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Inside

Maintaining Irrigation Efficiency in Greenhouses and Nurseries

by Larry Schwankl, Richard Evans and Ben Faber

Irrigation efficiency is a measure of how much of the applied irrigation water is "beneficially" used. Satisfying plant water needs is the major beneficial use, but water used for salinity control and other nursery management practices like frost protection can also be considered beneficial uses. Waters lost to runoff that is not reused and water that moves underground (infiltrated water), unused by plants, are considered non-beneficial uses. In formula form, irrigation efficiency is

$$\text{Irrigation Efficiency (\%)} = \frac{\text{Beneficially-used Water}}{\text{Total Applied Water}} \times 100$$

Two important factors must be known in order to determine irrigation efficiency. First, the amount of water required by the plant must be known. This is usually determined using irrigation scheduling techniques, such as weighing pots or using evapotranspiration values. Second, the irrigation application amount must be known. This requires measuring the applied

Editor's Note

This newsletter issue focuses on the historic drought situation in California and its significant impacts on the ornamental production industry. Strains on local water resources have resulted in unprecedented actions to reduce water withdrawals and use. In Ventura County, for example, system outages and emergency drought legislation includes a reduction of about 25% in groundwater extractions from the basins underlying more than half the county's farmland. In other areas of California, growers are more fortunate and are not yet facing imminent water supply cutbacks. However, all growers are being expected to maintain water conservation practices. Moreover, as we describe in this issue, the drought can negatively affect crop quality and exacerbate diseases in the nursery such as root rots. We hope that the water conservation, salinity and drought-related disease management practices described in this issue, along with the feature article on UC drought resources, will provide some assistance to growers during these challenging times.

- **Julie Newman and Steve Tjosvold**

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irrigation water. Using a flow meter installed in the irrigation pipeline is the easiest and most accurate way to measure the application amount. Multiple flow meters should be used when multiple, widely spaced sections of an irrigation system are operated.

Crop water use

Plant water use in container nurseries can be measured directly by weighing plant containers (fig. 1). The weight change in grams over a 24-hour period, with no intervening irrigation, represents the milliliters of water lost from the container during that time (1 milliliter of water weighs 1 gram). As with the other methods described here, it is important to select representative plants when measuring water use. 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. Since accurate scales can be purchased for less than $100, this method provides a fast, accurate, inexpensive way to monitor plant water use.

Fig. 1. Plant water use in container nurseries can be measured directly using a scale. The change in container weight of several representative plants immediately after any excess irrigation has drained and after 24 hours without irrigation represents the water lost from the container during that time. ***Photo*****: J. K. Clark.**

Estimates of evapotranspiration for field-grown plants can be made using evaporation pans, automated weather stations (fig. 2), or atmometers, all of which can provide estimates of the amount of water loss in a given surface area. Evapotranspiration values are expressed in units of inches per day or centimeters per day. Evaporation pans measure water evaporated from a standard sized pan of water and then a correction factor must be applied to estimate evapotranspiration. Atmometers measure the amount of water that evaporates from a porous surface designed to represent a leaf surface. Weather stations estimate evapotranspiration from calculations that use measurements of sunlight, wind speed, relative humidity and temperature. (For more information on using weather-based irrigation scheduling, see the California Department of Water Resources CIMIS website, http://wwwcimis.water.ca.gov/.) Regardless of which indirect method is used to estimate evapo-

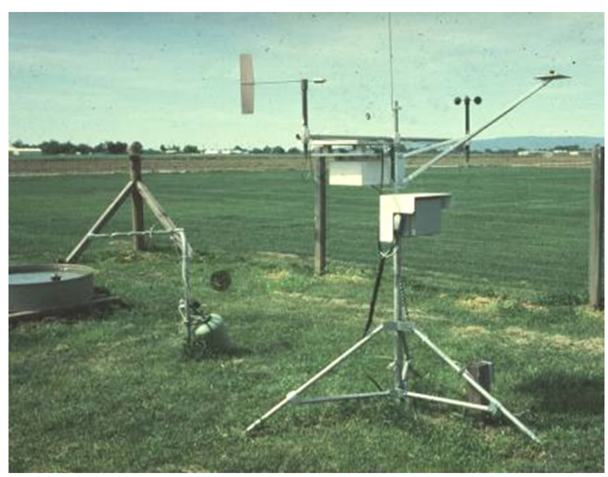

Fig. 2. A weather station (***right*****) or evaporative pan (*****left*****) can be used to estimate evapotranspiration.** ***Photo*****: L. Schwankl.**

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Fig. 3. A tensiometer probe for measuring moisture in media is connected by wire (lower left) to a computerized environmental monitoring and control system. The white tube contains a light sensor also used to help estimate irrigation need. *Photo*: J. K. Clark.

Fig. 4. Distribution uniformity of sprinklers can be measured with catch cans. *Photo*: A. Storm and J.P. Newman.

transpiration, the values obtained must be corrected for the size and type of crop being grown. In addition, since the results are only estimates of evapotranspiration, growers should check soil moisture in the field to verify the accuracy of water use estimations.

Direct measurement of soil moisture in the plant root zone can be made using moisture-sensing instruments such as tensiometers (fig. 3), resistance blocks, capacitance probes and time domain reflectance sensors. Capacitance probes and time domain reflectance sensors measure actual soil water content; tensiometers and resistance blocks measure soil suction, which indicates the relative ease with which plants can remove soil moisture. These instruments can be used to measure moisture in field soils or in container media, but resistance blocks do not perform well in coarse-textured media. The sensors should be placed in the root zone of plants selected to represent all of those in the irrigated area. Factors to consider when selecting representative plants include plant size and location. These moisture-sensing instruments can be connected to computers or data loggers so that data can be collected continuously and irrigation valves can be set to operate based on the measured soil moisture values.

Improving Irrigation Efficiency

Many irrigation management practices can be implemented in greenhouses and nurseries to increase irrigation efficiency. The following is a list of some of these practices. Most of these suggested practices can be done in concert, and it may well be that some of the suggestions are not appropriate for some operations.

