Phytomonitoring Technique for Fruit Trees and Grapes

Application Guide

Exclusively Distributed and Supported By:

edaphic scientific

environmental research & monitoring equipment

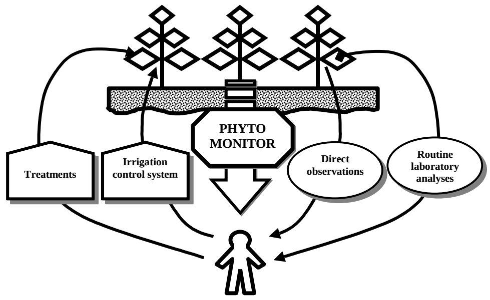
www.edaphic.com.au
info@edaphic.com.au
Ph: 1300 430 928

Authors:
Yuri Ton, Ph.D., Chief Scientist, Phyto-Sensor Group
Michael Kopyt, Ph.D., Senior Application Scientist, Phyto-Sensor Group

PHYTOMONITORING TECHNIQUE FOR FRUIT TREES and GRAPES

- ***A grower's assistant for detecting water deficit in plants and testing crop response to improvable irrigation regime***
- ***A tool for tuning irrigation for better crop and lower costs***

In modern horticulture, the human factor is still essential for reaping benefits. A grower's role is to provide and to keep necessary environment for plants within manageable limits. In fact, a grower is a key person for obtaining information about actual crop conditions, for operating control equipment and for planning and applying necessary crop treatments.



A grower applies treatments and provides irrigation, fertigation and other manageable environmental regimes. Usually, it is based on direct observations (made also with the use of instruments) and available laboratory analyses. The phytomonitor has become an extraordinarily responsive and informative feedback channel between a grower and cultivated crop.

Fruit trees and grapevines are very sensitive to irrigation. It is well known that final yield depends of plant water status during the season. The question is following: how to plan irrigation schedule for better crop and lower costs? More or less general recommendations are now available for major crops. However, they are sometime too broad and they can not anticipate many specific, native factors, such as fluctuations of local climate, soil and fertilizers peculiarities, pollutants, phenotypic variability of plants, infectious and non-infectious disorders in plants, etc.

Almost all modern irrigation scheduling methods are based solely on environmental factors, such as calculation of water budget using Penman equation or standard pan. A feedback related to plants' actual status is usually based on grower's experience, intuition, advises and available measurements.

The phytomonitoring technique is aimed on early, objective detection of crop problems and on well-timed disclosing of crop response to measures, which a grower may undertake for improving crop production.

It has become the extraordinarily responsive and informative feedback channel between a grower and cultivated crop. It is on duty round-the-clock! In case a grower is warned in due time, he is able to prevent any eventual loss of yield. ***Forewarned is forearmed!***

The phytomonitoring technique also enables to evaluate crop actual response in short time after changing irrigation regime. Consequently, a grower can either follow up his favorable attempts to improve irrigation regime or reject unfavorable ones. Important to note that the interactive phytomonitoring enables to improve crop performance even without making an exact diagnosis of the problem! Phytomonitor has no alternatives as a tool for examining and adjusting cultivation regime for new varieties or new irrigation equipment.

The Standard Phytomonitoring for Orchards and Vineyards

To make the phytomonitoring technique informative and representative, Phytech offers a standardized approach to sensors in use, measurement procedure, data processing and interpretation. This approach also provides comparability of the data obtained by different users.

There are two forms of standard recommendations: application protocols and application guides.

An **application protocol** is well-structurized document aimed at particular crop and task, such as irrigation scheduling of apple orchards with the use of internal reference block (so-called "triple-trick irrigation"), for instance. The protocol includes step-by-step instructions how to select plants, where and how to place sensors and how organize data collecting. The routine part of the protocol sets the data interpretation rules and decision-making procedure.

In turn, an **application guide** is aimed at a wider circle of technological tasks. It comprises methods for deriving information about physiological status and its trend from the phytomonitoring records. Examples of technological improvements may be also included in the document.

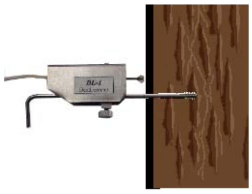
The present paper is the very application guide for fruit trees and grapes. The guide includes original experimental data from the following cultivars: apple, avocado, grapefruit, pamela, pear, persimmon, table grapes, wine grapes.

Modern LPS-05MD phytomonitor in apple orchard (left) and vineyard (right)

Electronic parts are located in heavy-duty cabinet. Some sensors (solar radiation, air temperature and humidity, wind speed) and solar panel are installed on the mast. Trunk diameter sensors are shielded with heavy-duty aluminum foil.

Phytomonitoring Sensors

Trunk and Shoot Diameter Variation Sensors (Dendrometers)



DE-1 Point Dendrometer

Suitable for trunks over 7 cm in diameter.
Measurement range: 0-12 mm

SD-6 Trunk (Arm) Diameter Variation Sensor

Trunk diameter range: 2-7 cm
Measurement range: 0-5mm

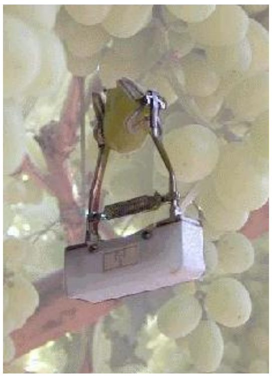
SD-5 Stem (Shoot) Diameter Variation Sensor

Stem diameter range: 5-25 mm
Measurement range: 0-2 mm

SA-3 Shoot Internode Auxanometer

Measurement range: 5-15 cm

Fruit Growth Sensors



FI-S Fruit Growth Sensor
<u>Measurement range: 7-30 mm</u>
FI-M Fruit Growth Sensor
Measurement range: 15-70 mm

FI-3EA Fruit Growth Sensor
<u>Measurement range: 30-100 mm</u>
FI-3EB Fruit Growth Sensor
Measurement range: 50-150 mm

Leaf Temperature and Sap flow sensors

a

b

c

LT-1 Leaf Temperature Sensor and SF-4 Stem Flux Relative Rate Sensor on a leaf petiole.

<u>Installation tips:</u>

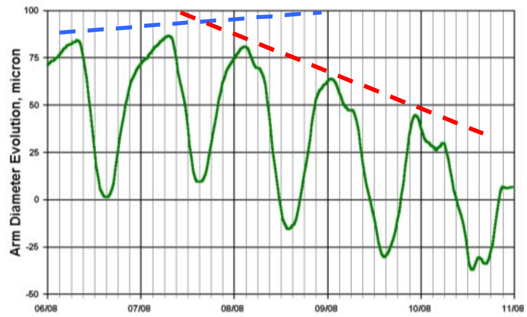
1. Cover any SF- type sensor with at least two layers of aluminum foil (see Fig. b).
2. Secure all plant related sensors' cables at the shoot near the sensors location with the use of adhesive tape (see Fig. c)

Basic Phytomonitoring Indications of Plant Status and Trend

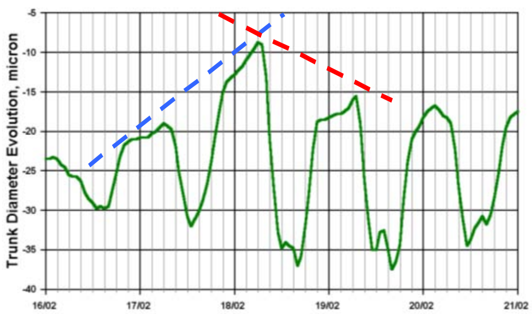
Computerized phytomonitoring technique incorporates many sophisticated algorithms. Most of them are based on analysis of time trends and plant/environment interaction. The most general, visually recognizable indications of plant performance are described below:

Daily Maximum Stem(Trunk, Arm,Shoot) Diameter Trend is an important indicator of plant physiological status. Supposedly, this trend comprises both growth, as a result of cell division in cambium, and rehydrating status of a plant. Normally, a plant manifests positive trend. Most likely, a negative trend is the evidence of unfavorable water regime and/or depressed growth conditions.

