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Soil, Water, Nutrient and Pesticide Agricultural Management Practices for Container Nurseries in the Upper Cohansey River Watershed

James Johnson
Agricultural Agent
Cumberland County

Dr. Salvatore Mangiafico
Environmental and Resource Management Agent
Cumberland & Salem Counties

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Introduction

New Jersey has many attributes that make it an ideal spot to produce nursery plants. The marketing potential is great since it is geographically located in the center of the "BosWash" megalopolis. The megalopolis is around 500 miles long from the areas of Boston, Massachusetts to Washington, DC and has a population of approximately 44 million people. That represents 16% of the total population of the United States.

Unfortunately, New Jersey is also an expensive state in which to conduct business. The cost of land and higher than average operational costs force producers to find ways to maximize production in a way that also protects the environment. While these factors are generally considered to be negative, they also provide opportunities for the good manager and a container operation.

In a perfect world, nurseries would be designed for maximum efficiency with minimal environmental impact. In reality, few nurserymen have financial resources adequate to complete the planning and installation of such a facility when they are starting out in the business. If an established nursery moves to a new site, one should take advantage of the opportunity. The result of not designing from the ground up is the need for retrofitting existing nurseries. One should remember, however, that lack of finances to build a state-of-the-art nursery doesn't mean one should not plan for that nursery. Nurseries should plan for the future while building for the present.

Infrastructure efficiency of plant and support materials handling is critical to profitability. One must maximize space use and minimized the number of times plants are moved. One should examine and evaluate everything. Included would be identifying where raw materials are stored, where substrate (container media) is prepared, the potting location, how plant material is moved within the nursery, and how plant material is sold off the nursery to include site selection of transportation docks and handling facilities.

When designing the nursery, there should be special attention toward water movement that minimizes environmental impact. Runoff water is typically higher in nutrient content than surface or groundwater and can carry sediment and pesticides. Because of the need to have minimal environmental impact, it is important to capture and re-use excess irrigation water. The need to also capture a certain amount of water from rainfall is a compounding factor. The reason for capturing water from rainfall is that there is typically a nutrient load that comes from the nursery associated with the early stages of a rain event. Optimally, nurseries should develop the capability to capture the first inch of a rain event.

A system for capturing and treating excess irrigation and rainfall water may include a biofilter, an impoundment and a filtration system. A biofilter is an area of vegetation where runoff is slowed, allowing sediment to be removed from the water. Plants and microbes in the biofilter help reduce nutrient content in the water. An impoundment is a natural or constructed basin that captures and stores runoff. Water in the impoundment can be recycled, which entails treatment and reuse for irrigation. When water from an impoundment is used for irrigation, a filtration system may be necessary to reduce water particulate matter so sprinklers won't plug. Because impoundments may overflow during significant rain events, an additional biofilter can be placed to further remove pollutants from the water leaving the nursery before it enters ground or surface waters.

Plant grouping is encouraged to help reduce water or nutrient use or to enhance pesticide use safety. A partial list of species with low, medium, or high irrigation requirements is included in Appendix 2. Foliage characteristics (dense vs. sparse leaves, and branching) will affect water use by plants. Certain plant species will channel more overhead water into a container than others; this is a lesser consideration if using micro-irrigation. Water use is also affected by plant growth. During rapid growth (usually spring and summer), the plants require more water than during times of slower growth (winter). A partial list of plants with low, medium, or high nutritional requirements when container-grown is included in Appendix 3. If fertilizer is applied through the irrigation system or it is applied overhead, many of the plant environment characteristics noted for irrigation requirements will apply. Grouping by pesticide requirements is usually much more difficult. Recommendations for pesticide use on nursery stock can be found in Rutgers Cooperative Extension Publication #E036: Pest Control Recommendations for Shade Trees and Commercial Nursery Crops (available online at <http://njaes.rutgers.edu/pubs/publication.asp?pid=e036>)

