NJ AGRICULTURAL EXPERIMENT STATION
RUTGERS
COOPERATIVE RESEARCH & EXTENSION

For a comprehensive list of our publications visit
www.rcre.rutgers.edu

E302

Bulletin

Irrigation Management Options for Containerized-Grown Nursery Crops

Gladis Zinati, Ph.D., Extension Specialist in Nursery Management

Introduction

Growing nursery plants in containers is a unique system compared to field-grown plants. Container plants are grown in substrates that contain a limited amount of water, retain smaller quantities of nutrients, and confine roots in a limited volume. Consequently, production inputs such as irrigation and nutrients require precise and properly timed applications in quantities that result in maximum benefit to the container plant production system.

Irrigation is a very important aspect of nursery crop production because nutrient and pesticide runoff are related to irrigation practices. There are several means by which to supply a crop with irrigation water: overhead sprinkler, hand-watering, drip or trickle irrigation systems. The first two irrigation systems are typically more wasteful delivery systems, and wet the foliage, increasing the potential for diseases. Drip or trickle irrigation systems are more efficient and provide greater control over the amount of water applied.

No matter which irrigation system is used, it is important that the system be well-designed hydraulically to assure high uniformity and distribution of water efficiently. Efficiency of water application depends on the system, design, management skills, and irrigation scheduling.

Irrigation Management and Water Quality

Irrigation management involves a combination of interrelated practices that improve irrigation efficiency, reduce runoffs, and protect, improve, and maintain water quality. Managing runoff at production sites reduces soil erosion from irrigation and rainfall, and minimizes contaminant carryover into surface and ground waters. In developing an irrigation management plan it is important to determine what is present in runoff or leached water and in what concentrations. High amounts of nitrate, phosphorus, salts, pesticides, and pathogenic organisms are the common problems. The simple tests for nitrates and other nutrients are relatively inexpensive. However, detailed nutritive and chemical tests (especially pesticides) will be more costly. Each grower or manager should make a list of the common chemicals and their concentrations they use in their nursery operations, especially those that have the potential to end up in the water supply. Seasonal analysis is the best plan. Occasional analysis for trace elements is necessary to determine their trends. It is important to follow the analytical laboratory instructions on sampling and handling of water samples. If the sample cannot be sent immediately after collection, then freeze it until sent to the laboratory. The following are irrigation management options that can be adopted to improve irrigation efficiency, reduce and conserve water usage and quality.

THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS
COOK COLLEGE

Maximize Irrigation Efficiency

Irrigation efficiency can be expressed relative to three aspects of water application: 1) **uniformity of application**, 2) **amount of water retained in substrate media following irrigation**, and 3) **amount of water that enters containers compared to that which falls between containers** (in the case of overhead irrigation).

Irrigation application efficiency is the ratio of the volume of irrigation water stored in the root zone and available for crop use (evapotranspiration) to the volume delivered from the irrigation system [Eq. 1]. This ratio is always less than 1.0 because of losses due to evaporation, wind drift, and leaching, which may occur during irrigation. Improved irrigation efficiency can lead to reductions in water and energy consumption, more effective nutrient use and disease management, better yields, and improved crop quality and erosion control management systems.

Irrigation Efficiency (IE):

$$\frac{\text{(Volume of applied water} - \text{Volume of leached water)}}{\text{Volume of water applied}} \qquad \textbf{[Eq. 1]}$$

Irrigation uniformity refers to how evenly water is distributed across the production beds. No irrigation is perfectly uniform. In all cases, some parts of the production beds receive more water than others. The degree of uniformity however, can be highly variable depending on the selected irrigation system and its management. While some irrigation systems are more efficient than others (drip vs. overhead), it is important to realize that poor management of a relatively efficient system can greatly reduce or negate system efficiency and increase pollutant discharge to runoff or percolating waters.