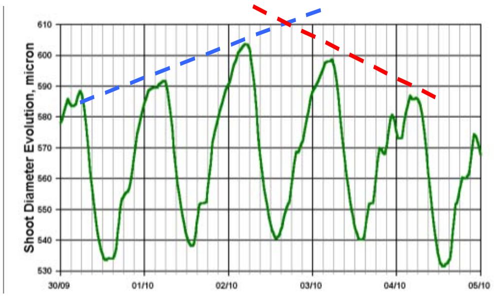
Examples of negative trend (a turn from normal positive trend to negative one)



Arm Diameter: Apple
(Baram, Israel, 1999)

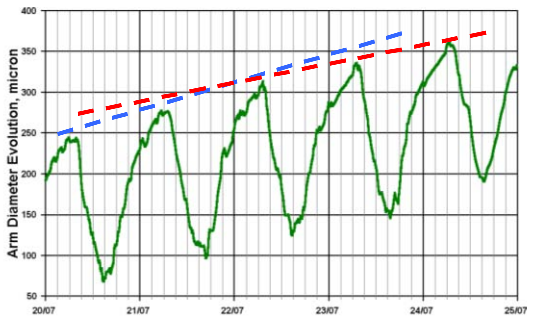


Trunk Diameter: Pear
(Yasod-Hamaala, Israel, 2000)

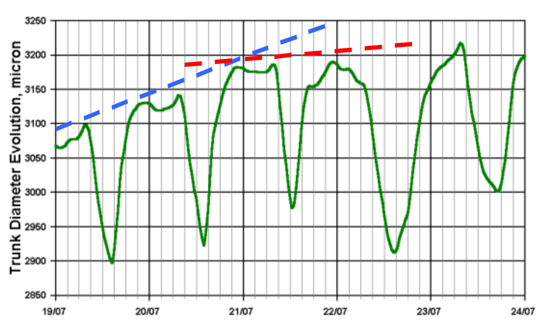


Shoot Diameter: Grapevine
(Hermosillio, Mexico, 1999)

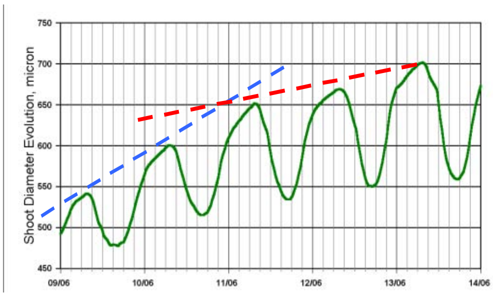
Examples of negative turn of the trend (inhibition of normal positive trend)



Arm Diameter: Avocado
(Afikim, Israel, 2000)

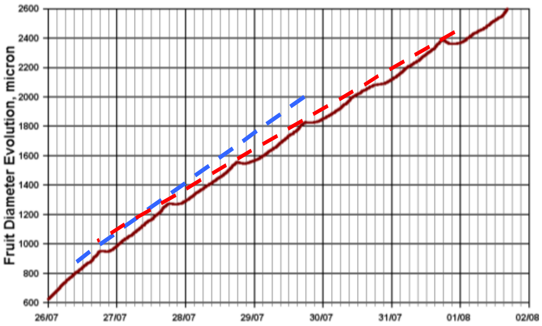


Trunk Diameter: Apple
(Yakima, CA, USA, 2000)

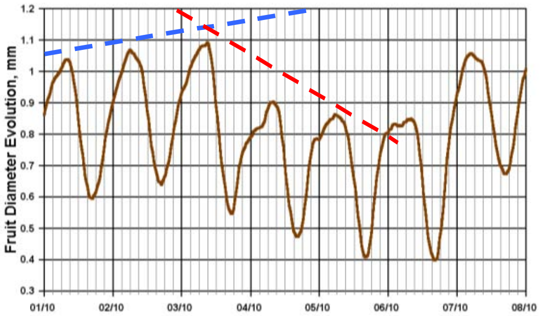


Shoot Diameter: Grapevine
(Fresno, CA, USA, 1999)

Daily Maximum Fruit Size Trend is used as indicator of fruit growth. Continual positive growth is considered as norm. The negative trend is an evidence of growth depression. In case of necessary number of replicates, the absolute fruit growth rate may also be used as a growth indicator.



Apple diameter turns to lower positive trend
(Baram, Israel, 1999)

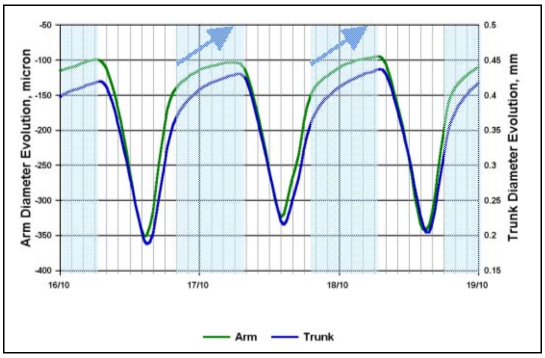


Avocado diameter change its trend to negative
(Afikim, Israel, 2000)

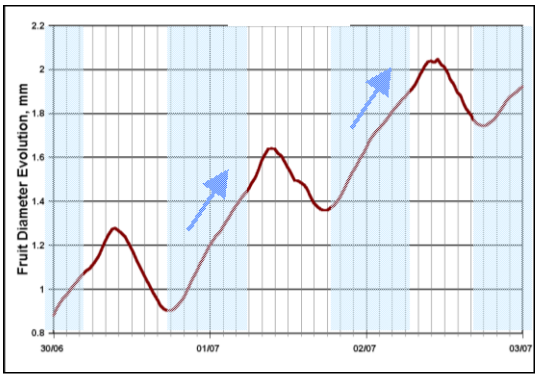
Some users prefer to consider a moving average curve instead of daily maximums. In the long-term view, the difference is almost negligible.

Stem or Fruit Diameter Nighttime Trend manifests the ability to restore normal water content and to keep normal growth. Nighttime swelling and/or growth are considered as norm. Any nighttime contraction is evidence of physiological disorder.

NORM

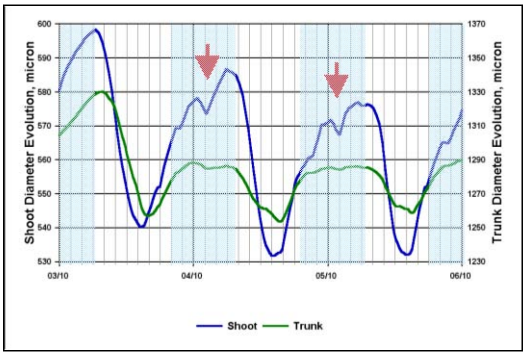


Avocado: Arm and Trunk (Afikim, Israel,2000)

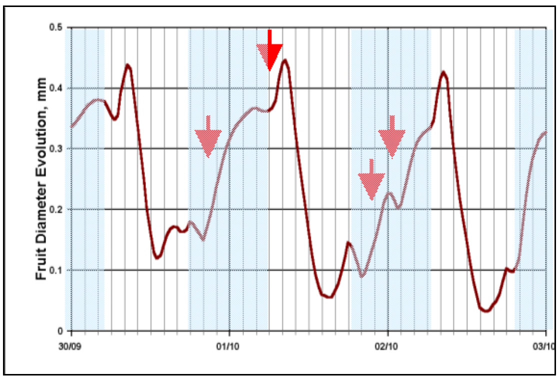


Apple (Manara, Israel,2000)

DEPRESSION

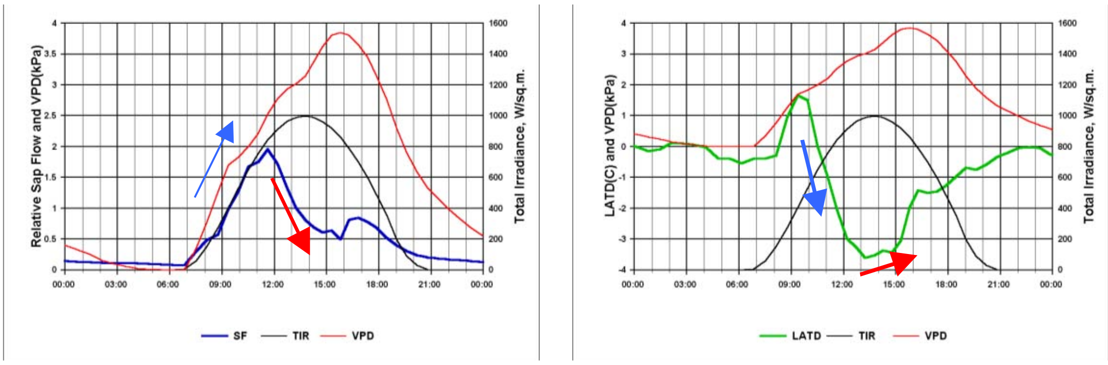


Grapes: Shoot and Trunk (Hermosilio, Mexico,1999)



Grapefruit (Hula, Israel,2000).

