

## IRRIGATION MANAGEMENT PRACTICES



### Introduction

Irrigation management is a key factor in the environmental and economic sustainability of commercial nursery and greenhouse operations, and therefore a major focus area to implement best management practices. Critical facets of irrigation management include (and require an understanding of) water quantity, water quality, water treatment, pumping options, mitigating and capturing runoff, irrigation application systems, the influence of technology on irrigation and the effects of irrigation on abiotic and biotic conditions in the nursery system. Water restrictions, principally at the consumer level in the last two decades, have been on the rise in the southern U.S. and have threatened the industry. Drought is always a concern in most regions of the U.S. As a result, efficient and uniform irrigation practices are necessary both at the producer and consumer level to minimize the environmental effects associated with inefficient and non-uniform irrigation practices and market the “green” industry as sustainable production systems. Irrigation efficiency can be defined simply as the fraction of irrigation that is held in the soil of a container or root zone of a field-grown plant, divided by the total volume of irrigation pumped (measured with flow meter) to that specific irrigation zone. Uniformity, however, is a measurement that indicates if all containers or field-grown plant material receive the same volume of water, regardless of the total volume applied to an irrigation zone. Irrigation application efficiency should be addressed relative to irrigation system design and management. While some irrigation systems are more efficient than others, it is important to realize that poor management and/or scheduling of a relatively efficiently designed system can greatly reduce system operational efficiency. Additionally, low uniformity can result in non-uniform plant growth and increased management problems, particularly in over-watered areas within an irrigation zone.

- # 1** Efficient and uniform irrigation practices are necessary both at the producer and consumer level to minimize the environmental effects associated with inefficient and non-uniform irrigation practices.

## Irrigation System Design

The irrigation design for a nursery depends on several factors: irrigation zone size(s), water supply pressure (PSI= pounds per square inch), operating PSI of system equipment or in-line equipment (e.g. chemical injectors), water volume available, plant water requirement, container size, number of irrigation zones, maximum flow rate to maintain PSI, critical (low or high) operating PSI at the furthest irrigation head/nozzle and whether the system is automated or operated manually. Because many factors impact the design of an efficient system, consultation with a professional irrigation and pump designer is recommended before system installation. Design your irrigation system to take future nursery expansion into account. It is easier and more cost-effective to design and install larger main irrigation lines than initially required and use pressure-reduction equipment, compared to scaling-up existing, undersized irrigation system(s). The irrigation main (pipe that distributes water to the main and subsidiary portions of the irrigation system) needs to be buried, usually along the sides of roads, with valves located at convenient intervals for isolation of production areas. These isolation valves, in conjunction with appropriately placed flow meters, drain valves, and pressure valves, allow the irrigation operator to easily audit irrigation system performance, isolate irrigation system failures, conduct repairs and avoid damage caused by freezing. All main and secondary pipes that include a T or 90° angle should also include thrust blocks to reduce pipe breakage, separation and blowouts due to water hammer.



*This illustrates cutoff valves in a micro-irrigation system. These valves allow for the partitioning of an irrigation system based on production needs, assist in identifying system problems and allow for the maintenance of irrigation systems without turning the entire irrigation system off.*

**# 2** Consultation with an irrigation design and pump professional is recommended before system installation.

**# 3** Irrigation systems are designed to operate within an optimal PSI range for maximum uniformity and efficiency.

Poorly designed irrigation systems can have extremely low uniformity within an irrigation zone (Niemiera, 1994). Proper nozzle or emitter selection and system design will maximize uniformity (Smucker, 1985). However, once a system has been installed, replacement of original components (maintenance) is required to maintain the efficiency and/or uniformity of the system. Conversely, replacement of non-like parts (not matching original specifications) can alter operation and result in a reduction of the overall system efficiency. Proper head and nozzle selection is critical for having an efficient/uniform irrigation system. The desired precipitation rate should

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also be matched for all heads within a zone regardless of radius and be operated within their specified PSI range. In addition, the distance between heads, the largest acceptable droplet size and the minimum trajectory angle should be used to reduce irrigation drift to ensure water is applied to the desired location as uniformly as possible. In some systems, particularly those with small droplet sizes, a wind break may be necessary to ensure desired uniformity and uniform wetting of the desired irrigated area. Irrigation system design, hydraulics and irrigation audit learning modules are available at <http://www.waternut.org/moodle> (Ross, 2008) that provide in-depth information on each of these topics.



*In this photo, a simple wind screen was constructed to reduce irrigation drift and reduce accelerated drying of containers along the edge of the production bed due to wind.*

Nozzle pressure can be checked using in-line PSI gauges or attaching a PSI gauge to the riser in place of an irrigation nozzle. There is a prescribed PSI range and application radius for each particular nozzle type that is provided by the manufacturer. Thus, when the entire irrigation zone is in operation, the PSI between the first (point of highest PSI) and last (point of lowest PSI) nozzle within a zone must be within the manufacturer's recommended PSI range for optimal uniformity. In scenarios where nozzle operation PSI is below manufacturer's recommendation, water droplet size will be larger, causing a doughnut effect to the irrigation pattern, with greater precipitation rates away from the irrigation nozzle. Conversely, PSI above the manufacturer's recommendation will result in smaller droplet size that will (in the absence of wind) result in higher precipitation rates near the nozzle. As a nozzle ages and the emitter/orifice becomes worn, uniformity of water distribution will be reduced, with higher precipitation rates occurring away from the nozzle in a doughnut pattern. Similarly, plugging of emitters/orifices can alter operating PSI of the system and reduce system efficiency/uniformity. An easy method to check the size of a nozzle orifice and to determine if it is worn and/or needs replacing is to place the back end of a drill bit of equal size into the nozzle and then to determine whether there is any abrasive wear from the original diameter.



*Monitoring system pressure is important in understanding the overall system performance and uniformity. This pressure gauge is located at the water source and monitors overall system pressure. Similar gauges should be placed throughout the irrigation system to monitor overall system performance.*

When nozzles become worn and require replacing, replacing an original nozzle with a nozzle of a different prescribed PSI and/or application radius will decrease system uniformity. The height of overhead irrigation nozzles should exceed height of the crop canopy to ensure uniform water distribution, yet be positioned low enough to minimize wind effects on application radius and precipitation rate. Nozzle spacing, system hydraulics (PSI and elevation), wind speed and duration, and plant canopy density may impact water distribution pattern and uniformity if overhead irrigation is used. A system with low uniformity will require more water than a uniform system. Thus, large areas will be over-irrigated, to ensure that plants in the low application rate area(s) receive adequate water. Low irrigation uniformity is a common flaw in nursery overhead irrigation systems (Fare et al., 1992).

Because pressure loss in an irrigation line increases with pipe length due to friction loss, it is important to design the irrigation system so that the end of the line has adequate water pressure and so that water velocity does not exceed five feet per second. Two methods are used to overcome low PSI in irrigation lines; the ideal solution is to correctly design and install an irrigation system to meet the current and future needs of a nursery operation. The first method used to overcome low pressure due to friction loss is to reduce pipe diameter as distance from the pump increases. It is important to note that reducing pipe size will increase PSI, but does not affect flow rate(s). The second method is to initially design an irrigation system to operate main lines at a high PSI and utilize pressure-reducing valves at the beginning of irrigation zones to match flow and PSI with nozzles/emitters being used in the zone. This is the preferred option of the two alternatives, as it allows for future expansion without the need for significant infrastructure alterations. Pressure compensated drip emitters can also be used with equivalent efficiency in field production, with long lateral lines or rolling topography.



A backflow prevention valve should be installed between the water source or pump and the point where chemicals are injected into the irrigation system. This will prevent contamination of the water source.

A backflow prevention valve should be installed between the water source or pump and the point where chemicals are injected into the irrigation system. Double backflow prevention valves may be required for injection of some chemicals. Such a valve will prevent injected chemicals from flowing back in the line toward the water source when an irrigation system is not operating or when back pressure is created. Many localities mandate the installation of specified backflow prevention valves or air gap between municipal and farm irrigation systems. Many states also require this at the well-head to avoid groundwater contamination. Please contact local government for backflow regulation if using a public water source.

- # 4** Replacement nozzles should be compatible with the original nozzle type. Altering the original components of an irrigation system can change the uniformity of the system.
- # 5** Nozzle orifices should be checked frequently for wear or plugging.
- # 6** A backflow prevention valve should be installed at the water source or pump, and checked regularly.

## ***Overhead Irrigation System Design***



*Overhead irrigation systems apply water uniformly across the canopy of plants, as shown in this photo.*

Overhead irrigation water is delivered over the entire production area from nozzles that are located above the crop canopy, and is typically measured in gallons per minute. There are several overhead nozzle types, grouped into impact, spinner, and fixed head categories based on mechanical operation. Nozzle selection depends on water flow, distance between irrigation heads, quality of water, and available PSI. Overhead systems are generally used for small containers (7-gallon or smaller) that are not spaced or have relatively short distances between containers.



*The most frequently used overhead irrigation is the impact-type, as shown here. This nozzle offers flexibility of irrigation pattern arc and distance from nozzle, is relatively inexpensive and is durable in production environments.*

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Because a significant portion of the applied water falls between containers and in aisles, overhead irrigation is less efficient than micro-irrigation based on the amount of water that enters and is retained within containers (not leached). Runoff water management is a primary concern when using overhead sprinklers, with the goal being to minimize water runoff from the production area. Collecting and reusing runoff results in higher water use efficiency over multiple irrigation events and helps to minimize nutrient and pesticide loss from the property (*see sections on Runoff Water Management and Collection Structures*). The amount of water intercepted by containers depends on container spacing (square versus offset), the amount of space between containers, and crop canopy architecture. **Table 1** illustrates how container spacing influences the percentage of land surface area that is covered by 1-gallon containers (Furuta, 1974).



*Collection and recycling of runoff, especially in overhead irrigation systems, will increase overall water use efficiency of the nursery and reduces the impact of fertilizer and chemical contaminants offsite/downstream.*

The water retention capacity of soilless substrates used in most container-nurseries is also important in understanding the efficiency of irrigation events. The ability of a soilless substrate to retain moisture is affected by substrate composition and physical characteristics. Substrates comprised of smaller particle sizes have the potential to hold greater volumes of water and therefore require less frequent irrigation. In addition, the incorporation of components with high water holding capacity, such as peat or clay, increases the water buffering capacity of the soilless substrate. Substrates with a higher water holding capacity can retain more of the water applied during an irrigation event or heavy rainfall, prior to initiation of a leaching event, increasing irrigation efficiency. The addition of surfactants (wetting agents) to soilless substrates at the time of mixing can further improve irrigation efficiency, ensuring maximum wettability of the substrate and preventing hydrophobicity (inability to wet, water repellence) that results in applied water not being retained in the container.



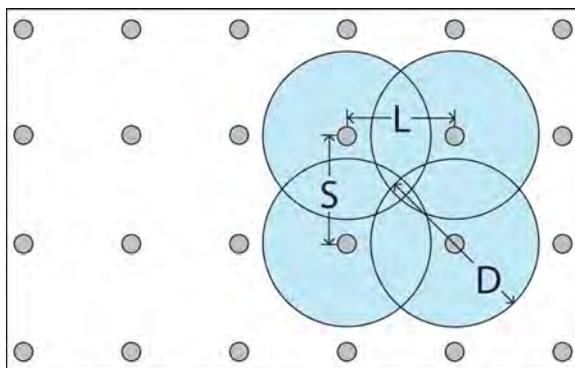
*Overhead irrigation systems are generally used for small containers (5-gallon or smaller) that are placed together or with relatively short distances between containers.*

The most efficient overhead irrigation system is one that provides matched (even) precipitation from head-to-head irrigation nozzle spacing. Matched precipitation requires specific selection of nozzles based on the position of the nozzle in the irrigation zone and the flow rate of the nozzle selected for the specific area in the irrigation zone. For example, corners of beds require a 90° spray pattern, yet these nozzles would apply 50% of the volume of 180° nozzles and 25% of the volume compared to a 360° nozzle. In the case of 180° degree nozzles, these would be placed on the non-corner sides of the bed and would apply 200% of the irrigation rate compared to a 90° nozzle and 50% of the irrigation volume compared to a 360° nozzle (Bilderback, 2002). A system with sprinklers and risers in a square pattern using circular patterns usually provides the most uniform irrigation distribution. This means that a sprinkler radius must equal the sprinkler spacing, also termed head-to-head or double-coverage. Regardless of sprinkler pattern, wind speed and direction should be considered when determining the distance between sprinklers. Creating a windbreak upwind of the **container area** will reduce the influence of wind on water application uniformity as well as reduce water loss from the container substrate due to **evapotranspiration**.

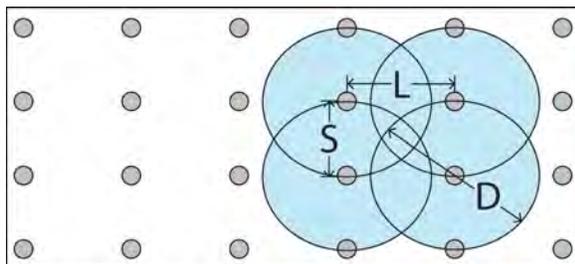
- # 7** Natural or constructed windbreaks should be used to abate wind and improve uniformity of irrigation. The effective distance behind a windbreak is about three to ten times the height of windbreak (Hanley, 1981).
- # 8** Height of overhead irrigation nozzles should be taller than the crop canopy to ensure uniform irrigation.