Irrigation Management

Water Use Certification

Prior to starting a nursery, it is important to establish the right to use water in the state of New Jersey. The New Jersey Department of Environmental Protection (NJDEP) administers the water use certification program. It is required that one be certified for water use when there is a water need in excess of 100,000 gallons per day or one has the capability to pump water at a rate over 70 gallons per minute. Remember that a permit to drill a well is not a permit to use the water from that well. It is increasingly important to use the most efficient methods of irrigation because of limits being placed on allowable water use. Factors that have increased water regulation include the need to conserve water in designated critical areas with limited water supplies and perceived overuse of water resources. One can get additional information on the water certification program through your local Rutgers Cooperative Extension Agricultural Agent or through the NJDEP.

Water Quality

High quality water is necessary for nursery industry success. Water should be evaluated for pH and soluble salts. If salts are elevated, water should also be checked for sodium. Iron and sulfur may also be of importance, especially in regard to their cosmetic effect on many species of plants (leaf discoloration). For container irrigation, it is generally preferable to use a groundwater source rather than surface water. If surface water is used, it may be necessary to filter it to prevent the clogging of irrigation nozzles, misters, or micro-irrigation emitters. If the pH of the water is elevated, pesticide labels should be carefully reviewed to determine the potential for pesticide deactivation.

Water Quality Monitoring

1. Water quality should be monitored at least twice a year (preferably during extended periods of wet and dry weather). More frequent monitoring may be needed to adjust production practices in response to changes in water quality.
2. Water quality should always be monitored prior to locating a new nursery, moving to a new site, or using a new water source. Test the water quality to ensure that the concentration of chemical constituents is acceptable for plant growth according to guidelines.

Irrigation Water Quality Guidelines

Table 1: General irrigation water quality guidelines for container plant production.

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

Table 2: Irrigation water quality guidelines for micro-irrigation.

	Degree of Problem		
Characteristic	None	Increasing	Severe
Hydrogen Sulfide (H_2S) (ppm)	< 0.1	0.1 – 0.5	> 0.5
Iron (Fe^{++}) (ppm)	< 0.2	0.2 – 0.3	> 0.3
Tannins, Phenolics, Humic Acids (ppm)	-	-	> 2.0
Total Dissolved Solids (TDS, ppm)	< 525	525 – 2100	> 2100
Suspended Solids (ppm)	< 50	50 – 100	>100

Water Treatment

Treatment of irrigation water may be necessary if the water quality is poor. In New Jersey there is usually no need to change the water pH. If it is necessary to reduce the pH, the addition of an acid to the water will work. Remember that acidification will not reduce the salt concentration of water with a high soluble salt content. Deionization and reverse osmosis can be used to remove salts from irrigation water. These water treatments are used if soluble salts, especially sodium, are high enough to cause plant damage. These are expensive treatments and so are generally limited to high value crops.

Water System Design and Management

Designing an Irrigation System

Irrigation systems should be designed to maximize the amount of irrigation water reaching the plant substrate while minimizing water that lands away from plant material. Test them with a water collection system to measure the amount of water applied and the uniformity of application. The water collection system can be as simple as placing same sized containers in various locations within the plant growing area, running the irrigation system and then measuring differences between water quantities collected in the containers. Different sprinkler heads will result in widely different dispersal patterns. Be sure to test when there is little air movement as well as when there is increased wind. Determine the maximum wind speed under which plant material can be effectively irrigated.

When to Irrigate

The amount of irrigation water needed per application depends on container size, growing substrate, plant species, and weather conditions. A substrate's water absorptive capacity is similar to that of a sponge. When relatively moist, there is a low water absorption capacity. When relatively dry, there is a high water adsorption capacity. Organic media tend to become hydrophobic when they get excessively dry, will tend to allow irrigation water to run through resulting in very little adsorption and will hold be quite difficult to re-wet. If the substrate is too wet, it will also hold very little water.

