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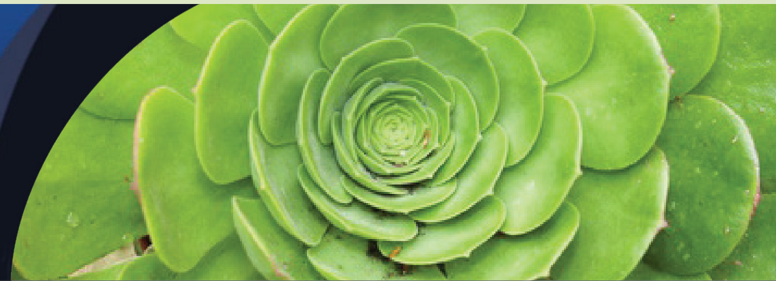

Inside

Reap Profits During Drought

by **Julie P. Newman, James Bethke and Steve Tjosvold**

California's historic drought continues to pose challenges for the greenhouse and nursery industry, especially for growers who produce plants for outdoor use. Water restrictions have resulted in fewer landscaping projects and many home owners have scaled back their garden projects, resulting in fewer sales of outdoor plants. Scott Klittich, chairman of the board of the California Association of Nurseries and Garden Centers (CANGC), estimates that there was a 20 to 25% decrease in business across the board in spring sales (McClellan 2015a), which historically is the most lucrative period for the industry. Moreover, even though most of the state's growers have already cut down on water use, higher water rates and restrictions on water usage have forced many nurseries to make additional capital-intensive renovations to their irrigation systems. Never-the-less, despite all of the problems that the drought has posed for nursery growers, there are still ways to make a profit.

The Focus of this Issue is Drought Management

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Grow and Market More Drought-Tolerant Crops

Some nurseries that produce outdoor plants have actually benefitted from the drought and report an increase in production and sales. These are nurseries that specialize in drought-tolerant plants and nurseries that have a broad range of plants but have stepped up production of drought-tolerant plants. Many drought-tolerant plants used in gardens and landscapes originate from areas around the world where Mediterranean climate predominates: coastal California, central Chile, the Western Cape of South Africa, southern and southwestern Australia, and around the Mediterranean basin (Gildemeister 2004). To obtain more information on how production of these drought-tolerant plants is affecting sales, we contacted the managers of four visionary nurseries: Suncrest Nurseries Inc., San Marcos Growers, Plug Connection, and Sierra Azul Nursery and Gardens.

Suncrest Nurseries, a wholesale nursery situated near Watsonville, offers a diverse range of plants from the five Mediterranean climate regions. Horticultural traditions of growing native plants at this nursery (fig. 1) stretch back 137 years to their origin as the Leonard Coates Nurseries. Two years ago, Suncrest opened up a business called Meadowland to provide lawn alternatives and contract growing for projects, including living roofs. Indirectly, lawn conversion rebates are significantly benefitting this nursery. "The drought has been a boon to business, and our production is way up," says Jim Marshall, general manager of Suncrest.

Fig. 1. Among Suncrest Nurseries' collection of native plants are 36 varieties of manzanita. Shown here: *Arctostaphylos edmundsii* 'Rosy Dawn'. *Photo*: **Courtesy of Suncrest Nurseries.**

San Marcos Growers, a wholesale plant nursery located in the eastern Goleta Valley in Santa Barbara, also specializes in growing plants appropriate to California's Mediterranean climate. This includes many California native plants, as well as vines, trees, shrubs, ferns, perennials, succulents, ornamental grasses and grass-like plants from other areas around the world. Currently there are about 20 acres in nursery production with an additional two acres dedicated to cutting and demonstration gardens. The eight demonstration gardens allow customers to visualize how mature plants from Mediterranean climates look in garden settings, which helps to promote sales. The nursery also maintains extensive online information about plants produced in the nursery, as well as recommended resources.

"Drought is one of our salesmen," claims Randy Baldwin, a partner and general manager of San Marcos Growers. "This has especially been the case this year. All of the new water regulations, media attention and lawn replacement rebates is making 2015 a banner year for us," he says.

Baldwin believes that the reason the nursery has continued to be successful is because they made the decision early on to specialize in plants from Mediterranean climate regions and succulents — plants that are adaptable to California gardens. Just a few years prior to the incorporation of the business in 1979, California suffered from a drought that kick-started the state's Xeriscape movement. Baldwin's participation in Xericape seminars and the Water Use Classification of Landscape Species (WUCOLS) committee made it clear to him that San Marcos Growers should focus on plants that require minimal irrigation. "We certainly were not the only nursery involved in promoting what became known as drought-tolerant or 'water-wise' plants but we were certainly in a minority of those actively promoting these plants," Baldwin says.

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Baldwin studied California native plant taxonomy and field botany at UC Santa Barbara, and this interest in native flora also led to an appreciation of plants from other Mediterranean climate regions. "From my own travels and connections with people involved in horticulture we have steadily been able to increase the number of plants that are suitable to being grown in California without needing regular irrigation, particularly native Californian, Australian and South African plants," he says.

Fig. 2. Approximately 30% of San Marcos Growers' current collection of plants are succulents. Shown is *Agave lophantha* 'Quadricolor' (quadricolor century plant). *Photo*: **Courtesy of San Marcos Growers.**

Over the years, San Marcos Growers has been steadily weaning out of production plants that do not do well when they are irrigated in the nursery only once every week or two. As a result, succulents currently comprise 30% of the current collection of plants (fig. 2), representing 492 different taxa. Succulents forgive missing an occasional irrigation, and Baldwin professes an affinity with these plants because there is also "an odd and wonderful diversity within the group." This is a fascination many of the nursery's customers share, and Baldwin says he has witnessed "a growing addiction to succulent plants." In response, the number of succulents San Marcos Growers produces has steadily increased over the years. "In 1980 we listed 4 succulents in our catalog, which represented less than 1% of the plants we were growing at that time," Baldwin says. "In comparison, by 2012, we had 424 succulents in production, which was 26% of the plants we then produced."