**Table 1.** Influence of distance between containers on percent of surface area covered by 1-gallon containers placed in square and offset (triangular) patterns.

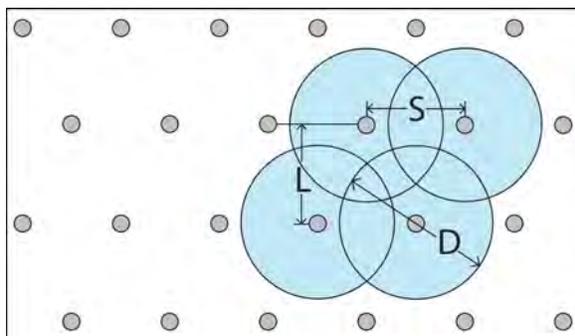
Inches Between Containers	Percent of Surface Covered	
	Square Pattern	Offset Pattern
0	79	91
1	58	67
2	44	51
4	28	33
6	20	23
12	9	10



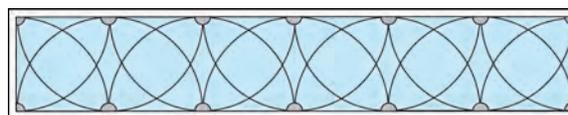
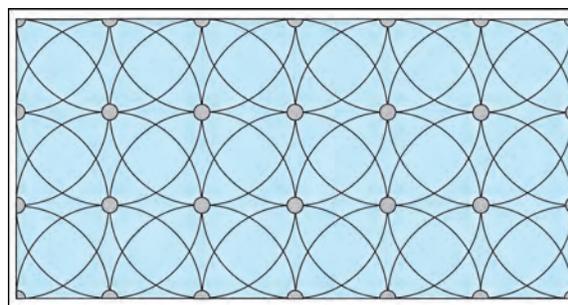
Rectangular pattern



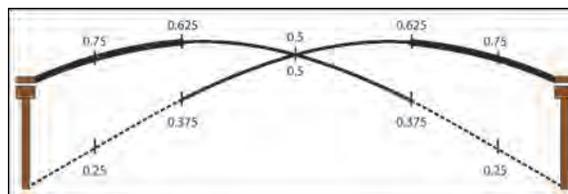
Square pattern



Triangular pattern



Examples of preferred overhead sprinkler layouts for container nurseries



Total amount applied = 1

Proper sprinkler overlay results in uniform distribution.

Overhead sprinkler configurations.

S = distance between sprinklers on a lateral;

L = distance between lateral lines;

D = diameter

L can be increased for triangular pattern relative to square and rectangular patterns.

Source: Design Guide for Turf and Ornamental Irrigation Systems, Rain Bird Sprinkler Mfg. Corp.

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The greatest limitation to efficient overhead irrigation systems is a lack of irrigation distribution uniformity within an irrigation zone. Distribution Uniformity (DU) is easy to measure, requiring very few tools (*see Irrigation System Audits (Ross, 2008); <http://www.waternut.org/moodle>*). To determine DU, a minimum of 16 rain gauges or open containers/cups are placed in a uniform grid pattern within an irrigation zone. If a crop is in place, rain gauges should be placed above the canopy. Once gauges are placed, a typical irrigation cycle is performed and the amount of irrigation in each gauge is recorded. Once the irrigation rates are recorded, the overall average volume of the container, or inches from the rain gauges is noted. Next, calculate the average of the lowest 25% (by volume) measurements. Divide the average of the lowest 25% of measurements by the overall (all 16 measurements) average and multiply by 100 to produce the percent uniformity of a particular irrigation zone. Irrigation DU should be greater than 80%, with a percentage lower than 60% indicating a more thorough irrigation system audit is required to identify design or hardware problems in the system. Note that irrigation uniformity can only be taken within a single irrigation zone and comparisons among different irrigation zones are not recommended.

- # 9** Irrigation distribution uniformity should be measured regularly. Excessive amounts of water are needed to irrigate crops when a system has poor uniformity.



*Use straight-sided cups of uniform size on grid pattern in a container area to determine irrigation distribution uniformity.*



*Periodically place rain gauges in a container area to measure irrigation amount.*



*Micro-irrigation, as seen here, can increase irrigation efficiency significantly compared to overhead irrigation, and is typically utilized in field-grown operations and in container operations growing 7-gallon or larger containers.*

### **Micro-irrigation System Design**

**Micro-irrigation** systems apply water through a micro-emitter (drip) or micro-sprinkler, typically to an individual container or small root zone in field or pot-in-pot production. Micro-emitter irrigation systems deliver smaller amounts of water, typically measured in gallons per hour. These systems are used mostly for large containers (7-gallon and larger) because the distance between containers is relatively large and production cycles are long enough to recoup increased equipment cost (compared to overhead irrigation). Irrigating container-grown plants with micro-irrigation can result in an 80% reduction in total irrigation volume compared to overhead irrigation (Ross, 1994).

These low-flow systems typically include using micro-spray (spray-stake), drip or drip-tape **emitters**. Drip emitters are manually (hand) installed into tubing at correct spacing, based on worker determination. Drip-tape includes internal, factory-installed drip emitters at predetermined spacing. Spray-stakes are manually (hand) installed and emit small streams of water just above the substrate surface yet below the plant canopy, to reduce drift. Drip systems are the standard in field nursery production, for cost considerations and ease-of-management. Both drip and micro-spray stakes often utilize secondary tubing called “leads” to deliver water from the pipe to the container or field-grown plant, whereas drip-tape does not offer this option. The result is greater flexibility of spacing utilizing drip or micro-spray irrigation, albeit at a greater cost with more equipment (“leads”) and labor requirements. Micro-spray has an advantage over drip emitters in that they wet larger areas (Regan, 1994).



*Drip emitters, as pictured here, apply irrigation water directly to the soil surface, minimizing drift and evaporative losses.*

Advancements in micro-irrigation include better pressure compensation, less clogging potential and dependable flow control (Regan, 1994). However, rodents, insects, spiders, and salt precipitation can cause performance problems. Non-pressure compensated systems typically result in poor uniformity, unless care has been taken with overall irrigation system design. Many emitters include internal pressure compensation system to improve uniformity of the micro-irrigation system. However, for pressure compensating emitters to function correctly, the PSI of the system must be greater than the manufacturer's minimum PSI rating for the emitter.

It is important to select an emitter that will wet a large area of the substrate surface to ensure maximum container wetness. In some cases, such as with large containers, two or more micro-emitters may be needed to ensure adequate wetting of the substrate surface. Nutrients from slow-release and other fertilizers are made available and taken up by roots along with water in the root zone, hence uniform soil moisture is needed to ensure uniform root and canopy growth. The amount of water that a container receives can be managed in four ways: 1) by adjusting the duration of the cycle; 2) by changing the number of irrigation cycles per day; 3) adding an additional micro-sprinkler or emitter per container; and 4) changing to a micro-sprinkler or emitter with a different output. When changing emitters with different outputs it is essential to check uniformity of the irrigation system. Changing the PSI of the system is not recommended because this can alter emitter output.



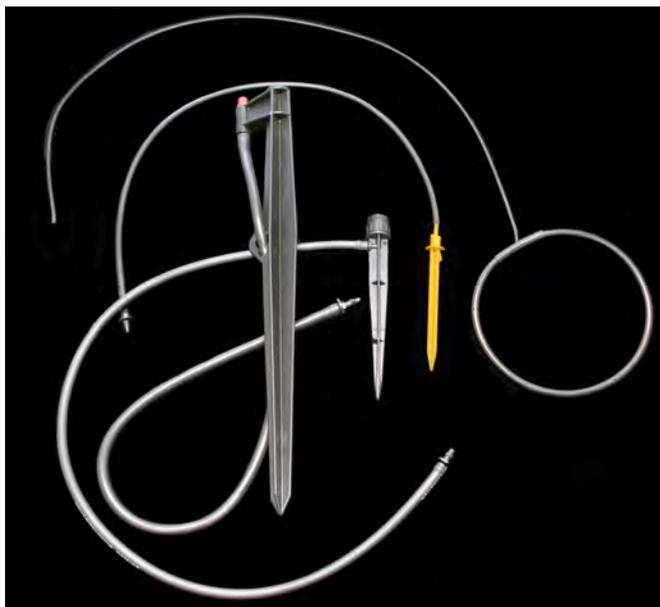
*In larger containers, oftentimes one emitter is not enough to uniformly wet the substrate. In this photo, the grower has inserted three emitters to ensure uniform wetting of the substrate.*

Micro-irrigation of field-grown plants is achieved with water applied gradually and directly to the soil surface, at a rate equal to or less than the infiltration rate of field soils. For example, infiltration rates of clay soils can be as little as 0.1" per hour. This can result in longer irrigation cycles, as total irrigation volume must be spread out over time to ensure proper infiltration. For this reason, micro-irrigation emitters are often "sized" with flow rates to match infiltration rate of field soils. Because micro-irrigation is applied water directly to the root zone of the nursery crop, roots tend to concentrate within the zone wet by the irrigation, leading to greater proliferation of roots in the root-ball of field-grown plant material. An added benefit of micro-irrigation is less weed seed germination (particularly summer-annual weeds) compared to areas with overhead irrigation, due to a reduction in surface area irrigated with micro-irrigation. Less weed competition can increase the effectiveness and reduce the costs of pre-emergence and directed post-emergence herbicides. Additional savings are realized because micro-irrigation systems require smaller pumps and pipe sizes. However, higher initial and continued maintenance costs are common with micro-irrigation when compared to overhead irrigation.

Most micro-irrigation system nozzles have a small emitter orifice and therefore require a water filtration system to remove small particles and avoid emitter clogging, if water quality is poor. Refer to manufacturer's recommendations for filtration requirements to ensure proper emitter performance. Installing emitters and/or leads on the top of the pipe will reduce particles from clogging the emitters. Well water and municipal water generally require minimal filtration while surface water from rivers, canals, ponds, or collection structures generally requires in-line disc or sand media filters to prevent plugging and reduced water flow to emitters. In some cases, emitters may become clogged when using ground water. This is the result of iron bacteria and could require additional water treatment.



*Micro-irrigation will require filtration prior to application. In this case, a three-stage disc filter is utilized to filter irrigation water. Sand filtration is also commonly utilized, and equally effective, in filtering particulate material from irrigation water.*



*Microirrigation applies water through drip, spray or sprinkler emitters in low flow irrigation systems.*

An analysis of the water source is necessary to identify potential clogging materials and determine the most effective filtration system. Most clogging starts inside the emitter body assembly and can progress slowly or occur rapidly. Slow clogging results in partial clogging and is nearly as serious as a complete clogging because application uniformity is reduced and the hydraulics of the entire system/zone are significantly altered. Filtration systems may not completely alleviate clogging of micro-irrigation systems, but will minimize occurrences of clogging. Pre-treatment (flocculating) systems to remove iron and other salts in irrigation water may be required, prior to filtration. Other problems, for example adult snails that can cause a physical clogging of a system, can be removed

from the water by simple filtration. However, their eggs and larvae can pass through some filtration systems and eventually mature to the adult form in the irrigation line, causing restricted water flow in the system. Additionally, algae can be a major clogging agent, even in irrigation systems with filtration installed at the water source. For these reasons, lines should be flushed to remove debris and periodically treated with a chemical disinfectant to remove algae and other biotic contaminants from the system. Chemical water treatment (e.g. chlorine for pathogen management) can also be an integral part of a properly functioning micro-irrigation system, especially when recycled pond water is utilized. Check local regulations regarding the use and storage of chemicals for water treatment.

Compared to traditional overhead irrigation systems, micro-irrigation has the potential to substantially reduce the amount of water applied to a production area and subsequent wastewater runoff. But improperly designed or managed systems, application of excess volume, neglecting variability among emitters or dislodged emitters, and/or improper filtration can negate any efficiency advantages of a micro-irrigation system.

**# 10** Filtration should be used in several stages if needed to prevent water-quality related-clogging. Sand filtration should be used for algae and screens for debris.

**# 11** Testing Distribution Uniformity (DU) of micro-irrigation systems is critical. Excessive amounts of water are used when a system has poor uniformity.

### **Subirrigation System Design**

**Subirrigation** systems, also called “ebb-and-flood” systems are designed so that the production area (bench or ground area) contains water within a barrier (reservoir). Subirrigation for container crops occurs when water is pumped from a reservoir onto the production area. The base of the container is submerged and water is absorbed up into the substrate by capillary action. Following irrigation, water drains from the production area back into the reservoir. Subirrigation is typically used in greenhouses because it entails considerable initial construction costs and requires advanced management skills for disease prevention and other water quality aspects. Subirrigation systems for container crops require less water and fertilizer compared to overhead irrigation systems because all of the water, with the exception of evaporative loss, is recycled.

**# 12** Nutrient-laden irrigation water used in subirrigation (ebb-and-flood) of container crops should be recycled in order to prevent discharge of contaminants into the environment.



