Interim Progress Report to the Wine Advisory Board, Agricultural Research Foundation, and Participating Growers

Title:
Monitoring of Soil Moisture: Methods, improving Wine Quality and Extent of Wetting

Duration:
May 2000 – April 2002 (expected)

Funding:
WAB: $3,500 for Fiscal year 2000-20001
ARF: $7,500
Cascade Water Systems: Products with value >$2,500
Growers: to date $2,500 (of $10,000 committed for year 1)

Team: John Selker, Carmo Vasconcelos and Wilson Rojas with: Marshall English (professor, Bioresource Engineering), Paul Ridgeway (owner, Cascade Water Systems); Bob Bailey, Cherry Hill Vineyard; Eric Lemelson, Lemelson Vineyards; Sterling Fox, Tualatin Valley Vineyard;

The Willamette valley has grown to be an important source of high quality grapes for the production of wine. These grapes are a very high value crop that has proven to be profitable in this region. Irrigation of this crop has been limited largely to the establishment stage, with most of the mature acreage being grown based on native rainfall. While this strategy has been successful in certain soils in most years, it has lead to relatively low productivity in terms of yield per acre, severely limited the range of soils suitable for wine grapes, and results in unnecessary variable quality based on the precipitation and temperature patterns of a given year. This represents an unacceptable loss of productivity and land resources to wine grape production.

During his sabbatical in Chile for the 12 months of 1998, Dr. Selker worked with investigators studying controlled deficit irrigation of wine grapes in Chile. These researchers obtained both increased yield, and moreover, improved wine quality, through use of strategic deficit irrigation. Dr. Selker initiated a collaborative research project under this project in the Willamette Valley with Wilson Rojas, a grape irrigation investigator from the National Institute for Agricultural Research (INIA). INIA supported over half of Mr. Rojas' living expenses while in Oregon from May 15 until Sept 15, 2000, as well as all travel costs. This win-win situation provided technology transfer in soil moisture monitoring to Chile, and brought valuable deficit irrigation expertise to bear on Oregon's vineyards.

Traditional irrigated agricultural activities involved applying essentially the full potential evaporative demand to the entire surface area of the developing crop. Contrary to this approach, the irrigation of grapes for wine focuses on strategic irrigation from drip emitters at the base of the vine only during critical developmental stages. Thus, a small fraction of the surface is irrigated, and for a small portion of the growing season. Although limited, this irrigation has been shown to directly lead to improved wine quality and greatly increased harvested yield. Growers are interested in the possibility of expanding water rights due to the partial wetting achieved in grape irrigation.

We initiated a study of irrigation on five vineyards in the Willamette Valley in the growing season of 2000 and hope to continue this work in 2001 (presently in serious question due to the lack of grower-participant follow through on financial commitments). In these studies the irrigation is controlled to provide water only during critical growth stages in contrast to non-irrigated vines. Water application will be monitored for both amount applied and the total wetted area. Our objectives are:

1. Demonstrate the improved yield and quality of product that can be achieved through precise and limited irrigation of wine grapes in the Willamette Valley.
2. Demonstrate water monitoring technologies that are practical and effective in the monitoring of soil water status to provide precise irrigation to vineyards
3. Demonstrate the fraction of wetted area to support the claim that water rights from previous full irrigation systems should logically be extended to greater surface area while maintaining the original commitment of water resources.

EXPERIMENTAL PROCEDURES

Experimental Design

Five commercial vineyards each growing pinot noir and currently under irrigation have been selected and instrumented. Experimental blocks include three rows each, with only the central row of vines being subject to measurement. There are two treatments: with and without irrigation. Irrigation is controlled by measured plant water status and developmental stage. 5 replicates are conducted for each treatment. Both yield and wine quality are assessed for each treatment, with separate batches of wine produced from each treatment. Soil moisture sensors have been installed to determine water content with depth to three feet from bud break through harvest. While under irrigation these vines are monitored for physiological response to irrigation as contrasted to the control without irrigation.

Soil Moisture

Soil water content is monitored at twenty vines at each location. Four distinct types of soil moisture measurement methods are employed to validate the utility of each method.