Growers can get a feel for the amount of water needed by checking the water content of the substrate as well as taking into consideration weather conditions since the previous irrigation. By adjusting the irrigation amount according to the amount of water lost since the last irrigation, growers can greatly reduce the amount of water they use and reduce the amount of fertilizer exiting containers through excess leaching.

Increasing the substrate's water-holding capacity can decrease the frequency of irrigation. Substrates with a higher proportion of fine particles, including water-holding organic materials like peat and coir, will retain more water. An increase in water-holding capacity of substrate must be balanced with the need to maintain air-filled pore space in the substrate. A substrate with insufficient air-filled pore space will be excessively wet and have a higher potential for the incidence of diseases such as *Phytophthora* or *Pythium*. Materials such as vermiculite, perlite or rice hulls are added to substrate mixes to increase air-filled pore space.

Cyclic Irrigation

Most nurseries irrigate on a daily basis with water being applied in a single, continuous application. An alternative approach to help increase the water-holding capacity is cyclic irrigation in which the daily water allotment is applied in more than one application with timed intervals between applications. For example, using cyclic irrigation, one might apply three 0.1-inch doses of water lasting about 20 minutes each. The first hour 0.1 inch would be applied, one hour later another 0.1 inch and the final 0.1 inch of water would be applied one hour after the last application. This would replace a single application of 0.3 inch in 1 hour.

Compared to continuous irrigation, cyclic irrigation has been shown to reduce the volume of irrigation runoff by 30% and the amount of nitrate leached from containers by as much as 41% (Fare et al. 1994). Growers have also indicated that the amount of water applied per cycle can be reduced because of better wetting characteristics, resulting in a net water savings. Cyclic irrigation can be used with both overhead and micro-irrigation systems. Using timers and solenoid valves is desirable when applying cyclic irrigation because manual control can become cumbersome.

Electronic control of irrigation systems has been developed using several different soil moisture sensing devices appropriate for use in containers. These systems can be used to indicate when to irrigate and how much water to apply. While they have been used successfully in nursery situations, an understanding of the limitations of individual sensors is important since many have some limitations such as erroneous readings caused by elevated salt levels in the substrate. A successful approach is to use more than one system, so that the strengths of one system offset the weaknesses of the other.

Micro-irrigation

Micro-irrigation is a method of irrigating where water is applied at a relatively slow rate and usually directly to the container substrate. While a variety of emitters can be used, point source emitters (in-line emitters, spray stakes, spaghetti drippers, etc.) are generally used for container production. Irrigating container-grown plants with micro-irrigation can result in water, fertilizer and pesticide savings as compared to overhead irrigation. Additional savings are realized because micro-irrigation systems require smaller pumps and pipe sizes. However, micro-irrigation systems generally have higher initial and maintenance costs. Use of micro-irrigation also affords the opportunity to harvest crops shortly after irrigation because most of the soil is not wetted.

Sub-irrigation

Use of a sub-irrigation system is another irrigation option. A capillary mat system employs a water-conducting porous plastic mat to conduct water to plants. The ebb-and-flow system uses a flooded bed in which the base of the container is submerged in water during the flood cycle and water is absorbed by the substrate through capillary action. Following irrigation, water drains from the production area into a reservoir. Sub-irrigation has become increasingly important in greenhouse production systems. Advantages include eliminating runoff leaving the production area and conserving water and fertilizer. Care must be taken to avoid salt accumulation in container substrate and disease transmission among plants through recycled water.

Irrigation Uniformity

The uniformity of water application and efficiency of an irrigation system tends to decrease over time because of wear. Maintenance is required to retain efficiency and that justifies the need to test the system annually at the start of the season. Use the same water collection system as described in the “Designing an Irrigation System” section. When irrigation uniformity decreases and water is wasted, disease problems tend to increase and crops become less uniform. Be sure to keep baseline information developed when the system was new for comparison during annual inspections. As irrigation uniformity becomes less acceptable, repairs, replacements and adjustments must be performed.