*This ebb and flood irrigation system floods the production area. Water enters the substrate via capillary uptake.*

## Irrigation System Management

Irrigation management is a dynamic and integrated process. In formulating an irrigation strategy, a nursery operator decides on the volume of water to be applied per application, the frequency and timing of applications, and method of application. These decisions are influenced by time of year, daily weather/environmental conditions, substrate or soil type, species, plant size, rooting volume and density, canopy architecture and substrate or soil moisture content. These decisions are complicated by the wide range of species, of varying sizes, typically grown in nurseries. Irrespective of these different conditions, the goal of irrigation is to supply the amount of water required by the plant while minimizing over-irrigation. The following sections will address methods, amount, and time of irrigation.

### *Methods of Application*

During the growing season, many container nurseries irrigate on a daily basis (except when rain supplies adequate moisture), with the daily water allotment applied in a single application (continuously). This is an accepted practice when ornamentals are grown in small containers (up to #7) with overhead irrigation. An alternative to continuous irrigation is cyclic irrigation. Cyclic irrigation means that the daily water allocation is applied in more than one application, with intervals of time between applications.

For example, plants are irrigated daily receiving 0.6 inches of water in a continuous irrigation lasting approximately an hour. With cyclic irrigation, 0.2 inches is applied in 20 minutes. Then a pause or break in the application occurs after which another 0.2 inches is applied. Finally, the last 0.2 inches is applied after another timed break. Thus, with cyclic irrigation, the 0.6 inches of irrigation is applied over an extended time period, compared to the one-hour period for continuous irrigation. Compared to continuous irrigation, cyclic overhead irrigation can reduce the volume of irrigation runoff by 30% and reduce the amount of nitrate leached from containers by as much as 41% (Fare et al., 1994).

When cyclic micro-irrigation is employed, the amount of leachate from the container could be reduced. Nursery operators can decide the number of micro-irrigation cycles to fit their production schedule. Research indicated that some trees grow larger with three cycles of micro-irrigation applied daily during the growing season compared to when two cycles were applied (Beeson and Haydu, 1995). Large containers in above-ground production may need more water and or more cycles per day than the same crop in a pot-in-pot system, due to reduced root zone temperature fluctuations in pot-in-pot production. Cyclic irrigation can be used with overhead and micro-irrigation, but automation with an electronic irrigation controller and solenoid valve is necessary, to program cycles between blocks. Otherwise, cyclic irrigation is too difficult to practically manage. It is important to note that cyclic irrigation must be managed to ensure the flow rate(s) of simultaneously operating zone(s) do not exceed the maximum allowable system flow rate.

**# 13** Cyclic irrigation should be used to decrease the amount of water and nutrients exiting the container.

### *Irrigation Application Amount*

The amount of irrigation water to apply per irrigation event will depend on container size, plant size, substrate properties, species, time of year, and delivery method. A survey of Alabama container nurseries (Fare et al., 1992) revealed that the average daily amount of water applied via overhead irrigation ranged from 0.3 to 1.3 inch (8,145 to 35,295 gallons/acre). The upper end of this range is certainly excessive, irrespective of plant density.

Immediately following field planting of liners or transplanting of liners into larger containers, water use is typically low. Much of the water required for plant maintenance and growth at this stage is easily held in the container substrate or field soil. Because of this, over-irrigation is common during this stage of production, leading to poor root distribution in the container or a higher incidence and severity of soil-borne pathogens. As plants become larger, their transpiration rate increases accordingly and irrigation needs will increase. This is especially true of containerized plants that have a limited soil volume from which to extract water. This is noted in the research conducted by Beeson (<http://mrec.ifas.ufl.edu/rcb/treewater>).

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Following irrigation, observe the moisture content of the substrate/soil or observe the amount of water exiting containers to fine-tune application amounts. Three factors are responsible for determining the percentage of irrigation water that is retained by a substrate/soil during an irrigation event; the maximum water holding capacity of the substrate/soil (field capacity), the pre-irrigation substrate water content of the substrate/soil and the amount of irrigation water applied. Without knowing any one of these three factors, it is impossible to accurately calculate the volume of irrigation needed to efficiently irrigate a crop. The maximum water holding capacity of a soil can be determined by laboratory testing services and may be available through substrate providers. It can range from as little as 25% to as high as 70% of the substrate/soil, by volume. Generally, substrates/soils with smaller particle/pore size will hold a greater volume of water whereas larger particle size/pore size will retain less water and have a lower water holding capacity. Additionally, when relatively moist, there is a low water **absorption** capacity. When relatively dry, there is a high water absorption capacity, unless substrates are so dry they become hydrophobic.

Nursery operators can estimate the amount of water to add by checking the water content of the substrate as well as by taking into consideration the weather conditions since the previous irrigation. By adjusting the irrigation amount according to the amount of water lost (evapotranspiration) since the last irrigation, nursery operators can greatly reduce the amount of water and fertilizer exiting containers. Obviously this can be difficult and very time consuming. Many weather services provide daily evapotranspiration data online that can give general estimates of plant water use. Newer technologies using water moisture sensors, can give growers much more precise measurements of soil/substrate moisture content, using specific daily water use information from “indicator” plant species that the nursery grower has experience with. These sensors use a dielectric current to determine soil/substrate moisture in the root zone, and relay that information logged in the field to a hand-held device or computer, where it is graphically displayed. This allows a grower to quickly and easily determine whether irrigation is needed or not, since the information is quickly displayed for any time period (minutes, days or months). Water savings of between 50 and 75% are typically achieved, even with precision irrigation systems, since growers have the information when irrigation cycles can be shortened or skipped to minimize water use, leaching, and pumping costs. More information on sensor tools and strategies to monitor substrate moisture in nursery and greenhouse operations can be viewed at <http://www.smart-farms.net>.



*The size of soil particles has a direct relationship with water holding capacity. Substrates with larger particles, such as the soils containing composted pine bark on the top will hold less water compared to the peat-based substrates on the bottom.*

- # 14 Amount of water applied to production areas should be based on plant needs.
- # 15 Irrigation volume should be adjusted according to the substrate water content to minimize leaching. A substrate's absorption capacity is related to the pre-irrigation substrate water content. The wetter a substrate, the less irrigation required to saturate a substrate.
- # 16 New technologies that utilize evapotranspiration or soil moisture sensors to calculate the irrigation requirements for a specific date can be helpful in reducing irrigation waste, leaching and pathogen pressure.

Measuring leaching fraction is another approach to estimate the required irrigation duration or volume of water needed for containers. Measure leaching fractions by placing plastic bags around several containers or placing containers in tight-fitting buckets and catching leachate during a typical irrigation cycle. The percent leachate draining from the container (volume of leachate/total volume irrigation entering the container\*100 = percent leachate or **leaching fraction**) should not exceed 15%. On a sunny, hot day, leachate will be less than on a cloudy, cool day. Thus, adjustments should be made in irrigation duration based on weather conditions. Another means of determining plant water use requirements based on environmental conditions is to utilize soil moisture sensors, as described above. Because plant water use will change with altering environmental conditions, soil moisture sensors will allow precise measurements of how plants decrease or increase their water use in reaction to changing environmental conditions.



*Measuring leaching fraction requires capturing all leachate during an irrigation cycle. To do so, simply place the container(s) over or into a larger catch can with a plastic liner to retain leachate, as shown in this photo.*

- # 17 Leaching Fraction should be maintained between  $\leq 15\%$ , with greater than 20% indicating too much irrigation is being applied. Tracking leaching during varying weather patterns (sunny/hot vs. cool/humid) can serve as an educational tool for irrigation managers.

## IRRIGATION MANAGEMENT PRACTICES

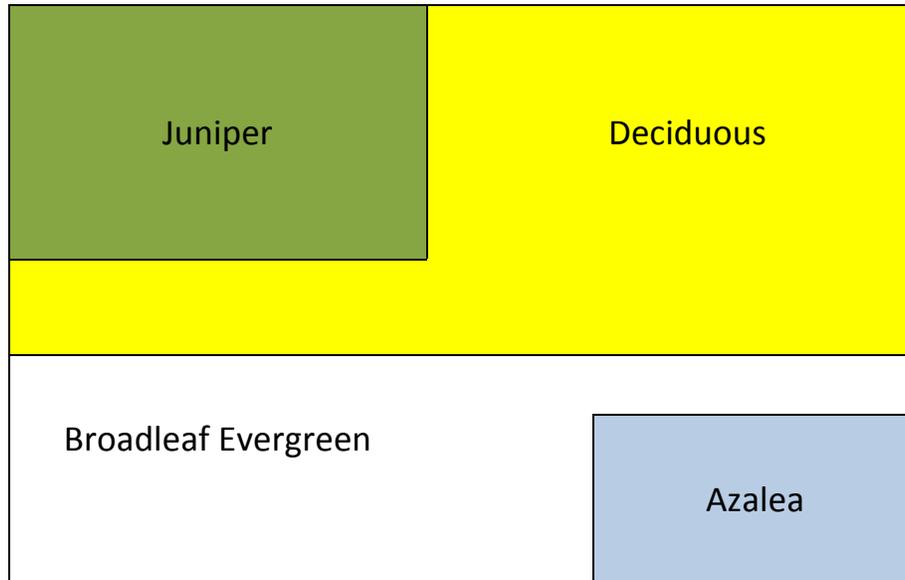
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When space allocation allows, grouping container plants based on water needs and similar canopy structure can result in increased irrigation efficiency and reduced root pathogen losses, particularly in low water-use plant material. In addition to the environmental factors previously discussed, a plant's water needs are also highly related to plant age (date since potted up or planted in a field), plant species, plant canopy architecture and leaf area in containerized plants. For example, a newly planted *Lagerstroemia indica* (crapemyrtle) will require far less irrigation than a crapemyrtle that has been in the same size container for one year. Additionally, a *Sedum* x 'Autumn Joy' in a 3-gallon container will use far less water than a crapemyrtle in the exact size container. Finally, an upright plant canopy with rigid cupped foliage will capture irrigation water into the center of the plant and direct that toward the root zone, whereas a cascading foliage plant with fine foliage typically sheds water away from the center of the plant and away from the container surface. Overall, grouping plants by water use and architecture can reduce water usage by about 80% (Burger et al., 1987). **Table 2** lists some commonly grown container plants according to their relative water needs. Grouping plants by container size, plant size, and substrate type may additionally help minimize amount of water applied. Plants that require large amounts of water and fertilizer need to be located at the farthest point from any body of water; whether a stream or drainage channel that may discharge into a body of water (Alexander, 1993). This location of plants will decrease the risk of polluting adjacent or nearby waters, by providing a buffer zone between the production area and surface water source.



*By maintaining a uniform crop type, age of crop and container size; growers can efficiently apply irrigation to meet the needs of all plants in the irrigation zone.*

**# 18** Grouping plants based on water needs, whenever possible, can increase irrigation efficiency and reduce pathogen damage.



*Plants should be grouped by water needs that might be influenced by container size, substrate type, or plant characteristics.*

## IRRIGATION MANAGEMENT PRACTICES

**Table 2.** A partial list of container-grown plants with their irrigation requirements is provided below. Plant requirement will vary depending on growth rate desired and cultural conditions.

<i>Scientific name</i>	<i>Common name</i>	<i>Irrigation Requirement</i>
<i>Abelia x grandiflora</i>	Glossy Abelia	medium
<i>Abutilon hybridum</i>	Chinese-Lantern	medium
<i>Acalpha hispida</i>	Chenille Plant	medium
<i>Acalypha wilkesiana</i>	Copper Leaf	medium
<i>Acca sellowiana</i>	Pineapple Guava	medium
<i>Acer palmatum</i>	Japanese Maple	medium
<i>Acer rubrum</i>	Red Maple	high
<i>Adenium obesum</i>	Desert Rose	low
<i>Adiantum</i> spp.	Maidenhair Fern	high
<i>Aechmea</i> spp.	Bromeliad	low
<i>Aeonium</i> spp.	Velvet Rose	low
<i>Aeschynanthus pulcher</i>	Lipstick Plant	medium-high
<i>Agapanthus</i> spp.	Agapanthus	low-medium
<i>Agave</i> spp.	Agave	low
<i>Ageratum houstonianum</i>	Ageratum	low-medium
<i>Aglaonema commutatum</i>	Aglaonema or Chinese Evergreen	low-medium
<i>Ajuga reptans</i>	Bugle-weed	low-medium
<i>Allamanda cathartica</i>	Allamanda, Golden Trumpet	medium
<i>Allamanda neriifolia</i>	Bush Allamanda	medium
<i>Alocasia x amazonica</i>	Elephant Ear	medium
<i>Alocasia cuprea</i>	Bronze Alocasia	medium
<i>Alocasia sandieriana</i>	Sander's Elephant Ear	medium
<i>Alocasia x sedenii</i>	Alocasia	medium-high
<i>Alternanthera ficoidea</i>	Alternanthera	medium
<i>Araucaria heterophylla</i>	Norfolk Island Pine	low
<i>Arctostaphylos</i> spp.	Manzanita	low
<i>Ardisia crenata</i>	Common Ardisia	low
<i>Ardisia crispa</i>	Curly Ardisia	low
<i>Ardisia pusilla</i>	Dwarf Ardisia	low
<i>Arundinaria pygmaea</i>	Dwarf Carpet Bamboo	low-medium
<i>Aspidistra elatior</i>	Cast Iron Plant	low
<i>Aucuba japonica</i>	Aucuba	low
<i>Bambusa glaucescens</i>	Hedge Bamboo	low
<i>Bambusa ventricosa</i>	Buddha Belly Bamboo	low