Plug Connection production maager Gregg Opgenorth also reports strong sales of succulents during the drought. Established in Vista in 1987, the Plug Connection produces plugs and liners in over 350,000 square feet of greenhouse space. This nursery serves an extensive network of 34 brokers, supplying a complete range of annuals, perennials, grasses, herbs and vegetables from seed and cuttings. As part of the broad palette of products supplied, there are over 100 types of succulents in a diverse array of colors, textures and shapes to meet the demands of retail and wholesale nurseries, garden centers and landscape professionals for water-wise solutions (fig.3). "As a propagator, our plant selections are driven by customer demand. We have a good succulent program that continues to do well as a result of demand for drought-tolerant products," Opgenorth says.

Sierra Azul Nursery and Gardens, located in the Pajaro Valley in Watsonville, is a grower/retail nursery that specializes in plants from the five Mediterranean-climate regions of the world. In addition to a retail sales area, the nursery features two acres of demonstration gardens that promote the use of drought-tolerant plants in aesthetic water-conserving gardens and landscapes. The demonstration gardens attract many visitors:

Fig. 3. Plug Connection's Tessera Succulents include more than 100 varieties of low water-use succulents in 72- or 102-trays. *Photo*: **Courtesy of Plug Connection.**

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gardeners come for ideas and inspiration, retail nursery customers come to see plants as they look full-sized in a garden setting and landscapers bring their clients (fig. 4). The nursery also offers design and consultation services to their customers.

Fig. 4. Each, year Sierra Azul Nursery receives many visitors to their demonstration gardens that promote the use of drought-tolerant plants. The whimsical statues are part of the charm. *Photo*: **Courtesy of Sierra Azul Nursery.**

Jeff Rosendale, owner of Sierra Azul Nursery and Gardens, says that the nursery has increased production of drought-tolerant varieties such as manzanitas, salvias, California natives and proteaceous species in response to the drought. "We are [also] focusing more on lavender production and a small lavender farm," Rosendale says. In addition to promoting the use of drought-tolerant plants and practices, he hopes that the lavender farm will "promote tourism to our site." As a result of the drought, there is a high demand for the nursery's design and consulting services. "We are consulting with customers on xeriscape plant selection, design and layout for lawn removal conversions, and water district rebate programs in Santa Cruz, San Benito, Monterey and Santa Clara counties," Rosendale says.

Help Educate Plant Consumers

The California nurseries we contacted for this article are all financially benefitting from the drought because they specialize in plants that are drought tolerant or because they have increased production of an already-strong succulent program in response to consumer demand. Many wholesale container nurseries produce drought-tolerant plants because there has always been a high demand for these plants from retail and landscape customers, but they also grow other plants commonly found in California gardens and landscapes that require more water. So, what can you do to offset sagging sales of plants that are not among the most drought-resistant? Should you cease production of these plants? Should you simply cut back on the size of plant production areas? And how do you help your customers reach consumers who have completely stopped gardening?

Probably the best solution for declining plant sales during drought is to help retail and landscape professionals educate their clients. Everyone needs to pitch in to change the public perception that equates drought with foregoing plants. Scott Klittich has urged CANGC members to have conversations with their customers about using water conserving practices. In addition to his CANGC responsibilities on the board of directors, Klittich manages Otto and Sons Nursery, a 22-acre wholesale/retail nursery in Fillmore that produces a large selection of roses, fruit trees and berries. These traditional types of plants still have a place in gardens and landscapes when water-conserving practices are used. Klittich uses e-newsletters to provide his customers with tips for conserving water. "Nurseries are the go-to resource for that information," he says. "Every nursery I've been to, those that are promoting that they are the place to find that information are more successful than those that are just sitting back" (McClellan 2015b).

David House, CEO of Village Nurseries, a wholesale operation based in Orange with 900 acres of growing facilities in California and four landscape centers, also believes in the importance of outreach. "People are concerned about spending their discretionary dollars on plants for two reasons: Will they live? And is it the right thing to do?" House says in an interview for *Nursery Management* magazine (McClellan 2015a). Moreover, House is uneasy with the idea of drought-tolerant plants conjuring up "visions of arid

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landscapes with little more than cacti, succulents and rocks." This is the reason he is launching a Save Water, Stay Green campaign, which will use news media, the Village Nurseries website and e-newsletters to get the message out that "that buying plants and having a beautiful landscape is still easy to do."

Australia championed this philosophy that "you can have your cake and eat it too" during a 13-year drought, when many beautiful gardens were created and maintained. One example is the Adelaide Botanic Garden, where careful plant selection and appropriate irrigation design conserved significant amounts of water (Adelaide and Mount Lofty Ranges Natural Resources Management Board 2014). An image of the Adelaide Botanic Garden can be found on the Gardening in Mediterranean climates website (see *References*, below).

The University of California is a good source of information for home gardeners and landscaping professionals, and nurseries can use this information to educate their clients. Many of these publications with pertinent information related to water conservation are listed in the reference section below, and most can be downloaded for free at the UC Agriculture and Natural Resources publications website. In addition, the UC Davis Center for Urban Horticulture (CUH) maintains a "Landscaping Resources During Drought" web page with resources that nurseries can use for their outreach (see *References*).

Continue Conserving Water

Because water rates have increased and may be one of the highest operating costs (Gallagher 2013), obviously it is important to ensure that a broad spectrum of water-conserving measures is implemented in the nursery. Not only will this save water, but in the long run it will also reduce costs.

Suncrest Nurseries has reconfigured their irrigation system to improve distribution uniformity and adjusted their soil mix to improve water holding capacity in response to the drought. "Adding earthworm castings gives our mix a higher cation-exchange rate, allowing us to reduce the fertilizer charge and enhance the safe use of recycled water from our 22-year-old water recycling system," Marshall says. "We also pay more attention to consolidating crops so we don't water areas that are sparsely populated."

McClellan (2015a) provides several other examples of water-conserving technologies and practices in California nurseries. This has included converting more acreage to drip irrigation systems, incorporating pulse irrigation and recycling water, as well as making necessary adjustments to incorporate the use of reclaimed water (Merhaut 2015). Many nursery growers have conserved water as a result of implemented water quality improvements to comply with State Water Resources Control Board agricultural conditional waiver requirements (Mangiafico et al. 2010). Although most growers have already cut back significantly on water use, it is important to conduct an annual irrigation audit to evaluate the irrigation program and plan for appropriate future improvements (Newman et al. 2008).