Test on limited transpiration (or "Stomatal Test") is used for detecting plant response to water deficit. Coordinated behavior of **stem flux rate** (SF) with **vapor pressure deficit** (VPD) and solar radiation (TIR) is a good indication of unlimited transpiration. The opposite behavior manifests probable stomatal response to water stress. Interpretation for **leaf-air temperature difference** (LATD) is inverse because of cooling effect of transpiration.



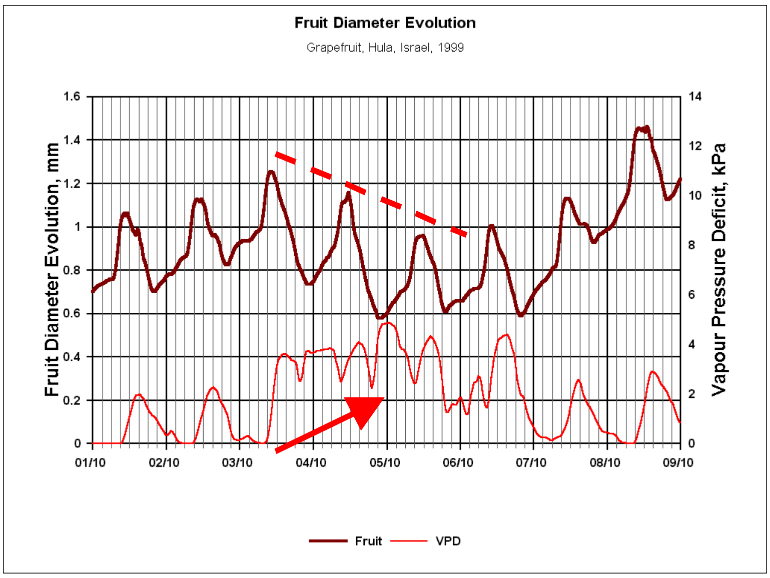
Stomatal response reveals itself in reversal behavior of stem flux rate (left figure, blue curve) and leaf-air temperature difference (right figure, green curve) vs. VPD and solar radiation

(Grapevine, TJG, South Africa, 1998)

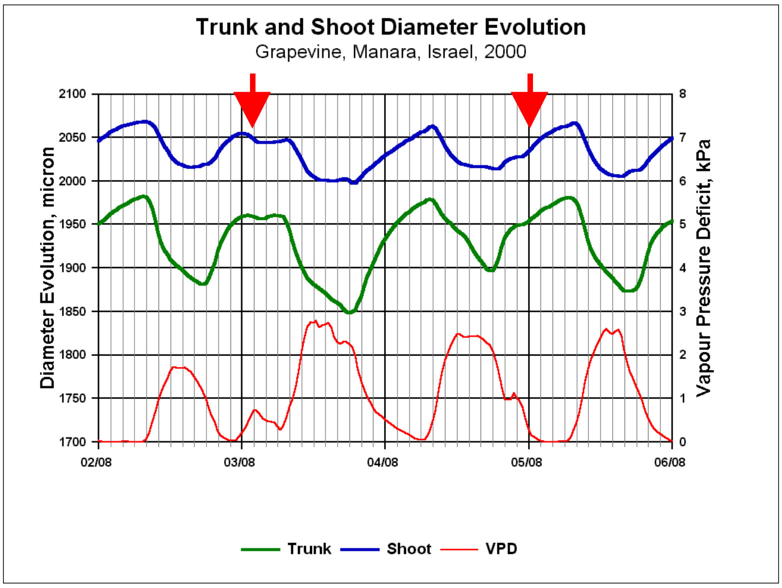
INTERACTION of plant related values and major influencing environmental factors is A KEY POINT of the PHYTOMONITORING ANALYSIS:

Any of above mentioned indicators of plant status should be analyzed and interpreted in relation to environmental factors affecting the plant. Interaction of plant-related characteristics and major environmental factors is a key point for correct data interpretation.

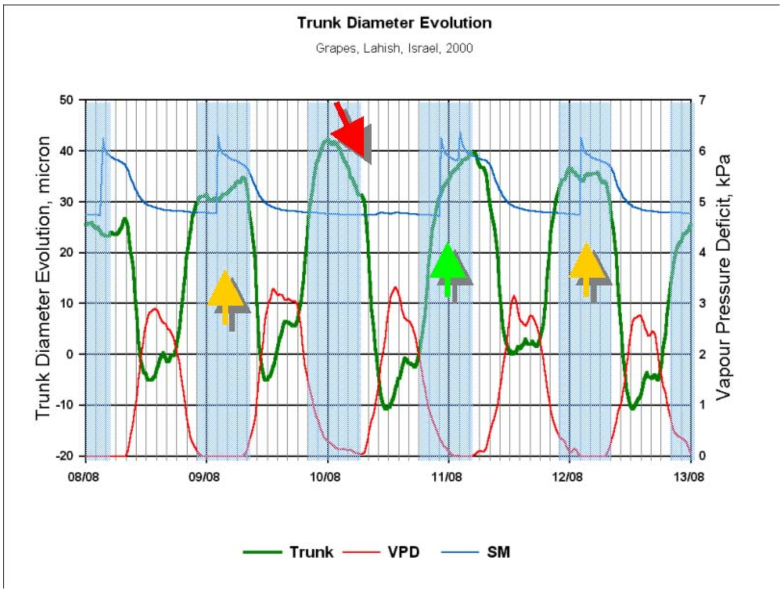
Some examples are shown below.



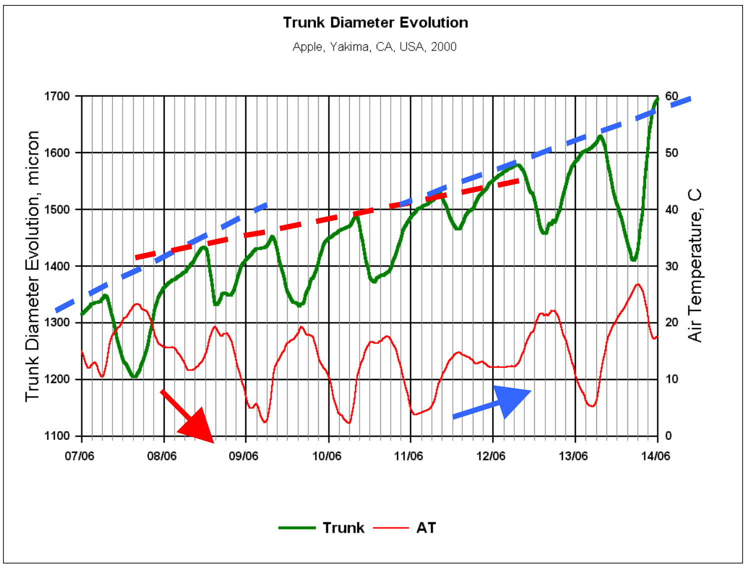
A negative turn of **grapefruit** growth trend was the result of air drought, which took place during October 3-6 both at daytime and nighttime. This conclusion follows clearly from mutual consideration of **fruit diameter** behavior (brown curve) and **VPD** (red curve). During those critical days, VPD exceeded 2 kPa at nighttime and reached 4 kPa or even more at daytime. The extremes of 38 °C at 20% RH were registered that time.



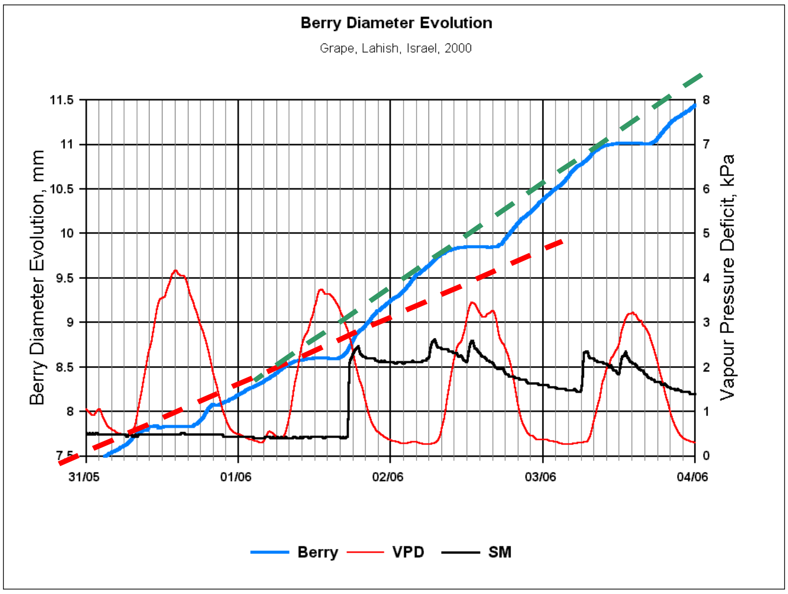
Effects of certain **nighttime depression** of both **shoot and trunk diameters** were observed at nights on 4rd and 6th of August (red arrows). The only factor, which was able to induce that phenomenon, was elevated **nighttime VPD**. In contrast with the most of other typical humid nights, those two nights characterized by certain periods of relatively dry and warm wind (20 °C and 70% RH). Excessive nocturnal evapotranspiration caused an unexpected water loss and subsequent dehydration of plants that was revealed in stem and trunk diameter depression.