Table 2. (Continued)

Scientific name	Common name	Irrigation Requirement
<i>Bambusa textilis</i>	Giant Clumping Bamboo	low-medium
<i>Bambusa tuldooides</i>	Tuldooides Bamboo	low
<i>Berberis thunbergii</i>	Japanese Barberry	low
<i>Berberis thunbergii</i> 'Atropurpurea Nana'	Japanese Barberry	low-medium
<i>Betula</i> spp.	Birch	high
<i>Bougainvillea glabra</i>	Bougainvillea	low
<i>Breynia disticha</i>	Snow Bush	medium
<i>Browallia speciosa</i>	Sapphire Flower	medium
<i>Brugmansia x candida</i>	Angel's Trumpet	medium-high
<i>Brunfelsia pauciflora</i>	Yesterday-Today-and-Tomorrow	medium
<i>Buddleja davidii</i>	Butterfly-Bush	high
<i>Butia capitata</i>	Pindo Palm	low
<i>Buxus microphylla</i>	Japanese Boxwood	medium
<i>Buxus microphylla</i> var. <i>japonica</i>	Japanese Boxwood	medium
<i>Buxus microphylla</i> var. <i>koreana</i>	Korean Boxwood	low-medium
<i>Calamagrostis epigejos</i>	Reed Grass	low
<i>Calliandra haematocephala</i>	Powderpuff	medium
<i>Callicarpa japonica</i>	Japanese Beautyberry	high
<i>Callistemon</i> spp.	Bottlebrush	medium
<i>Calycanthus floridus</i>	Sweetshrub, Carolina Allspice	medium
<i>Camellia japonica</i>	Camellia	medium
<i>Camellia sasanqua</i>	Sasanqua Camellia	medium
<i>Canna flaccida</i>	Yellow Canna	medium
<i>Canna x generalis</i>	Common Canna	medium
<i>Carissa macrocarpa</i>	Natal Plum	low
<i>Carpinus caroliniana</i>	American Hornbeam	low
<i>Cassia fistula</i>	Golden Shower	medium
<i>Cedrus deodora</i>	Deodar Cedar	medium
<i>Cephalotaxus harringtonia</i>	Harrington Plum Yew	low-medium
<i>Cercis canadensis</i>	Eastern Redbud	medium
<i>Cercis</i> spp.	Redbud	high
<i>Ceropegia woodii</i>	String of Hearts	low
<i>Cestrum nocturnum</i>	Night Jessamine	medium
<i>Chaenomeles speciosa</i>	Flowering Quince	medium

Table 2. (Continued)

Scientific name	Common name	Irrigation Requirement
<i>Chamaecyparis pisifera</i>	False Cypress	medium
<i>Chamaerops humilis</i>	European Fan Palm	low
<i>Chasmanthium latifolium</i>	River Oats	medium
<i>Chionanthus virginicus</i>	Fringe Tree	medium
<i>Cinnamomum camphora</i>	Camphor	medium
<i>Cissus rhombifolia</i>	Grape Ivy	low-medium
<i>Clethra alnifolia</i>	Clethra	medium
<i>Cleyera japonica</i> (see <i>Ternstroemia</i> )	Japanese Cleyera	medium
<i>Clivia minata</i>	Kaffir Lily	low
<i>Columnnea microphylla</i>	Goldfish Vine	medium
<i>Cordyline terminalis</i>	Ti Plant	medium
<i>Coreopsis tinctoria</i>	Coreopsis	low-medium
<i>Cornus florida</i>	Flowering Dogwood	medium
<i>Cornus kousa</i>	Kousa Dogwood	medium
<i>Cornus</i> spp.	Dogwood	low
<i>Cortaderia selloana</i>	Pampas Grass	medium
<i>Cotoneaster</i> spp.	Cotoneaster	high
<i>Crataegus</i> spp.	Hawthorn	medium
<i>Cryptanthus</i> spp.	Earth Star	low
<i>Cryptomeria japonica</i>	Japanese Cedar	medium
<i>Cuphea hyssopifolia</i>	False Heather	medium
<i>x Cupressocyparis leylandii</i>	Leyland Cypress	medium-high
<i>Cupressus arizonica</i>	Arizona Cypress	medium
<i>Cupressus sempervirens</i> 'Italica'	Italian Cypress	medium
<i>Curculigo capitulata</i>	Palm Grass	medium
<i>Cyathea australis</i>	Australian Tree Fern	high
<i>Cycas revoluta</i>	King Sago	low
<i>Cyperus alternifolius</i>	Umbrella Plant	high
<i>Cyperus haspans</i>	Dwarf Papyrus	high
<i>Cytisus scoparius</i>	Scotch Broom	low
<i>Daphne odora</i>	Winter Daphne	low
<i>Dianthus barbatus</i>	Sweet William	low-medium
<i>Dietes vegeta</i>	African Iris	low
<i>Duranta repens</i>	Golden Dewdrop	low-medium

Table 2. (Continued)

Scientific name	Common name	Irrigation Requirement
<i>Echeveria</i> spp.	Echeveria	low
<i>Echinacea pallida</i>	Pale Coneflower	medium
<i>Elaeagnus pungens</i>	Silverthorn	low-medium
<i>Eriobotrya japonica</i>	Loquat	medium
<i>Eucalyptus cinerea</i>	Silver Dollar Gum	low
<i>Eugenia</i> spp.	Eugenia	medium
<i>Euonymus japonicus</i> 'Albomarginatus'	Variegated Japanese Euonymus	low
<i>Eupatorium purpureum</i>	Joe Pye	high
<i>Euryops pectinatus</i>	Golden Shrub Daisy	medium
<i>Euryops pectinatus</i> 'Viridis'	Green-leaved Euryops	low-medium
<i>Eustoma grandiflorum</i>	Lisianthus	low-medium
<i>Evolvulus glomerata</i>	Blue Daze	medium
<i>Exacum affine</i>	Persian Violet	medium
<i>Fatsia japonica</i>	Fatsia	medium
<i>Faucaria tigrina</i>	Tiger's Jaws	low
<i>Ficus benjamina</i>	Weeping Fig	medium
<i>Ficus elastica</i>	Rubber Plant	medium
<i>Ficus lyrata</i>	Fiddleleaf Fig	medium
<i>Ficus nitida</i>	Cuban Laurel	medium
<i>Ficus pumila</i>	Creeping Fig	medium
<i>Ficus triangularis</i>	Triangle-leaved Fig	medium
<i>Forsythia</i> spp.	Forsythia	medium
<i>Gaillardia pulchella</i>	Gaillardia	low
<i>Galphimia glauca</i>	Thryallis	medium
<i>Gamolepsis chrysanthemoides</i>	Bush Daisy	medium
<i>Gardenia augusta</i>	Gardenia	medium
<i>Gasteria</i> spp.	Cow's Tongue	low-medium
<i>Gazania rigens</i>	Gazania	low
<i>Gelsemium sempervirens</i>	Carolina Jessamine	low-medium
<i>Gibasis geniculata</i>	Tahitian Bridal Veil	medium-high
<i>Ginkgo biloba</i>	Ginkgo, Maidenhair Tree	medium
<i>Gomphrena globosa</i>	Globe Amaranth	low-medium
<i>Gypsophila elegans</i>	Baby's Tears	medium
<i>Hamelia patens</i>	Firebush	low-medium

Table 2. (Continued)

Scientific name	Common name	Irrigation Requirement
<i>Haworthia</i> spp.	Haworthia	low
<i>Hedera canariensis</i>	Algerian Ivy	low
<i>Hedera helix</i>	English Ivy	low
<i>Helichrysum bracteatum</i>	Strawflower	low-medium
<i>Heliconia</i> spp.	Heliconia	medium-high
<i>Hemerocallis</i> spp.	Daylily hybrids	medium
<i>Hemigraphis</i> 'Exotica'	Purple Waffle Plant	medium-high
<i>Hibiscus rosa-sinensis</i>	Hibiscus	high
<i>Hibiscus</i> spp.	Mallow species and hybrids	medium
<i>Hibiscus syriacus</i>	Rose of Sharon, Shrub Althea	medium
<i>Homalomena</i> spp.	Homalomena	medium-high
<i>Hoya carnososa</i>	Wax Plant	low
<i>Huernia</i> spp.	Dragon Flower	low
<i>Hydrangea macrophylla</i>	Hydrangea	high
<i>Hydrangea quercifolia</i>	Oakleaf hydrangea	high
<i>Hymenocallis latifolia</i>	Spider Lily	low
<i>Hypoestes phyllostachya</i>	Polka Dot Plant	low
<i>Ilex cornuta</i> 'Burfordii Compacta'	Dwarf Burford Holly	medium
<i>Ilex crenata</i>	Japanese Holly	medium
<i>Ilex crenata</i> 'Compacta'	Compact Japanese Holly	medium
<i>Ilex crenata</i> 'Helleri'	Helleri Holly	medium
<i>Ilex dimorphophylla</i>	Okinawan Holly	low
<i>Ilex glabra</i>	Inkberry Holly	medium
<i>Ilex vomitoria</i>	Yaupon Holly	low
<i>Ilex vomitoria</i> 'Nana'	Dwarf Yaupon Holly	medium
<i>Ilex vomitoria</i> 'Schilling's Dwarf'	Schilling's Dwarf Holly	medium
<i>Ilex x attenuata</i> 'Nellie R. Stevens'	Nellie R. Stevens Holly	medium
<i>Ilex x attenuata</i> 'East Palatka'	East Palatka Holly	medium
<i>Ilex x attenuata</i> 'Fosteri'	Foster's Holly	medium
<i>Ilex x meserveae</i> cvs.	Blue Holly	medium
<i>Illicium parviflorum</i>	Anise	medium
<i>Impatiens</i> (New Guinea hybrids)	New Guinea Impatiens	high
<i>Indocalamus tessellatus</i>	Broadleaf Bamboo	medium
<i>Itea virginica</i>	Sweetspire	medium

Table 2. (Continued)

Scientific name	Common name	Irrigation Requirement
<i>Ixora coccinea</i>	Ixora	medium
<i>Ixora taiwanensis</i>	Dwarf Ixora	medium
<i>Jasminum mesnyi</i>	Primrose Jasmine	medium
<i>Jasminum multiflorum</i>	Downy Jasmine	medium
<i>Jasminum nitidum</i>	Star Jasmine	medium
<i>Jasminum simplicifolium</i>	Wax Jasmine	medium
<i>Jatropha</i> spp.	Jatropha	low-medium
<i>Juniperus chinensis</i>	Chinese Juniper	low
<i>Juniperus chinensis</i> 'San Jose'	San Jose Juniper	high
<i>Juniperus chinensis</i> 'Blue Vase'	Blue Vase Juniper	low
<i>Juniperus chinensis</i> 'Sargentii'	Sargent's Juniper	medium
<i>Juniperus chinensis</i> 'Torulosa'	Hollywood Juniper	low
<i>Juniperus conferta</i>	Shore Juniper	low
<i>Juniperus conferta</i> 'Blue Pacific'	Blue Pacific Shore Juniper	low-medium
<i>Juniperus davurica</i> 'Parsonii'	Parson's Juniper	low
<i>Juniperus horizontalis</i>	Creeping Juniper	low
<i>Juniperus horizontalis</i> 'Plumosa Compacta'	Plumosa Compacta Juniper	high
<i>Juniperus horizontalis</i> 'Wiltonii'	Blue Rug	low
<i>Juniperus procumbens</i>	Jaggarden Juniper	high
<i>Juniperus scopulorum</i> 'Tolleson's Blue'	Tolleson's Blue Weeping Juniper	low
<i>Juniperus silicicola</i>	Southern Red Cedar	low-medium
<i>Juniperus squamata</i> 'Star'	Star Juniper	low-medium
<i>Juniperus virginiana</i> 'Grey Owl'	Eastern Redcedar	high
<i>Justicia brandegeana</i>	Shrimp Plant	medium
<i>Justicia carnea</i>	Plume Plant	medium
<i>Kalmia latifolia</i>	Kalmia	low
<i>Kniphofia uvaria</i>	Red-hot Poker	low
<i>Lagerstroemia indica</i>	Crepe Myrtle	high
<i>Lantana camara</i>	Lantana	low
<i>Lantana montevidensis</i>	Trailing Lantana	medium
<i>Leptospermum scoparium</i>	New Zealand Tea	low
<i>Leucophyllum frutescens</i>	Texas Sage	low
<i>Ligustrum japonicum</i>	Wax-leaf Ligustrum	medium
<i>Ligustrum lucidum</i>	Green Ligustrum	medium

Table 2. (Continued)