- *Irrigation System Improvements.* Many steps can be taken to improve the performance of the sprinkler and/or drip systems used for irrigation. An irrigation audit, in which the irrigation systems are evaluated for irrigation uniformity (fig. 4) and other irrigation performance measures, is an excellent first step in improving irrigation system performance. Regular maintenance of the irrigation system is criti-

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cal. This includes detecting and repairing leaks (fig. 5), flushing to unclog lines, replacing worn nozzles (avoiding unintentional mixing of different-size sprinkler nozzles and drip emitters) and checking to ensure that appropriate pressure throughout the system is maintained (fig. 6).

- *Pulse Irrigations*. Applying water in short, "pulsed" irrigation durations can significantly reduce runoff and improve irrigation efficiency. Pots hold only a certain volume of water, and any irrigation in excess of that amount simply runs through or off the pots. Multiple pulsed irrigations during the day can prevent runoff while satisfying plant needs.
- *Irrigation Zones*. Establishing zones in which irrigation is constant and can be controlled improves irrigation water management. It allows a nursery manager to operate only those zones needing irrigation for only the time needed.
- *Group Plants with Similar Water Needs*. Placing plants with similar irrigation needs together in an irrigation zone allows efficient irrigation water management. This prevents a situation in which the plants with the greatest water needs dictate the watering schedule, which can cause other plants to be overwatered.
- *Avoid Irrigating Where No Plants Are Present*. Avoiding applying water where there are no plants seems like common sense, but it can be difficult to accomplish. It is made easier when numerous irrigation zones, each of which can be controlled separately, provide increased irrigation control. As plants are sold, group remaining plants that have similar needs together and shut off irrigation in unused areas (fig. 7). When using overhead sprinkler systems on container plants, space plants

Fig. 5. Irrigation systems should be regularly checked to ensure that they are not leaking, as shown above, or clogged. *Photo*: D. Zurawski and J.P. Newman.

Fig. 6. Regular system maintenance includes checking to ensure that appropriate pressure throughout the system in maintained. *Photo*: K. Gilbert and J. P. Newman.

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Fig. 7. In this photo, the overhead irrigation system is watering large areas with no plants. It is important to shut off irrigation in unused areas after plants are harvested for sale. *Photo*: D. Zurawski and J.P. Newman.

Fig. 8. Spray patterns of overhead irrigation systems should not create overspray in walkways and edges, as illustrated here. *Photo*: D. Zurawski and J. P. Newman.

as close as possible while still maintaining adequate light to minimize the empty area where water does not land in a pot. Adjustable sprinkler heads that irrigate only part of a circle should be used on the edges of irrigated areas to prevent water from landing on bare areas adjacent to plants during irrigation (fig. 8).

- *Automation*. Irrigation automation can improve water management, but it should be used in conjunction with good human management. In automated irrigation, a controller operates solenoid-equipped valves at specified times and durations. While the controller may be scheduled to turn the irrigation system on and off, it takes human management to determine whether there is too much runoff or too few or no plants in an irrigation zone being irrigated. Automation is a tool to help the operator improve water management, not a substitute for human judgment.

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Leaching to Manage Salinity in Ornamental Crops

by Richard Evans

One of the problems ornamental crop producers face when they contend with the current drought is that reduced water use can affect crop quality and yields by increasing soil salinity. It is important for growers to know how irrigation water quality affects plant growth, and how they can mitigate the impact of salinity on their crops through judicious management of irrigation water quantity.

Soil salinity results from the accumulation of salts from several sources, but the most important ones are irrigation water, fertilizers and soil amendments (particularly animal manure and some composted organic matter). Growers concerned about salinity should be aware of the contributions to salinity that come from the fertilizers and soil amendments they apply, but those are topics beyond the scope of this article.

Most irrigation water, especially from wells, contains salts that it picks up from the rock, soil and organic matter it comes in contact with. The salinity of naturally occurring waters in California varies widely, but it tends to be relatively high along California's south and central coasts, where most ornamental crop production occurs. The salts dissolved in irrigation water ionize to form positively charged cations and negatively charged anions. Six ionized constituents normally are responsible for nearly all of the salinity of irrigation water. Of these six, three are cations: calcium, magnesium and sodium. The other three are anions: bicarbonate, chloride and sulfate.

Salinity in water and soil is usually measured by electrical conductivity. A water's ability to conduct an electrical current is directly related to the concentration of salts present in solution—the saltier the water, the better it conducts electrical current. Electrical conductivity is usually reported in decisiemens per meter (dS/m). Water electrical conductivity is often abbreviated EC_w. This value is important for managing salinity, but it doesn't indicate the true salinity to which plant roots are exposed. A more direct value is obtained by saturating soil samples with distilled water, then extracting some of the soil solution and measuring its electrical conductivity. This saturated soil extract electrical conductivity is abbreviated EC_e. Typically, crop salinity tolerance is expressed in relation to EC_e.

As the salinity of the soil solution increases, plant water uptake becomes more difficult. In effect, a high salt concentration in the soil solution reduces the amount of water that is available to the plant. Therefore plants in saline soil must devote more of their energy to taking up water, instead of using that energy for growth. That's why yields tend to decrease when soil salinity is high.

Growers who use irrigation water of marginal quality must take steps to avoid negative effects on crops (see fig. 1). One possibility is to treat water (usually by deionization or reverse osmosis) to improve its quality, but this approach is expensive. A practical alternative for many growers is to develop an effective leaching program to prevent excessive accumulation of salts in the root zone. Leaching is best achieved on ornamental crops by applying the proper leaching fraction. This is the ratio of the volume of water leached below the root zone (for example, the water that runs out of the bottom of a pot) to the volume

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Fig. 1. Salinity must be managed to avoid negative effects on crops. Here, marginal chlorosis and necrosis of the lower foliage of poinsettia (*left*) and necrosis of the lower foliage of chrysanthemum (*right*) are a result of high salinity in irrigation water. However, salinity effects are not always accompanied by visible symptoms. Often, yield reduction is the major problem, and no other symptoms are apparent. *Photos*: J.K. Clark.

of water applied (for example, the total amount of water applied to a pot).