These include Tensiometers, Watermark Sensors, the Theta Probe and the Aqua-Pro high Frequency Dielectric Sensor. Each of these methods is based on a commercially available tool. The results are benchmarked against gravimetric samples taken with depth through the season.

Gas-Exchange

Photosynthesis, transpiration and water use efficiency is measured five times during the season between bloom and harvest at key phenological stages, with a portable infra-red gas analyzer (Ciras-1, PP SYSTEMS, Hitchin, Herts SG5 1RT UK). The measurements are performed under fully saturated light conditions (>1000,umol PAR m-2 s-1). One leaf per vine is measured on the central vine of each replicate. This is undertaken to demonstrate the importance of reduced plant stress on photosynthetic efficiency. These data are not reviewed in this report.

Yield and fruit composition

The crop of each replicate are harvested separately. A 25 cluster sub-sample is used to determine cluster weight, crushed to determine soluble solids, pH, and titratable acidity. An additional 5 cluster sub-sample is used to determine berry weight and berries per cluster. These data are not reviewed in detail in this report.

Vegetative growth

Leaf area of one shoot per vine and three vines per replicate are measured destructively at mid ripening using a leaf area-meter from Li-Cor (LI-3100, Li-cor Inc., USA). Leaf area arising from the main and from lateral shoots will be measured separately. Shoot lengths are recorded monthly from May until hedging in July. These data are not reviewed in this report.

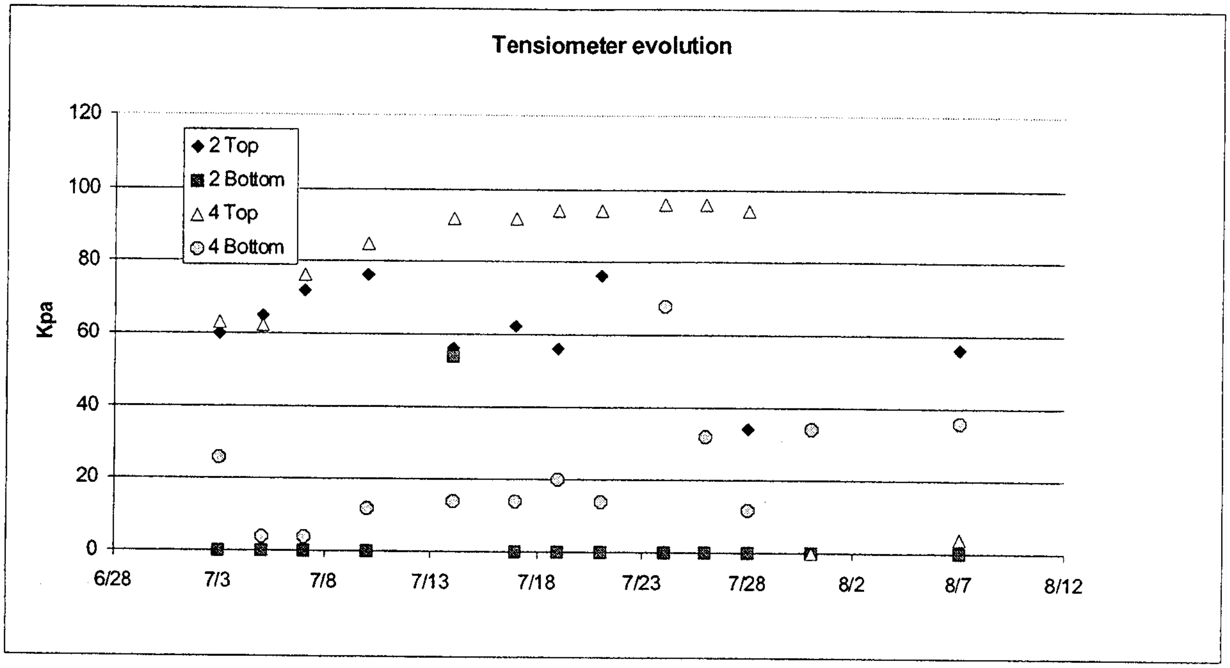

Figure 1. Evolution of tensiometer readings over first six weeks of project. Since these devices are limited to read between o and −1bar, the dry conditions found in the vineyards of Oregon are not well monitored using this technology (note scatter and lack of consistency in readings).

