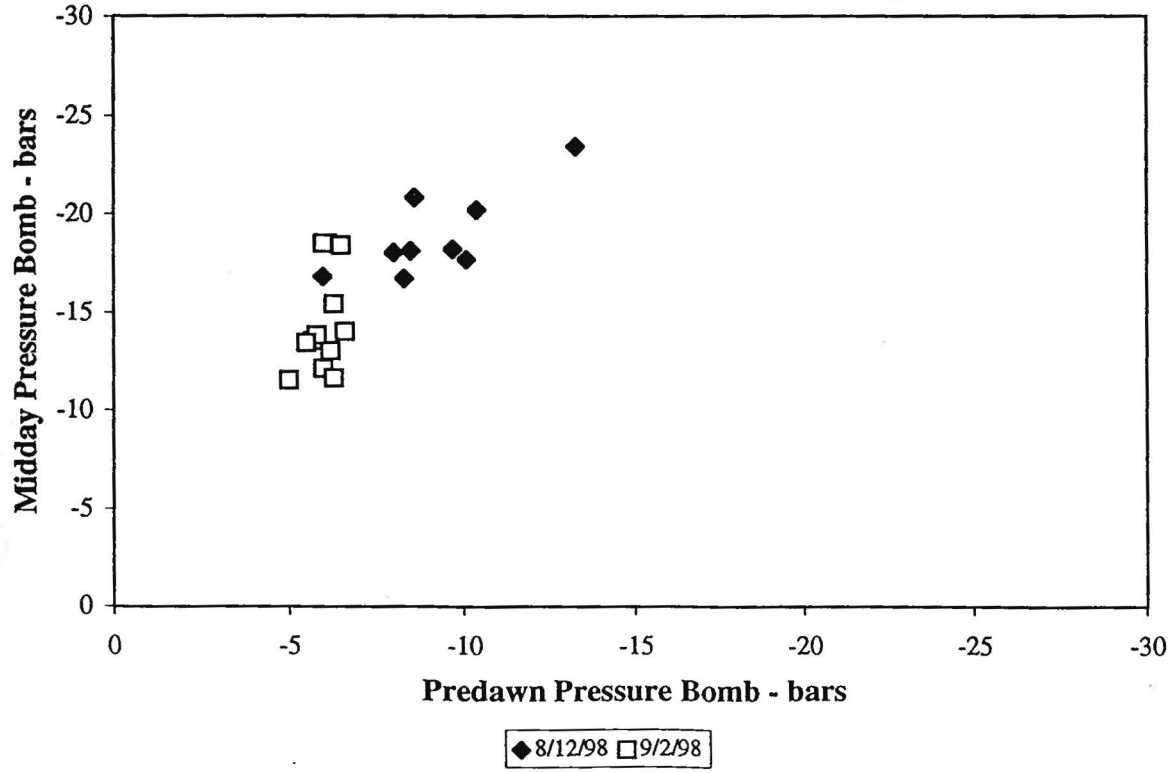


Fig. 10 **Midday vs. Predawn Leaf Pressure Bomb Measurements**
Marine Ave. Microsprinkler Almonds 1998