Response of **trunk diameter trend** to watering (or sharp variation of **soil moisture**) is also a good indicator of plant water requirements. Significant swelling of **grapevine** trunk diameter followed watering on August 9 and 12 (yellow arrows). On August 10, a missed watering caused continual negative trend of the trunk after midnight (red arrow). Only on August 11, a double watering induce a typical, normal re-hydration of the grapevine (green arrow). Thus, one may see three easily interpretable incidents of trunk-moisture interaction.



In this case, temporarily reduced air temperature (AT- red curve) caused a lower trunk growth rate of apple tree (Trunk - green curve) . Comparing various combinations of examined plant-related value with affecting factors one may find interpret correctly most of observed phenomena.

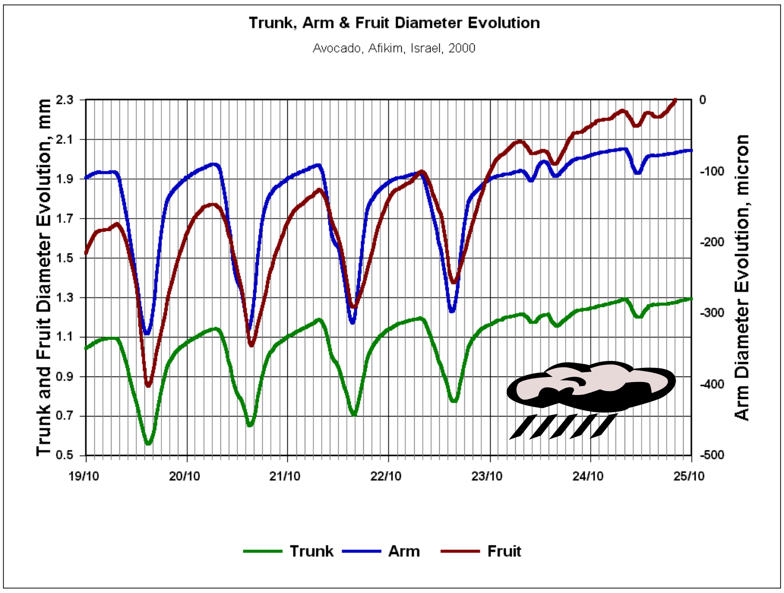


There are two environmental factors shown in the figure at the left. A grower started **irrigation** of his **vineyard** the 1st of June (see SM - black curve). At the same time, the diurnal **air VPD** (red curve) was gradually lowering during the four days presented on the graph. As a result of this favorable combination (most likely, due to irrigation), the measured **size of berry** became to grow faster than before.

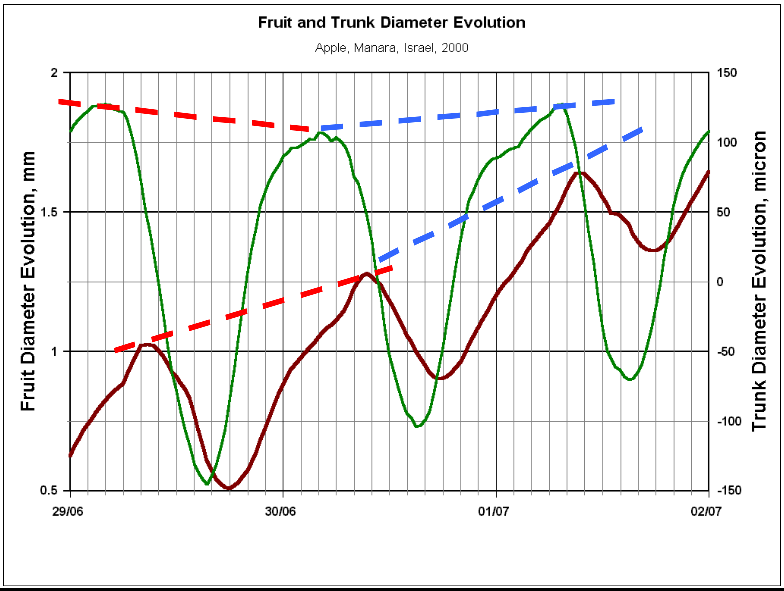
Plant dynamic response to variation of any environmental factor is a foundation of data interpretation in the Phytomonitoring technology. It enables a grower to disclose physiological disorder in plant at very early stages. In case of examining irrigation regime, the phytomonitoring technique helps a grower to evaluate plant water stress and make a right decision. Consideration of plant axial organs behavior versus solar radiation, vapor pressure deficit and soil moisture is a common way to investigate dynamics of water status and to find probable limiting factor (bottleneck). Then a grower may try to improve situation within manageable limits. The response of plants to new regime is to be used for planning further technological measures.

INTERRELATION of different plant related values is A KEYNOTE of the PHYTOMONITORING ANALYSIS:

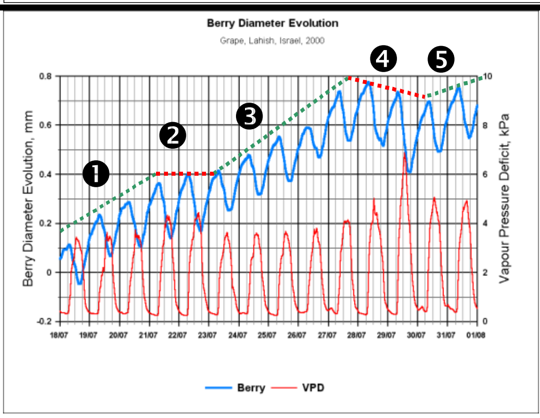
Obviously, all plant related measurements are highly interrelated as long as they represent the same organism. In most cases, contraction (or swelling) is observed for all axial organs simultaneously as a result of plant dehydration (or rehydration). Xylem is a common conducting system, which equalizes a long-term trend of hydration processes in ramified plant organism. At the same time, growing plant organs with meristematic tissue may compete for water with older parts containing mainly perenchymal tissue. In the phytomonitoring practice, most often, young growing fruits are in competition with older vegetative organs like trunk or shoot.
Some examples of solidarity of different plant organs in response to external effects are shown below.



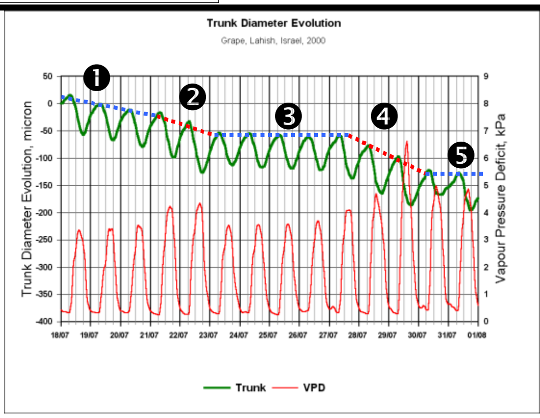
As it is shown in figure at the left, behavior of **trunk**, **arm** and **fruit** of **avocado** were alike in form and trend. Response to rainy conditions, which took place after October 23, was also similar for all objects: daily contraction became much less expressed while the general growth trend turned to more positive value.



In some cases, the trends of different organs may be different, as it is shown in figure at the left. During June 29-30, **apple diameter** (brown curve) manifested positive trend while the trunk **diameter** (green curve) daily maximum trend was negative. However, due to more rich irrigation, both responded alike: the trunk turned its trend from negative to positive and the fruit showed higher growth rate.
In this regard, the following example of relationship between **grapevine trunk** and **berry** is very indicative.