Preliminary Results

The results reported are preliminary and do not cover all aspects of the project. A complete final project report will be prepared following the 2001 growing season provided non-payment of project expenses by cooperating growers can be resolved prior to the 2001 growing season.

We installed instrumentation and collected data from soil moisture sensors on the four fields included in the study throughout the growing season. Due to the unusual climatic conditions of this summer, little or no irrigation was required in all but one of the mature fields included in the test. Thus, our trial data is limited to observation of the un-irrigated drying of soil in un-irrigated sites, and replicated observations of water use and irrigation distribution on one mature field. These data are continuing to be processed, but several observations can be made at this time.

A. Moisture Monitoring Systems

A key objective of this project is to identify moisture measurement tools that are appropriate and cost effective for wine grape irrigation management. Three technologies appeared most promising: tensiometers, Watermark sensors, and a new high-frequency dielectric system sold under the trade name "Aqua-Pro."

Figure 1 presents the data obtained from a set of tensiometers during the summer of 2000. It is immediately apparent that the data are widely scattered, and are limited to sub-1 bar levels, as is widely known of this technology. Given the frequent occurrence of soil water potentials far dryer than 1 bar, clearly tensiometers are not generally useful in this context.

Figure 2 illustrates the field performance of the Watermark sensors. The sensors worked much better than we had seen in previous Willamette valley studies, but the inherent limitation of reading only up to 2 bar proved to be problematic given the frequent very dry conditions required to develop stress and limit vegetative growth in the vineyards. Thus we conclude that this technology is not appropriate for vineyard management.

The most successful technology in this study appears to be the Aqua-Pro sensors, which not only provided consistent readings, but were able to track conditions over the entire growing season (Figures 3-6). The sensors are economical (under $500 for the meter and instrument), and preliminary efforts suggest that the calibration is linear and soil independent (Figure 5), as would be expected given the frequency of operation of the device (80 mHz). Installation is straight forward using the auger provided with the system (Figure 4), although given the need for installation of 180 access tubes in this project, we employed an electric drill to produce the installation holes.

B. Vine Physiological Status, Grape and Wine Quality

The project did include frequent measurements of leaf water potential as well as periodic measurement of plant physiologic status. These data are presently being analyzed, with a typical data-set shown in figure 7. It can be seen that the irrigated plants had lower average and peak leaf water potential. The difference was small due to the mild nature of the climate in this growing season. The literature suggests that red varieties produce better wine when stressed beyond 12 bars during verasion, which both the irrigated and non-irrigated treatments achieved in this field. Given the general sufficiency of water without irrigation, no statistically significant differences were observed in berry size, berries per cluster, sugar content, yield per acre, titrateable acids, or pH. Visually the irrigated berries appeared more robust, so we feel that there is a chance that differences will be observed in the quality of the wine produced.

C. Distribution of Water

An objective of this study was to observe the wetting patterns resulting from deficit drip irrigation as employed by the grape growers of the Willamette valley. Figure 6 presents soil moisture readings taken immediately following the application of 7 hours (3.5 gallons per emitter) of water over two irrigation cycles. The data show that increases in water content were only observed in the line of the plants 15 and 30 cm from the point of application, and only then to a depth of 50 cm. The 15 and 30 cm readings are nearly identical, while 30 cm away from the emitter in the ally between rows only a 1.5 % change in moisture content was observed. If we infer that the wetted area was extended 20 cm toward the alley and 30 cm in the direction of the row, the total wetted surface area per emitter would be 2,400 cm^2, only 12% of the surface area of the field. Using the data provided in Figure 7, with the wetted area deduced above, the total change in stored water per emitter was +1.3 gallons, indicating that more than half of the 3.5 gallons of water was consumed by the plant through the course of the week of observation. It appears that only about $1/8^{th}$ of the field is wetted by irrigation, supported by these data, and a simple calculation of the amount of soil that could be wetted by an application of 7 gallons of water over a week.