Management of Irrigation Systems

1. Irrigation should be scheduled (both when to initiate irrigation and the duration) based on plant demand. Schedules can be determined by container weight, color or feel of substrate, or electronically measuring substrate moisture content. Remember, when plants show moisture stress growth has been lost.
2. A substrate’s water-holding capacity is related to the pre-irrigation substrate water content. Substrates that are moist will require less irrigation water to complete wetting than a substrate that has excessively dried.
3. Irrigation should be managed to minimally exceed the water-holding capacity of the substrate. Be sure there is enough water applied to have 15% of the water leach through the substrate to control soluble salts. It is helpful to occasionally measure the actual volume of the leachate to avoid insufficient or excessive leaching. When attempting to limit water use during extended periods of limited rainfall, soluble salts can build up in the center portion of containers. Leaching is critical to avoid plant injury.
4. When using timer-controlled automated systems, a main shutoff device should be used to prevent irrigation system operation during significant rainfall events.
5. Where practical, use substrate moisture sensors or a class A evaporation pan calibrated to plant demand to help schedule irrigation applications.
6. Where practical, use cyclic irrigation to decrease the amount of water and nutrients exiting the container.
7. Micro-irrigation should be used for large containers (7 gallons and larger) to minimize water loss between containers.

8. When practical, the irrigation system should be separated into zones to match plant irrigation needs. If possible, plants with similar irrigation requirements should be grouped into the same irrigation zone.
9. Irrigation should be scheduled to allow the maximum time following pesticide applications.
10. When practical, irrigation should be applied during time of minimal wind.
11. Personnel need to be trained in irrigation management, procedures for recording water use and problem reporting.
12. Avoid irrigating areas without plants, considering both non-crop areas like roads and walkways and crop areas where plants have been removed. Consolidate plants from partially filled irrigation zones.
13. When using overhead irrigation, keep plant spacing close to minimize water falling between pots, while leaving enough space between pots to allow sufficient air flow around foliage.
14. Use a well-designed irrigation system and keep it maintained. Maintain water pressure appropriate for sprinklers to maintain desired drop site. Use identical emitters within a zone. Maintain filters and inspect the performance of the irrigation system. Space overhead sprinklers to achieve head-to-head coverage.

Irrigation for Heat or Cold Protection

1. Water application should be initiated as the air temperature nears the critically hot temperature for plant injury. Intermittent syringing of the foliage is important to avoid serious wilting. One must carefully consider not only the temperature, but also the wind speed and relative humidity, as they will increase plant stress as winds increase and the relative humidity decreases.
2. Water application should be initiated as the air temperature nears critically cool temperatures for plant injury. When irrigation is started for cold protection, it should continue until ice has melted off the plant material. Review weather forecast. Irrigating for cold protection is only effective for relatively short cold snaps.

Runoff Water Management

Erosion Control

Water erosion is the process by which the land surface is worn away by water flowing over exposed soil. In the process, water picks up detached soil particles and debris that may contain chemicals harmful to receiving waters. Erosive forces increase as the velocity of flowing water increases resulting in small channels and eventually gullies of varying widths and depths. Soil erosion, therefore, should be avoided for two reasons: first, because it entails a loss and degradation of soil onsite; second, because the sediment and chemicals associated with the sediment particles can be harmful if it enters surface water bodies. Sedimentation is the process where soil particles settle out of suspension as the velocity of water decreases. Larger and heavier particles (gravel and sand) settle out more rapidly than fine silt and clay particles. It is difficult to totally eliminate the transportation of these fine particles even with the most effective erosion control program. A well-designed nursery facility will help reduce erosion from both irrigation and rain events.