<i>Scientific name</i>	<i>Common name</i>	<i>Irrigation Requirement</i>
<i>Ligustrum sinense</i>	Chinese Privet	medium
<i>Limonium sinuatum</i>	Statice	low-medium
<i>Liriope muscari</i>	Liriope, Lilyturf	medium
<i>Liriope</i> spp. 'Evergreen Giant'	Evergreen Giant Liriope	medium
<i>Lonicera japonica</i>	Japanese Honeysuckle	medium
<i>Lonicera periclymenum</i> 'Serotina Florida'	Serotina Honeysuckle	low
<i>Lonicera sempervirens</i>	Honeysuckle	low-medium
<i>Loropetalum chinense</i>	Fringe Bush	medium
<i>Lysimachia nummularia</i>	Golden Globe	medium
<i>Lysimachia punctata</i>	Golden Girl	low-medium
<i>Magnolia grandiflora</i>	Southern Magnolia	medium
<i>Mahonia bealei</i>	Leatherleaf Mahonia	low
<i>Mahonia fortunei</i>	Fortune's Mahonia	low
<i>Malus</i> spp.	Crabapple	medium
<i>Mandevilla splendens</i>	Mandevilla	medium
<i>Mandevilla x amabilis</i>	Dipladenia	medium
<i>Maranta leuconeura</i>	Red Maranta	medium-high
<i>Maranta leuconeura</i> var. <i>kerchoveana</i>	Green Maranta	high
<i>Melampodium paludosum</i> 'Medallion'	Melampodium	medium
<i>Miscanthus sinensis</i>	Wire Grass	low-medium
<i>Monstera deliciosa</i>	Split-leaved Philodendron	medium
<i>Muhlenbergia capillaris</i>	Muhly Grass	medium
<i>Myrica cerifera</i>	Wax Myrtle	medium
<i>Myrtus communis</i>	True Myrtle	medium
<i>Nageia nagi</i>	Nagi Podocarpus	medium
<i>Nandina domestica</i>	Heavenly Bamboo or Nandina	medium
<i>Nemopanthus</i> spp.	Goldfish species and hybrids	medium
<i>Nerium oleander</i>	Oleander	medium
<i>Nolina recurvata</i>	Pony Tail	low
<i>Ophiopogon japonicus</i>	Mondo Grass	low
<i>Osmanthus fragrans</i>	Sweet Olive	medium
<i>Pachyphytum</i> spp.	Pachyphytum	low
<i>Pachyveria</i> spp.	Pachyveria	low
<i>Pandanus utilis</i>	Screw Pine	low

**Table 2.** (Continued)

<i>Scientific name</i>	<i>Common name</i>	<i>Irrigation Requirement</i>
<i>Pandorea jasminoides</i>	Pandora Vine	medium
<i>Pennisetum alopecuroides</i>	Pennisetum	low-medium
<i>Pennisetum setaceum</i> var. <i>rubrum</i>	Red Fountain Grass	medium
<i>Persea borbonia</i>	Red Bay	medium
<i>Philadelphus coronarius</i>	Mock Orange	medium
<i>Photinia x fraseri</i>	Fraser's Photinia	medium
<i>Phyllostachys</i> spp.	Bamboo	low
<i>Pilea nummularifolia</i>	Creeping Charlie	medium
<i>Pimpinella anisum</i>	Anise	low
<i>Pittosporum tobira</i>	Pittosporum	medium
<i>Platanus</i> spp.	Plane Tree	medium
<i>Platyclusus orientalis</i>	Arborvitae	medium
<i>Platyclusus orientalis</i> 'Conspicua'	Berkmann's Golden Arborvitae	low
<i>Plumbago auriculata</i>	Plumbago	medium
<i>Podocarpus falcatus</i>	Podocarpus	medium
<i>Podocarpus macrophyllus</i>	Podocarpus	medium
<i>Prunus caroliniana</i>	Cherry Laurel	low-medium
<i>Prunus laurocerasus</i> 'Schipkaensis'	Schipka Laurel	medium
<i>Pseuderanthemum laxiflorum</i>	Amethyst Star	medium
<i>Psidium guajava</i>	Guava	medium
<i>Pyracantha coccinea</i>	Firethorn	medium
<i>Pyracantha</i> spp.	Pyracantha	high
<i>Pyrus</i> spp.	Pear	medium
<i>Quercus laurifolia</i>	Laurel Oak	medium
<i>Quercus nuttallii</i>	Nuttall Oak	high
<i>Quercus phellos</i>	Willow Oak	medium
<i>Quercus virginiana</i>	Live Oak	medium
<i>Radermachera sinica</i>	China Doll	medium-high
<i>Rhaphiolepis</i> spp.	Indian Hawthorn	low
<i>Rhipsalis</i> spp.	Rhipsalis species and hybrids	low
<i>Rhododendron</i> spp.	Kurume Azalea	medium
<i>Rhododendron</i> spp.	Indica Azalea	high
<i>Rhoeo spathacea</i>	Oyster Plant	low
<i>Rosa</i> spp.	Rose	medium

Table 2. (Continued)

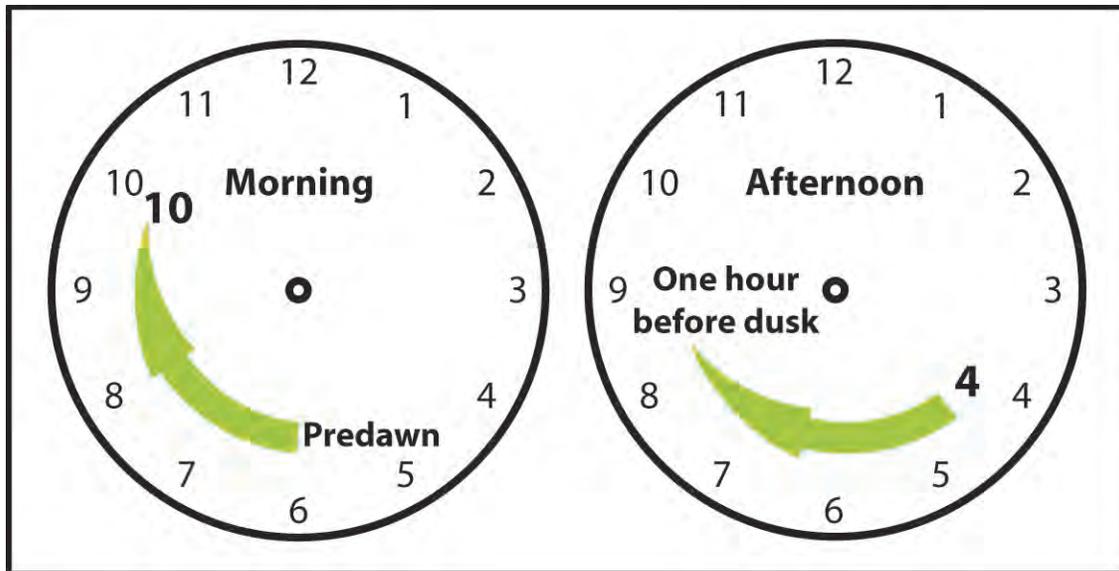
<i>Scientific name</i>	<i>Common name</i>	<i>Irrigation Requirement</i>
<i>Rudbeckia hirta</i>	Blackeyed Susan	medium
<i>Russelia equisetiformis</i>	Firecracker	medium
<i>Salix</i> spp.	Willow	high
<i>Sanseveria trifasciata</i> 'Laurentii'	Goldband Sanseveria	low
<i>Scaevola aemula</i> 'Blue Wonder'	Blue Wonder	medium
<i>Schefflera</i> (=Brassaia) <i>actinophylla</i>	Common Schefflera	medium
<i>Schefflera actinophylla</i> 'Amate'	Amate Schefflera	medium
<i>Schefflera arboricola</i>	Dwarf Schefflera	medium
<i>Scilla violacea</i>	Scilla	low
<i>Scutellaria javanica</i>	Chinese Skullcap	medium
<i>Sedum morganianum</i>	Burro's Tail	low
<i>Senecio</i> spp.	Senecio	low
<i>Serissa foetida</i>	Serissa	medium
<i>Severina buxifolia</i> 'Nana'	Dwarf Boxthorn	low
<i>Spiraea japonica</i> 'Little Princess'	Little Princess Spiraea	medium
<i>Spiraea</i> spp.	Spiraea	medium
<i>Spiraea x bumalda</i> 'Anthony Waterer'	Anthony Waterer Spiraea	medium
<i>Stemodia tomentosa</i> 'Namu'	Stemodia	low
<i>Strelitzia nicolai</i>	Giant Bird of Paradise	medium
<i>Strelitzia reginae</i>	Bird of Paradise	medium
<i>Streptocarpus saxorum</i>	Dolphin Violet	high
<i>Syngonium podophyllum</i>	Nephtytis	medium
<i>Tecomaria capensis</i>	Cape Honeysuckle	medium
<i>Ternstroemia gymnanthera</i>	Japanese Cleyera	medium
<i>Thuja x 'Green Giant'</i>	Green Giant Arborvitae	medium
<i>Thunbergia alata</i>	Blackeyed Susan Vine	medium
<i>Tibouchina granulosa</i>	Purple Glory Tree	medium
<i>Tibouchina urvilleana</i>	Tibouchina	medium
<i>Tilia</i> spp.	Linden	low
<i>Torenia fournieri</i>	Wishbone Flower	medium
<i>Trachelospermum asiaticum</i>	Dwarf Jasmine	medium
<i>Trachelospermum jasminoides</i>	Confederate Jasmine	medium
<i>Trachycarpus fortunei</i>	Windmill Palm	low
<i>Tradescantia pallida</i> 'Purple Heart'	Purple Queen	medium

Table 2. (Continued)

Scientific name	Common name	Irrigation Requirement
<i>Tsuga canadensis</i>	Canadian Hemlock	medium
<i>Ulmus parvifolia</i>	Chinese Elm	medium
<i>Vaccinium</i> spp.	Blueberry	low-medium
<i>Viburnum awabuki</i> 'Chindo'	Chindo Viburnum	medium
<i>Viburnum obovatum</i>	Walter's Viburnum	low-medium
<i>Viburnum odoratissimum</i>	Sweet Viburnum	high
<i>Viburnum plicatum</i> var. <i>tomentosum</i>	Shasta Doublefile Viburnum	high
<i>Viburnum</i> 'Shasta'	Shasta Viburnum	medium
<i>Viburnum suspensum</i>	Sandankwa Viburnum	medium
<i>Viburnum tinus</i> 'Compactum'	Spring Bouquet	low-medium
<i>Viguiera stenoloba</i>	Golden Eye	low
<i>Vitex agnus-castus</i>	Chaste Tree	high
<i>Washingtonia robusta</i>	Mexican Fan Palm	low
<i>Wedelia trilobata</i>	Wedelia	low
<i>Xylosma congestum</i>	Compact Xylosma	medium
<i>Zelkova</i> spp.	Zelkova	medium

### Time of Irrigation Application

When possible, overhead irrigation should occur during the early morning hours (no more than 2 hours after sunrise) or late afternoon (from 1-3 hours prior to dusk). This schedule will reduce the potential of wind blowing the irrigation water from the targeted area, reduce evaporation of irrigation water, and minimize foliar diseases. Disease severity may increase for some plants if foliage is wet for an extended amount of time, particularly during evening and night when temperatures and relative humidity are high. Overhead application during other times should be made only when the substrate water content is limiting growth or when excessive heat requires plants to be cooled via evaporation of irrigation water from foliage. As much as 30% of overhead irrigation may evaporate on hot, dry days (Ross, 1994). Micro-irrigation has a much greater window of application, as micro-irrigation does not wet foliage and thereby reduces occurrence of foliar pathogens. Micro-irrigation can be applied at any time of the day or night, although night is typically recommended to reduce pumping (electricity) costs and further reduce evaporative losses. Research (Warren and Bilderback, 2002) suggests that afternoon cycles such as 12 pm, 3 pm, and 6 pm may be advantageous to replace water as it is used by the plant, resulting in less plant stress and subsequently increasing plant growth.



Overhead irrigation should be applied during the early morning hours (before 10 am) or late afternoon (after 4 pm) to increase the irrigation efficiency and reduce the potential of water loss.

**# 19** Overhead irrigation should be applied before 10 am or after 4 pm.

**# 20** Rain events of  $\frac{1}{4}$  to  $\frac{1}{2}$  inch or greater should be substituted for the next irrigation cycle.

## Irrigation Water Sources

Any source of water may be suitable for irrigation as long as the quality is adequate (*see section on Irrigation Water Quality*), particles are removed from the water, disease organisms are controlled, and there is adequate volume to meet plant growth demands. Many nurseries use one or more of the following sources for irrigation: wells, lakes or ponds, rivers, streams, canals, municipal water, reclaimed (“gray”) water, and recycled water. Regardless of water source, whether public or privately managed, the nursery owner should be familiar with federal, state, and local riparian (water rights) laws.

Plants watered with overhead sprinkler irrigation typically receive 5-10 acre-feet of water during the year. During summer months, weekly water requirements may exceed three inches per acre. An alternative irrigation supply is necessary for containerized nursery stock to assure a reserve supply in the event of an emergency and generators or PTO-driven pumps may be needed to pump water. One possible way to reduce water consumption and runoff is to use a micro-irrigation system, but clean water is essential to prevent clogging of emitters. The irrigation water source can be chemically treated to improve quality. Commonly used treatments are filtration (*see section on Micro-irrigation System Design*), acidification, **deionization**, **reverse osmosis**, and disinfection.

## Irrigation Water Quality

Irrigation water quality is the most critical factor for production of container-grown nursery plants (**Tables 3 and 4**). Poor quality water applied with overhead irrigation can result in foliar damage, significantly alter substrate *pH*, and/or result in unsightly foliar residues or stains.