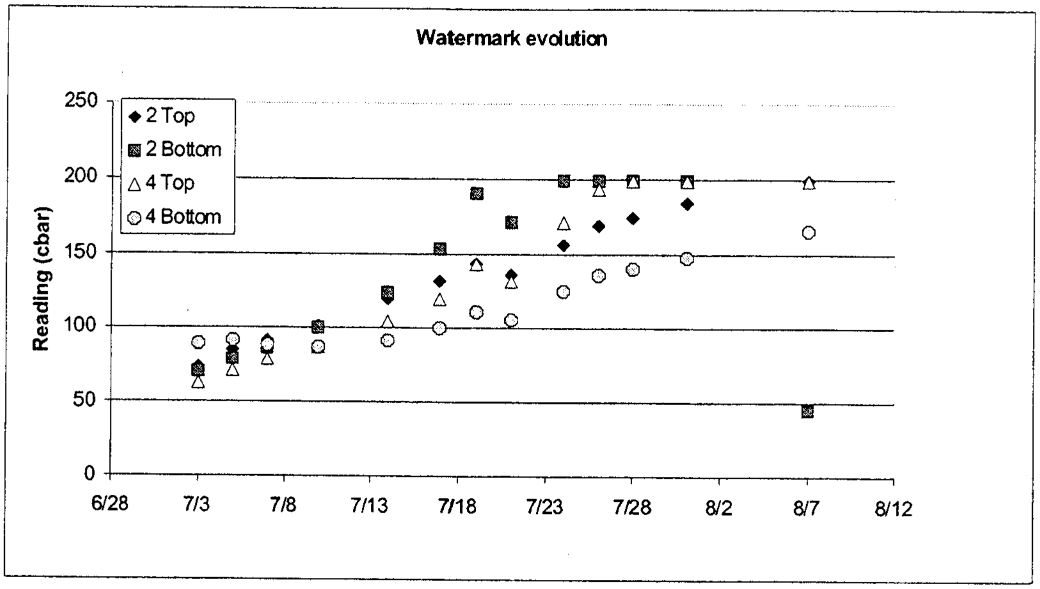

Figure 2. Evolution in time of readings from watermark sensors at 30 cm depth in four trials from the first 6 weeks of the project. The Watermark sensors are limited to reading between 0 and –2 bar (200 cBar), which is an improvement over the range of traditional tensiometers, but is still insufficient for the requirements of vineyard management where controlled deficit irrigation is sought. We were otherwise pleased with the performance of the Watermark sensors in this study in that almost all of the devices provided at least some readings that followed the soil drying observed.