Each container nursery should develop a plan for erosion and sediment control. Personnel from the local Natural Resources Conservation Service (NRCS) and Soil Conservation District (SCD) can help with design planning. The plan should address: 1) preventing slope soil erosion by using vegetative cover and other means; 2) a system to capture excess irrigation water; 3) a method to remove sediment from excess irrigation water; 4) a designed biofilter to remove nutrients and other chemicals from the water (e.g.: vegetated buffers, wetland areas, or grassed waterways).

Most slopes can be stabilized with a permanent vegetative cover. A temporary cover can be used for quick establishment until a permanent cover can be established. While grasses will form the basis for stabilization, woody plant material can be incorporated to reduce wind, noise and dust as appropriate. Ground covers can also be used in the stabilization scheme, especially on slopes where mowing is not feasible or in shaded areas where grass establishment is difficult.

Mulching includes using a protective layer of straw, plant residues, stone, or synthetic materials to protect the soil surface from the forces of raindrop impact and overland flow. Mulch fosters the growth of vegetation and reduces evaporation. Organic mulches such as straw, wood chips and shredded bark have been found to be the most effective materials. A variety of erosion control blankets have been developed in recent years for use as mulch, particularly in critical areas such as waterways and channels. Jute mesh or various types of netting are very effective in holding mulch in place on waterways and slopes before grasses become established.

A filter strip is an area of vegetation that removes sediment, organic matter and other contaminants from runoff and wastewater. They do this by filtration, deposition infiltration, absorption, decomposition and volatilization, thereby reducing pollution and protecting the environment. Often they do not filter out soluble materials. This type of filter is often wet, difficult to maintain and should not be used as travel lanes.

A vegetated buffer strip is a form of a filter strip. It is usually viewed as a protective barrier to a sensitive area such as a river. It should be retained in its natural state if created along the banks of water bodies. Vegetated buffers prevent erosion, trap sediment, filter runoff and function as a floodplain during periods of high water. Design of filter strips should be site specific because of topographic differences in sites. Slope, soil type, vegetative cover and other runoff control measures may differ for different sites. It is important in the design of the slope that buffer strips do not cause flow concentrations that will result in erosion or carry sediment across the buffer.

Collection

A water collection basin or impoundment is a primary means of reducing potential water quality problems. It should be the goal of each container nursery operation that no irrigation water leaves the property.

During the irrigation season, to the maximum extent practicable, all irrigation return flows should be recycled with no discharge back to public waters. As a general rule, newly constructed water collection and recycling facilities should be designed to accommodate the irrigation return flow.

Basins are typically constructed with an emergency overflow to prevent dike damage that can result from storm water overtopping. Basins or other structures that are planned for construction must have all permits. Where rainwater is allowed to discharge from the property, it must be considered in the design of the water collection basin. The Natural Resources Conservation Service and/or the local Soil Conservation District can provide design criteria and expertise to help develop the best plans for the nursery collection or retention basin.

Systems should be designed to collect a certain amount of storm water runoff in addition to irrigation water. Some locations require that the first inch of storm water be collected. Storm water runoff should not be discharged directly into surface or ground waters. Runoff should be routed over a longer distance, through grass waterways, wetlands, vegetative buffers and other places 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.

Wetlands

A constructed wetland is an aquatic ecosystem with rooted emergent hydrophytes designed and managed to treat agricultural wastewater. The plants extract water and nutrients and add oxygen to the root zone to help in the treatment process. There are a number of attractive herbaceous and woody plants that are adapted to permanently saturated soil conditions including species of cattails, bulrushes, iris, oak, willow, rose, hibiscus and lobelia. A constructed wetland used to treat runoff typically includes an impervious subsurface barrier, a suitable substrate for the hydrophytic vegetation, the plants, wastewater or runoff flowing at a slow 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. The wetland concept has been identified as a beneficial filter for environmental contaminants. The Natural Resources Conservation Service may be able to assist in design.