It is recommended that the irrigation manager perform irrigation system maintenance regularly. The manager should check for leaks and clogged nozzles, measure operating pressures, do simple tests to measure application rate and distribution uniformity (DU). Distribution uniformity can be measured using a grid of collection format with straight-sided containers and placing them in the defined area. The sprinkler system is run for a set period of time; the water volumes in the containers are collected and measured. Additionally, using an anemometer (wind gauge) and a pressure gauge provides information on whether the sprinkler heads in the test area are operating under the same water pressure. Distribution uniformity tests must be repeated several times to conduct an accurate evaluation. Irrigation distribution can be affected by pressure, wind speed, and distance from the pumping water source. In addition, test well water regularly for potential contamination (nitrate, phosphorus, and pesticide), check and record results of back-flow prevention devices at least once a year.

The amount of water retained in a growing substrate medium depends on the physical properties of components that make up the nursery growing medium. Substrate media with coarser particle size require better management to ensure reduced leaching amounts. For example, substrate media prepared from composted pine bark and sand has less water holding capacity (water retention) than medium that includes peat. The **water-holding capacity [Eq. 2]** is the percent of the total volume of the medium that is filled with water after irrigation and drainage. The volume of water used to saturate the medium is the total pore space of the medium. When a medium is saturated and allowed to drain, air replaces the volume of water drained. **Measuring the drainage water then gives a quick measurement of drainable pore space or air space [Eq. 3]**. Understanding and knowing the physical properties of the growing medium aid in designing and making correct decisions on adopting the appropriate irrigation system (rate and frequency) and in selecting the appropriate nursery crops to grow. A simple procedure can be used for this that costs little except time. Materials needed are a measuring cup, masking tape, a pencil, the containers to be used, a bucket or pan, and a few containers for water. Steps in the procedures for determining air space and water-holding capacity can be found at the website link *http://edis.ifas.ufl.edu/pdffiles/CN/CN00200.pdf*. Such information can be useful when a nursery grower produces nursery plants that require high amounts of water (such as hibiscus, see Table 1). It is recommended to include higher ratios of peatmoss in the soilless mix than just using bark with sand alone. The peatmoss increases the water holding capacity and provides a longer period of available water in the medium and hence, for root absorption, than if the plants are grown in a mix that contains only bark and sand. Additionally, the grower will benefit from reducing water consumption, less irrigation frequency, runoff, and leaching. On the other hand, with plants that require less irrigation and more air space, it is advisable to incorporate more coarser particles in the medium to ensure oxygen availability to plants' roots.

$$\text{Water holding capacity} = \frac{(\text{Total pore space} - \text{Volume drained water})}{\text{Container volume}} \times 100 \quad \textbf{[Eq. 2]}$$

$$\text{Percent air space} = \frac{(\text{Volume of drained water})}{\text{Container volume}} \times 100 \quad \textbf{[Eq. 3]}$$

The amount of water that enters the containers depends on plant spacing and plant structure. It is estimated that 50% to 75% of the water applied, through overhead irrigation systems, falls outside and missing the containers completely. The **Interception Efficiency (IE)** is a theoretical measure of the amount of applied water that is captured by the containers during an overhead irrigation event excluding the amount of water that falls onto the land around the containers. It is expressed as a percentage of the applied water but, in terms of area, it is the "container top area" divided by the "land area (L x W) allotted to one container" (Fig. 1). The "container top area" is the open area of the top of the container through which irrigation water enters the container (calculated by multiplying 3.1416 with the container radius squared). Land area is defined by the container spacing. The percentage of irrigation water or fertigation solution (injecting liquid fertilizer into irrigation water) that falls directly onto the land is calculated as 100 - IE,%, and that contributes more directly to nutrient runoff. The value is particularly important in those operations that "fertigate", i.e., apply soluble nutrients in the irrigation water. Containers placed closely have a higher interception efficiency compared to spaced "unjammed" containers. Properly installed drip irrigation should have 100 percent interception efficiency. On the other hand, not all intercepted water is held within the container. The irrigation water in excess leaches out through the bottom openings of the container.

Optimize Leaching Fraction (LF)

Leaching fraction is a measure of the excess water that is applied during an irrigation event (Fig. 2). It is the amount of water that drains out the bottom of the container divided by the total amount of water applied to the container. Leaching factor is mainly affected by the physical properties of the soilless media used for growing plants, plant growth stage, and the volume of water applied per irrigation. The goal is to manage water applications more accurately and reduce the leaching that contributes to runoff. A LF between 10 and 15 is considered safe for plant growth and environmentally friendly. However, care should be practiced when LF is below 5, especially because soluble salts build up in the soilless media and may injure roots of sensitive plants to salts. Irrigate plants with fresh water from time to time with LF about 20 to reduce soluble salt levels and to protect plants from salt injury. When fertilizer concentrations are reduced, less leaching will be needed and conversely, if leaching is reduced you will need to use less fertilizer to avoid buildup of salts in the medium.