**Turbidity**, or sediment in irrigation water, influences irrigation water chemical characteristics, equipment performance, and plant growth. Sediment in irrigation water supplies can clog micro-irrigation emitters. Sediment also causes excessive wear of orifices in overhead irrigation nozzles and is deposited on foliage, reducing photosynthetic rates and crop appearance. Filtration and water runoff best management practices discussed in the Runoff Water Management section are the best methods to reduce turbidity of irrigation supplies. Laboratories can analyze irrigation water samples for turbidity, measured as Nephelometric Turbidity Units (NTUs). The turbidity limit for runoff and sediment deposition from construction sites in some states is limited to 50 NTUs. Nurseries using surface water with upstream construction activities frequently have problems with sedimentation in irrigation storage structures. Gypsum application can reduce turbidity by flocculation of suspended sediments; however, it may require 500-2000 lbs of gypsum per acre-foot of water, that may alter the *pH* of stored water, particularly if used often as a treatment method.

Irrigation, fertilization, and pesticide efficacy are more easily managed when using high quality water. Irrigation water constituents should be monitored and managed to ensure desired water quality. Monitor water quality at least twice a year (summer and winter). More frequent monitoring is needed to alter production practices in response to changes in water quality. Develop a monitoring plan and record results so that baseline information regarding water quality and seasonal variability are available in the event of land use changes in surrounding properties. Irrigation water quality should be analyzed and evaluated prior to locating a new nursery, moving to a new site, or using a new water source. A list of laboratories is provided in **Appendix A**. Treatment of irrigation water may be necessary if water quality is poor.

An **acid** such as sulfuric, phosphoric, or nitric acid can be added to the water to adjust *pH* and neutralize **carbonates** and **bicarbonates**. This treatment is necessary when the irrigation water is alkaline and injurious to crop growth, especially susceptible species such as azaleas. Acidification does not reduce the salt concentration of water that has a high soluble salt content. When requested, most commercial labs measure *pH*, alkalinity or bicarbonate concentrations, and calculate the amount of an acid to inject into water supplies. If nursery operators have *pH*, alkalinity, or bicarbonate concentrations expressed in ppm or meq, alkalinity calculators (acid injection) are available from either: <http://www.ces.ncsu.edu/depts/hort/floriculture/software/alk.html> or <http://extension.unh.edu/Agric/AGGHFL/Alkcalc.cfm>

**# 21** Alkalinity calculators help with determination of the amount of acid to inject (based on water hardness and alkalinity), and the cost per 1000 gallons of irrigation water.

Deionization and reverse osmosis are used to remove salts from the irrigation water. These water treatments can be used if **soluble salts**, especially sodium, are high enough to cause plant damage. These are expensive treatments and are generally limited to high value crops or to regions where high quality water is simply not available.



*Foliar residues are the result of poor quality irrigation water.*

Residues generated from water treatment should be collected in covered structures, similar to that used for pesticide residue degradation (*see section on Operation and Maintenance for Pesticide Management*). Treatment before use of reclaimed or recycled runoff water may be required because disease organisms, soluble salts, and trace organic chemicals may be present. The quality of these water sources should be tested regularly to ensure that the concentration of chemical constituents is acceptable for plant growth. If monitored and managed properly, the risk of concentrating pollutants in recycled runoff that may be discharged to surface or leached into ground water should be minimal.

Various materials are commonly used to kill organisms in water and include chlorine, UV light, and ozone. Chlorine is used extensively because of its broad spectrum of activity on plant *pathogens*. Ozone generators can treat large quantities of recycled water faster and more safely than chlorine and bromine. Check with local officials regarding proper notification and reporting when using chlorine and bromine. Hydrogen dioxide or hydrogen peroxide products are also marketed as disinfectants, algacides, and natural fungicides for irrigation water treatment. Their mode of action is oxidative chemical reactions that denature enzymes and proteins in simple celled organisms. The cost of injecting hydrogen dioxide or hydrogen peroxide into irrigation supplies may be significantly higher than that of chlorination systems.

### ***Sampling Irrigation Water***

Water samples should be collected in unused, opaque plastic bottles, with a minimum volume of approximately one half gallon. Samples should be collected from both near the well or pond pump intake and from emitters at the furthest irrigation location. Run water long enough to flush pipes and tanks of any injected materials. Then rinse lid and bottle three times with running water. Collect a full bottle without air at the top, secure the lid, label bottle, chill on ice or in a refrigerator (do not freeze) and send the cold sample immediately to a laboratory. Collect and submit samples at the beginning of the week so that the sample does not sit over the weekend, as some compounds of interest degrade in a short amount of time.



Periodically monitor irrigation water to ensure acceptable quality.

### Irrigation Water Quality Guidelines

Potential for an irrigation water quality impairment to cause adverse plant circumstances can be based on severity of the impairment. The severity of some impairments is provided in **Table 3**.

**Table 3.** General irrigation water quality guidelines for plant production.

Characteristic	Degree of problem		
	None	Increasing	Severe
<b>Potting Substrate pH Maintenance</b>			
pH	6.5 to 7.0	>7.0	-
Bicarbonate (ppm <i>alkalinity</i> )	< 61	61 to 214	> 214
Bicarbonate (meq/L)	< 1.0	1.0 to 3.5	> 3.5
<b>Soluble Salts</b>			
<i>Electrical Conductivity</i> (EC, dS/m)	< 0.75	0.75 to 1.4	> 1.4
<b>Toxicity - Root Absorption (<i>Sensitive Crops</i>)</b>			
Sodium ( <i>Sodium Adsorption Ratio</i> (SAR))	< 3	3 to 9	> 9
Chloride (ppm)	< 70	70 to 345	> 345
<b>Toxicity - Foliar Absorption</b>			
Sodium (ppm)	< 70	> 70	-
Chloride (ppm)	< 100	> 100	-
<b>Foliar Residues</b>			
Bicarbonate (ppm <i>hardness</i> )	< 40 to 90	90 to 520	> 520
Bicarbonate (meq/L)	< 0.7 to 1.5	1.5 to 8.5	> 8.5
Iron (ppm)	< 3	> 3	-
<b>Permeability - Organic Potting Substrate</b>			
Sodium (Sodium Adsorption Ratio (SAR))	< 35	> 35	-

**Table 4.** Irrigation water quality guidelines for microirrigation.

Characteristic	Degree of problem		
	None	Increasing	Severe
Hydrogen Sulfide (H <sub>2</sub> S) (ppm)	< 0.1	0.1 to 0.5	> 0.5
Iron (Fe <sup>++</sup> ) (ppm)	< 0.2	0.2 to 0.3	> 0.3
Tannins, Phenolics, Humic Acids (ppm)	-	-	> 2.0
Total Dissolved Solids (TDS, ppm)	< 525	525 to 2100	> 2100
Suspended Solids (ppm)	< 50	50 to 100	> 100
Turbidity (NTU)	< 10	> 25	> 50

### Management Strategies Irrigation Water Problems

Strategies within each water quality problem are listed from least to most intense management. Water purification, such as reverse osmosis, is a very intense management strategy applicable to each water problem.

Water Problem	Potential Management Strategies
<b>Bicarbonates (high pH)</b>	<p>Do not overwater.</p> <p>Apply acids or acid-forming materials to the substrate.</p> <p>Inject acid into irrigation water.</p>
<b>Excess soluble salts</b>	<p>Do not underwater.</p> <p>Monitor soluble salts levels in substrate.</p> <p>Leach containers with at least two container capacities of water.</p> <p>Reduce fertilizer rates.</p> <p>Use less soluble fertilizer.</p> <p>Use fine-textured substrate.</p> <p>Dilute poor quality water with good quality water.</p> <p>Change to better quality water.</p> <p>Grow salt tolerant crops.</p>
<b>Chloride toxicity</b>	<p>Do not underwater.</p> <p>Leach containers with at least two container capacities of water.</p> <p>Convert to a microirrigation system (to avoid foliar absorption).</p> <p>Aerate water to increase degassing of chloride.</p> <p>Dilute poor quality water with good quality water.</p> <p>Change to better quality water.</p>
<b>Sodium-induced problems</b>	<p>If water contains calcium and magnesium, follow management strategies for chloride toxicity.</p> <p>Apply gypsum (pH neutral) or <i>lime</i> (alkaline) to flush sodium.</p>
<b>Residue on leaves</b>	<p>Irrigate less frequently.</p> <p>Irrigate at night or when evaporation is minimal.</p> <p>Convert to a microirrigation system.</p> <p>Remove residues on leaves with <i>oxalic acid</i> (for iron).</p> <p>Inject acid to adjust pH (for calcium carbonate).</p>
<b>Sediment</b>	<p>Upgrade filtration.</p> <p>Install vegetative buffers adjacent to production areas, runoff return channels and retention basins (<i>See section on Runoff Water Management</i>).</p> <p>Install and maintain sediment catch basins.</p>
<b>Algae</b>	<p>Reduce light penetration into exposed PVC irrigation lines by painting PVC pipe or using Schedule 40 gray PVC pipe.</p> <p>Disinfect or oxidize irrigation supplies with chlorine, bromine, ozone, or hydrogen dioxide/peroxide.</p>
<b>Iron</b>	<p>Install aerifiers in surface water supplies to oxidize iron and cause settling.</p> <p>Disinfectants or sequestering agents should be injected inline before filters to reduce change of clogging irrigation lines.</p> <p>Change water supplies.</p>
<b>Iron bacteria</b>	<p>Remove iron from water supplies as mentioned above.</p> <p>Inject bactericides in water supply.</p>

### ***Management Strategies for Water Conservation***

Water conservation practices should be implemented not only to reduce water waste but also to reduce the economic costs associated with pumping and treating water. Some management strategies for conserving irrigation water are given below.

- # 22** Irrigation should be scheduled based on plant demand. Increasing the water holding capacity of the substrate can decrease irrigation frequency.
- # 23** Cyclic irrigation practices should be used. Cycles increase easily-available water content in container substrates and reduce total irrigation volumes required. Substrates with a high proportion of fine particles retain more water than substrates with low proportion of fine particles.
- # 24** Care should be used not to apply too much water, especially to small plants in large containers.
- # 25** Irrigation system uniformity should be checked annually. Some irrigation systems may need to be redesigned to achieve uniform delivery.
- # 26** Plants should be grouped based on daily water requirements and plant age. *See Table 2 for list of species with low, medium, or high water requirements.*
- # 27** Rain shutoff devices should be used to prevent irrigation system operation during storm events and to minimize nutrient runoff.
- # 28** Substrate temperatures should be reduced using cyclic irrigation to reduce root stress and to minimize water evaporation from containers.
- # 29** Plants should be consolidated to avoid empty production areas receiving irrigation or use shutoff valves.
- # 30** Irrigation runoff and stormwater runoff should be collected and used for irrigation (*see section on Runoff Water Management*). Some states require these water sources be collected and maintained in separate storage reservoirs.
- # 31** Irrigation runoff should be managed to minimize the possibility of nutrient-laden water contaminating surface or ground waters (*see section on Runoff Water Management*).



*Use a rain shutoff device to prevent irrigation system operation immediately following rain.*

## Runoff Water Management

Erosion is the process by which the land surface is worn away by the action of water, wind, ice or gravity. Water flowing over exposed soil picks up detached soil particles and debris that may possess chemicals harmful to receiving waters. As the velocity of flowing water increases, additional soil particles are detached and transported. Water flows have tendency to concentrate, creating small channels and eventually gullies of varying widths and depths. **Sedimentation** is the process where soil particles settle out of suspension as the velocity of water decreases. The larger and heavier particles (e.g. gravel and sand) settle out more rapidly than fine silt and clay particles. It is difficult to totally eliminate the transport of these fine particles even with the most effective erosion control program. Container nurseries are especially susceptible to erosion during times of development and prior to filling empty container areas.

An erosion and sediment control plan should be developed which explains and stipulates the measures and actions to be taken to control potential erosion and sedimentation problems. The plan should serve as a blueprint for the location, installation, and maintenance of practices to control all anticipated erosion, and prevent sediment from leaving the nursery. This plan should be developed in cooperation with personnel from the local Soil and Water Conservation District and the Natural Resources Conservation Service (NRCS). Each state may have specific information for plans developed to manage erosion and sediment, for example the Alabama Handbook for Erosion

Control, Sediment Control, and Storm Water Management on Construction Sites and Urban Areas and the Storm Water, Erosion, and Sedimentation Control Inspector's Manual for Florida.

### ***Critical Area Stabilization***

Newly constructed slopes and other barren areas should be seeded or sodded as soon as possible after grading. If the areas are seeded, mulch to prevent erosion during establishment of the seeded crop (or hydroseed). Where feasible, grading operations should be planned around optimal seeding dates for the particular region. The most effective times for planting perennial grasses and legumes generally extend from March through May and from late August through October. Outside of these dates, the probability of failure is higher.



*Container nursery areas are especially susceptible to erosion during development and when the production areas are empty.*



*Seeding or sodding recently graded areas will reduce or prevent erosion.*

If the time of year is not suitable for seeding permanent cover (perennial species) a temporary cover should be planted, or the area may be stabilized with gravel or mulch. Temporary seeding of annual species (small grains, ryegrass, millets, etc.) often succeeds during times of the year that are unsuitable for seeding perennial species. Planting dates may differ for temporary species depending on the geographical area. Growing seasons must be considered when selecting species.

**# 32** Newly constructed or barren areas should be seeded, sodded, or stabilized in some manner to prevent erosion and sediment loss.