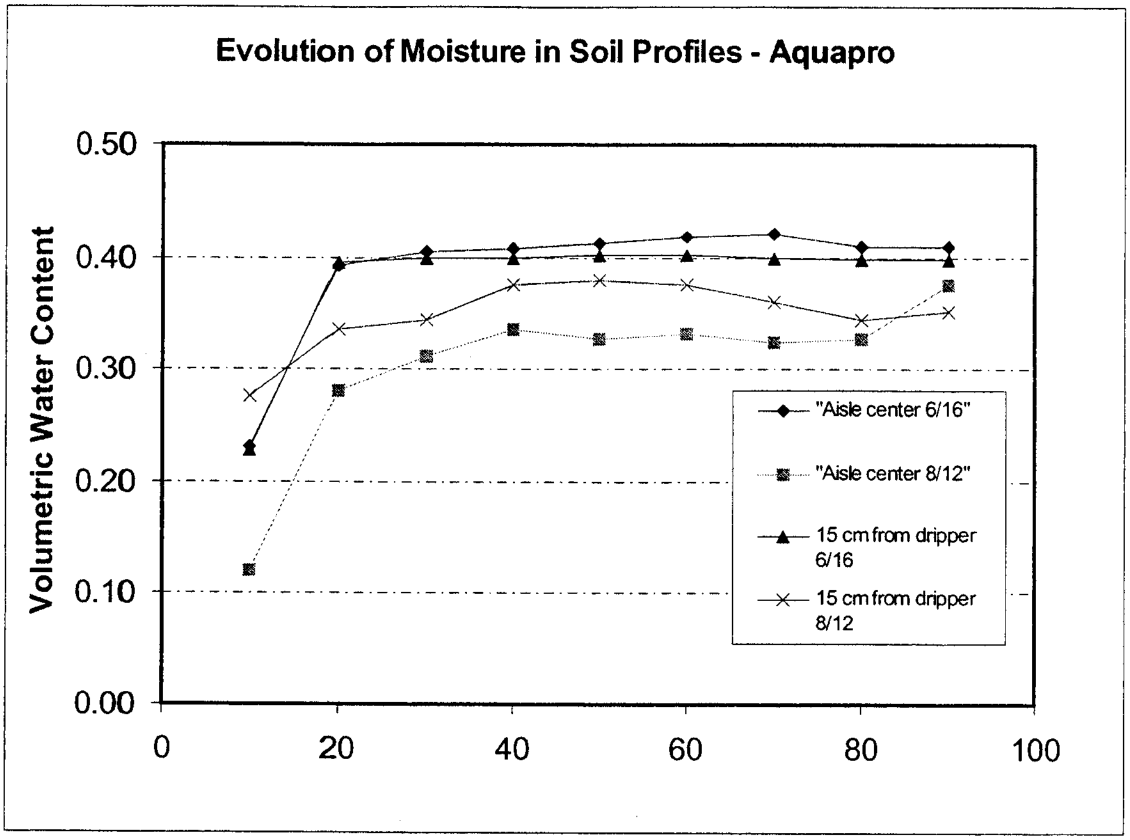

Figure 3: Evolution of Aqua-Pro readings taken from tubes nearest to the dripper (15 cm) and furthers from the dripper (in the middle of the aisle) over two months of the project. The Aqua-Pro appeared able to monitor changes in moisture content across the full range of conditions encountered in the vineyards. The device appears to be affordable (less than $800 for the meter, probe, installation auger, and 20 1-m long access tubes), and suitable to the needs of vineyard management. The output of the Aqua-pro were calibrated to volumetric moisture content by the using the data from Figure 5.

Figure 4. Installation and use of the Aqua-Pro high frequency dielectric moisture monitoring system. Careful installation is critical to accuracy of the readings.

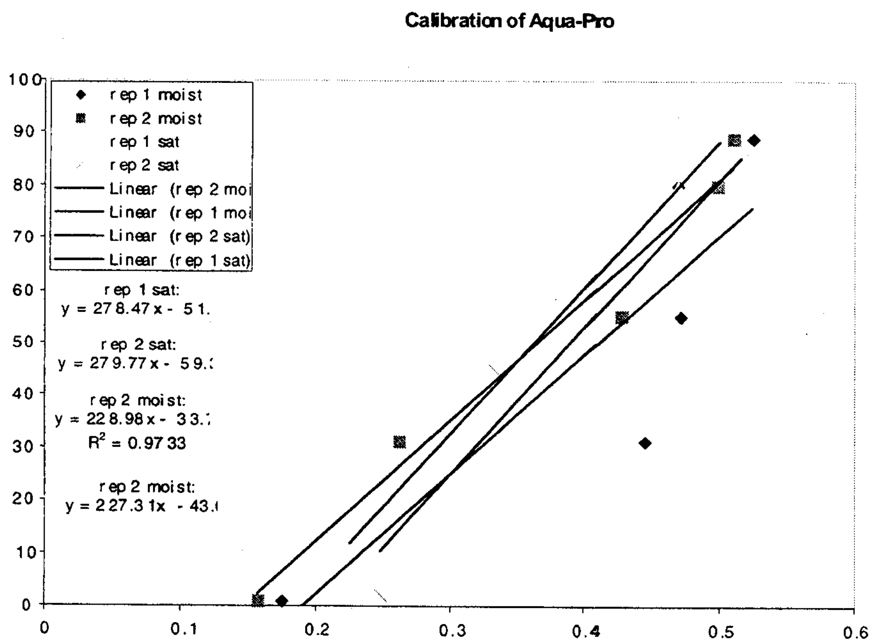

Figure 5: Preliminary calibration results for the Aqua-Pro sensor system as obtained in packed sand samples. The linearity and consistency of the data is encouraging. In addition, we have field data from the study which shows the same slope, with an off-set. Given the basic requirement of being able to track changes in water content in time, this data suggests that the system will be viable in vineyard irrigation management.