Interception efficiency and leaching fraction provide a means of assessing potential runoff, which is the excess water that flows out of the growing area being irrigated and moves toward off-site surface water. For overhead irrigation, runoff is made up of water that leaches through containers plus the water that is not intercepted by individual containers. For drip irrigation, runoff is measured by leachate.

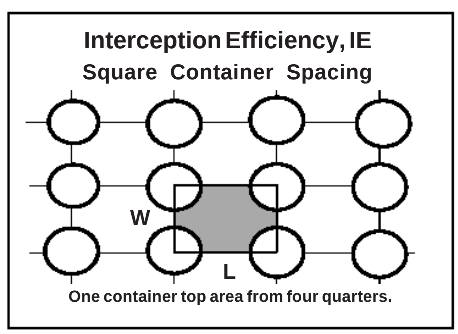

Figure 1. Interception Efficiency†

†Adopted from Lea-Cox, J. D., K. M. Teffeau, D. S. Ross and P. D. Schreuders. 1999. Defining Nitrogen and Phosphorus Flows in Container Nursery Production. pp. 211-212. In: Sharpley, A. N. (ed.) Agriculture and Phosphorus Management –The Chesapeake Bay. Lewis Publishers, Boca Raton, FL.

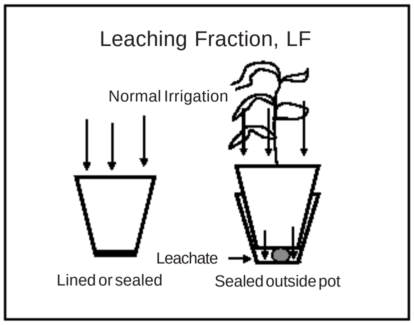

Figure 2. Leaching Fraction†

†Adopted from Lea-Cox, J. D., K. M. Teffeau, D. S. Ross and P. D. Schreuders. 1999. Defining Nitrogen and Phosphorus Flows in Container Nursery Production. pp. 211-212. In: Sharpley, A. N. (ed.) Agriculture and Phosphorus Management –The Chesapeake Bay. Lewis Publishers, Boca Raton, FL.

Optimize Irrigation Scheduling

Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper irrigation scheduling improves crop production and/or quality, conservation of water and energy, and lower production costs. Several methods used to successfully reduce irrigation volume and runoff, include micro-irrigation and pulse (cyclic) irrigation. Pulse irrigation refers to the practice of alternating small volume irrigations and resting intervals. Pulsing can work with sprinkler, or drip irrigation. Thus, the opportunity exists to make sure the appropriate management strategies are used, recognizing the site-specific nature of nursery production facilities.

If you do not have a control irrigation system, a simpler method can be used to determine when and how much to water. A target weight for watering must be set. The target weight can be determined in a simple method. Check the weight of container at full water holding capacity, and then at the plants' point of wilting. The goal is to water most plants when approximately 60–70% of the available water has been used and re-water to full water holding capacity and not beyond unless salt build up is a problem. The target weight may have to be increased as the crop grows.

Adjusting irrigation frequency through scheduling and irrigation efficiency can reduce water use and reduce water pollution. Some growers tend to rely on the "eyeball" method to determine when plants need water. As a result, many crops get more water than they need, creating excess runoff. Also, EC levels in leachates can be used as an indicator on whether more irrigation time to reduce salt build up in the growing media or fertilization is required. For example, collected leachate from containers with EC levels in the range of 1.8–2.0 mmhos/cm indicate that more irrigation is necessary in the next week's irrigation to reduce the excess soluble salts and conversely, an EC in the range of 0.2–0.3 mmhos/cm indicates less irrigation is needed because excess irrigation is leaching out nutrients.

Consider Using Indicator Plants

Choose indicator plants that help trigger the decision to irrigate. For example, Japanese Barberry may be used as an indicator plant for plants with low water requirement. Japanese Boxwood and Crape Myrtle can be indicator plants for plants with medium and high water requirement, respectively. Drooping leaves and a change in leaf color are signs of wilting.