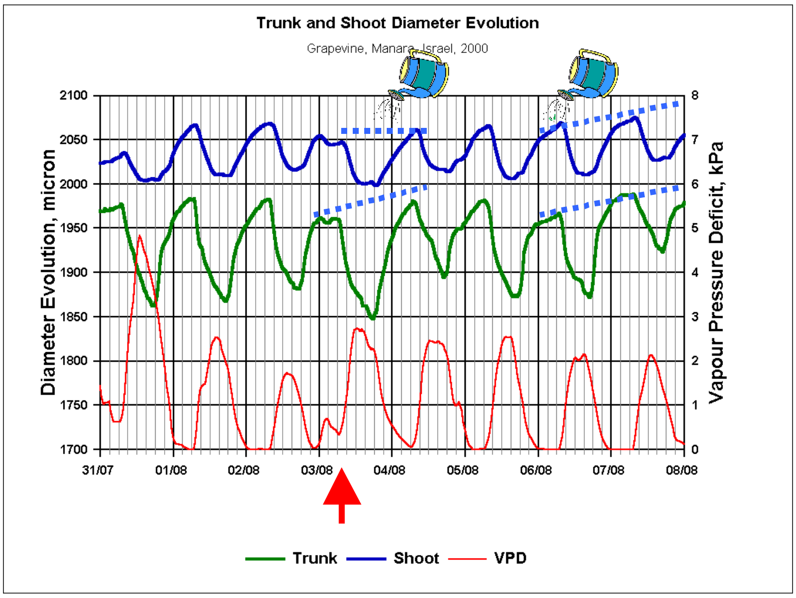


Berry size



Trunk Diameter

Due to combined effect of soil moisture, VPD and other environmental factors, the traces of trunk diameter and berry size had complex but different form (see above). General trend of berry size was mostly positive and, in turn, was mostly negative for the trunk diameter. However, every time the turn of both traces was alike: ❶ to❷: negative turn, ❷ to❸: positive turn, ❸ to ❹: negative turn, and ❹ to❺: positive turn. One may conclude that, despite of different general trend, both trunk and berry experienced improvements or problems synchronously.



The last example shown in figure to the left, emphasizes similar response of **grapvine's trunk** and **shoot** to watering made on August 4 and 6 and to dry night on August 3.

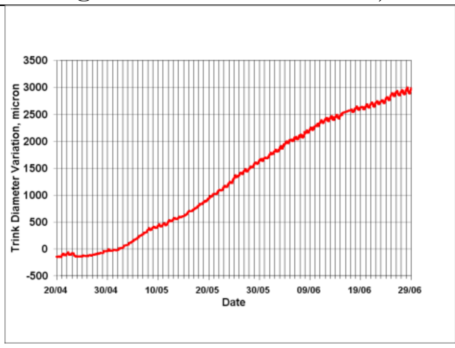
Thus, the phytomonitoring technique comprises many useful indications of plant physiological status and development. They are based on analysis of trends, plant-environment interaction and interrelation of different plant-related characteristics.
A few following examples demonstrate application of the phytomonitoring technique for some routine practical tasks.

When start to irrigate?

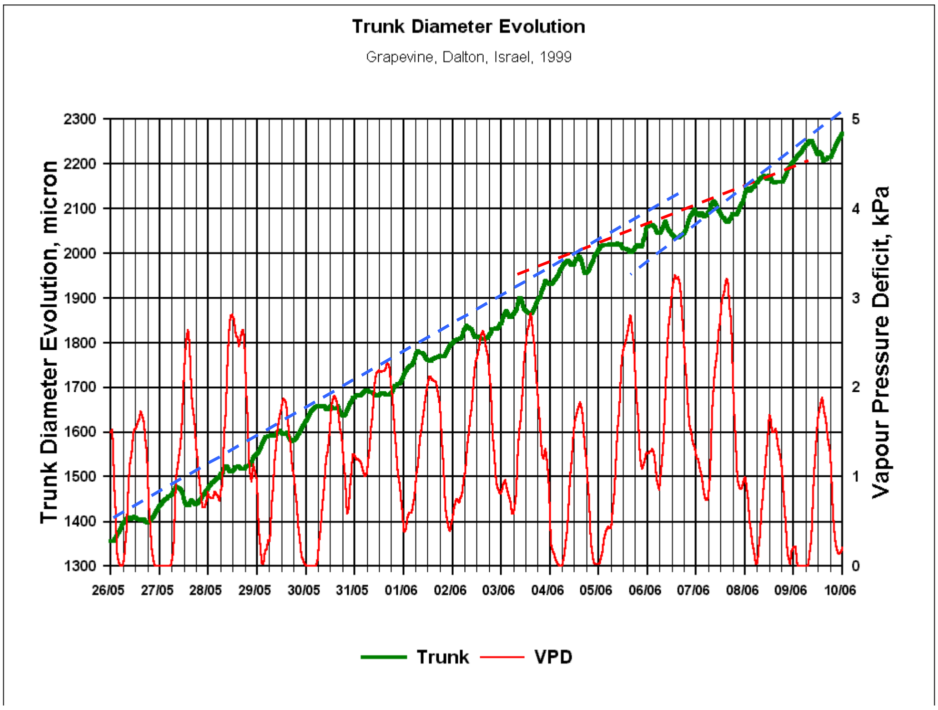
In spring, soil still may hold a substantial amount of water. To start irrigation, a grower has to know precisely when irrigation can provide extra return. Early irrigation is not only a waste of water, but can lead to lowered crop quality and yield. The late irrigation is also risky because of probable crop damage and loss of yield. With certain reservation, we may assume that significant inhibition of growth rate at vegetative stage may be considered as indication of water deficit if it was not caused by low temperatures or another external reason. In this regard, a trace of trunk diameter seems to be a very good indicator of plant growth.

Example 1 and 2. DETECTING PLANT NEEDS IN WATER
(Cabernet-Sauvignon, Dalton Winery, Israel, 1999. Cabernet-Sauvignon, Manara, 2000, Israel)

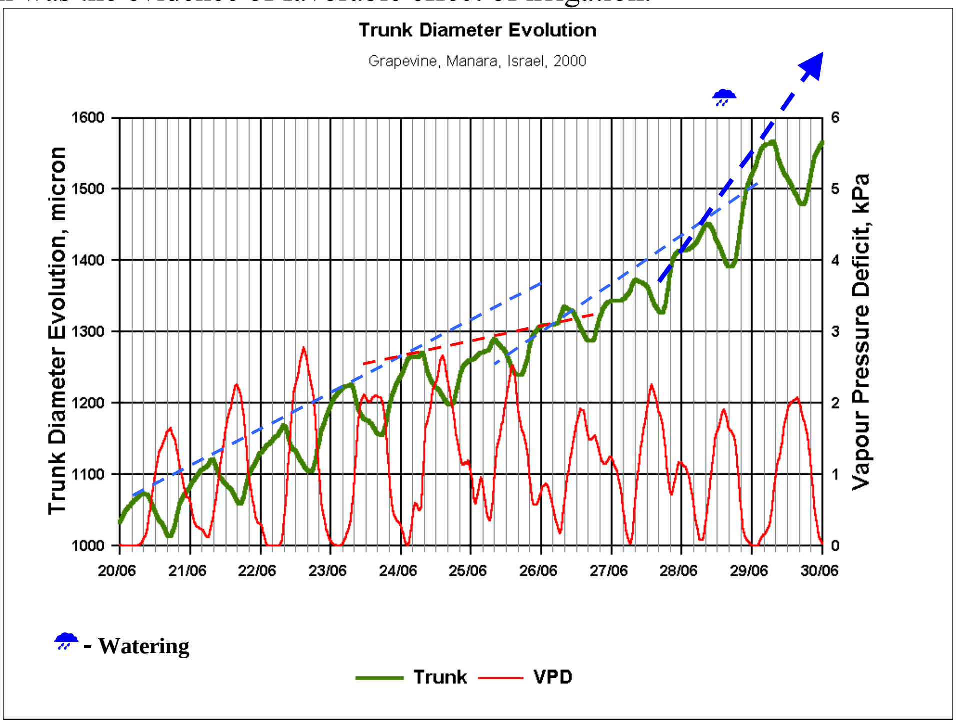
The curve shown in figure to the right represents a normal trunk diameter variation curve from April to end of June. During this period of a season, a grower was estimating trunk diameter daily maximum trend in relation to VPD, soil moisture and temperature everyday. Till the beginning of June, the trunk did not respond to VPD even when it reached 5 kPa at daytime and 2 kPa at nighttime. Some short growth inhibitions were caused by low temperature.



Since June 6, the trunk response to high VPD was first time detected. Most likely, it was a moment when plant actually felt certain water deficit. However, to come to the final decision, a grower may take into consideration other available methods for estimating plant water requirements as well as the weather forecast.