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Irrigating Greenhouse and Nursery Crops Based on Soil Moisture Measurement

***by* Loren Oki**

All ag producers in California, including greenhouse and nursery growers, are impacted by the multi-year drought we are experiencing here. Greenhouse and nursery growers may be particularly affected because of the intensive production of crops of plants grown at high densities either in the ground or in containers. High productivity is almost always linked to greater use rates of resources, including water.

To improve the efficiency of water used for irrigation, changes to management practices have been applied to application methods and scheduling. Alterations to application methods have included changing from impact sprinklers to rotors to improve distribution uniformity, expanding the use of drip irrigation systems, and managing water pressure.

Improving irrigation scheduling is another way to reduce water use. Irrigating plants only when it is needed and applying only the amount that is necessary optimizes irrigation efficiency and leads to reduced water use. Improving irrigation scheduling might utilize weather information, which affects plant water demand, or measuring soil moisture content.

When utilizing weather to manage irrigation, there needs to be an understanding of how weather relates to the amount of water that a plant would use. This relationship is dependent on a number of things including: plant species, size of the plant canopy, soil characteristics, irrigation history, and others. So, although using this method can be very effective, it is merely an estimation of plant water use.

Plants obtain almost all of water needed from the soil. So, measuring the amount of water in the soil that is available to plants can be an efficient method to managing irrigation: When the soil is dry, apply water; and only apply enough to re-wet to a specific level.

There are two main types of soil moisture sensors and they can be grouped by the characteristic they measure. One group measures an energy component of soil water called "matric potential" (MP), which describes how tightly the soil holds onto water. This is the force that plants need to overcome to obtain the water. As soil dries, it holds onto the water that remains in it more tightly. Moist soils "give up" water more readily than drier soils, so it is easier for a plant to extract water from a moist soil compared to a dry one. There is an amount of water that plants cannot extract because it is very tightly held by the soil and is called "unavailable water". Matric potential is measured in units of kPa (kilopascals) or MPa (megapascals). A saturated soil has a measurement of 0 kPa and becomes more negative as the soil dries. Soil moisture "tension" is simply the matric potential measurement with the negative sign removed.

The other characteristic measured by sensors is volumetric water content (VWC), the amount of water in the soil. This is usually described as a percentage of the soil volume that is water. For example, a volumetric water content measured at 12% tells us that 1 liter (1,000 mL) of soil contains 120 mL of water. The amount of water that can be held in soil depends on the soil type. VWC would never be 100% since that would mean that there is no soil, but is only water. Field capacities of soils vary from about 20% for a silty soil, 15% for a clay, and 5% for a sandy soil.

There is a relationship between volumetric water content and matric potential. Graphically this is relationship is called a "moisture release curve" (fig. 1) and has several synonyms where "water" might be replaced by "moisture" and "release" might be replaced by "retention," "holding," or other similar terms. Usually these graphs are configured so that the horizontal X-axis represents matric potential or tension in kPa or MPa. The vertical or Y-axis is volumetric water content in percent.

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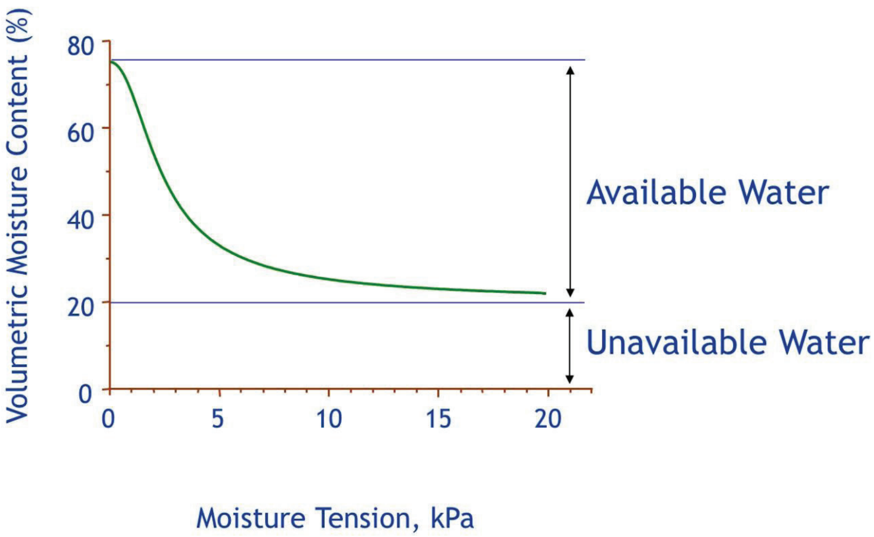

Fig. 1. Moisture release curve of UC mix which consists of 1/3 bark, 1/3 sand, 1/3 peat. This graph shows that this substrate holds a large amount of water (~75% VWC at saturation) of which 20% is unavailable. At container capacity the VWC is about 70% and tension would be ~1 kPa, leaving 50% that is available for plant use. Plant water stresses will begin to occur at about 30% and about 5 kPa. The portion of the graph where the curve is flatter, where tensions are greater than about 7 kPa, tells us that it is difficult for the plant to extract water. *Graphic by*: **L. Oki, adapted from J. Lieth.**

Sensors that measure matric potential include electrical resistance blocks and tensiometers. Electrical resistance blocks are also known as gypsum block sensors which are simply a plug or block of gypsum into which two electrodes are inserted. As soil moisture changes, the moisture content within the gypsum block also changes which is measured by the resistance between the electrodes embedded in the block. Wetter soil is indicated by lower resistance in the block. The gypsum material also partially removes effects of soil salinity. The name given to these sensors is misleading since it is the conductance, not resistance, between the electrodes that is measured. This requires an alternating current (AC) which is provided by a handheld meter used to read the sensor.

Granular matrix sensors are improvements of gypsum blocks but instead of a block of gypsum, some other medium or "matrix" is used in which the resistance is measured. This matrix might be a fine sand, as in the Watermark (Irrometer Co., Riverside, CA, fig. 2) that improves the speed of the sensor response to changes in soil moisture. This sensor is reconfigured as a cylinder wrapped within a membrane further enclosed in a stainless steel mesh and includes a wafer of gypsum to moderate salinity effects.