The proper leaching fraction is calculated by dividing EC_w by the maximum tolerable EC of the soil solution that has passed through the root zone (which I will call $EC_{leachate}$). EC_w, for our purposes, should be measured downstream from fertilizer injectors. Growers can measure $EC_{leachate}$ directly by capturing the initial leachate from a pot after irrigation and measuring its EC. Tolerable $EC_{leachate}$ values have not been determined for ornamental crops, but most ornamentals can tolerate $EC_{leachate}$ values between 6 to 9 dS/m. The target $EC_{leached}$ should be about 3 dS/m) for salt-sensitive species. I have done the math for you in table 1, which presents target leaching fractions in relation to EC_w and $EC_{leachate}$.

The leaching fraction is used to calculate the amount of irrigation water that must be added to achieve leaching of salts in addition to replacing evapotranspiration. The values for leaching fraction can be rounded off to conform to the values in table 2, which provides the multiplier for adjusting irrigation volumes to achieve leaching. For example, a block of plant that requires 100 gallons of irrigation water to replace what was lost to evapotranspiration should be irrigated with 143 gallons of water if the EC_w is 2 dS/m and the desired $EC_{leached}$ is 6 dS/m (the leaching fraction is 0.33, rounded off to 0.30). In other words, for every 100 gallons of water use by the crop, salinity will "use" an additional 43 gallons.

The effectiveness of leaching should be monitored periodically by measuring $EC_{leachate}$ to en-

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Table 1. Recommended leaching fractions.

	$EC_{leached}$ (dS/m)			
EC_w (dS/m)	3	6	9	12
0.50	0.17	0.08	0.06	0.04
0.75	0.26	0.12	0.09	0.06
1.00	0.33	0.17	0.11	0.08
1.25	0.43	0.20	0.15	0.10
1.50	0.50	0.25	0.17	0.12
1.75	0.60	0.28	0.21	0.14
2.00	0.67	0.33	0.22	0.17
2.25	—	0.36	0.27	0.18
2.50	—	0.42	0.28	0.21
3.00	—	0.50	0.33	0.25
5.00	—	—	0.56	0.42

Table 2. Factor to multiply irrigation volume by to meet leaching requirement.

If the leaching fraction is:	Multiply the required irrigation volume by:
0.075	1.08
0.100	1.11
0.125	1.14
0.150	1.18
0.175	1.21
0.200	1.25
0.225	1.29
0.250	1.33
0.275	1.38
0.300	1.43
0.400	1.67
0.500	2.00

sure that it is near the target value. To do this, select plants to test just before irrigation is scheduled. Add enough water to each pot to cause a small amount of leaching, capture the leachate and measure its EC. If $EC_{leachate}$ is higher than the target value, the leaching fraction may need to be increased; if $EC_{leachate}$ is lower than the target, it may be possible to reduce the leaching fraction.

It is also worthwhile to test the soil EC_e, or have it tested periodically by a commercial lab. There is no salinity problem for plants when EC_e is below 2 dS/m. Salt-sensitive species are likely to have reduced growth when EC_e exceeds 2 dS/m, and most other crops will experience growth reductions when EC_e exceeds 4 dS/m.

Table 2 also indicates indirectly how much the irrigation water quality and crop salinity tolerance can affect total water use. If EC_w were 1 dS/m in the example given in the preceding

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paragraph, the leaching fraction would be 0.17 and about 120 gallons would be required to manage salinity and replace 100 gallons of crop water use (extrapolating from the table where a leaching fraction of 0.175 has a factor of 1.21). That is a 16% savings in water use.

Growers rarely have the luxury of switching water sources. However, it may be feasible to replace some crops with more salt-tolerant species. In the first example above, switching to a crop that could tolerate an $EC_{leached}$ of 9 dS/m would change the leaching fraction from 0.33 to 0.22. This would decrease the total volume applied in that example from 143 gallons hto 129 gallons, a savings of 10%. In situations where irrigation blocks contain a mixture of plant species, growers can save water by grouping salt-sensitive plants separately in a block so that these plants don't dictate the amount of water applied to more salt-tolerant species.

All of these recommendations should be tempered by observations of crop performance in relation to soil salinity. Growers who monitor and record soil salinity and leaching fractions, and who relate those values to crop growth, will be able to tweak the leaching practices as needed to keep water use efficiency as high as possible.

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UC Resources Available to Assist California through the Drought

by Doug Parker and Faith Kearns

California is in the midst of a historic drought (http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?CA.) The combination of three years of below-average precipitation, the driest year on record (2013), and a 15 year below-average precipitation trend have led the state to take unprecedented actions to limit water withdrawals and use. Because agriculture uses approximately 80% of developed water supplies, the drought is being felt particularly hard in that sector. Urban use accounts for about 20% of developed water supplies, and about half of that is for outdoor (primarily landscaping) purposes. As consumers become more aware of how much water is used for landscaping, they are increasingly interested in drought-tolerant landscaping. Therefore, the horticulture and landscaping sectors may face costs due to agricultural water restrictions, and benefits from increased demands for drought-tolerant landscaping. These costs and benefits will not be felt equally across the state or across the industry.

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The University of California, Division of Agriculture and Natural Resources (ANR) has been helping producers and users of horticultural and landscaping materials increase water use efficiency and adapt to drought restrictions. Throughout California, ANR is an engine for problem solving. Serving as the bridge between local issues and the power of UC research, ANR has more than 300 campus-based specialists and county-based advisors working to bring practical, science-based answers to Californians.

Within ANR, the California Institute for Water Resources, CIWR, works with producers, consumers and stakeholders on water resource management. The Institute is enabled by the federal Water Resources Research Act (WRRA), with the mission of supporting research and extension activities that contribute to the efficient management of California's water resources. Headquartered at ANR's offices within the University of California's Office of the President, CIWR is well positioned to coordinate research, education and extension activities across ANR, the 10 campuses of the UC system, as well as academic institutions across the state.