Adopt New Irrigation Technologies

A variety of computers and irrigation scheduling software is available. The cost of such a system can be a worthwhile investment. Install rain sensors to ensure irrigation does not occur during rain events. To lower costs and runoff, irrigate plants when needed based on media moisture content. This can be assessed by a) appearance or feel, b) remote sensor tensiometers, c) weight of media moisture, d) light accumulators, and e) moisture conductivity. Several devices relate media moisture to electrical conductivity. When the growing media dries to a preset level, the electronic circuit activates the solenoid valve.

Plan and Install Irrigation Systems That Provide Efficient Water Use

Do careful research to install the most appropriate system for your operation. Types of plants, soil/ container media, and location of the site to water bodies should be included in the decision making. Growers producing nursery crops that are sensitive to water molds and to pathogens that cause leaf diseases should consider using drip irrigation system versus overhead irrigation system, where amounts can be better controlled and leaf tissue is not wetted frequently.

Select Appropriate Growing Medium

Growers are recommended to choose components of container substrates that are best adapted to plants and management. Recommended physical characteristic values for nursery container substrates after irrigation and drainage are (percent of volume): total porosity 50 to 85%, air space 10 to 30%, available water content 25 to 35%, and bulk density 0.19 to 0.70 g/cc. A container medium with a high proportion of coarse particle size has a high air space and a relatively low water holding capacity. Consequently, leaching of pesticides and nutrients is likely to occur if not managed well. Humic substances such as peat moss, will enhance water and nutrient-holding capacity substantially.

Consider the Use of Wetting Agents

Research showed that wetting agents increase water absorption of many peat-based media, when using drip irrigation. Wetting agents not only allow quicker wetting and uniform water distribution, but also allow more water to be held by the peat and reduce channeling of water down the sides of containers, which consequently can result in reducing leaching. Select a quality product designed for horticultural use and do not over use wetting agents, as they can be toxic to plants.

Group Plants with Similar Water Needs

Establishing irrigation zones improves irrigation efficiency. Prioritize water use on plants of most value and least drought-tolerant. For example, the water requirements of evergreens are usually less than those of deciduous shrubs during summer and should not be placed in the same irrigation zone. Similarly, conifers have lower water requirements than broadleaf evergreens and should be grouped separately. Plants can be categorized into three categories, those with high, medium, or low water requirement. Refer to Table 1 for list of plants that are grouped according to water needs.

Collect and Recycle Irrigation Water

Look at options for installing collection (retention) basins, storage ponds, storage tanks, and additional pumping capacity. Use of collection basins may be a primary means of reducing water quality problems. The goal is to prevent irrigation water from leaving the nursery property. Design newly constructed water collection recycling facilities to accommodate the irrigation return flow. Construct collection basins with clay-like materials with good scaling characteristics or line them with an acceptable membrane liner. Keep in mind, to construct the basins with an emergency overflow to prevent dike damage in the event of overtopping. When rainwater is allowed to discharge from the property, it must be considered in the design of the water collection basin. Design collection basins to collect about 90 percent of the applied irrigation water. More information is available under the National Handbook of Conservation Practices at the Natural Resources Conservation Service (NRCS) website URL address: *www.nrcs.usda.gov/technical/standards/nhcp.html*. For irrigation water management and system design, which may qualify for USDA Environmental Quality Incentives Program (EQIP) cost share programs, contact your local USDA NRCS office. For more information visit the website: *www.nj.nrcs.usda.gov/programs/eqip/2005EQIPApplicationInfo.html*.

Monitor Recycled Water

Monitor recycled water for pH, salts (electrical conductivity - EC), nutrients, pathogens, and pesticide content before application to nursery plants at least three times a year. Simply, in clean dark-colored plastic bottles, collect 3–5 water samples from tail-water recovery system early in the morning. Each bottle may contain around one liter of water. Arrange with a local laboratory to send your samples for analyses in the same day or next day (keep bottled water refrigerated). More information on certified water testing laboratories available per county in New Jersey can be found on website address: *www.rcre.rutgers.edupubspublication.asp?pid=FS343*. Onsite, you can measure pH and EC using pH and EC meters. Dilute recycled water with fresh water when recycled water has a high salt level greater than 1.4 mmhos/cm. An acceptable salt content of irrigation water before application is less than 0.3 mmhos/cm. Water with pH value 6.5–7.0 is considered acceptable, whereas pH values above 7.0 may cause concern when used for irrigation or mixing pesticides.