Tensiometers (fig. 3) are simple instruments consisting of a plastic (typically) tube, a porous ceramic cup at one end, and a vacuum gauge at the other. The tube is filled with water to exclude air and the tensiometer is inserted in to the soil. As the soil dries, water is pulled from the tensiometer through the ceramic into the soil creating a vacuum within the tube that is measured by the gauge. The drier the soil, the greater the pulling force and vacuum. When irrigation occurs, the vacuum in the tube pulls water back into the tube from the soil which reduces the vacuum. The "pulling" force of the soil on water is matric potential. The gauges of tensiometers may be labeled in units of centibars (cbar) which is a pressure term. This makes sense since a vacuum is opposite of pressure or, more correctly, is a negative pressure. Fortunately for us, cbar and kPa are the same and can be interchanged. The vacuum gauge can be replaced with a pressure transducer that converts the vacuum to an electrical signal that can be "read" and converted to a measurement. Tensiometers are available in different lengths to be able to place the ceramic tip at different soil depths.

Sensors that measure volumetric water content that are commonly used include time domain reflectometry (TDR), capacitance, and other variations. These sensors measure dielectric

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Fig. 2. Watermark (Irrometer Co., Riverside, CA) sensor. *Photo*: **L. Oki.**

Fig. 3. Tensiometer (Irrometer Co., Riverside, CA). *Photo*: **L. Oki.**

permittivity, which is the ability of a nonconducting material to transmit electromagnetic pulses. There are other ways to measure VWC including gravimetric permittivity, which is the ability of a nonconducting material to transmit electromagnetic pulses. There are other ways to measure VWC including gravimetric (weighing the soil as it dries), neutron probes, and heat pulse but this article will focus on the dielectric sensors. This discussion will focus on advantages and disadvantages of the different types of sensors and less about how they work. (Editor's note: see also Steve Tjosvold's article on gravimetric method for containers.)

TDR uses an electronic module that generates an electromagnetic pulse through a cable to the sensor exposed to the soil. As the pulse travels down the rods, the characteristics of the pulse changes depending on water content, among other things. The benefits of this method are that it is very fast, with results returning from sensors in microseconds (μS), and the sensors are inexpensive and rugged. The electronics, however, are very expensive but can support large numbers of sensors. TDR can also

Fig. 4. Decagon 10HS sensor (Decagon Devices, Pullman, WA).
Image: **http://www.decagon.com/products/soils/volumetric-water-content-sensors/10hs-large-soil-moisture-sensor/.**

measure salinity. This method is also affected by high organic matter content, high salinity levels, and clay soils.

Capacitance sensors (e.g., Decagon IOHS, fig. 4) are more affordable for greenhouse and nursery growers compared to TDR, but also measure dielectric permittivity. The sensors are more expensive than TDR sensors, but “reading” them can be simple.

Understanding the Data

The information collected about changes in soil moisture is used to assist with the management or control of irrigation. But we need to understand how to interpret the information that comes from the sensors. Remember that the type of data that is collected since VWC and MP are very different and depends on the type of sensor used. So, be

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clear which type is being reported. Data of volumetric water content (VWC) will change from a relatively higher value when the soil is wet and will decline as the soil dries. In comparison, tension (remember that "tension" is "matric potential (MP)" without the negative sign) will start out low when the soil is wet and increase as it dries. Tensions will fall to 0 kPa when the soil is saturated. Tensions can be less than 0 if the soil is supersaturated and can occur during irrigation (see lower graph of fig. 8). Once the irrigation is stopped, the tension will change as excess water drains from the soil and briefly stabilize at some level. This information can be used to reduce over-irrigation by avoiding application durations that result in negative tension values.

If a system using soil moisture sensing is installed to control irrigation, it is a good idea to disable the irrigation control part of the system. Continue to irrigation as usual and collect data of soil moisture for awhile until you have good understanding of what the data represents. Pay particular attention to the data just before irrigations occur and try to link that to the condition of the plants before the irrigation. If plants show any stress symptoms, you may be able to relate those symptoms to soil water status and use the soil water data as ones to avoid. Also continue to record the duration of the irrigations as that will be helpful when programming irrigation control.

Once you are comfortable with understanding the data, turn on the irrigation control feature. You will probably be required to enter a "dry set point," the level when irrigation is needed and either a "wet set point" or the duration of the irrigation. Use the knowledge you have gained from observing the data to help you determine what that set point is. You should know that applying irrigations in short "pulses" is more efficient than applying water in a single long application. The shorter pulses apply water and the interval between the applications allows the applied water to be absorbed by the soil. You'll need to do some trials to determine the duration of the pulse and the interval between the pulses. When pulse irrigation is used it is highly likely that there will be a reduction in the total length of time the valve is on compared to a single longer "on-time" duration.

It is probably obvious that when the irrigation feature is enabled, it needs to be watched very closely to make sure the irrigations are applied properly. It will take some time until there is a level of "trust" in the system. Keep an eye on the soil moisture measurements and plant condition. If both appear to be "okay" even though irrigation might appear to be inadequate, then the irrigation is also probably okay. Adjustments will need to take place if the plant condition is not as desired.