In early 2014, as it was clear the drought would be severe, CIWR developed a series of drought information and education webpages (http://ucanr.edu/drought). We began with a list of drought and water experts from across the state's academic institutions. This experts list became a popular resource that quadrupled our web traffic (http://ciwr.ucanr.edu) and our Twitter following (https://twitter.com/ucanrwater). In the last four months alone, over 400 articles in a variety of major media outlets including the *New York Times, Washington Post, Time, BusinessWeek* and *Mother Jones* have included interviews with California's academic water and drought experts.

In addition, drought events ranging from seminars to workshops have been held across the state. Many of the early drought impacts were first felt by the communities that ANR serves, such as ranchers, farmers and the horticultural industry. As word of the drought spread beyond the agricultural community, workshops on drought response in the urban sector became in demand. Many of those programs have been captured on video that are available on the web, and we continue to develop and promote new programs on our drought webpages.

As the drought continues, we are gathering practical resources from across the UC system that have been of immediate use in agriculture, rangelands, and home and commercial landscape management. We have a wide variety of tools, including a virtual tour of California's water system, developed by researchers throughout the UC system, and a series of drought and water- related scientific presentations known as "Insights: Water and Drought Online Seminar Series." These CIWR drought resources are continually updated to provide the latest information and resources addressing the California drought.

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SCIENCE TO THE GROWER: Hydrogels do not decrease water use in container plant production

by Richard Evans

When drought strikes California, ornamental crop producers are urged to incorporate water-absorbing polymers (hydrogels) into container media. It's as sure to happen as the appearance of yard cleanup service ads on my porch whenever I neglect my garden. I should use those ads to mulch my flower beds 4 inches deep and suppress the weeds, but I'm too lazy. But enough about me. Let's talk about hydrogels.

The typical claim is that these polymers, which can hold several hundred times their weight in water, increase the water-holding capacity of container media and decrease crop water requirements. These claims are backed by some reports indicating that hydrogel addition increases time to wilt, reduces required irrigation frequency and decreases plant water use. However, there are many reports that hydrogel incorporation has little or no effect. In this article I will review what we know about how hydrogels behave in container media.

The attraction of hydrogels comes from their ability to hold astounding amounts of water, and the idea that adding them to a potting mix would increase water retention. The usual way of increasing water retention is to use a finer mix that has smaller pores, because water retention in pots is inversely proportional to the average pore size of the medium: small pores tend to hold water, and large pores don't. Most commercial container media have pore sizes that enable them to hold a lot of water, typically between 50% to 80% by volume. Only media with very coarse pores might be expected to benefit from hydrogel addition.

Unfortunately, the ability of hydrogels to hold water isn't as impressive after incorporation into a typical potting mix. Research in my lab (Evans and others 1989) and at UC Riverside (Letey and others 1992) showed that addition of a polyacrylamide gel to a potting mix at the recommended rate had no effect on water retention. Both studies reported that doubling the rate of addition increased water retention slightly, but, since plant water use was unchanged, water was not conserved.

Why don't the hydrogels retain water? We found that polyacrylamide gels exposed to typical concentrations of fertilizer solutions hold as little as 10% of their maximum water-holding capacity (Bowman and others 1990). We think that the positively charged ions in the fertilizer solution—especially multivalent ions of calcium, magnesium and iron—interfere with the ability of hydrogels to attract water molecules, and constrain hydrogel expansion. We also showed that the inhibition of gel hydration by fertilizers can be partially reversed by applying a solution of a potassium salt, followed by repeated leaching with water (Bowman and Evans 1991). As you can imagine, that exercise would not be practical in commercial horticulture.

The picture for hydrogels hasn't changed much since then. Fonteno and Bilderback (1993) reported that hydrogel addition to an

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unfertilized, coarse mix of pine bark and sand increased water holding capacity slightly, but at the expense of lower air-filled porosity. They noted, however, that the small increase in water retention may not benefit plants because of an "oasis effect," whereby the water held by gel particles may not be hydraulically connected to roots and therefore not available to the plant. More recently, Green and others (2004) confirmed the earlier findings and reported that the response to fertilizer salts limits the usefulness of hydrogels in field soils, too.

The most important point regarding hydrogel use during droughts is that they do not decrease the water requirement of crops. If irrigation is managed properly, the total amount of water applied will be the same in hydrogel-treated soil as in untreated soil.

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GET CULTURED: Managing media to optimize water use

by Don Merhaut

Media is only second to irrigation management in optimizing water use efficiency in containerized plants. With the proper selection of substrates or prepared media, irrigation frequency and water availability to plants can be optimized. This article will summarize the major physical and chemical characteristics of substrates to take into consideration when selecting or preparing media. Best Management Practices (BMPs) of container media to minimize irrigation frequency and optimize water use efficiency are highlighted.

Hydrophobic Vs. Hydrophilic

Hydrophobic roughly means water hating: any substrate or planting medium that is hydrophobic will repel water. *Hydrophilic* means water loving: any substrate or medium that is hydrophilic readily absorbs water. In container production, dry peat moss is the most notorious for being hydrophobic. On the other hand, moist peat moss is hydrophilic; therefore, it is critical that moist peat moss never be allowed to dry out. Other substrates such as perlite are hydrophobic; however, hydrophobic substrates such as perlite are often used to increase drainage and porosity of media.

BMP: Never allow peat moss and similar organic materials that are likely to become hydrophobic when dry to completely dry out. Rewetting will be difficult if not impossible.

BMP: Consider the use of wetting agents to rewet media that has become hydrophobic.

BMP: If preparing a medium, consider substrates that are hydrophilic instead of hydrophobic.

Water Movement in Media

When irrigation is applied to containers, the water will either remain on the surface, channel down the sides (especially if the medium is hydrophobic), or soak into the medium.

Water-holding capacity. The ability of container media to hold water is referred to as the water-holding capacity. It is expressed as the volume of the root medium that is filled with water at container capacity. Container capacity is the amount of water remaining in the container after runoff. Water-holding capacity is an important indicator of the required irrigation frequency. If water-holding capacity of a container media is low, then water must be added frequently.

