Methods for assessing vineyard water use

Shannon Pudney1 and Michael McCarthy2
1South Australian Research and Development Institute, Adelaide
2South Australian Research and Development Institute, Nuriootpa

Introduction

Soil water monitoring should be, by now, an integral component of best practice vineyard management. The benefits of using soil water monitoring equipment have been clearly demonstrated and now that Australian grape growers have access to a wide range of soil moisture monitoring devices there should be no reason why they are not in universal use. Devices vary in price and sophistication, such that there is equipment available to suit nearly all requirements. This in itself creates problems for growers who are often confused as to which type of soil water monitoring equipment they should purchase. The objectives of this paper are to:
1. provide an overview of soil moisture sensors commonly used in southeastern Australia
2. discuss sensor response times
3. discuss the spatial variability in soil moisture across a vineyard block

Measuring soil moisture status

Soil water content may be determined gravimetrically; this involves removing a portion of soil from the sample site and hence it is not appropriate for continuous long term monitoring. In situ sensors have thus been developed. It is important to recognise that although all soil moisture sensors (SMS) measure soil moisture status, they use different measurement techniques. The output from SMS systems is recorded as either volumetric soil water content or soil water tension. Volumetric soil water content is a measure of the amount of water contained in a volume of soil, whereas soil water tension is a measure of the force (pressure) that a plant must overcome to extract water from the soil matrix.

Products that measure soil water tension can be classified as porous media instruments (Table 1). The operating principle of such devices is relatively simple: water is drawn out of the porous medium in a dry soil and absorbed by the medium in a wet soil. The flux of water is quantified by a pressure gauge or by a change in electrical resistance; both measures are related to soil moisture content. Products that fall into this category include gypsum blocks (heavy and light) and tensiometers.

Sensors that measure volumetric soil water content are currently more widely available than those that measure soil water tension. Volumetric soil water content sensors are generally placed in one of three categories—soil dielectric, neutron moderation, and heat dissipation (Table 1), based on the operating principle of the sensor. Sensors included in the soil dielectric category utilise the dielectric properties of the soil to measure volumetric soil water content. Such instruments apply an electromagnetic pulse or wave to the soil; the ability of the soil to conduct this energy is related to soil water content. There are many subtle differences between the operating principles of ‘soil dielectric’ sensors; this is where the terminology capacitance, time domain reflectometry (TDR) and time domain transmissometry (TDT) emerges (Table 1). It is not the intention of this paper to describe these subtle differences, rather it is important to appreciate that capacitance, TDR and TDT all utilise the dielectric properties of the soil to measure volumetric soil water content.

Neutron moderation is another technique for measuring volumetric soil water content. In this technique, fast moving neutrons emitted from a small radioactive source are slowed or thermalised when they collide with hydrogen ions in the soil. This technique assumes that the components of the soil matrix are constant with the exception of air and water. Air has very little effect on the dielectric property of the soil (cf water), hence the number of neutrons that are thermalised is related to the water content of the soil (George, 1999).

Table 1: Measurement unit and operating principle of soil moisture sensors commonly used in South Eastern Australia.

<table>
<thead>
<tr>
<th>Unit of Measurement</th>
<th>Gravimetric</th>
<th>Tension</th>
<th>Volumetric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Principle</td>
<td>Destructive Soil Sampling</td>
<td>Porous Media</td>
<td>Soil Dielectric</td>
</tr>
<tr>
<td>Products Available</td>
<td>Gypsum Block Heavy</td>
<td>C-Probe (C)</td>
<td>CPN Neutron Sensor</td>
</tr>
<tr>
<td></td>
<td>Gypsum Block Light</td>
<td>Diviner 2000(C)*</td>
<td>Hydorprobe*</td>
</tr>
<tr>
<td></td>
<td>Tensiometer</td>
<td>EnvirosCAN(C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Theta Probe(C)</td>
<td>Gopher (C)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reflectometer(TDR)</td>
<td>Theta Probe(C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GroPoint (TDT)</td>
<td>Theta Probe(C)</td>
<td></td>
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</tbody>
</table>

C=Capacitance, TDR=Time Domain Reflectometry, TDT=Time Domain Transmissometry
*It is not possible to continuously log these sensors. All other sensors can be continuously logged and remotely accessed.
The third category of volumetric soil water sensors is ‘heat dissipation’. These sensors consist of a heater separated by a known distance from a thermometer. A known amount of heat energy is emitted from the heater and the peak soil temperature reached is recorded, this information is used to calculate volumetric soil water content (Charlesworth, 2000).