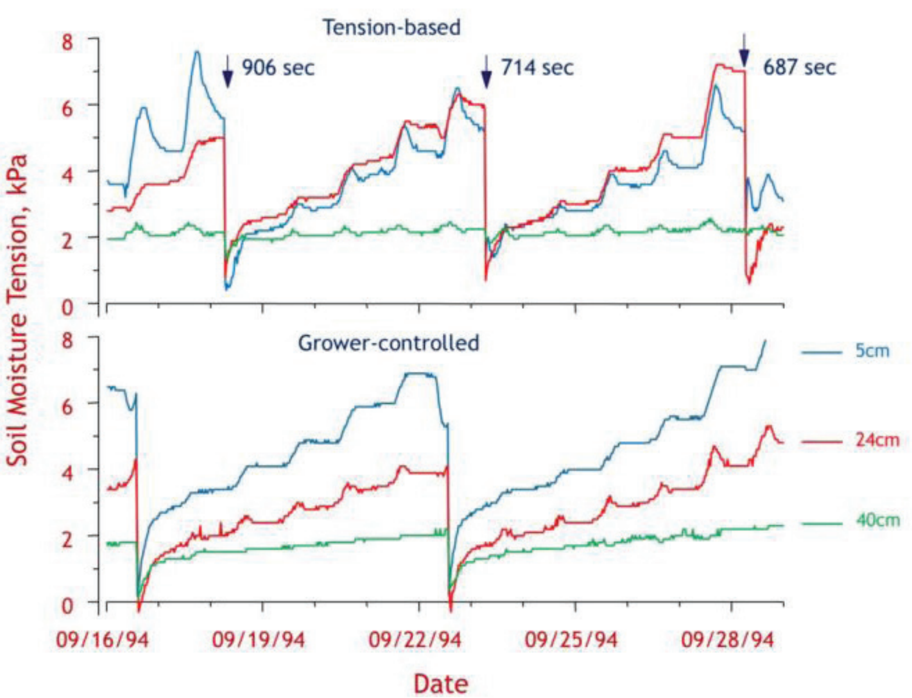

Fig. 5. Soil moisture tension data. A comparison of soil moisture in rose production bed where irrigation is controlled by the grower (lower) and by soil tension (upper). The portions of the curves are flatter are during the night when transpiration rates are low. Increases in tension occur during the day but can fall in the evening as water moves upward from wetter, deeper soil. The times in the upper graph are the total durations the valve was on. Where tensions fall below 0 kPa (lower graph), the soil cannot hold onto excess water and runoff had occurred.. *Data and graphic*: **L. Oki.**

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In addition to understanding that soil type determines the amount of water that will be available to plants (known as "plant available water"), another important parameter is how fast water can enter the root media (known as "infiltration rate" or "intake rate"). For example when comparing sandy and clay soils, sandy ones hold less water but have a high intake rate, whereas clay soils hold more water but the infiltration rate is low. Water should be applied to sandy soils frequently in short durations and slowly, for longer durations, and less frequently to clay soils. Knowing the intake rate can also affect the type of application since different sprinklers and drip systems apply water at different rates. If an intake rate of a soil is 0.2 inches per hour, then runoff will occur if the precipitation rate of the irrigation system is 1.0 in/hr. In that case, either the systems would need to be modified to reduce the application rate or short pulses will be required to allow applied water to be absorbed into the soil before another pulse is applied.

What's on the Horizon?

Wireless communication isn't new to you if you have a cell phone and most of us do. But it is also becoming more prevalent in the case of irrigation control and sensing. There are wireless nodes that include a radio package and a control function that allows a base station running an irrigation program to communicate with the node to turn valves on and off. Some of these nodes also include the ability to attach a soil moisture or other sensor. Communication can occur directly between the node and the base or through a wireless mesh network where the signal hops through nodes until it reaches the node where control needs to occur. An advantage of these mesh networks is unlimited distance as long as each node is within range of another. Another advantage is that as long as there are alternate communication paths between nodes, the communication can be re-established should a node fail if there is another working node within range.

There is also the ability for irrigation managers to access information using an interface on a smart phone. Most of us carry one nowadays, so it makes sense to use it to adjust irrigation or modify a program due to crop changes that are observed in the field instead of having to return to the base station to make those adjustments. The control program can also be integrated with other parameters that affect disease pressure or reduce or delay irrigation if rain is forecast, for example.

Irrigation based on soil moisture measurement has been around for awhile (did you notice the dates on the soil moisture tension graphs?), but it hasn't been until recently that computers, programs, user interfaces, wireless communications, and other features have developed sufficiently and come together to make it easy for grower to implement and manage. When in use and properly managed, irrigation systems using soil moisture sensors can reduce water use, reduce irrigation runoff, improve water use efficiency, and provide growers information to assist in crop production.

Loren Oki is UC Cooperative Extension Landscape Horticulture Specialist, Department of Plant Sciences, UC Davis.

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SCIENCE TO THE GROWER: Do plants need water? Science has the answers!

***by* Richard Evans**

I sighed when the Editors asked me to write about drought-related research. (Our long California drought already was getting me down. I recently was standing in an airport restroom, wondering if the guy in line behind me would think I'm a loser for not flushing the urinal, or if he'd think I'm a loser for flushing it. So I asked him. He replied that I'm a loser.) I told the Editors my philosophy: When life gives you drought, resort to dry humor. I offered to relate some jokes about camels and deserts. The Editors ignored that and reminded me of the deadline for my article about drought-related research. I felt like I was "lost with a witch in a tunnel of love."[1]

O.K., fine, I'll do it. Maybe you'll laugh when I tell you that scientists have studied the possibility that drought could improve ornamental crop production. It's true!

This research has followed two main paths. The scientists on one path recognize that greenhouse and nursery plants will be affected by water deficits; they ask whether deficit irrigation — always irritating with some fraction of the total amount of water the crop could use — could replace use of chemical growth regulators. Scientists on the other path may agree with their colleagues, but they wonder whether there are stages of crop development during which the plants are relatively insensitive to drought. Their objective is to save water, not control growth, so they propose using deficit irrigation only at times when the crop is drought-insensitive — a method they call regulated deficit irrigation.

Research on deficit irrigation of ornamental crops has yielded mixed results. The growth of one-gallon rosemary plants that were irrigated at soil moisture sensor setpoints near container capacity was about twice that of plants grown in drier media, and roughly similar results were obtained with columbine (*Aquilegia canadensis*) and pinks (*Dianthus gratianopolitanus*).[2] When one-gallon Bougainvillea plants were irrigated to replace 100%, 50%, or 25% of normal daily water use, those in the latter two treatments were smaller and had fewer leaves.[3] However, water stress also increased the number of flowers and cut the total irrigation volume in half. The authors of the study concluded that deficit irrigation could be used to save water during a drought without losing the ornamental value of Bougainvillea. Six-inch geraniums (*Pelargonium×hortorum*) subjected to deficit irrigation (60% or 40% of normal irrigation) were smaller, with fewer leaves, but they also had fewer flowers.[4] The height, weight, and leaf number of four-inch marigolds (*Tagetes erecta*) decreased in proportion to the amount of moisture maintained in the growing medium.[5] Unfortunately, height was less affected than plant weight or leaf area, so deficit irrigation did not increase the compactness of the plants. Together, these results cast some doubt on the utility of deficit irrigation for businesses that produce a variety of crops.