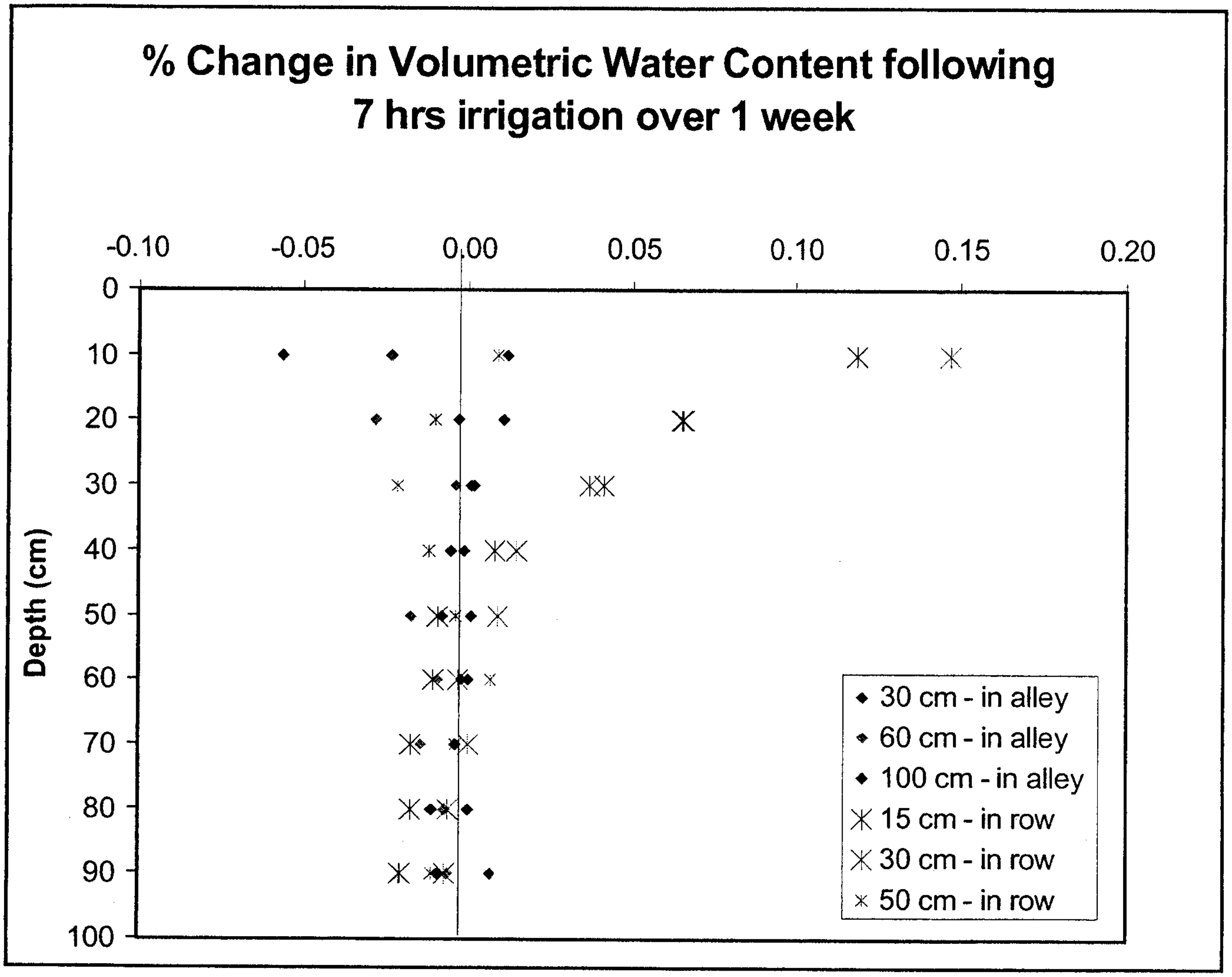

Figure 6. Percent change in soil water content with depth and position from drip application. Measurements were taken 15, 30 and 50 cm from the emitter in the row of the plants (which are on 100 cm spacing), and were taken at 30, 60, and 100 cm from the emitter into the alley perpendicular to the row (rows of vines are on 2 m spacing in this vineyard). The field received 7 hours of application in this