Keep in mind that the container shape and size will also influence water holding capacity. As the container height increases, the water-holding capacity decreases. This phenomenon is demonstrated with the classic rectangular sponge: a water-saturated sponge lying flat on its side will retain more water

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than the same sponge when it is placed in an upright vertical position.

Infiltration rate. The rate at which water soaks into the medium is called the infiltration rate. The infiltration rate of a medium will decrease as the medium becomes wetter. Infiltration rates can be improved with substrates that have larger particle sizes which are porous. Substrates such as perlite and pumice will increase infiltration rate, but will not increase water-holding capacity since these substrates do not absorb water.

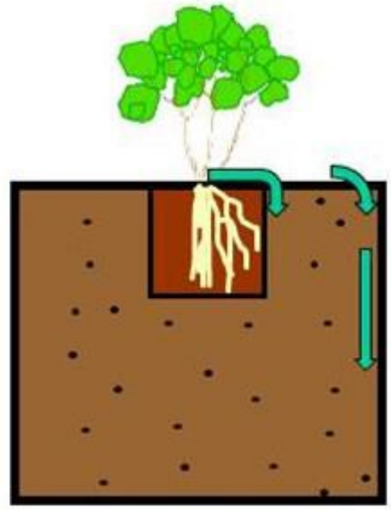

Fig. 1. Plant liner placed into a larger container. If the liner's medium physical/ chemical properties are different from that of the container medium, it may be difficult to have uniform watering of both the liner medium and container medium. Arrows indicate potential channeling of water down sides of liner or container if medium becomes hydrophobic.

Sodium adsorption ratio (SAR) of water is the relative ratio of sodium (Na) to calcium (Ca) and magnesium (Mg) in the irrigation water. As the amount of sodium increases in irrigation water, the amount of sodium adsorbed onto clay surfaces increases, which causes clay particles to disperse or "run together." This, in turn reduces water infiltration into soil. This chemical-physical problem only occurs on field soils. SAR problems do not occur in organic soils or containerized media.

Channeling water in containers. No, we are not summoning up the water spirits! Water channeling in containers occurs when water takes the path of least resistance when flowing through the pot or container. Usually, when a part of the container medium becomes hydrophobic, the water will flow around this hydrophobic portion, which often results in water channeling down the inside edge of the container or soaking into the portion of the medium that is hydrophilic.

Water channeling may occur if liners planted in a substrate that dries out quickly and becomes hydrophobic are then planted into a larger container with a different media that is moist. This can be critical in new plantings where the liner medium can dry out quickly, since this is where water uptake is occurring (fig. 1). In full sun, the southwest side of containers will dry out faster than the northeast side of the containers, making it difficult to uniformly rewet the container media.

BMP: Select a medium that has a higher water-holding capacity to reduce the frequency of irrigations required, but do not reduce aeration of the medium to the point of impairing root growth of select plant species. For most crops, the recommended water-holding capacity is approximately 50%. Crops such as orchids and other epiphytes require media with more air spaces, and therefore, the ideal water-holding capacity is much lower.

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BMP: Where suitable for the plant type, consider "squat" pots to increase water-holding capacity.

BMP: Use substrates with larger particle sizes to improve infiltration rate. Use substrates such as coarse particles of peat moss and coconut husks to increase infiltration rate while simultaneously increasing water-holding capacity.

BMP: To prevent water channeling, use frequent but brief irrigation cycles on newly planted liners in larger containers until the roots grow out of the liners and into the larger container.

BMP: Maintain uniform moisture within the container media by using cultural practices to reduce direct sun exposure to container sides, such as pot-in-pot production, shade cloth around containers on the southwest side of production beds, or "can-tight" placement of containers. Alternatively, in larger containers, place drippers on the southwest side of containers to reduce this problem.

Media Shrinkage

Media "shrinkage" occurs when organic particles break down. This happens to media containing compost that isn't fully mature or substrates such as sawdust, which easily break down. When nitrogen fertilizer is added to these materials, microorganisms break down the carbon and the container medium will shrink. Media shrinkage may also seem to occur if fine particles such as clay drain or run out of the container drainage holes.

BMP: To prevent shrinkage, use barks, which break down slowly, rather than sawdust when preparing container media.

BMP: Use only mature compost in media.

BMP: Drainage from containers is required, but make sure drainage hole size is appropriate for media particle sizes.

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INSECT HOT TOPICS: Euonymus caterpillars

by James A. Bethke

Dan Gilrein is the extension entomologist at the Long Island Research and Extension Center, a part of Cornell University in New York, and he recently shared some photos that I found quite interesting. I think you will find it just as interesting. The photos were not taken during Halloween, and they're not staged. The copious webbing you see in figure 1 is from the euonymus caterpillar (fig. 2), *Yponomeuta cagnagella* (Hüber), an invasive moth species (fig. 3) that was reported in New York in 1982 and reported sporadically in Wisconsin, Illinois and Michigan since 1989. It subsequently spread to Delaware and Maryland, and was found in Iowa in 2012. The native habitat of the euonymus caterpillar is in Europe, Asia Minor, the Middle East, Siberia and the British Isles. It is assumed that the euonymus caterpillar was introduced to North America through Ontario on seedlings of European spindle, *Euonymus europaeus*, imported from Holland.

Euonymus caterpillars are defoliators of the tree form of European spindle (*E. europaeus*), the spreading euonymus (*E. kiautschovicus*), the winged or burning bush euonymus (*E. alatus*), the Japanese euonymus (*E. japonica*), the wahoo euonymus (*E. atropurpureus*) and the winter creeper euonymus (*E. fortunei*). The young larvae are gregarious (feed in groups, fig. 2). It's been observed that they usually begin feeding on the ends of branches and work their way toward the center of the plant. If not controlled early in their development, these caterpillars can quickly defoliate entire plants. Figure 1 represents a severe attack with complete defoliation, and the webbing is unsightly and can remain on the plant for a very long time. Euonymus caterpillars usually do not kill the host, but as you can imagine, death can occur with repeated defoliations.