Regulated deficit irrigation was introduced in the 1970s as a method to reduce the need for summer pruning of peach trees. The earliest ornamental research subject, as far as I know, was rhododendron.[6] One-gallon plants were exposed to 150%, 75%, or 25% of normal daily water use, and the deficit treatments were maintained for 8 weeks at four different times of year. Later experiments with *Choisya ternata*, *Cornus alba*, *Cotinus coggygria*, *Forsythia ×intermedia*, *Hydrangea macrophylla*, *Lavandula angustifolia*, and *Lonicera periclymenum* produced roughly similar results.[7,8] Severe deficit irrigation generally produced more compact plants, and damage was limited to minor tip burn of leaves in a few cases. However, the studies were conducted in England, which is not exactly Drought Central, and the authors note that careful management would be necessary to prevent leaf damage under high light and high temperature conditions. Potted geraniums subjected to mild regulated deficit irrigation in Spain were smaller than control plants, but flower

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production was normal unless the deficit irrigation occurred during the flowering phase.[9]

These experiments tell us that deficit irrigation can be used to reduce nursery water use by about 20% to 40% without causing severe damage, but flowers and vegetation may be affected differently in different species. Furthermore, the timing and intensity of the deficit irrigation affect outcomes. Since regulated deficit irrigation involves closer control of water stress, it is more likely that it can be employed successfully, as long as species requirements are attended to. However, the success of these methods depends on both accurate measurement of plant irrigation requirements and accurate delivery of water to the plants. Nurseries that meet those requirements already save a tremendous amount of water. And that's no joke. (Editor's note: see Summer 2014 Issue article: "Maintaining Irrigation Efficiency in Greenhouses and Nurseries".)

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GET CULTURED:
Fertilizer management when using secondary water sources

by **Don Merhaut**

Historically, fertilizer management has been based on clean water sources which contributed minimal amounts of the essential plant nutrients. In addition, these clean water sources usually had insignificant concentrations of impurities such as sodium, and other nonessential elements. Now that high quality water sources are limited, less pure secondary water sources such as reclaimed water, recycled water or well water containing high concentrations of salt may need to be utilized in plant production. If the quality of these waters cannot be improved, then there are some plant nutrition concerns that will need to be monitored and/or corrected so that plants receive proper nutrition. While there are many pretreatment options for improving the quality of secondary water sources, which we have discussed in past articles, this portion of the newsletter will focus only on the fertilizer options that may help alleviate some problems associated with poor water quality.

Secondary water sources may compromise nutrient availability in four primary ways:

1) **Water pH**. If pH is too high or low, it may impact the stability and thus the solubility of compounds, especially chelates.

2) **Electrical conductivity (EC)**. High salt concentration (>1 mhos/cm or dS/m EC) or a Total Dissolved Solid (TDS) level > 640 ppm, will become a problem, especially if fertilizer is supplied through the irrigation supply.

3) **High sodium (Na^+) and chloride (Cl^-).** High concentrations of Na^+ and Cl^- will accumulate in oldest leaves and cause tissue necrosis. Also, Na^+ is a positively-charged element, and therefore may limit the uptake of positively-charged essential nutrients such as potassium (K^+), and ammonium-nitrogen (NH^{4+}-N).

4) **Boron (B).** Some groundwater supplies are high (0.5 ppm) in boron and can cause plant toxicity.

The Symptoms and Solutions

It's important to be able to diagnose water quality problems correctly so that appropriate management practices can be implemented. So let's look at each of these four factors that affect water quality in depth.

Water pH

Problem symptoms. If the water pH gets too high (>7.0) or too low (<4.5), micronutrients may precipitate out. Low pH scenarios may occur when water is acidified before passing it through heat exchangers, a heating treatment done to sanitize water sources. In either case, if precipitation is a problem, it will usually be evident in the plants as chlorosis of the new growth, primarily because of iron deficiency. Evidence of micronutrient-chelate precipitation may be found in water storage tanks, especially in hydroponic systems — there will be a rusty-orange film developing on the bottom of the tanks. This orange slime is the denatured chelates and the micronutrients. When a chelate is "denatured," its molecular structure is irreversibly changed by heating, which inactivates its ability to bind micronutrients and causes the chelate and micronutrient to form a solid. The analogy of this would be similar to egg whites, which, when raw, are a clear white liquid; however, when egg whites are cooked, they become a solid white "omelet"!

Treatment. If water pH is high, choose acid forming fertilizers. These usually contain sulfates and ammonium-nitrogen, which will acidify the media. If acidification is not an option, consider the selection of chelates that are stable at a higher pH. As seen in table 1, chelates such as CDTA, DTPA and EDDHA will

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be stable at pH 7.0 or higher.

High Electrical Conductivity

Problem symptoms. The concentration of salts in irrigation water can cause several problems. An ideal EC is 0.2-0.5, especially for seedlings and other young plants and plug production. This lower EC range also allows most operations to safely incorporate fertilizer into the irrigation water without major elevations in EC. Most crops can tolerate >1.0 mS/cm. Usually crops in the families: Ericaceae, Theaceae and Proteaceae have close mycorrhiza associations and therefore have a lower EC tolerance ~1.5 mS/cm because of apparent issues with mycorrhiza and soluble salts. Many other more common crops, especially woody perennials, will tolerate a water EC ~2.0 to 3.0. Symptoms of high salts include root dieback, necrosis of oldest leaves (where salts will accumulate), and plant wilting.

Treatment. From a fertilizer perspective, keeping plants well fertilized so that growth continues will sometimes appear to "mask" the symptoms of the necrosis of the oldest foliage. Some growers will do this on faster-growing crops. Fertilization through controlled release fertilizers (CRF) rather than injecting fertilizer into irrigation water will minimize EC elevations. Another recommendation is using media which is very well drained, such as substrates containing cedar shavings, and resorting to more frequent irrigation episodes. This allows the grower to satisfy the water needs of the crop, while simultaneously leaching the salt-laden irrigation water from the media.

High Sodium (Na^+) and Chloride (Cl^-)

Problem symptoms. Excess salts, including Na and Cl, will accumulate in the oldest leaves causing necrosis, leaf curling, marginal leaf scorch and leaf drop. In severe cases, plants may also wilt.