Many of the sensors listed in Table 1 have been trialled at the South Australian Research and Development Institute Nuriootpa Research Station. Over the last two seasons the sensors have produced consistent seasonal soil moisture trends (Pudney et al. 2000, 2001), however at any one point in time there was variation between soil moisture readings. It is likely that the variation was due to differences in response time and spatial variation in soil moisture. The remainder of this paper explores these issues.

Soil moisture sensor response times

It is important to understand the response time of a sensor in order to interpret soil SMS data accurately. Response time must be considered when frequent irrigations are applied or if fine control over irrigation is desired.

An opportunity to investigate soil moisture sensor response times presented itself in May 2002, when over a 40-hour period 56.2mm rain was received. The rain commenced at 10:30 am on 18 May and continued until 1:45 am on 20 May. At the time of the rainfall event there was no foliage on the vines, hence it can be assumed that the water application was even (i.e. not biased by irrigation wetting patterns). The response of four types of SMS to the rainfall event was assessed.

The soil at the Nuriootpa site consists of a sandy loam over heavy clay. Northcote et al. (1954) classified the soil as Light Pass Fine Sandy Loam. Most roots (90%) are located within 60cm of the soil surface (Pudney et al. 2000). The sensors have been installed in a 15-year-old block of Chardonnay for approximately 1.5 years for this entire period they have had an identical irrigation history. Two sensors (no. 1 & 2) are porous media instruments, while two sensors (no. 3 & 4) are dielectric instruments. Three sensors of each type were installed alongside consecutive vines in the same relative position in the irrigation wetting zone. One at a depth of 20 cm, one at 40 cm and one at 60 cm. The vine and row spacings are 2.25m and 3m respectively.

Results

Sensor four detected the wetting front at 20cm approximately 3 hours after the commencement of rain, (Figure 1), sensor three 6.5 hours, sensor one 16.5 hours and sensor two 18.5 hours after the commencement of rain. Sensors one, three and four all detected the wetting front at 40cm approximately 25 hours after the commencement of rain. Sensor two responded some 10 hours later (37.5 hours after the commencement of rain—Figure 1). At the 60cm depth level the differences were the greatest. There was a 28-hour difference between the first and last sensor responding (sensor three, 35.5 hours after commencement of rain, sensor four, 38 hours, sensor one, 54.5 hours and sensor two 63.5 hours).

Discussion

Sensor response times were variable. The dielectric sensors tended to detect the wetting front at each of the sensor depths prior to the porous media instruments. Factors that may have contributed to such variation can be grouped as site and sensor influences. Site influences include irrigation history and soil factors. Sensor influences include mode of operation, sphere of influence, installation and soil type specificity. Each of these factors is discussed below.

Site Influences

Water will move through the soil profile at variable rates depending on the initial soil moisture status. The initial (pre-rainfall) soil moisture content was comparable for each of the sensors as all have identical irrigation (and rainfall) histories. They have also been installed in the same relative position in the irrigation wetting zone. Given the above it could be assumed that the sensors were in identical soil environments, however, soil is not a homogenous medium. There will always be some variation in soil properties even in the most “uniform” soil types (such as the Light Pass Fine Sandy Loam into which the sensors have been installed). Variation in soil properties (and the presence of preferential pathways) will inevitably contribute to the observed variation in response time.

Sensor Influences

Some of the observed variation in response time may be attributed to the mode of operation of the sensors. Two of the trialled devices were porous media instruments and two were dielectric sensors. When moisture levels are raised in the soil surrounding a porous media instrument, matric potential (and capillary action) will drive water into the porous medium. It is only after water has been ‘absorbed’ by the medium that an increase in soil moisture content is indicated in the soil moisture sensor output. When the soil moisture content increases in the soil surrounding a dielectric instrument, the dielectric properties of the soil are altered and this is immediately reflected in the sensor’s output. In this regard it is not surprising that the dielectric sensors detected the wetting front at each of the depths before the porous media instruments.

Sensors also differ in their spheres of influence. The sphere of influence of a sensor can be defined as the volume of soil surrounding the sensor within which a change in soil moisture content will alter the sensor’s output. Although the sensors in this study were installed at the same depths they had different sized spheres of influence. The effect of such a
phenomenon is that different sensors installed at the same depth are ‘reading’ different soil volumes. Once again this will inevitably contribute to the variation in response time.