Similar example is shown below. A grower started irrigation at the end of June when significant response of trunk diameter to VPD was detected. Further acceleration of growth was the evidence of favorable effect of irrigation.

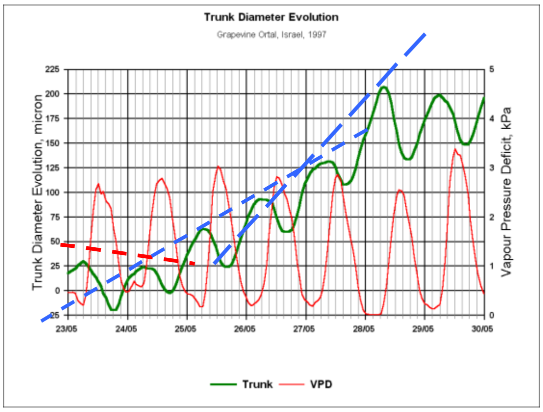


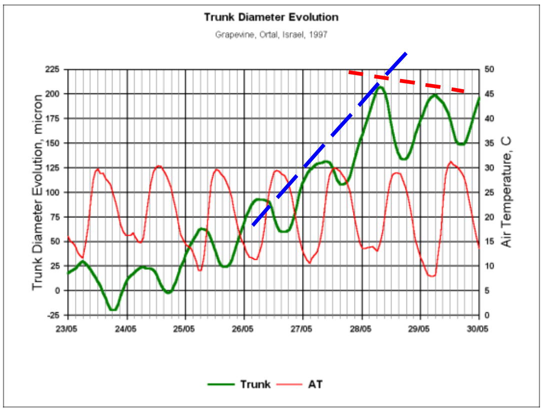
How to diagnose a problem?

To come to correct decision on irrigation scheduling, a grower has to make sure that the problem he found out is connected with water deficit and not with any other environmental factor.

Example 3. EFFECT OF LOW NIGHTTIME TEMPERATURE *(Grapevine, Ortal, Israel, 1997)*

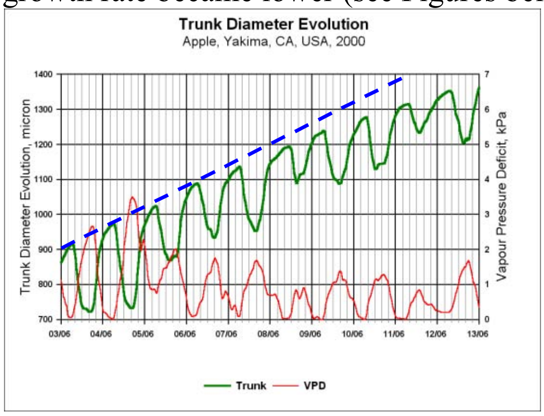
To disclose a chilling stress, a grower has to analyze trunk and shoot diameter trends in relation to air temperature and VPD. In the figures below, one may see that trunk diameter behavior was affected mainly by air dryness at nighttime till May 29 (see Figure to the left). The followed negative trunk diameter trend was not connected with VPD but it was the most probable result of lowering temperautre below 10 °C (see Figure to the right).

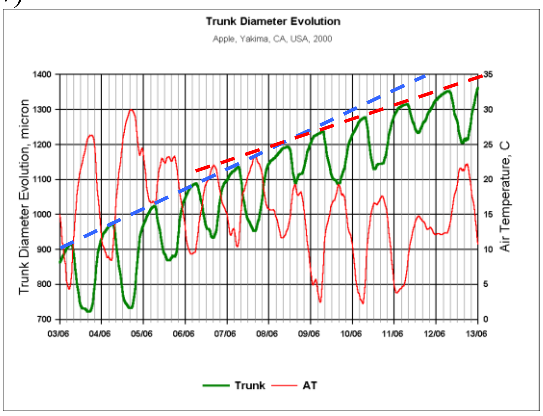




Example 4. INHIBITION OF GROWTH AT LOW TEMPERATURES *(Apple, Yakima, CA, USA, 2000)*

The plants were not sensitive to air drought neither at daytime nor at nighttime. However, when the temperature gradually went down after June 9, the trunk diameter growth rate became lower (see Figures below)



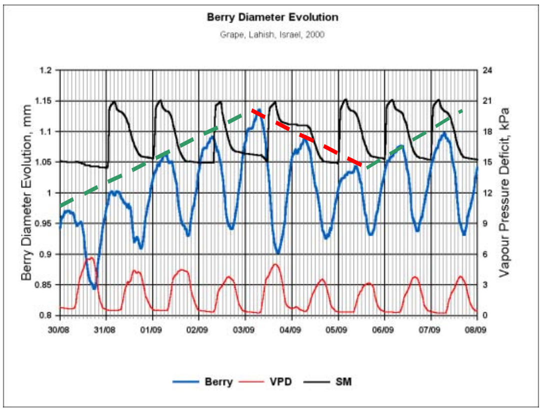


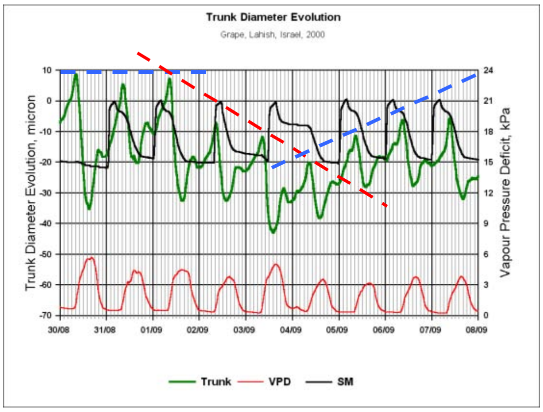
How to tune irrigation scheduling?

In many cases, even a time of a day when water is supplied to plants is also important for crop performance.

Example 5. EFFECT OF WATERING TIME *(Grape, Lahish, Israel, 2000)*

Results of grower's attempts to shift the nighttime watering to daytime between September 2 and 5 are shown below. In this particular case, the daytime watering had significant negative effect both on trunk and berry size. Returning to nighttime watering restored previous trends as it is seeing in figures below.

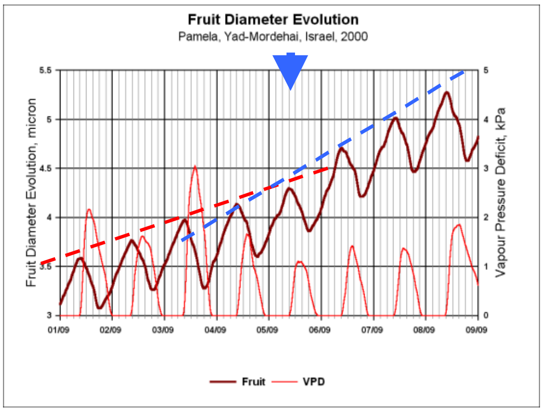


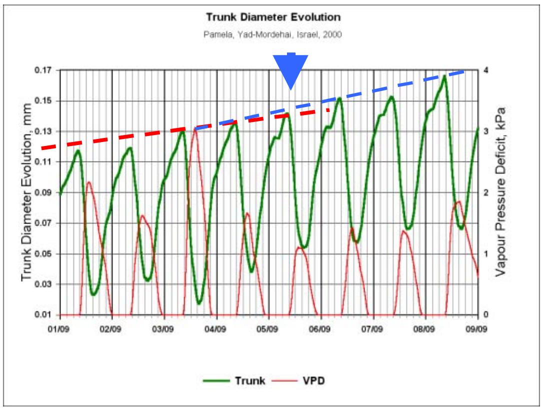


The effect of watering may also depend on portions and number of watering cycles within a day

Example 6. EXAMINING IRRIGATION SCHEDULING *(Pamela, Yad-Mordehay, Israel, 2000)*