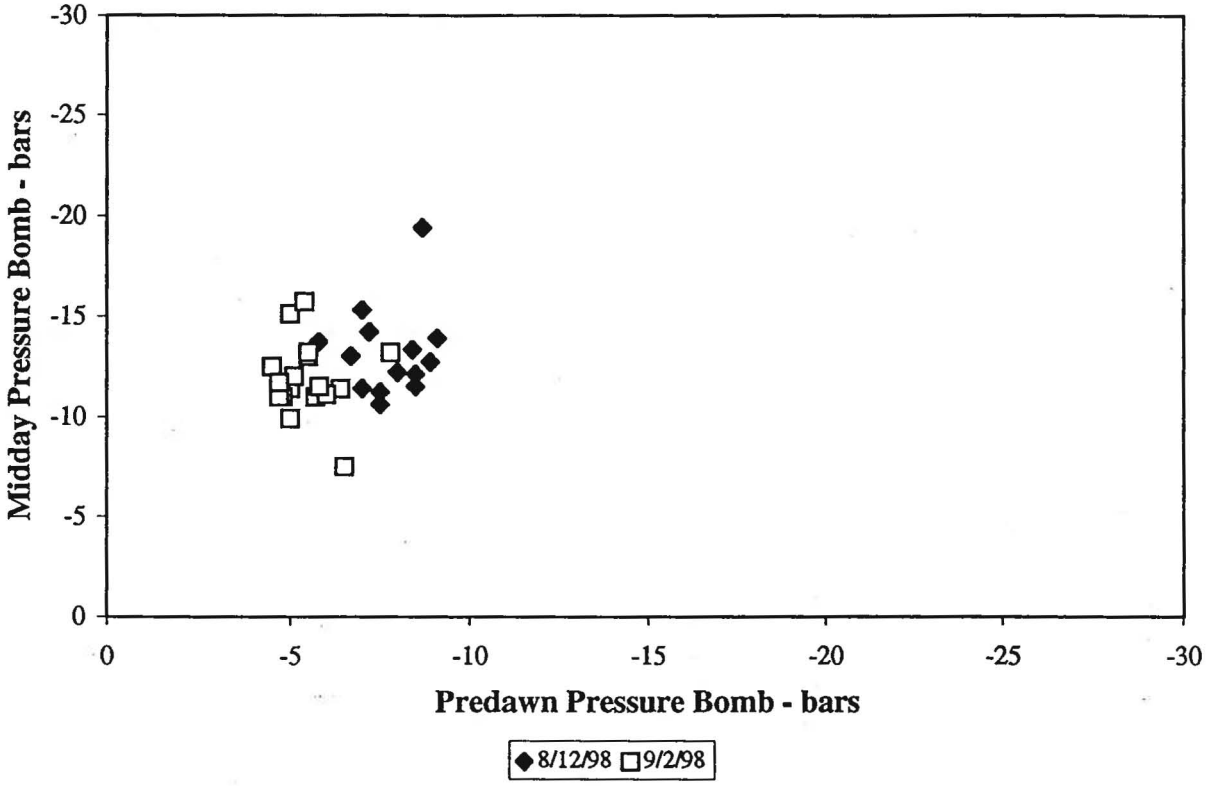


Fig. 11 **Midday vs. Predawn Leaf Pressure Bomb Measurements**
Marine Ave. 1.2 ET Microsprinkler Almonds 1998