Manage Solubility of Pesticides

Water solubility of a pesticide determines how easily it goes into a solution with water. When a pesticide goes into solution with water, the pesticide will move where the water goes. Pesticide solubility is usually given in parts per million (ppm) or as milligrams per liter (mg/l). These are equivalent. It tells the maximum number of milligrams that will dissolve in one liter of water. Simply being water soluble does not mean that a pesticide will leach into ground water or run off into surface water. However, solubility does mean that if a soluble pesticide somehow gets into water, it will probably stay there and go where the water goes. For more information on fate of pesticides and their solubility in water, refer to RCRE bulletin E-299. The major concern in using recycled water for mixing and spraying pesticides is when recycled water has a high pH value (7.0–9.0). The high pH value affects the efficacy of pesticides. Many pesticides undergo hydrolysis at high pH. For example, the half-life of Captan at pH 9.0 is 2 minutes, while it is 10 hours at pH 5.0. The half-life of Lannate at pH 9.0 is 12 hours, but it is 60 hours at pH 5.0. General information on half-lives of selected pesticides at different pH values, and methods for testing and adjusting the pH of alkaline water used for mixing pesticides can be found at the website: *www.ag.unr.edu/wsj/Factsheets/96-18h20.pdf*.

Monitor Pathogen Levels in Recycled Water

Some diseases that attack nursery crops are in what is known as the "water mold" group of fungi, such as *Pythium* and *Phytophthora*. These pathogens thrive in high moisture. Runoffs collected in water recovery systems may carry these pathogens. Water can be sampled at different points and sent to any local plant disease diagnostic laboratory to determine pathogen presence and levels. Treat recycled water for disease organisms with any decontamination system such as retention and dilution, filtration, chlorination, ozonation, and or UV light. The selection of a decontamination system depends on the nursery size: volume of runoff to be captured, topographic features that determine the number of collection basins needed to capture runoff water, value and susceptibility of plant species to major diseases, and types of applied pesticides.

Chlorine and bromine can be used to treat recycled runoff water. Chlorination involves the use of granular calcium chloride or gaseous chlorine, although the latter should be used only for larger operations. The key is having enough free chlorine (about 0.5 ppm) in the water long enough (roughly one minute) to kill pathogens. If you choose to work with chlorine, remember that chlorine gas is very hazardous and must be handled with adequate safeguards. Another agent available to control water borne pathogens is a bromine biocide, commonly known as Agribrom. The concentration required is higher (5 to 10 ppm of free residual bromine), than chlorine, it is safer to handle than chlorine and is equally effective.

Manage Storm Water Runoff

Storm water runoff is water flowing over the land, during and immediately following a rainstorm. Storm water storage systems can reduce peak runoff rates, provide settling and dissipation of pollutants, lower probability of downstream flooding, stream erosion and sedimentation, and provide water for other beneficial uses. Develop a system to deal with storm water retention and runoff from the nursery. Invest in planting vegetated grassed waterways, wetlands, and vegetative buffer. These components increase infiltration and evaporation, allow suspended solids to settle and remove potential pollutants before they are introduced to other water resources. Constructed wetlands serve as a biological filter for removing chemical pesticides and fertilizers. In addition, the extra water surface of the wetland area increases the oxygen available to decompose organic compounds and to oxidize dissolved metals in the water. For references on filter strips, contact the local office of the Natural Resources Conservation Service (NRCS).

References

Lea-Cox, J. D., K. M. Teffeau, D. S. Ross and P. D. Schreuders. 1999. *Defining Nitrogen and Phosphorus Flows in Container Nursery Production.* pp. 211-212. In: Sharpley, A. N. (ed.) Agriculture and Phosphorus Management - The Chesapeake Bay. Lewis Publishers, Boca Raton, FL.