Table 1. Chelates, chemical formula, molecular weight (M.W.), formation constants, and the pH range at which the chelate usually forms a stable complex with iron (Fe)

CHELATE	FORMULA	M.W.	Fe	Cu	Zn	Mn	Lower Limit	Upper LImit
CDTA[1]	$C_{14}H_{22}O_8N_2$	346	29.4	22.2	19.6	17.7	4.0	7.0 - 7.5
DTPA[2]	$C_{14}H_{23}O_{10}N_3$	393	29.2	22.6	19.7	16.7	4.0	7.0 - 7.5
EDDHA[3]	$C_{18}H_{20}O_6N_2$	360	35.3	>24.9	17.8	---	4.0	9.0
EDTA[4]	$C_{10}H_{16}O_8N_2$	292	26.5	19.7	17.2	14.5	4.0	6.3
EGTA[5]	$C_{14}H_{24}O_{10}N_2$	380	21.9	18.6	13.8	13.2	4.0	5.2
HEDTA[6]	$C_{10}H_{18}O_7N_2$	278	20.8	18.2	15.2	11.5	4.8	6.7

The formation constant indicates the ability of the chelate to bind each of the nutrients: the higher the formation constant, the higher the ability of the chelate to or "hold onto" the micronutrient and keep that micronutrient in solution, rather than the micronutrient binding to another compound and precipitating out of solution. (Bachman G.R. and W.B. Miller. 1995. Iron chelate inducible iron/manganese toxicity on zonal geranium. Journal of Plant Nutrition 18(9):1917-1929; Norvell, W.J. 1971. Equilibria of metal chelates in soil solutions. pp. 115-138. In: J.J. Mortvedt, P.M. Giordano, W.L. Lindsay (eds.) Micronutrients in Agriculture. Soil Science Society of America. Madison, WI.).

Treatment. The treatment options are similar to those recommended for water with high EC. Where possible, select fertilizers that have no Na^- or Cl^-.

High Boron

Problem symptoms. Boron (B) toxicity will be expressed in plants with symptoms usually on older leaves: brown blotches on leaf tips, necrosis, cupping and curling of leaves, or marginal chlorosis

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in more severe cases. Occasionally, even new growth may exhibit B toxicity symptoms. Boron toxicity in plants can occur at concentrations in water as low as 0.5 ppm. Knowing the B sensitivity of the crop is important, as some plant species are much more tolerant of higher B concentrations. Usually recommendations are to conduct a tissue analysis; however, , even within a species, boron levels can be quite variable and may not provide any helpful information.

Treatment: Boron is taken up into plants as electro-neutral boric acid (H_3BO_3). There are no known adjustments in fertilizer programs to mitigate boron toxicity. The only method to remove B from the water supply is to increase water pH above 9.2. At this high pH, the majority of the boric acid is converted to borate ($H_2BO_3^-$), a negatively charged compound which can then be removed through anion exchange systems. A more feasible solution may be to apply foliar and soil applications of zinc (Zn), since this has been shown to alleviate boron toxicity symptoms in the field when B toxicity occurred with Zn deficiency (Nable, R.O., Bañuelos, G.S. and J.GH. Paull. 1997. Boron toxicity. Plant and Soil 193:181-198).

There are management options for the fertilizer programs to optimize plant growth that will help alleviate issues associated with poor water quality (improper pH and high salts, boron, sodium and chloride). Depending on the water quality concern, these options include: (1) selecting fertilizers with lower levels of nonessential salts (Na, Cl), (2) choosing chelates with suitable pH tolerances, and (3) utilizing controlled release fertilizers rather than fertigation.

Caution!! In all cases, close monitoring and proper record keeping of plant growth and water quality are important. It is always recommended to conduct a small trial to evaluate the performance of new fertilizer, media, and irrigation methods on one's cropping system before investing on changing these horticultural programs on the entire operation.

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DISEASE FOCUS:
Detecting Phytophthora in nursery plants

***by* Jim Downer**

Currently there are over 100 known *Phytophthora* species with an estimated 200 to 600 unknown members (Brazier, 2009). *Phytophthora* belongs in the Kingdom Chromalveolata, once considered fungi, these Oomycetes are no longer included in the kingdom fungi. *Phytophthora* is in a group of pathogens called water molds because they are often isolated from very wet soils, ponds, creeks or marshy/boggy areas in landscapes. The word "Phytophthora" means plant destroyer.

Since *Phytophthora* species grow into the cells of its host and its reproductive structures are microscopic, it is hard to detect by examination of samples for symptoms and signs. Since many are soil inhabitants and form resting spores in soil, they can remain undetected until plants begin to die. Prior to the advent of modern serological and molecular methods, *Phytophthora* was isolated form soil tissues or detected in dilutions of soil on selective media. *Phytophthora* can also be baited from soil with leaf disks or pear and apple fruits (Erwin and Ribiero, 1996) and identified based on morphological features. Microscopic identification of *Phytophthora* species requires considerable experience and with

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the advent of many new species, it is more and more challenging. Since the onset of *Phytophthora ramorum* in California a number of papers have described isolation, baiting and identification methods for determination of various species of *Phytophthora*. Kox and others (2007) compared different *Phytophthora* detection methods. The most accurate method of detection was with nucleic acid amplification via the polymerase chain reaction (PCR) and sequencing of the resultant amplified DNA. *Phytophthora* was also positively detected by culturing and subsequent microscopic identification and by use of the Enzyme Linked Immunosorbent assay (ELISA) and Lateral Flow Device (LFD) test kits. Lane and others (2010) reported similar capability of *Phytophthora* detection with both ELISA and LFD kits.

ELISA serological kits (AgDia Inc. Elkhart In) are simple field test kits that use antibodies to recognize proteins that are unique to specific organisms. ELISA has a low detection limit and can detect *Phytophthora* at populations below detectability with dilution plating (Graham and Timmer, 1994). A variant of the ELISA serological method is the lateral flow device (LFD) available from Abingdon Health Products (Foresite Diagnostics Ltc. UK, also known as Pocket Diagnostics), as well as AgDia Inc. Both ELISA and LFD kits detect all known *Phytophthora* species.

Lateral flow device assays may give a bit of an edge over ELISA test strips as they do not frequently cross react as frequently with other fungi or Ooomycetes. ELISA *Phytophthora* test kits are known to cross react with *Pythium* and *Peronsopora* (Macdonald et al., 1990). The limitation of both ELISA and LFD's is that they do not identify *Phytophthora* to species. This may be done the old-fashioned way by culturing and identifying of microscopic morphologies or more commonly and typically by PCR and sequencing of the amplified DNA.