week (28% of the total season application of 25 hours). The emitter applied 0.5 gallons per hour, or 3.5 gallons.

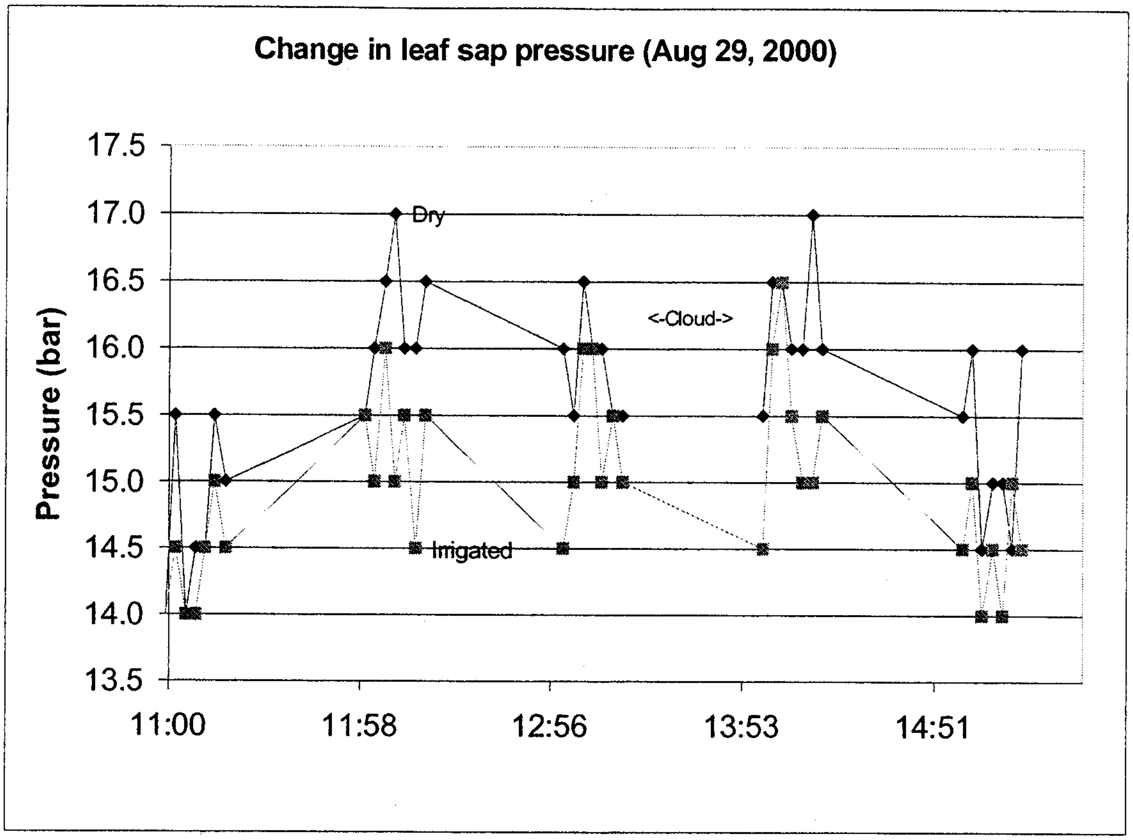

Figure 7. Leaf sap potentials as measured with a portable pressure bomb on August 29th, 2000, two days after the final irrigation on this field (same date as shown in figure 6). A small but clear separation between irrigated and un-irrigated plants is apparent, averaging 0.67 bars (4%).