Evans. M. Greenhouse management online. *Water Quality Issues and Irrigation Systems. www.uark.edu/~mrevans/4703/learning_units/unit_09/unit_09.html*.

Fare, D.C., C.H. Gilliam, G. J. Keever, and J. W. Olive. 1994. *Cyclic Irrigation Reduces Container Leachate Nitrate-Nitrogen Concentration*. HortScience 29:1514-1517.

Ingram, D. L., R.W. Henley, and T.H. Yeager. 2003. *Diagnostic and Monitoring Procedures for Nursery Crops*. CIR556. *http://edis.ifas.ufl.edu/pdffiles/CN/CN00200.pdf*.

Karam, N.S., and A.X. Niemira. 1992. *Low Water Application Rate and Intermittent Irrigation Increase Irrigation Efficiency of Sprinkler-Irrigated Container-Grown Plant*s. Proc. SNA Conf. 37:41-44.

Mathers, H. 2002. Nursery Irrigation Management. *Part 2: Efficiency and Water Conservation. http://hcs.osu.edu/basicgreen/english/IrrMan2b.pdf*.

Smajstrla, A.G., B.J. Boman, G.A. Clark, D.Z. Haman, D.S. Harrison, F.T. Izuno, D.J. Pitts, and F.S. Zazueta. 2002. *Efficiencies of Florida Agricultural Irrigation Systems. http://edis.ifas.ufl.edu/BODY_AE110*.

Tyler, H.H., S.L. Warren, and T.E. Bilderback. 1996. *Cyclic Irrigation Increases Irrigation Application Efficiency and Decreases Ammonium Losses*. J. Env. Hort. 14:194-198.

Von Broembsen, S.L. and M. Schnelle. 2002. *Best Management Practices (BMPs) for Nurseries to Protect Water Quality*. In E-951, Water Quality Handbook for Nurseries, Oklahoma State University Cooperative Extension Service. *www.okstate.edu/ag/agedcm4h/pearl/e951/e951ch2.htm*.

Von Broembsen, S.L. 2002. *Disease Management for Nurseries Using Recycling Irrigation Systems*. Department of Entomology and Plant Pathology, Oklahoma State University. *www.ento.okstate.edu/zoospore/*.

Yeager, T.R., C.H. Gilliam, T.E. Bilderback, D.C. Fare, A.X. Niemiera and K.M. Tilt. 1997. *Best Management Practices Guide for Producing Container-Grown Plants*. Southern Nurserymen's Association.

Zinati, G. M. 2005. *Pest and Pesticide Management Practices in Nursery Operations*. Rutgers Cooperative Research & Extension (RCRE), bulletin E299, 7pp. *www.rcre.rutgers.edu/pubs/publication.asp?pid=E299*.

Table 1. Nursery crops grouped according to their water needs. Water requirement may vary with growth rate and management practices.

Low water requirement[†]	Medium water requirement	High water requirement
Berberis thunbergii, Japanese Barberry	*Buxus microphylla*, Japanese Boxwood	*Acer rubrum*, Red Maple
Cornus spp., Dogwood	*Camellia japonica*, Camellia	*Cotoneaster* spp.
Euonymus Japonicus, 'Albo-Marginata'	*Gardenia jasminoides*, Gardenia	*Hibiscus rosa-sinensis*, Hibiscus
Juniperus conferta, Shore Juniper	*Hibiscus syriacus*, Shrub Althaea	*Lagerstroemia indica*, Crape Myrtle
Mahonia fortunei, Fortune's Mahonia	*Ilex crenata*, Japanese Holly	*Pyracantha spp.*, Pyracantha
Rhaphiolepsis indica, Indian HawthornAzalea	*Juniperus chinensis* var. sargentii	*Rhododendron* spp., Indica Azalea

[†]Adopted from Yeager, T.R., C.H. Gilliam, T.E. Bilderback, D.C. Fare, A.X. Niemiera and K.M. Tilt. 1997. Best Management Practices Guide for Producing Container-Grown Plants. Southern Nurserymen's Association.

Desktop publishing by Rutgers' Cook College Resource Center

Published: July 2005

RUTGERS COOPERATIVE RESEARCH & EXTENSION
N.J. AGRICULTURAL EXPERIMENT STATION
RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY
NEW BRUNSWICK