Recycling Water

Water collected in an impoundment can potentially be recycled. Use of recycled water may require some treatment because elevated soluble salts or concerns about disease organisms. Reduction of soluble salts is most cost-effectively addressed by blending recycled water with clean water. Blending also offers safety benefits if concerns exist with regard to residual farm chemicals in the water.

Techniques used to reduce biological organisms in the water include use of chlorine, bromine and ozone or treatment with UV light. Chlorine has been used most extensively in the past, but bromine has been reported to have a broader spectrum of activity on plant pathogens. Bromine in the form of tablets is also safer and easier to handle than chlorine gas. Ozone and UV lighting has been tested with apparent success in nurseries for treating recycled water. Ozone generators can treat large quantities of recycled water faster and safer than chlorine or bromine. It is important to check with the NJDEP to determine if there are any use restrictions on treatment options. Local officials should also be contacted regarding proper notification and reporting when using acid, chlorine, bromine or ozone.

Limited investigation into possible problems with traces of organic chemicals remaining in recycled water has not confirmed that this is a significant concern. A brief review of the subject was prepared (2). It is presently available on the Internet. Even with limited risk it is important to be observant for possible damage to plants from chemical residues in recycled water, especially considering that most nurseries produce a wide variety of plant materials and that some types will be more sensitive than others.

Nutrient Management

The goal of a nutrient management program is to apply the minimal amount of fertilizer that will result in the maximum desired growth rate, flower production, foliage color enhancement, or expected plant quality. The amount of fertilizer needed to achieve the desired response is impacted by container irrigation management practices, as previously discussed, and properties of the substrate, which is discussed below. Considering these factors, nursery operators can develop a nutrient management plan and achieve minimal fertilizer losses from containers.

Substrates

Many terms, including *soil*, *soil-less media*, *potting mix*, *container mix* and *substrate* are used to describe potting materials for growing plants. However, many of these terms are imprecise or can be confusing. *Container mix* and *potting mix* imply that more than one component is used. The term *substrate* avoids much of the confusion of other terms and is descriptive of the entire composition. *Substrate* is the term used in Europe and most other parts of the world to describe the components of the root rhizosphere within containers.

Many materials are used as nursery container substrates. The predominant components in the New Jersey and the mid-Atlantic area are pine bark, sphagnum peat moss, vermiculite and sand. Many other materials have been used with varying levels of success. The wetability, stability, chemical and physical characteristics tend to limit the portion of alternative materials that can be used in a potting substrate. Organic components that have not been aged are not stable and may decompose rapidly, causing what is referred to as “shrinkage”. Containers that were full at the potting can rapidly lose substrate volume resulting in a change in characteristics of that substrate. Some composted materials lack the coarse large particles necessary for adequate aeration and limit their use as a container substrate. Some composted materials have high salt levels.

Use of a line-mixer for blending components of the substrate is the optimal method. If blending on the ground, use a concrete slab that does not allow for standing water. In all cases, be sure areas surrounding substrate preparation and storage are kept mowed to prevent weed seeds from contaminating the substrate. Sanitation is the first step toward a weed-free nursery.

When choosing a container substrate, determine ones that are best adapted to plant growth and management. Use stable substrate components that do not decompose rapidly. Check potential organic substrates for weed seed, nematodes, pathogens and chemical contaminants.

Preparing Substrates

Substrate preparation (mixing) systems used in Southern New Jersey include pad mixing, paddle mixing and line mixing. While each has their strengths and weaknesses, all mixing systems have the potential for releasing particulate matter to the air. The pad, tumble and line mixers are the primary types used in commercial operations, although the paddle type of mixer has been used for starting nurseries and for small batch mixing.

Of the three systems used commercially, line mixing generally results in the best media quality and consistency. This is because they produce a uniform product and they tend to have fewer problems breaking down medium components. Breaking down medium components reduces porosity and ultimately can increase the incidence of root diseases.