### ***Temporary Vegetation-Seeding***

Temporary vegetation seeding is defined as planting rapid growing annual grasses, small grains, or legumes to provide initial, temporary cover for erosion control on disturbed areas. The purpose of temporary vegetation seeding is to temporarily stabilize bare areas that will not be brought to final grade for a period of more than 30 days. Temporary seeding controls runoff and erosion until container areas are prepared for planting or permanent vegetation or other erosion control measures can be established.

**# 33** Temporary vegetation should be planted when bare areas will exist for 30 days or longer.

### ***Permanent Vegetative Establishment***

Permanent vegetative establishment controls runoff and erosion on disturbed areas by establishing a perennial vegetative cover. The purpose of permanent vegetation is to reduce erosion and decrease sediment yield from disturbed areas, and to permanently stabilize such areas in a manner that is economical, adapts to site conditions, and allows selection of the most appropriate plant materials.

**# 34** Permanent vegetative establishment should be used to stabilize disturbed areas, reduce erosion, and sediment loss.

### ***Establishment of Vegetation***

Establishment of vegetation should not be attempted on sites that are unsuitable until measures have been taken to correct problems associated with inappropriate soil texture, poor drainage, concentrated overland flow (often a concern at container nurseries), or steepness of slope. Water movement from nursery irrigation areas needs to be directed to permit vegetation establishment.

**# 35** Unsuitable site-specific topographical characteristics should be resolved before attempting vegetation establishment.

### ***Mulching***

Mulching is defined as the application of a protective layer of straw, other plant residues, stone, or synthetic materials to the soil surface. The purpose of mulching is to protect the soil surface from the forces of rain and overland flow. Mulch fosters the growth of vegetation and reduces evaporation. Surface mulch is the most effective, practical means of controlling runoff and erosion on disturbed land prior to vegetation establishment. Organic mulches such as straw, woodchips, and shredded bark are effective mulch materials.



*Permanent vegetative establishment will stabilize disturbed areas, reducing erosion and sediment loss.*

- # 36** Mulch should be used on disturbed land prior to vegetation establishment as a practical means of controlling erosion.

### ***Erosion Control Blankets and Netting***

Several erosion control blankets have been developed in recent years for use as mulch, particularly in critical areas such as waterways and channels. Erosion control blankets promote seedling growth in a similar way as organic mulches. They are very useful in establishing grass in channels and waterways. Jute mesh or various types of netting are very effective in holding mulch in place on waterways and slopes before grasses become established.

- # 37** Erosion control blankets or netting should be used to hold mulch in place during vegetation establishment.

### ***Ground Covers***

Shrub, herbaceous perennial, vine, and groundcover plantings can stabilize disturbed areas by establishing a vegetative cover. These plants may be used on slopes where mowing is not feasible, as ornamentals for landscaping purposes, or in shaded areas where grass establishment is difficult. Short-term stabilization efforts must be used in conjunction with groundcovers to ensure establishment. There are many different species of shrubs, herbaceous perennials, vines, and groundcovers from which to choose. It is essential to select plant material suited to both the intended use and site.

- # 38** Groundcovers should be used as a means of erosion and sediment control on slopes where mowing is not feasible or grass establishment is difficult.

### ***Vegetative Zones/Buffer Zones***

A vegetative zone is defined as a filter strip or area of vegetation facilitating removal of sediment, organic matter, and other contaminants from runoff and wastewater. Vegetative zones remove sediment and other pollutants from runoff by filtration, **deposition**, **infiltration**, sorption, decomposition, and **volatilization**, thereby reducing pollution and protecting the environment.

Vegetative zones should be protected and retained in their natural state along the banks of water bodies. Vegetative zones prevent erosion, trap sediment, filter runoff, provide public access, enhance the site amenities and function as a floodplain. They also provide a pervious strip along a shoreline that can accept “sheet flow” from developed areas and help minimize the adverse impacts of untreated storm water. Design of vegetative zones should be site specific because of topographic differences in sites. Slope, soil type, vegetative cover, and other runoff control measures will differ among sites. It is important in the design of the zone that the slope will not result in flow that will cause erosion or carry sediment across the zone.

Vegetative zones that receive runoff from nurseries may trap organic material, solids, or nutrients and pesticides, which become adsorbed to the vegetation or the soil within the zone. Often they do not filter out soluble materials. Vegetative zones or filter strips often have wet soils, are challenging to maintain, and should not be used as travel lanes.

**# 39** Vegetative zones should be used to prevent erosion and trap pollutants.

### **Grass Waterways**

A grass waterway is natural or constructed, channel-shaped or graded to required dimensions, and established with suitable vegetation for the stable conveyance of runoff. This practice may reduce erosion in a concentrated flow area, such as in a gully or in temporary gullies. Grass waterways may also reduce the amount of sediment and substances delivered to collection structures, lakes, and streams. Vegetation may serve as a filter, removing some of the sediment delivered to the waterway, although this is not the primary function of a grass waterway. Grass waterways should not be used as travel lanes and vegetation must be maintained to prevent erosion and control runoff.

**# 40** Grass waterways should be used to control the movement of runoff and to reduce the loading of sediment and other substances into collection structures.

**# 41** Grass waterways should not be used as travel lanes and vegetation must be maintained.

### **Constructed Wetlands (See Also Constructed Wetlands Section)**

A constructed wetland is a constructed aquatic ecosystem with rooted emergent *hydrophytes* designed and managed to treat agricultural wastewater. The plants filter nutrients and other contaminants from the water, while adding oxygen to the root zone, during the treatment process. Aquatic plants used to treat agricultural water will typically include cattails, bulrushes, calla lily, cannas, iris, and related water tolerant vegetation.

A constructed wetland used to treat wastewater and runoff consists of an impervious subsurface barrier, a suitable substrate for establishment of aquatic vegetation, wastewater or runoff flowing at a consistent velocity through the system, and the structural components needed to contain and control the flow. The system can be designed as either 1) a free-water or surface flow system or 2) a subsurface-flow system. Constructed wetlands are beneficial filters for removing environmental contaminants from runoff. It is a conservation practice for which the NRCS has developed technical requirements under a trial program leading to the development of conservation practice standards. This is an option with potential for use in some container nurseries. Check with state environmental agencies about permits. For additional information on constructed wetlands for nurseries refer to <http://tinyurl.com/CWshowto>.



*Free-water surface constructed wetlands effectively cleanse agricultural runoff and can be tailored to handle various flow and nutrient loading rates.*

**# 42** Wetlands should be tailored and managed to treat agricultural wastewater.

### ***Management of Stormwater***

Stormwater runoff is water flowing over the land, during and following a rainstorm. On-site storage of stormwater reduces water movement offsite and provides for settling and dissipation of pollutants; it also lowers the probability of downstream flooding, stream erosion, and sedimentation, and provides water for other beneficial uses. Stormwater runoff should never be discharged directly into surface or ground waters. Runoff should be routed over longer distances and through grass waterways, constructed wetlands, vegetative buffers, and/or other areas designed to increase overland flow. These components increase infiltration and evaporation, allow suspended solids to settle, and remove potential pollutants before they are introduced to other water sources.

Whenever possible, construct the components of the stormwater management system following the topographic contours. This practice will minimize erosion and stabilization problems caused by excessive velocities; it will also slow the runoff, allowing for greater infiltration and filtering. If the components of storm water are not constructed on the contour, the components must be stabilized to prevent erosion. Other methods to stabilize the components of stormwater management could include tile outlet terraces and grade stabilization structures.



*Stormwater catchment area which reduces runoff velocity, permits settling, and filters runoff before discharge over a concrete ledge into a grassed riparian zone for further filtration before water movement offsite.*

**# 43** A stormwater management system should be used to minimize erosion.

## Collection Structures

Collection structures serve as a means of reducing potential water quality problems. California and Oregon have endorsed this concept with varying degrees of regulation, with the goal of minimizing contamination of surface waters with agricultural runoff. However, containment of irrigation runoff is not possible at every operation, as some operations have high water tables (high groundwater). In regions with high groundwater, containment ponds are not a reasonable BMP and riparian buffers and constructed wetlands are an accepted alternative BMP (see *Vegetative Zones, Grass Waterways, Constructed Wetland sections*) in many states. Site by site evaluation will determine if collection structures are necessary or even possible.

During the irrigation season, to the maximum extent practical, all irrigation return flows should be re-circulated with no discharge back to public waters. As a general rule, newly constructed water collection and recycling facilities should be designed to accommodate irrigation return flow and have extra storage capacity for a rain event.

Collection structures should be constructed with clay-like materials with good sealing characteristics or be lined with an acceptable membrane liner. These structures should be constructed with an emergency overflow to prevent dike damage in the event of overtopping. Structures or other structures that are planned for construction must have all necessary state and local permits. Where rainwater is allowed to discharge from the property, it must be considered in the design of the water collection structure. NRCS can provide design criteria and expertise to help you develop the best plans for your nursery collection or retention structure.

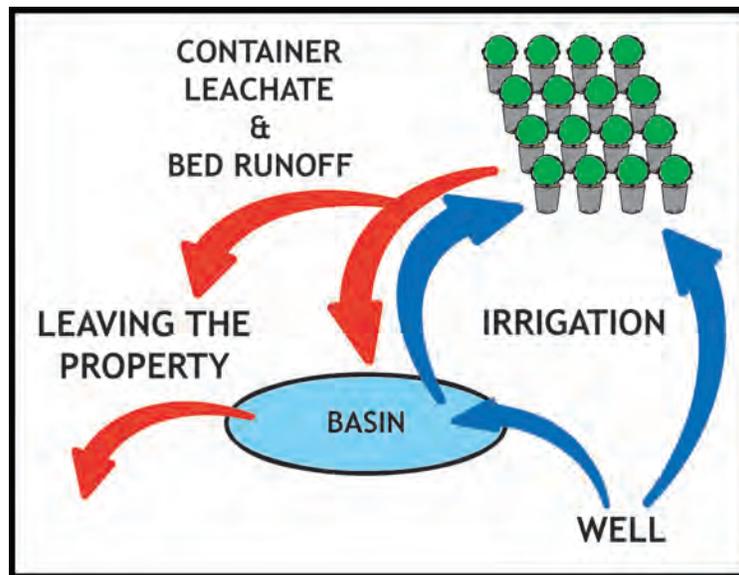
**# 44** Collection structures should be used to minimize any runoff water leaving the container nursery site.

## Volume of Water Collection

Collection structures should be designed with sufficient volume to hold all of the irrigation runoff that can drain back to the basin from the irrigation system and additional storage for a rain event. If you irrigate a 1-acre container area with 1 inch of water (27,150 gallons), assume that you would need the capacity to catch and process the runoff from about 90% of the irrigation water (24,435 gallons). Plastic may be necessary on production surfaces so that water falling between containers and leaching from containers flows to roadsides and into collection structures. If plastic is not used on production surfaces, then underground drainage tile may be used to channel water to a collection structure.



*Collection structures should be design to collect both production and stormwater runoff.*



*This schematic shows the potential means and movement of water in container nursery production facilities.*

- # 45 Collection structures should be designed with capacity to retain about 90% of the maximum daily irrigation water applied.
- # 46 Collection structures should be designed with capacity to retain the first 1/2 inch of rainwater runoff.

### ***Lined vs. Non-lined***

A lined waterway, or outlet, is a waterway having an erosion-resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes, to a designed depth. The earth above the permanent lining may be vegetated or otherwise protected. This practice may reduce the erosion in concentrated flow areas, resulting in the reduction of sediment and substances delivered to receiving waters. Lined waterways may increase the likelihood of dissolved and suspended substances being transported to surface waters due to high flow velocities.

- # 47 Lined waterways should be used in order to direct concentrated flows of water to collection structures and thus reduce erosion in these areas.

## Managing Pesticide Runoff

Plants produced for the landscape require careful attention during production to maintain suitable plant quality. Container-grown landscape plants are grown under conditions that often favor development of pests that adversely affect plant growth. These pests may include weeds, insects, and diseases. In the past, pest control utilized preventative **pesticide** (for example; herbicides, fungicides, or insecticides) applications. Pesticide runoff primarily results from pesticides that land off-target (not on the plant or substrate) on non-adsorptive surfaces. Current pest control involves designing nurseries for minimal runoff, scouting for pests on a regular basis, identifying the pest, and understanding and selecting appropriate chemicals that are environmentally friendly and target existing pest problems. Other considerations are low volume applicators, proper sprayer calibration, and nozzle adjustments.

Design nursery site for minimal pesticide runoff and maximum containment on site. Ground covers differ in absorptive capacities and infiltration abilities. Plastic has the least infiltration and absorptive rates with fabric materials and gravel having increased absorption rates.



*Lined waterways may be useful to direct concentrated flows of water to collection structures.*

**# 48** Slope of production area should be designed to slow the flow of runoff water.

**# 49** Use of drainage systems to channel runoff through vegetation will reduce runoff flow and erosion.

### ***Integrated Pest Management (IPM)***

Integrated pest management (IPM) strategies should be used to reduce the need for pesticides and to minimize the amount of pesticides applied. In addition, pesticides should be applied efficiently and at times when runoff losses are unlikely. The use of IPM strategies is a key element of pesticide management. The following is a list of IPM strategies:

**# 50** Good sanitation practices should be used in and around the nursery to minimize weeds, insects and pathogens.

**# 51** Weed-free substrate should be stored away from areas with weeds or standing water.

**# 52** Production areas should be kept clean of weeds and plant debris.

**# 53** Roadways and surrounding areas should be kept weed free and/or mowed so that weeds are not allowed to produce seeds.