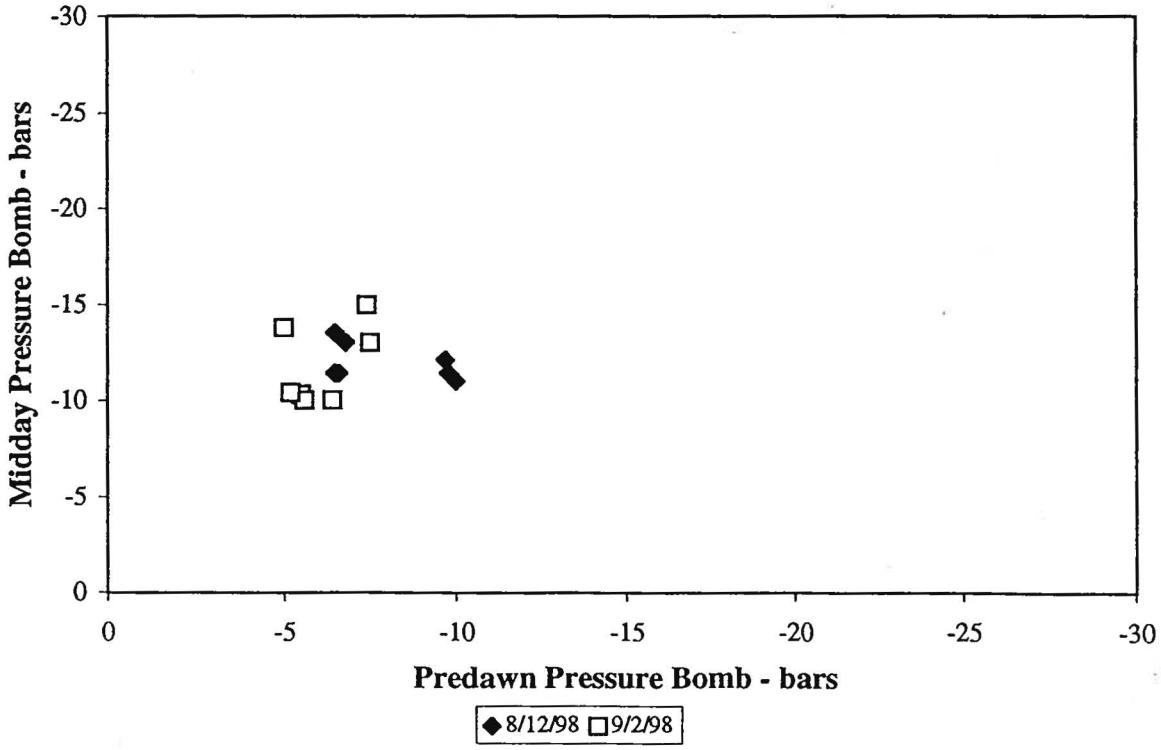
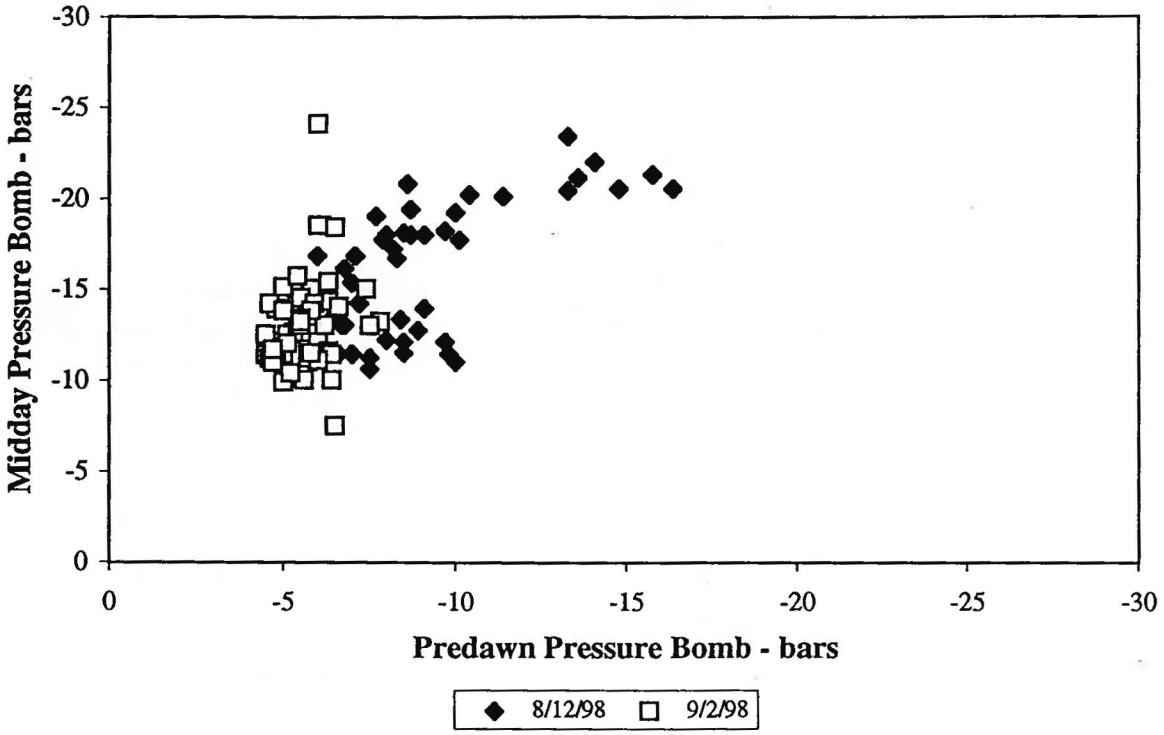


Fig. 12 **Midday vs. Predawn Leaf Pressure Bomb Measurements**
All Treatments of Marine Ave. Almonds 1998



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6 May 1999

Chris Heintz
Research Director
Almond Board of California
1150 9th Street, Suite 1500
Modesto, CA 95354

Dear Chris:

Enclosed are two copies of the 1998 annual report for our project "Water Stress Effects on Growth and Yield" - Project No. 98-LS-o0. Thank you very much for giving us the opportunity to do this work.

If you have any questions, please feel free to contact me.

Sincerely,

Lauren F. Schwankl

Larry Schwankl
Irrigation Specialist