If this invasive moth makes its way to California, I think it will be reported more quickly than most invasives because of the ghostly looking remnants of an infested plant. Regardless, we should be on the lookout for this moth. It could become quite a problem in the ornamental plant production industry. Its presence in California may hinder movement of nursery plants due to regulations. In addition, the western burning bush, *E. occidentalis*, is a native species that could be severely impacted in the wild.

Fig. 1. Copious webbing produced by the euonymus caterpillar, *Yponomeuta cagnagella*. *Photo* (*left*): Jennifer Grier, Cornell Extension, Lewiston, NY. *Photo* (*right*): John Sharpe, Town of Lewiston, NY.

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Fig. 2. Aggregation of euonymus caterpillar larvae. *Photo*: John Sharpe, Town of Lewiston, NY.

Fig. 3. Euonymus caterpillar adult moth. *Photo*: Michael Kurz. *Source*: http://commons.wikimedia.org/wiki/File:Yponomeuta_cagnagella_E-MK-17376a.jpg.

Web pages of interest with lots of interesting photos:

http://msue.anr.msu.edu/news/euonymus_caterpillars

http://learningstore.uwex.edu/assets/pdfs/A3633.pdf

http://www.ipm.iastate.edu/ipm/hortnews/2012/6-13/euonymuscaterpillar.html

http://www.gov.pe.ca/af/agweb/index.php3?number=74328

http://plantdiagnostics.umd.edu/level3.cfm?causeID=63

http://greenindustry.uwex.edu/problemdetails.cfm?problemid=50

http://www.natgeocreative.com/photography/1163764

http://msue.anr.msu.edu/news/euonymus_webworm_causing_some_damage_to_burning_bush_around_grand_rapids_mi

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James Bethke is Farm Advisor for Nurseries and Floriculture, UC Cooperative Extension, San Diego and Riverside Counties.

REGIONAL REPORT — UC Cooperative Extension
Santa Cruz/Monterey Counties

Retrospective on improving irrigation management

by Steve Tjosvold

In the spring of 1983, I planted myself in Watsonville as a new farm advisor. I needed to determine the major issues facing the ornamentals industry, prioritizing my efforts to address the most important issues with research and educational programs. Many growers were producing cut carnations at the time, and the carnations were being attacked by fusarium wilt, a serious soil-borne disease. Upwards of 40% of a carnation crop could be killed in a two-year crop cycle. So I began field research with growers and plant pathologists on soil disinfestation treatments, fungicides and biological control agents to fight this disease. At the same time, salt water intrusion into underground aquifers was starting to be detected in coastal wells from Castroville to Watsonville. In 1984, the Pajaro Valley Water Management Agency was formed to begin to address these concerns. Today, carnation production and its associated diseases are essentially non-existent because markets have changed dramatically. But water quality and availability issues are still significant. With the current drought, of course, the needs of managing irrigation water is more important than ever. In this article, I look back to the research work we did then and how it applies today.

My colleague Kurt Schulbach and I began research to improve water use in greenhouses, initially focusing on cut roses which was a crop commonly grown in this area. We developed an innovative way of measuring a rose crop's water needs with an evaporation pan placed in the greenhouse. The pan results were calibrated with tensiometers. This is a simple instrument that is placed in the soil and measures soil moisture tension—a guage of the wetness / dryness of the soil relative to the needs of the plant. We demonstrated how tensiometers could be monitored to help determine when rose plants were stressed. We found that roses really liked to be watered frequently; soil tensions needed to be below 10 centibars or plants were stressed and flower production fell. Today, tensiometers (fig. 1) and other soil moisture measurement sensors are widely available but still mostly unknown or underutilized. To that point, at a recent irrigation management meeting, a grower noted he first learned of tensiometers while visiting flower nurseries in Bogota, Colombia!

Tensiometers are usually placed in a field soil in sets of two: one is placed to measure soil water tension in the root zone and one placed below

Fig 1. This tensiometer with a vacuum pressure gauge is one of several available devices for measuring soil moisture and scheduling irrigation. *Photo*: David Rosen.

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the root zone to detect water movement below the roots. In highly-amended porous field soils, container soils, or sandy soils typically preferred in ornamental production, you want to use the tensiometers that can measure low tensions (such as the Irrometer LT model).

If you are a newcomer to the use of tensiometers, you might first try installing a set of tensiometers and irrigate for several weeks as you normally do. Record tensiometer readings for at least 3 weeks. What you might see is that irrigations begin when the root zone tensiometer measure around 10 centibars or lower. Crops should be irrigated before they are stressed and certainly before they wilt. In general, tensions as low as 5 centibars would offer the plants a moisture stress-free environment. With more records and some evaluation, a grower could start using the tensiometers to time irrigations more accurately. With added accuracy and reduced water applications comes the importance of insuring that enough water is applied at each irrigation to leach accumulated salts and compensate for imperfect irrigation systems. Imperfect irrigation systems relate to another major project completed over 20 years ago.

In that project, we evaluated 23 micro-irrigation systems used in greenhouse cut flower production. The ability of the micro-sprinklers and drip systems to apply water uniformly varied widely. The drip tape systems usually provided very uniform application of water as measured by a common measure called the distribution uniformity (DU). With drip tape, DU was measured at upwards of 96%, while the perimeter micro sprinkler systems averaged mostly between 60% and 70%. We were able to demonstrate an important concept in irrigation management. The lower the DU, the more water is required to meet crop needs. The amount of extra water needed to ensure adequate irrigation could be estimated by dividing the water requirement by the DU. Relative to a system with a perfect 100% uniformity, a system with a DU of 85% requires about 18% more water than the crops need to make sure that the drier areas receive enough water (1.0/0.85 = 1.18). An irrigation system with a DU of 51% (1.0/0.51=1.96) would require nearly 80% more water than one with a uniformity of 85%. Often, this amount of extra water is not applied and in some areas there may be yield losses due to water stress. This research illustrated significant water savings with drip tape irrigation and preceded a big shift from sprinkler irrigation to drip and other micro-irrigation systems in cut flowers and other crops.