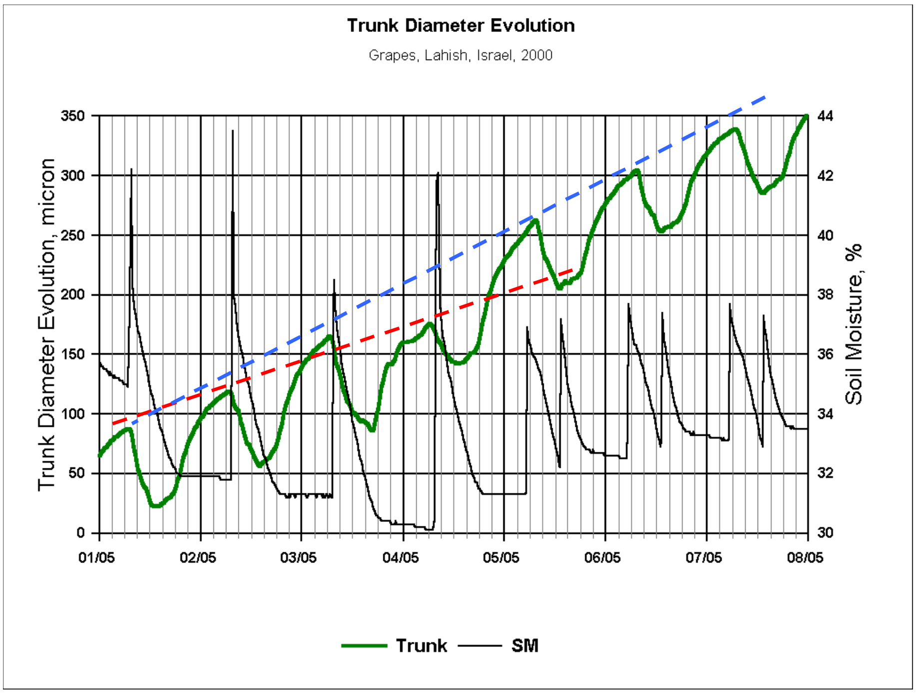
The pamela trees were irrigated once a day before September 5. Later on, a two irrigations a day were examined. Both fruit and trunk growth became more intensive under two-times-a-day irrigation.



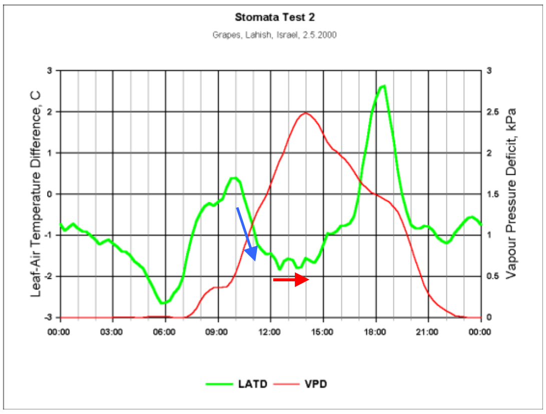


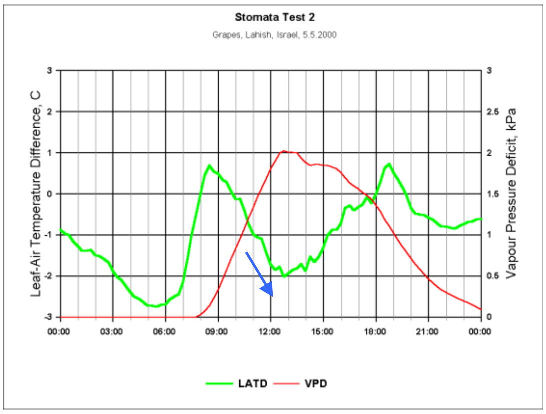
Example 7. EXAMINING IRRIGATION SCHEDULING *(Grapes, lahish, Israel, 2000)*

The use of two waterings a day instead of one was also favorable for grapevine trunk growth (see figure below). It also reduced magnitude of soil moisture daily variations.



It is important to note that new irrigation scheduling had also favorable effect on stomatal response.

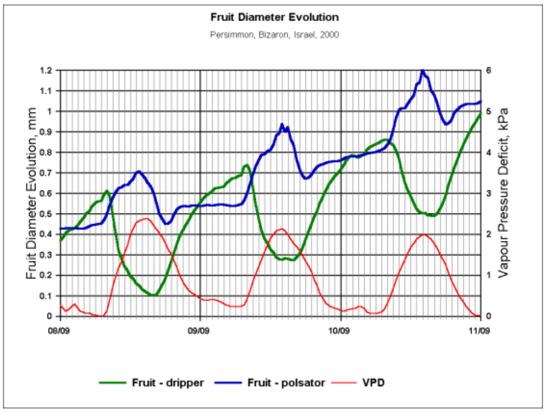


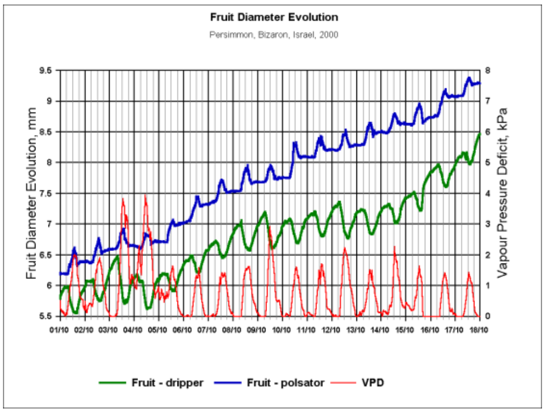


Which irrigation technique is better?

Example 8. EXAMINING IRRIGATION TECHNIQUE *(Persimmon, Bizaron, Israel, 2000)*

Two irrigation techniques were under examination: regular once-a-day watering (green curve) and pulse watering (blue curve). It gave not only a different daily forms of fruit growth (see figure below to the left). The pulse watered plants manifested also higher tolerance to air drought (see figure below to the right).



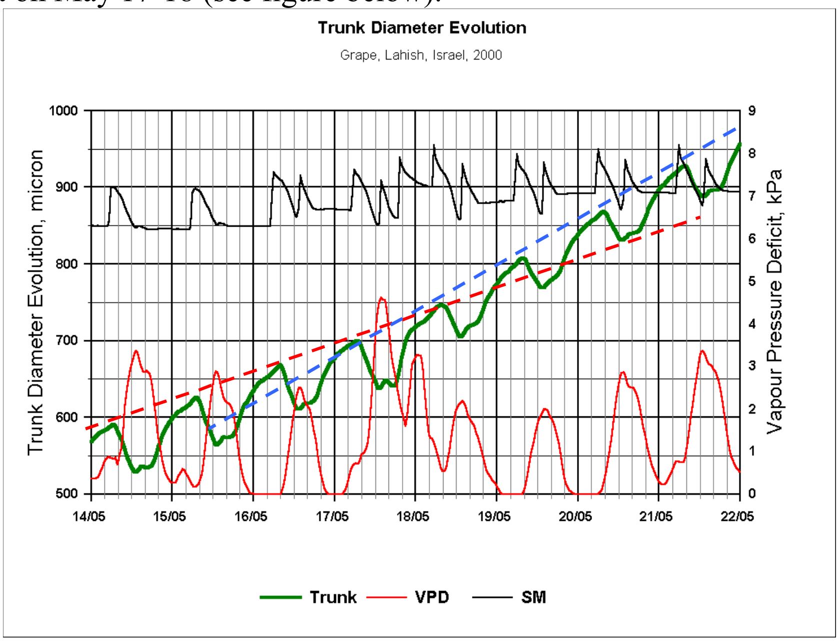


What amount of water does crop need?

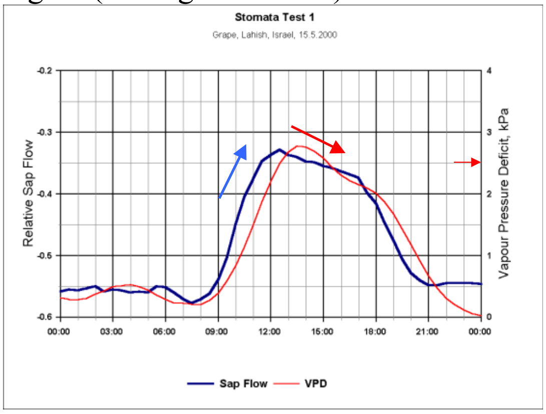
The phytomonitoring technique is a perfect tool for examining sensitivity of plants to more rich irrigation. At the same time, a grower should estimate economical aspects of more water application that is not considered in present poper.

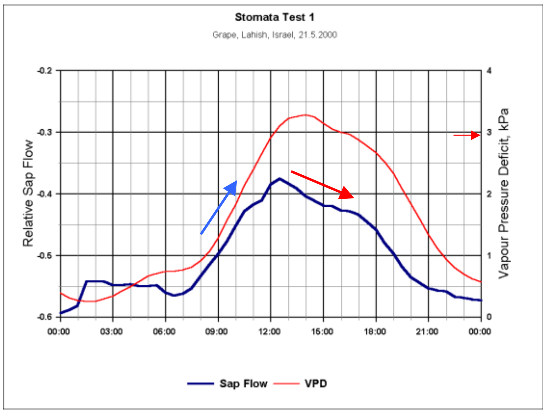
Example 9. EXAMINING IRRIGATION NORM *(Grapes, Lahish, Israel, 2000)*

More reach application of water leaded to higher trunk growth rate despite developing air drought on May 17-18 (see figure below).