Installation is yet another factor that may be responsible for the observed differences in response time. It is necessary to disturb the soil profile in order to install a soil moisture sensor. There are various installation techniques. Some involve augering a hole, placing the soil moisture sensor in the bottom, and backfilling with the original soil—with or without a foreign medium to ‘plug’ the hole. Others involve augering a hole and then inserting an ‘access tube’ into which the sensors are placed. Every method has the potential to alter soil properties, particularly bulk density, which will affect infiltration rates and consequently response times.

Finally, the soil type into which the sensor has been installed must be considered. Some soil moisture sensors are designed for use in a specific soil type, referred to above as soil type specificity. For example, the composition of porous media instruments (ratio of macro to micro pores) is designed to mimic the soil type in which it is to be used; this is necessary as pore size influences the rate of water movement. Sensor one is suited for use in heavier soils, whereas sensor two is designed for use in lighter soils. This is perhaps why sensor two is the last sensor to detect the wetting front at 40cm and 60cm.

Summary

The data presented in this paper demonstrates that the response times of soil moisture sensors are variable. The time that a sensor takes to respond to a wetting event is the product of complex interactions between sensor and site factors. These factors include irrigation history, mode of operation, sphere of influence, soil specificity, soil variability and installation. It is imperative that these factors are understood when SMS data are used to schedule irrigations. It may be appropriate to use a sensor with a slow response time when irrigations are infrequent, however in vineyards where daily crop water use is high and water may be applied every day, or second day, sensors with a short response time may be required. The ideal SMS will behave in a manner that perfectly mirrors the soil dynamics.

Spatial variation in soil moisture

The rainfall event on 18 May 2002 also provided the opportunity to investigate the spatial variation in soil moisture across a vineyard block. Data are presented from three sets of soil moisture sensors (soil moisture stations) installed in different locations in a one hectare vineyard block (described above). Sensors of the same type were installed in June 2000, at depths of 20, 60, and 80cm at each of the three locations. They have received the same level of irrigation since 2 April 2002.

Results and Discussion

Spatial variability in soil moisture was assessed by comparing pre- and post-rainfall soil moisture readings at each of the three locations (Figure 2).

Each of the sensors responded to the rainfall event, hence they were all operating satisfactorily. Following the rainfall event all sensors indicated that the soil was wet (wetter than the lower measuring limit of the device). However, the pre-rainfall event values were highly variable. The soil moisture readings from location 1 (SMS Station 1) indicated that the soil was wet at 20cm, drying at 60cm and completely dry at 80cm. The readings from location 2 (SMS Station 2), indicated that the soil was wet to 60cm and completely dry at 80cm. The group of sensors at Location 3 (SMS Station 3), indicated that prior to the rainfall event the soil was drying at a depth of 20cm, wet at 60cm and drying at 80cm. If the block was being managed to maintain high rootzone soil moisture levels, based on pre-rainfall data three very different management decisions could be reached (Table 2).

<table>
<thead>
<tr>
<th>Location</th>
<th>Most appropriate course of action</th>
</tr>
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<tbody>
<tr>
<td>Station 1</td>
<td>Apply a deep penetrating irrigation</td>
</tr>
<tr>
<td>Station 2</td>
<td>No need to irrigate</td>
</tr>
<tr>
<td>Station 3</td>
<td>Apply a light irrigation</td>
</tr>
</tbody>
</table>

Summary

This data set highlights the problem with point monitoring in a vineyard. In this study soil moisture status was found to be variable in a small vineyard block, planted on a uniform soil type, with an identical irrigation history. Whilst vineyard managers attempt to reduce differences in soil water content within a vineyard irrigation shift (by matching readily available water and variety to valve shifts) it must be recognised that variation will still exist. A single SMS installation site in an irrigation shift may not give sufficiently accurate information to enable ‘best practice’ irrigation scheduling.
Conclusion

There are many types of soil moisture sensors, they differ in the way they express soil moisture content and in their mode of operation. To gain the maximum benefit from the use of soil moisture sensor data it is important to understand how the information is generated. Soil moisture sensors generate data values that reflect the soil moisture status within the sensor’s sphere of influence. This value may or may not be reflective of the water status in the entire irrigation shift. Soil moisture sensors will take varying lengths of time to respond to a wetting event. Factors such as irrigation history, mode of operation, sphere of influence, soil specificity, soil variability and installation will all influence the response time of a sensor. Soil moisture sensors are a powerful management tool, however their limitations must be appreciated. Data from SMS should always be integrated with other plant based vineyard measures.

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References