**# 54** Pesticides should be applied based on economic thresholds, i.e., apply pesticides when an economic threshold level has been reached as opposed to applying pesticides in anticipation of pest problems (some disease pathogens require preventative sprays on susceptible crops).

**# 55** Regular scouting schedules should be used to determine when pest problems reach the economic threshold.



*Scouting is an essential component of an IPM program.*

- # 56 A diversity of plants should be grown throughout the container nursery. Monocultures may encourage pests and their proliferation.
- # 57 The least environmentally persistent, toxic, and/or mobile pesticides should be used and rotated to minimize development of pest resistance.
- # 58 Records should be maintained on past pest problems, pesticide use, and other information for each plant production area.
- # 59 Biological control should be used. Examples of biological control include the following:
  - introduction and fostering of natural enemies of pests
  - preservation of predator habitats
  - release of sterilized insects
  - use of biological control agents, i.e. pheromones for monitoring populations, disrupting mating, or other behaviors of pests and to attract predators/parasites
- # 60 Pest breeding, refuges, and over wintering sites should be eliminated.
- # 61 Spreader/stickers should be used with fungicides and insecticidal sprays to increase efficiency and reduce losses due to rain or irrigation.
- # 62 Plants that harbor or transmit organisms associated with quarantines should be isolated.

### ***Pesticide Applications***

When pesticide applications are necessary, producers are encouraged to choose the most environmentally benign pesticide products and remember the goal is to reduce off-target pesticide placement. Consider the persistence, toxicity, and runoff and leaching potential of products along with other factors, including current label requirements, when making a pesticide selection.

Characteristics of pesticides vary so it is important to understand the characteristics of the selected pesticide. Some things to consider include the following:

- Usage rates vary depending upon pest and host species, container substrate characteristics, and environmental conditions
- Pesticide fate is dependent upon the characteristics of the chemical, environmental conditions, application technique, and the nature of the crop/area to which applied
- Some factors influencing fate of pesticides are:
  - High temperatures favor volatilization
  - Light may catalyze physical and chemical breakdown of pesticides
  - Alkaline water pH may cause alkaline hydrolysis and breakdown of select pesticides in short (<1 hour) time periods
  - Wind may increase off-target losses of spray-applied pesticides
  - Pesticide applications in cooler, wetter time of the year have greater possibility for higher pesticide runoff levels
  - Sprayable formulations cover more surface area than granular formulations allowing for more rapid pesticide dissipation
  - Adsorption to other materials
  - Physical, biological, and chemical degradation
  - Aquatic plants may absorb pesticides from water and support microbial populations that breakdown pesticides



# Sevin® 80 WSP

**CARBARYL INSECTICIDE**
*Specimen Label*

FOR AGRICULTURAL OR COMMERCIAL USE ONLY

<b>ACTIVE INGREDIENT:</b>	
Carbaryl	
(1-naphthyl N-methylcarbamate)	80% by wt.
<b>INERT INGREDIENTS:</b>	
TOTAL	100% by wt.

KEEP OUT OF REACH OF CHILDREN  
WARNING AVISO

Si usted lo entiende la etiqueta, lea el etiquetado antes que se lo explique a usted en detalle.  
(If you do not understand the label, first someone to explain it to you in detail.)

EPA Reg. No. 432-1226
EPA Est. No. 66387-AR-002

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IN CASE OF MEDICAL, ENVIRONMENTAL, OR  
TRANSPORTATION EMERGENCIES OR INJURIES,  
CALL 1-800-334-7577 (24 HOURS/DAY).  
For Product Information, Call Toll-Free: 1-800-331-2867

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NET CONTENTS: 1.25 Pounds
**BACKED  
by BAYER.**

ENVIRONMENTAL HAZARDS

This product is extremely toxic to aquatic and estuarine invertebrates. For terrestrial uses, do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Discharge from rice fields may kill aquatic and estuarine invertebrates. Do not apply when weather conditions favor drift from area treated. Do not contaminate water by cleaning equipment or disposal of wastes. Do not contaminate water when disposing of equipment washwaters.

**BEE CAUTION: MAY KILL HONEYBEES IN SUBSTANTIAL NUMBERS.**

This product is highly toxic to bees exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees are visiting the treatment area. Contact your Cooperative Agricultural Extension Service or your local Bayer Environmental Science representative for further information.

DIRECTIONS FOR USE

is a violation of Federal law to use this product in a manner inconsistent with this label.

**GENERAL**  
Contact a physician immediately in case of poisoning. Do not induce vomiting unless directed to do so by a physician. Transport to a physician or hospital immediately. THIS LABEL TO THE PHYSICIAN. If poisoning is suspected, contact a veterinarian.

**ANTIDOTE STATEMENT**  
ATROPINE SULFATE IS HIGHLY EFFECTIVE AS AN ANTIDOTE. Atropine and other anticholinergics should not be used. Butane-2-diol (2-PAM) (pyridostigmine bromide) is not recommended. See NOTE TO PHYSICIAN.

**NOTE TO PHYSICIAN**  
Treat symptomatically. Overexposure to materials other than this product may be assumed. Carbaryl is an N-methyl carbamate insecticide, which is a cholinesterase inhibitor. Overexposure to this substance may cause toxicities and symptoms due to stimulation of the cholinergic nervous system. These effects of overexposure are spontaneous and rapidly reversible. Gastric lavage may be used if the product has been swallowed. Gastric lavage may occur rapidly after ingestion and prompt removal of stomach contents is indicated. Specific treatment consists of general atropine sulfate. Atropine should be administered to prevent overstimulation. Improve blood coagulation as much as possible before administering atropine to minimize the risk of ventricular fibrillation. Mild cases may be given 1 to 2 mg intravenously every 10 minutes until full atropinization has been achieved and repeated thereafter whenever symptoms reappear. Severe cases should be given 2 to 4 mg intravenously every 10 minutes until fully atropinized, then intramuscularly every 30 to 60 minutes as needed to maintain the effect for at least 12 hours. Danger for children should be appropriately reduced. Complete recovery from overexposure is to be expected within 24 hours.

**USER SAFETY RECOMMENDATIONS**  
Users should wash hands before eating, drinking, chewing gum, using tobacco, or using the toilet. Remove clothing immediately if pesticide gets on. Wash thoroughly and put on clean clothing.

**ENVIRONMENTAL HAZARDS**  
This product is extremely toxic to aquatic and estuarine invertebrates. For terrestrial uses, do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Discharge from rice fields may kill aquatic and estuarine invertebrates. Do not apply when weather conditions favor drift from area treated. Do not contaminate water by cleaning equipment or disposal of wastes. Do not contaminate water when disposing of equipment washwaters.

**BEE CAUTION: MAY KILL HONEYBEES IN SUBSTANTIAL NUMBERS.**

This product is highly toxic to bees exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees are visiting the treatment area. Contact your Cooperative Agricultural Extension Service or your local Bayer Environmental Science representative for further information.

DIRECTIONS FOR USE

is a violation of Federal law to use this product in a manner inconsistent with this label.

Read the label carefully before using this product.

This Supplemental Label must be in possession of the user at the time of pesticide application.

Note environmental considerations – users must apply pesticides following instructions on the label of each pesticide.

## IRRIGATION MANAGEMENT PRACTICES

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Nursery operators should be familiar with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) that regulates label requirements. Users must apply pesticides in accordance with the instructions on the label of each pesticide product and, when required, must be trained and certified in the proper use of the pesticide.

**# 63** Evaluate the soil and physical characteristics of the site including mixing, loading, and storage areas for potential leaching or runoff of pesticides.

If pesticide leaching or runoff is likely to occur, steps should be taken to prevent contamination. In situations where the potential for pesticide loss is high, emphasis should be given to management practices that minimize potential losses. Physical characteristics considered should include limitations based on environmental hazards or concerns, some of which are listed below.

- Sinkholes, wells, and other areas of direct access to groundwater
- Proximity to surface water
- Runoff potential
- Wind erosion and prevailing wind direction
- Highly erodible soils
- Soils with poor adsorptive capacity
- Highly permeable soils
- Shallow aquifers
- Wellhead protection areas
- Proximity to dwellings
- Domestic animals, wildlife, and animal feed

**# 64** Pesticides used should have a low water solubility and/or a low potential risk for leaching.

**# 65** Pesticides used should have a short half-life to reduce the persistence of the pesticide in the soil, and thus the opportunity for leaching.

**# 66** Pesticide applications should be timed well in advance of irrigation and unfavorable weather conditions (preferably 48 hours if possible).

The interval between pesticide application and irrigation or rain is closely related to the amount of pesticide runoff and leaching loss. Use timing of container operations (potting and irrigating) to minimize applications, pest habitats, and runoff of pesticides. Apply pesticides to dry foliage. Foliar applications result in only a small amount of the pesticide reaching the soil surface, and incorporation decreases runoff. Banding of pesticides, applying to non-spaced containers (containers pot-to-pot), or staggering applications so the total land area does not receive an application at one time can also minimize runoff.



*Pesticides should be applied to non-spaced containers to reduce non-target pesticide losses.*

- # 67** Limit the irrigation volume in the first irrigation after pesticide application to reduce runoff volume. The pesticide load in runoff is directly related to the volume of runoff water.
- # 68** Cyclic irrigation should be used to minimize pesticide runoff volume.
- # 69** Runoff should be channeled through vegetated or physical (gravel, bark) waterways to trap sediments and pesticides and to permit infiltration and degradation.
- # 70** Pesticides should NOT be injected into the overhead irrigation system unless permitted by label and regulations.
- # 71** To minimize chemical waste and potential contamination of runoff, growers should (when possible) apply pesticides to non-spaced (jammed) containers.

## Operation and Maintenance for Pesticide Management

### Equipment

All pesticide application equipment should be maintained in good working condition and have known replacement, repair, and wear items identified. Frequently replaced spare parts should be kept on hand. Calibration of equipment should be conducted prior to pesticide mixing and loading, and at a minimum, prior to each season of application or when a change in pesticide application is made.

**# 72** All pesticide application equipment should be maintained and calibrated on a regular basis.

**# 73** Anti-backflow devices should be on hoses used for filling tanks.

### Storage

Chemical storage facilities must be designed and located such that weather conditions or accidental spills or leakage will not result in undesirable effect on the soil, water, air, or plants. Chemical storage facilities should be posted with adequate safety warning signs.

Pesticides are stored in their original containers in environmentally safe and secure locations. Storage should be secure and include proper ventilation and control for any potential chemical leakage that may contaminate water sources or be a detriment to living organisms. Container exposure to sunlight and weather should also be considered. Designs for chemical storage and handling facilities can be obtained from your local University Extension Service office or from your local NRCS office.



*Pesticide storage facilities must be designed to reduce undesirable effects of pesticide spills on the environment.*

**# 74** Chemicals should be stored in their original container within a properly designed facility that is adequately posted with warning signs.

### ***Mixing, Loading, and Rinsing***

Research has indicated that one of the greatest potentials for groundwater contamination from pesticides comes from spills, which may occur during mixing and loading. The location and design of proper mixing, loading, and equipment rinsing stations relative to potential contamination of ground or surface water should be considered.

To protect from groundwater contamination, mixing, loading, and rinsing should be done on an impervious surface covered with a roof and surrounded by impervious curbing. Clean pesticide application equipment so that wash water and waste products can be disposed of safely. Rinse water from equipment and containers should be stored and used in the following batch mixture where possible. Where disposal is necessary and allowed by law and regulations, it should be performed avoiding runoff and leaching to areas such as: ponds, lakes, streams, canals, and other water bodies.

Mixing and cleaning operations should not be performed on highly permeable soil and all operations should be performed at a safe distance (100 ft.) from any well. When wells are in close proximity, extreme care must be exercised when mixing or applying chemicals. Anti-siphon devices should be used to prevent backflow into the well.



*Mixing, loading, and rinsing of pesticides should be done on an impervious surface covered with a roof and surrounded by impervious curbing.*

- # 75** Pesticide mixing and rinsing should be done on an impervious surface covered with a roof and surrounded by impervious curbing.
- # 76** Pesticide mixing and rinsing stations should have capture and recycle capability to prevent pollution by contaminated runoff from the station.
- # 77** Spray tank rinse water should be sprayed onto crops or placed in a storage container.
- # 78** Empty pesticide containers should be disposed of according to instructions provided on the container.

### ***Other Pesticide Considerations***

Pesticide applicators will follow recommended rates, use recommended methods of container disposal, and follow all other instructions on the label (re-entry interval, worker protection standards, etc.). Monitor the pH of makeup water, as alkaline water, unless buffered, can decrease the efficacy of alkaline sensitive pesticides. Disposal of excess pesticides often cause water quality concerns.

**# 79** Only the amount of pesticide needed should be mixed for application.

Conduct and document Worker Protection Standards training sessions to train nursery workers and pesticide handlers to use correct procedures for pesticides: applications, mixing, loading, handling, posting, record-keeping, re-entry of treated areas, use of personal protective equipment (PPE), and emergency assistance. Provide decontamination sites and post information in a central location.

**# 80** Participate in pesticide recycling programs.