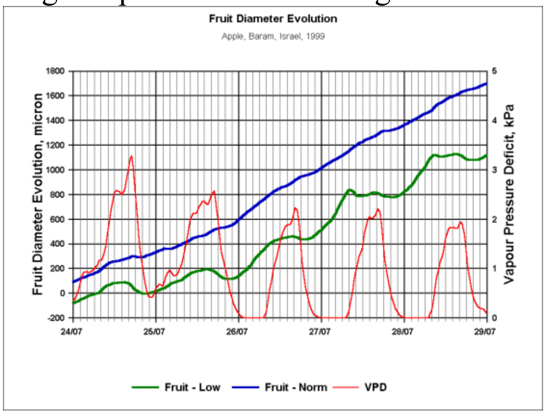
Stomatal response also showed favorable effect to more intensive irrigation: the critical level of VPD (when sap flow rate showed trend opposite to VPD) became higher (see Figures below).

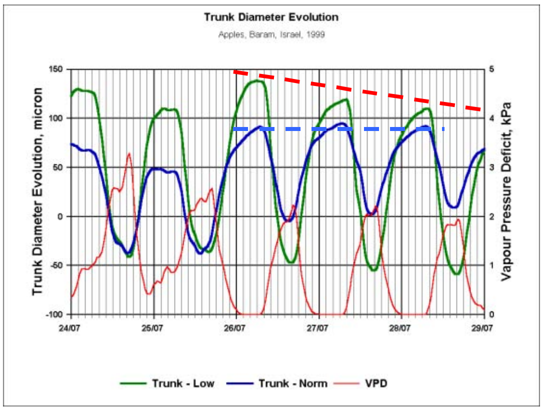




Example 10. EXAMINING IRRIGATION NORM *(Apple, Baram, Israel, 1999)*

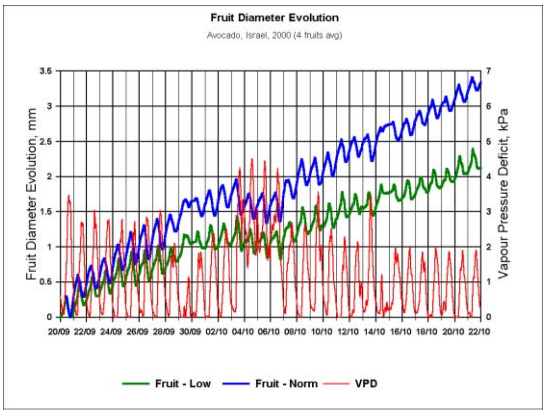
Two irrigation regimes were tested: the norm (based on calculation of potential evapotranspiration) and 60 % of the norm. Lesser watered plants (green curves) were more sensitive to VPD and manifested even short negative trends while the normally irrigated plants was remaining stable.

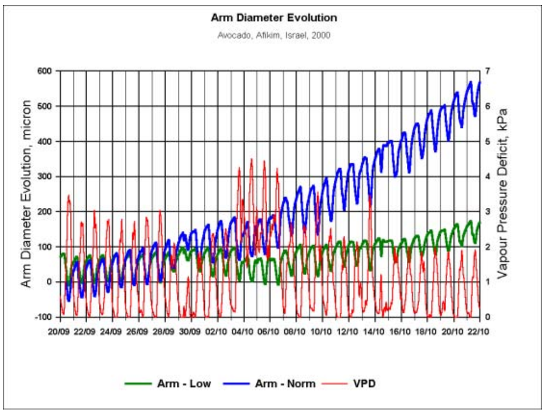




Example 11. EXAMINING IRRIGATION NORM *(Avocado, Afikim, Israel, 2000)*

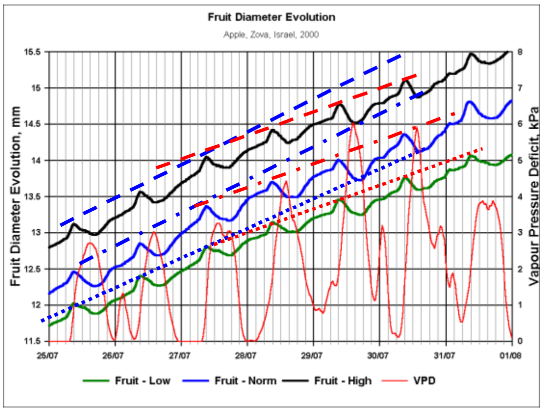
As in above-mentioned example, two irrigation regimes were tested for avocado: the norm and 70% of the norm. Lesser-irrigated plants (green curves) had lower fruit growth rate. Behavior of the arm trend was even more differentiated between treatments (see figure to the right).

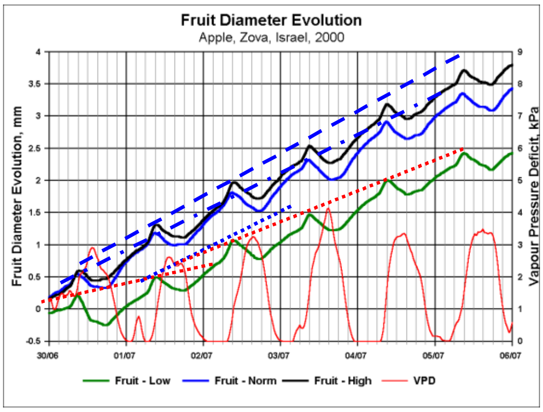




Example 12. **EXAMINING IRRIGATION NORM** *(Apple, Zova, Israel, 2000.)*

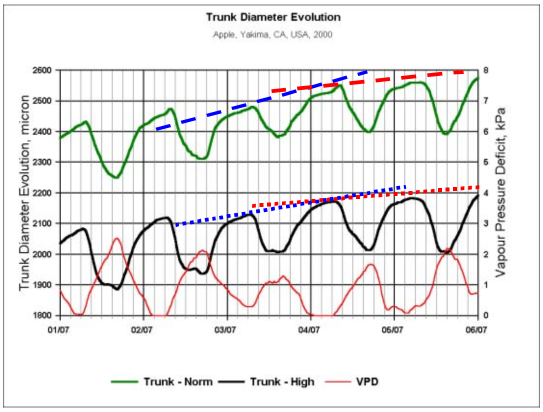
Three irigation regimes were tested: the norm (green curve), 130% (black curve) and 70% of the norm (green curve). Fruit diameter trends for all three treatments are shown in the figure below. Similar response of trends to air drought (see left figure) is probable evidence of excessive irrigation norm in this particular period of the season. A few weeks before the trend of lesser-irrigated plants was lower that might be interpreted as well-balanced irrigation norm (see figure to the right).

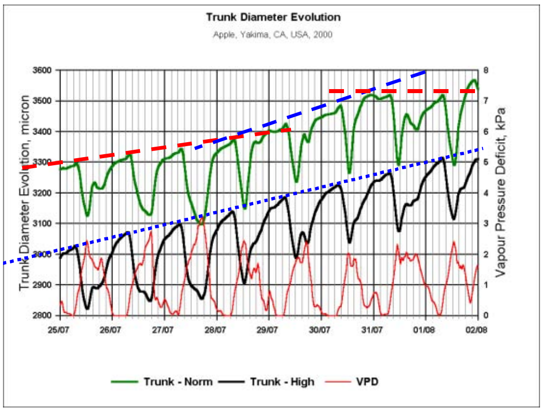




Example 13. **EXAMINING IRRIGATION NORM** *(Apple, Yakima, CA, USA, 2000)*

Two irrigation regimes were examined: the norm (green curve) and 130% of the norm (black curve). Similar response of trunk diameter trend to air drought is probable evidence of well-balanced norm (see figure to the left). More expressed response shown in the right figure may be interpreted as water deficit in normally irrigated plants.





GENERAL NOTE:

All above-mentioned examples can not be used as common recommendations for cultivation. The everyday application of the phytomonitoring technique may open a new exciting opportunities for initiative grower or agronomist.

Exclusively Distributed and Supported By:

edaphic scientific

environmental research & monitoring equipment

www.edaphic.com.au
info@edaphic.com.au
Ph: 1300 430 928