Fine tuning irrigation scheduling with phytomonitoring technology in Chile

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Abstract

The introduction of phytomonitoring technology in table grape and avocado production in Chile is reported. Results in significant yield increments, modifications of fruit size distribution curves, as well as water and energy savings are discussed, and several irrigation strategies are quantitatively compared.

Information about continuous sensing of trunk, shoot and fruit growth is correlated with soil water dynamics and climatic conditions, enabling us to schedule irrigation events (frequency and water depth applied on each cycle) according to actual and precise plant water requirements. The agronomic implications and irrigation decision support activities included in the phytomonitoring advisory scheme provided to farmers are discussed.

Historic database management provided by the phytomonitoring set-up, sensors, data storage, data transmission features and software enabled us to evaluate applied research strategies to modify plant response, according to specific production objectives, optimizing crop water use efficiency.

Keywords: phytomonitoring, irrigation scheduling, table grapes, avocado

1 Introduction

Application of various sensors for assessing plant physiological conditions is becoming a common practice in crop growing (Kopyt, Ton and Tsadok, 2005; Naor and Cohen, 2003.). Despite many attempts to realize a control system with the direct plant-related feedback, most plant sensors have been used as supplemental inputs in human-aided control practice. These types of applications require many aspects of the measurement process to be standardized. An efficient information system for crop growing online continuous evaluation must integrate sensors and measurement protocols (sampling, allocation and positioning of sensors), crop-specific data interpretation techniques, and decision-support procedures. Phytomonitoring has become a first embodiment of the appropriate technical know-how (Goldhammer and Fereres, 2001; Gurovich and Gratacós, 2003).

Measurement techniques consist of a variety of crop-specific and task-specific standards that includes recommendation for selecting sample plants and defines a particular rational set of sensors and allocation of sensors on a sample plant. It represents the application technique in combination with the data processing and analysis. Data processing and analysing include specific phytomonitoring indicators of plant stress, dynamic indicators of soil water availability to plants, data interpretation algorithms and trial-and-error techniques for validation and/or fine-tuning of irrigation regimes, also being able to perform data processing for automatic diagnostics, alert messaging, quick data review, etc. (Ton and Kopyt, 2003).
Most of on-line techniques for assessing crop growth are based on environmental monitoring. Soil moisture and weather factors like solar radiation, wind speed, precipitation, air temperature and relative humidity and are commonly used for scheduling irrigation of open field crops (Wolf, 1996). Some other micro-environmental factors are treated and controlled in cultivation of protected crops (Challa and Bakker, 1995).

Many attempts have been made to create plant feedback control systems based on instrumental monitoring of leaf temperature, sap flow rate, and stem or fruit micro-variations (Jackson et al., 1981; Steinberg et al., 1989; Huguet et al., 1992).

Phytomonitoring techniques (Ton, 1997; Ton et al., 2001) have been proposed as an alternative to plant-based direct feedback control. They have been developed as the information and decision-support systems for human-aided control of crop growth. During the last few years, the phytomonitoring approach has demonstrated its effectiveness due to large-scale trial and commercial applications on many horticultural crops (Gaudillere, 2001) This paper describes some methodological aspects of phytomonitoring information and irrigation decision-support system, illustrated with practical examples from commercial table grape and avocado plantations in Chile.

2 Materials and Methods

Standard phytomonitoring systems (Phytech Ltd., Yad Mordechai, Israel) were installed in a commercial avocado orchard (Persea americana var. Hass) and in a commercial table grape (Vitis vinifera var. Thompson seedless) plantation located respectively at Mallarauco, and Viña Macaya, Placilla, in central Chile. Plant-related measurement sets included four fruit growth sensors and two dendrometers, as well as environmental sensor sets consisting of soil moisture (TDR), solar radiation, air temperature, air humidity and wind speed sensors; all sensors were connected to a solar powered data logger installed within the orchard. Sensor data was collected with a laptop computer from the field data logger, and was analyzed with software provided by Phytech Co.; data collected was validated with information obtained from conventional automatic weather stations, soil tensiometers and neutron moisture probes.

Two adjacent visually representative trees, located in the middle of the experimental plot, were selected for deploying replicated sensors. Dendrometers and fruit growth sensors were installed on the base of each trunk and on representative fruits, respectively. Continuous trunk and fruit growth data were registered, associated to trends on variable environmental factors (Kopyt et al., 2002; Gurovich and Gratacós, 2003, Ton and Kopyt, 2004). These data were used for short-term detection of physiological stress (trunk and fruit diameter growth and contraction rates), fine-tuning irrigation scheduling and for long-term analysis of plant water status and growth.