Both ELISA and LFD kits provide inexpensive (as low as under ten dollars a test) and rapid (under ten minutes) identification of *Phytophthora* in diseased plant tissues in a field setting and provide a fast and efficient screening method for nurserymen and others who want do detect *Phytophthora*. If an accurate diagnosis is essential labs can use PCR technology and sequencing to obtain the most accurate identifications for under ten dollars per sample but it requires two days run time.

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REGIONAL REPORT — UC Cooperative Extension

A simple approach to knowing when to irrigate ornamental potted crops

***by* Steve Tjosvold**

A grower knows that a wilting plant is a sure sign of a need for water. But a grower also knows that wilting is bad for the plant. So at what point before wilting occurs should a grower water plants? To figure out how that process might be improved, think about what a grower normally does to evaluate a plant's need for water. If it is a potted crop, he or she intuitively picks up the pot and feels its weight! The grower is sensing how much water is in the potting soil. If a pot feels heavy with water it may not need water, or if that the pot feels relatively light it probably needs water.

This process could be improved by actually measuring the weight of the plant container. There is a nifty relationship: 1 milliliter of water weighs 1 gram. So the weight change in grams, with no intervening irrigation, represents the milliliters of water lost from the container during that time (fig. 1). It is important to select representative plants when measuring water use by any method. Large plants tend to use more water than small ones, and those on the borders of fields, benches, or nursery blocks tend to use more than those in the interior. It is probably better to use select plants that might use relatively more water to meet at least the water requirements of these plants. Since accurate scales can be purchased for less than $100, this method provides a fast, accurate, inexpensive way to monitor plant water use. Try a scale that is accurate to a gram for 1 gallon or smaller pots. One that is accurate to 5 grams might be used for larger pots.

Fig. 1. Plant water use in container nurseries can be measured directly using a scale. *Photo*: **S. A. Tjosvold.**

Not all the water in the soil is available for use by the plant. After the pot has been fully watered, the water is readily available to the plant. But as the plant uses water and the soil dries, the water held by the soil is less available. Eventually the plant wilts. To determine the total amount of water that is available to the plant, first measure the weight of a representative pot just after it is fully watered and drains. Then measure the weight daily until the plant just starts to wilt. The difference between the beginning and end weights in grams (and therefore milliliters) is the available water.

So when should water be applied and how much? Generally, irrigation is initiated when one-half of the available water is used. This minimizes the energy that is needed by the plant to extract water and the hazard to roots by concentrating salts in the soil solution. So if there are 300 mililiters of available water in a pot, then irrigation should be made when 150 mililiters of water has been used. (That occurs when 150 grams are lost as you are measuring with your gram scale).

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How much water to apply to each pot? In this case, the pot needs at least 150 mililiters to replace water the plant used. The grower is probably thinking about the total water that needs to be applied to a particular irrigated block (perhaps the total time that the sprinklers or drip irrigation will be on). There are couple more factors that should be considered.

Salts in the soil solution can concentrate because not all them contained in irrigation water are extracted by the plant. This can cause harm to the plant, so a little extra water is usually needed to "leach" salts out the bottom of the pot. Leaching is best achieved on crops by applying the proper leaching fraction. This is the ratio of the volume of water leached out of the bottom of a pot to the volume of water applied to a pot. This factor depends on the salt concentration of the irrigation water (with soluble fertilizer) and the tolerance of the plant to salt. Often 10 to 15% more water has to be applied just to take into account the need to leach. (Editors note: Please see Richard Evans UCNFA article for more information on the management of salinity. http://ucanr.edu/sites/UCNFAnews/Feature_Stories/Leaching_to_Manage_Salinity_in_Ornamental_Crops/)

Another important factor that will affect the final amount of water to apply is the efficiency of the irrigation system to apply water uniformly to a nursery crop. The irrigation system's distribution uniformity is commonly calculated using measurements made in the field. But in general, sprinkler irrigation is relatively inefficient and drip irrigation is relatively efficient in distributing irrigation water to plants in a field. For sprinkler systems another 10 to 60% more water might be needed to account for these inefficiencies, while a drip system might only need up to 10% more water. (Editors note: Please see the chapter "Irrigation Management Practices" in Container Nursery Production and Business Management Manual.)

So the sum of the water used by the plant (P) plus the water needed for salinity (S) control plus the water needed to account for sprinkler irrigation (I) inefficiency is equal to the total water that is applied. That is, P+S +I = total water that must be applied.

Growers that have used this method often find it to be enlightening. At the very least, they find that it supports an already successful irrigation program. It often helps fine tune irrigation practices. And it often points to the importance of irrigation systems as a crucial factor in using water efficiently. Because of the diversity of crops and crop water needs, it might be best to start with similar plants and pot sizes. Use the method through a crop cycle (from placing the pots in the field or greenhouse to establishment) and see if generalizations can be made and followed, and then maybe move on to another group of similar crops and pot sizes.

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CAMPUS NEWS

Retirements Announced

John Kabashima's personal note on his retirement: June 26th, 2015 marks the end of my 27 year career as the University of California Cooperative Extension Environmental Horticulture Advisor in Orange and Los Angeles Counties. I never thought in my lifetime that I would see the dramatic changes that have occurred during my career. I have seen agriculture and nurseries survive droughts, recessions, and benefit from science-based research, mechanization and the rapid changes of the computer and robot revolution. However, changes in marketing, public opinion, regulatory and political pressures will impose new challenges for the industry. I am optimistic that just as the industry has survived past insurmountable challenges, it will survive future challenges by adapting and forming new alliances and partnerships to continue to provide the plant material that provides important aesthetic and environmental benefits to the world around us.

Linda Dodge, Staff Research Associate, UC Davis: Since 2009, Linda has been the essential organizational glue that kept the UCNFA programs and newsletter running smoothly. Linda has a long history working on research with UC too. Beginning her career with UC in 1988, she worked with various researchers in the Environmental Horticulture Department including Drs. Richard Evans, Michael Reid, and most recently Loren Oki. She was the program representative for the Saratoga Horticultural Research Endowment and the Elvenia J. Slosson Ornamental Horticulture Research Endowment. Linda Dodge will be greatly missed by the UC educational and research team.

New Publications from Agriculture and Natural Resources

***compiled by* Steve Tjosvold**

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