Another observation in our evaluation demonstrated an important concept about irrigation design that is still important today. In general, we observed the flow rates in the sprinkler perimeter systems were too high for the ¾-inch laterals used in some sprinkler irrigation systems and it caused large friction losses. In one system, the pressure was 75 psi at the pump but only 2 psi at the end of the sprayer lines. This pressure drop was caused by friction losses through valves, pipe bends and small diameter pipe. As a result, the average DU measured in the sprinkler irrigation systems was only 70%.

Although large pressure losses in the mainlines do not necessarily result in low distribution uniformity, these losses increase pumping

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costs and waste energy. Large friction losses in mainlines can be compensated for by using pressure regulators (fig. 2) that even out the water flow to each separately controlled area. Another method to compensate for large pressure losses in the mains is to adjust the irrigation set times. For example, in areas of the greenhouse or nursery where pressures are low, the run time can be increased until the total amount of water applied to the irrigation block is the same as in the high-pressure areas.

Automatic timing devices rather than manual operation of solenoids could significantly improve uniformity. It was noted many times that a worker operating the solenoid valves was distracted and thus not keeping an eye on the timing of the irrigation. Although not common, pressure compensating valves along water mains, when they are set properly, could significantly increase uniformity.

Plugging of the outlets was the other major cause of low uniformities. The mainlines in most of the systems were iron pipe and as a result rust flakes were commonly found plugging emmiters. Chemical precipitates and sand were often the cause of plugging in other systems. Only the drip systems utilized water filtration, and the overall higher uniformity of these systems demonstrates the value of filtration. A regular maintenance program, including chemical treatment and flushing of the laterals, will also help keep systems clean and reduce plugging without the damage often caused by manual cleaning.

Fig 2. This adjustable pressure regulator (Hardie pressure compensating valve) is used to ensure that appropriate and uniform pressure is maintained throughout the irrigation system. *Photo*: J.K. Clark.

The Resource Conservation District of Santa Cruz County (RCD) with various sponsors will be offering a program in the fall of 2014 to evaluate irrigation systems with the Mobile Irrigation lab, as we did over 20 years ago. Contact the RCD (http://www.rcdsantacruz.org/) for further information.

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REGIONAL REPORT — UC Cooperative Extension
Ventura County

Drought exacerbates root rots

by Jim Downer

The drought has firmly set in for the third and historically driest year in California history. Drought affects not only plants in production but in landscapes as well. Sudden and long-term weather changes can cause physiological harm in many plants resulting in damage symptoms. Dehydration during drought leads to physiological wilting but can also be associated with sunburn of leaves or stems of many ornamental plants. Plant disfiguration from leaf drop and dead leaves, twigs and branches increase on drought-stressed plants. Drought can occur in nurseries if temperatures suddenly increase or wind events create greater transpiration resulting in water deficits. The immediate effects of drought are easily seen in aboveground plant parts, usually as a loss of bright color, and ultimately wilt, sunburn or death of leaves and small stems. Many plants don't wilt, so they can become very dehydrated before other symptoms are noticed.

Root systems are also affected by drought. Drought causes chemical, physical and biological changes of soils that ultimately affect the health of the root systems and thus the plant's susceptibility to Oomycete root rots. As irrigation water is removed from media by plants and evaporates from media or soil surfaces around plants, salts are left behind in soil. Each year rainfall can potentially leach accumulating salts, but rainfall volumes need to be large enough to move water down in the soil or media profiles while also dissolving salts and flushing them from the root zone. These last three years have not provided any significant leaching opportunities. Large containerized trees and landscape plants are all affected by the resultant increasing soil osmotic potentials (higher salt content) which accompanies drought. Nursery growers may need to develop an effective leaching program to prevent excessive accumulation of salts in the root zone (***editors note:*** see Richard Evans feature article "Leaching to manage salinity in ornamental crops").

Chemical factors in soil have long been known to affect the outcome of *Phytophthora* diseases (Schmitthenner and Canaday 1983). Drought-affected plants growing in saline soils have less ability to regulate the influx of salts entering their root systems because roots growing in saline soils are more likely to have increased exudates that are attractive to the spores of Oomycete pathogens which further disable root ion selectivity. Specific ions can alter the progress of many *Phytophthora* diseases either increasing or decreasing them. While chlorides and sodium in solution are root rot predisposing (MacDonald and others 1984), calcium ions (Ca++) have been shown to control root rots by interrupting the swimming ability of zoospores and by decreasing sporangial volume, thus decreasing inoculum potential (Messenger et al.

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2000). Unfortunately, many waters in California are alkaline and thus cause calcium to precipitate from solution as limestone minerals. Schmitthenner and Canaday noted that pH reduction (below pH 5) was associated with reduced incidence of disease from most reported *Phytophthora* species. Therefore, decreasing irrigation water pH and adding calcium ions may be an effective control measure against *Phytophthora* in nurseries.

Nursery growers are especially aware that peat moss and other highly organic media can dry out and become hydrophobic. This physical change in the media repels water, making the media hard to rewet and difficult to manage. Severe soil moisture deficits may cause plant to permanently wilt and also affect the soil microbial community (soil food web). Soil microbes such as mycorrhizae, plant growth promoting bacteria and saprophytic fungi that are also fungal hyperparasites of *Phytophthora*, all have a role in regulating soil-borne diseases (Hornby 1990). In dry soils, many microbial partners are lost or die off — the food web simplifies, loses resiliency and is open to the effect of opportunists (plant pathogens) that can rapidly invade soils when moisture levels come back to normal and disease begins.

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REGIONAL REPORT — UC Cooperative Extension

San Diego/Riverside Counties

First detection of *Colletotrichum cymbidiicola* in California

by James A. Bethke

In a recent nursery inspection, the San Diego County plant pathologist noticed black spots on some leaves in a greenhouse full of cymbidium orchids and thought it was a common foliar infection. You can walk into most orchid greenhouses and see black spots on leaves, especially the older leaves. Following procedure, the plant pathologist sent the samples to a diagnostic lab and the disease was determined to be caused by *Colletotrichum cymbidiicola*. This was the first detection in North America of this fungus. The infected plants sampled in San Diego County originated in Santa Clara County and subsequently the pathogen was found there too.