The phytomonitor unit used at the avocado orchard included the following sensors: 4 Dendrometers (0-10 mm; 1-2 µm resolution); 2 Soil moisture sensors; 1 Air temperature Sensor and 1 Air humidity Sensor. The following sensors at the table grape plantation were placed on every examined plant: 1 trunk diameter variation sensor; 1 fruit growth sensor (7-30 mm; 1-2 µm resolution); 1 soil moisture sensor; 1 air temperature and 1 air humidity sensor. Sampling time interval was 30 minutes.

In order to quantitatively describe the effect of environmental factors on growth and productivity, data collected by phytomonitor sensors was statistically analyzed using a normal least squares multiple linear regression model, on which dependent variables were fruit and trunk growth rates (Gurovich, Ton and Vergara, 2005).

3 Results

Negative deviation of trunk and fruit diameter trend in response to combined influence of gradually reducing soil moisture and cyclic daily variations of vapour pressure deficit (VPD) or actual crop ET, has been reported as a good indicator of soil water deficit. In Avocado, trunk diameter diurnal curves (Fig. 1) reflect the appropriate variations of plant water content.
Normally, trunk contracts at daytime due to water loss by transpiration and swells at night while replenishing water reserves. Amplitude of such variations is proportional to water deficit. Thus, the daily contraction amplitude (DCA) may be used as a criterion for scheduling irrigation. Continuous recording allows disclosing the intimate effects of plant water state and growth; in Fig. 1, the grower irrigated his plants when DCA exceeds 250 µm. The response of fruit avocado diameter increment to irrigation, is shown in details in Fig. 2. Data presented in Fig. 1 and 2 was obtained directly from the phytomonitor software, indicating that trunk and fruit diameter sensors can detect day - night contraction - expansion dynamics.

Trunk and fruit diameter contractions are clearly related to micro environmental conditions; soil water content fluctuated between irrigation events, detecting no saturation conditions and a rapid water internal drainage. The day before each irrigation event, soil water content does not seem to be a limiting factor for fruit growth. Because there was no evident depression of trunk and fruit growth rates, a successful attempt of saving water was implemented by the grower, adopting a new irrigation strategy, changing from a twice-a-day irrigation regime with 47 L/h emitters, to one daily watering cycle, using 35 L/h emitters. Thus, trunk and fruit diameter trends and diurnal fluctuations may be used for evaluation of environmental effects on plant water state and growth as well as for detecting plant water stress in avocado.
In table grapes, duplicate sensors sets were used on different plants within the same plantation in 2004; the goal of this preliminary study was oriented to demonstrate that shoot and fruit diameter dynamics are very similar in different plants located at any specific plot, if the irrigation strategy implemented is uniform within the plot, regardless of soil variability, cluster number per plant, or previous plant vigour or productivity (Fig. 3).

Shoot diameter daily contraction dynamics, and the effects of a reduction in vapour pressure deficit for February 16 and 17, 2004 is almost parallel in both plants, grown in soils that vary significantly on its texture, but are subjected to the same irrigation strategy (frequency and water depth applied). The net increment in shoot diameter is negligible, indicating that soil water content was too high. This is confirmed by data presented in Fig. 4, showing a depressed berry growth, even during days of an high VPD, considering that normally grape berries should steadily be incrementing its diameter after veraison.

In the next season (2005), a positive response of shoot and berry growth was observed, if the maximum VPD did not exceed 2.5 kPa (Fig. 5). In such cases, additional irrigation had two positive effects: a.
acceleration of berry growth, which was sensitive to irrigation until maturing stage and b. lesser midday shoot diameter shrinkage, being shoot diameter fluctuations more sensitive to soil moisture fluctuations, as compared to VPD fluctuations. Also, a significant shoot and berry sensitivity to irrigation during the season was detected, if soil moisture content (measured continuously at 30 cm. depth and 15 cm normal distance from drip irrigation lateral) is maintained 30% over field capacity, by using 3 to 4 pulses.day\(^{-1}\) (Fig. 6).

Fig. 5. Shoot and berry diameter response to irrigation during the ripening period. Viña Macaya, Placilla, February 2005

Fig. 6. Shoot and berry diameter response to vapour pressure deficit during the ripening period. Viña Macaya Placilla, February 2005

5 References