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The genus *Colletotrichum* includes a number of plant pathogens of major importance, causing diseases of a wide variety of woody and herbaceous plants, and was recently voted the eighth most important group of plant pathogenic fungi in the world, based on perceived scientific and economic importance (Cannon et al. 2012, Dean et al. 2012). It is primarily found in tropical and subtropical regions. Strains of *Colletotrichum* often belong to aggregates of species that can be difficult or impossible to distinguish morphologically. The fungus, *Colletotrichum cymbidiicola*, is one of a group of related *Colletotrichum* that belongs to an aggregated species (*C. boninense*) and is associated with orchids, appearing host specific at plant genus level (Damm et al. 2012).

As plant pathogens, *Colletotrichum* species primarily cause anthracnose diseases. On cymbidium orchids, anthracnose is characterized by black spots on lower leaves and premature loss of infected leaves. Under humid conditions tiny black dots that look like lumps of coal emerge from the diseased tissue in a circular pattern. Spores are spread by water so keep water off of the leaves. Additionally, remove infected leaves, handle infected plants as little as possible and reduce crowding to ensure good air circulation. These measures will reduce disease expression and spread.

At the time of this writing, *C. cymbidiicola* has been given a Q rating by CDFA, which means the fungus is a potentially destructive organism of limited distribution in California and control measures must be taken. A delimitation survey is underway, and if it is found widespread in California, there is a chance it could receive a different rating. We will have to wait and see.

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Water Supply Update

Following two straight dry years and an extraordinarily dry start to a third, the San Diego County Water Authority's Board of Directors activated its Water Shortage and Drought Response Plan on February 13. The Board also declared the region to be in a Drought Watch condition, which calls for increasing voluntary water conservation efforts by homes and businesses.

However, although mandatory supply cuts were imposed on the region by the Metropolitan Water District (MWD) between July 2009 and April 2011, the Water Authority is not expecting any cutbacks to its imported water supply sources this year. San Diego County is being protected from immediate impacts of the drought by several factors, including significant investments in diversification of the region's water supplies and an effort to increase water storage levels. In addition, San Diego County residents, businesses and agricultural water users have done a great job using water more efficiently (per capita water use fell 27 percent between 2007 and 2013). By developing new local and imported supplies and boosting conservation, the San Diego region has reduced its reliance on MWD supplies to 46%, a reduction of 49% from 1991.

It's with great anticipation that the region will begin purchasing up to 56,000 acre-feet of desalinated seawater annually from the new Carlsbad Desalination Project. This will further increase local water supplies and reduce the reliance on MWD supplies.

While recommended water use practices or restrictions may vary by local agency, the San Diego County Water Authority recommends typical conservation steps during the Drought Watch condition. For more information on the Drought Watch Plan, water conservation practices and the region's water supplies, see the San Diego County Water Authority website (http://www.sdcwa.org/) and the following links: http://www.sdcwa.org/sites/default/files/watersupplyoutlook-fs.pdf, http://www.sdcwa.org/drought-response. UC Cooperative Extension is also a resource on water conservation measures. For example, UCNFA held a workshop, "Irrigation Management Efficiency in Nurseries" in San Marcos on June 25. The ongoing UC Cooperative Extension, San Diego County Water Schools (http://ucanr.edu/sites/agwaterquality/) include management practices that reduce runoff and conserve water.

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CAMPUS AND COUNTIES NEWS: Jim Bethke receives the 2014 CANERS research award

by Linda Dodge and Loren Oki

Jim Bethke, Farm Advisor and County Director for UC Cooperative Extension, San Diego County, received the 2014 CANERS Research Award on June 25, 2014 at the UC Nursery and Floriculture Alliance (UCNFA) Irrigation Management Efficiency in Nurseries Workshop in San Marcos.

Other industry awards that Jim has recently received for extension activities which have benefited the nursery industry include the Outstanding Contribution to Agriculture Award, 2013 (from CAPCA) and the Outstanding Person of the Year, 2013 award (from the San Diego County Flower and Plant Association). Jim has worked extensively to address invasive insect species, including serving as a member of the CDFA Palm Weevil Technical Working Group and the Gold Spotted Oak Borer Steering Committee and serving as Co-Chair of the European Pepper Moth Technical Working Group. During the past year, in addition to his leadership of the floriculture and nursery program at UC Cooperative Extension, San Diego County, he assumed management of other extension programs, including the Master Gardener, Wildfire Zone, Gold Spotted Oak Borer, Ag Water Quality, and the Rainbow Creek Nutrient Management programs, and was successful in receiving grants for administering these efforts. Jim has an extensive list of peer reviewed, technical and popular publications. He has been continuously invited to make presentations at scientific and industry meetings nationwide concerning his research to address industry problems.

Congratulations, Jim, on receiving this prestigious award. Thank you for your contributions to the nursery industry!

Dr. Loren Oki, UCNFA Co-Director (*left*) presents Jim Bethke, UCCE San Diego County (*right*) with the 2014 CANERS Research Award.

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New Publications from Agriculture and Natural Resources

Compiled by Steve Tjosvold

Container Nursery Production and Business Management Manual

This colorful new manual includes research-based information on all aspects of production of landscape plants in commercial nurseries. Written primarily for wholesale nursery growers and propagators; a wide range of those involved in the nursery industry will find this a valuable reference.

Twenty chapters in five broad sections cover topics from nursery site selection to crop production, water management to business and labor management, along with pest, weed, and disease management. This easy-to-use manual contains the photos, tables and clearly written text that make UC ANR's publications the go-to references industry professionals rely upon.

Chapters include:
Nursery Site Selection and Development
Plant Growing Structures
Mechanization and Automation
Soils and Container Media
Nutrition and Fertilization
Irrigation Management Practices
Controlling Runoff and Recycling Water, Nutrients, and Waste
Plant Propagation
Controlling Plant Growth
Diagnosing Plant Problems
Integrated Pest Management
Plant Diseases
Insects, Mites, and Other Invertebrate Pests
Integrated Weed Management
Vertebrate Pest Management
Invasive Pests
Business Management
Marketing Considerations
Increasing Labor Productivity

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