All mixing systems will generate dust. There are things one can do to minimize worker exposure. Requiring use of a dust mask can dramatically reduce worker exposure. The following are some infrastructure changes that may help and should be evaluated.

- Install a sprinkler system on the mixer to settle dust that might be generated.
- Install a semi-permeable screen to reduce the effect of wind on any dust that might be generated (semi-permeability reduces turbulence effects that may occur as wind wraps around a non-permeable structure).
- Mix during times of the day when there is less wind.

Further reductions can be accomplished by locating the mixing site away from property borders. If centralizing the location is either not practical or wind continues to move dust, windbreaks may be planted near property boundaries. Windbreaks should contain both deciduous and evergreen species. Be sure to evaluate movement of dust during the various times of the year one may be mixing since wind direction changes seasonally.

Container Substrate Physical Properties

The physical characteristics of container substrate dictate how much water and oxygen are available to roots. The characteristics that have the majority of impact on plant growth are bulk density, air space and container moisture capacity. Achieving a fundamental understanding of these physical characteristics is essential to proper irrigation and fertilization management.

The bulk density refers to the weight of substrate per unit volume of substrate particles (usually expressed in grams per cubic centimeter, g/cc). Bulk density values for pine bark range from 0.19 to 0.24 g/cc depending on the particle size distribution of the pine bark. The bulk density for peat ranges from 0.05 to 0.5 g/cc. Particle size distribution refers to sizes of particles (dust-like to chunks) that compose a substrate.

The particle size distribution, particle density and nesting of substrate component particles greatly influence the size and distribution of pore spaces in the substrate and therefore the amount of water and air the wetted substrate will hold. Many sizes of pine bark are available ranging from fine to coarse; the size to be used is dependent on the type of crop and grower practices. Generally, coarse particles are better for peat and vermiculite while one should avoid bark that is either too small or too large. Experience is usually the best judge of which to use.

Pore spaces exist between substrate particles and within particles. When the substrate is fully wetted and allowed to drain, some pores will hold water and some will hold air. Water-filled pore space is critical in a substrate because these pores hold the water that will be taken up by the plants. Air-filled pore space is critical because these pores hold oxygen that is essential for root growth. The term "total porosity" refers to the total volume of pore space in a substrate and is expressed as a percentage of the total substrate volume. Recommended total porosity values range from 50 to 85 %. The term "air space" refers to the fraction of air-filled large pores (macropores) from which water drains following irrigation. Air space values are also expressed as a percentage of the total substrate volume and recommended values range from 10 to 30 %.

In general, a substrate with a relatively high proportion of micropores will have a high water-holding capacity due to the attraction of water for the walls of small pores. Also, such a substrate will have a relatively low total porosity value since small particles tend to nest or settle within each other. Substrates with a high proportion of micropores are substrates with a high proportion of fine particles.

Container capacity is the maximum volume of water that a substrate can retain following irrigation and drainage and is a measure of the potential water reservoir of a container. The term “water-holding capacity” is used synonymously. An area of saturation, called a perched water table, exists at the bottom of a container following irrigation and drainage. The height of the saturated area is greater for a fine textured (small pores) substrate than for a coarse textured (large pores) substrate. Above the perched water table there is a gradient of air-filled pore spaces. The amount of air-filled pores increases with the distance above the perched water table.

Container capacity is expressed on a volume basis as the percent of water retained relative to the substrate volume. Recommended container capacity values range from 45 to 65 %. The water in a substrate can also be classified as "available" or "unavailable." Available water is that fraction of the water that can be absorbed by roots. Unavailable water (hygroscopic water) is that fraction of water that is held tightly to particles and is unavailable to roots.

Container dimensions can affect the air space and container capacity. For example, a typical bark- filled 1-gallon container (6 inches tall) might have a perched water table that is 1 inch tall. Thus, the perched water table occupies 1/6 (17 %) of the container volume. Using the same substrate, a flat (3 inches tall) will also have a 1 inch perched water table; however, the water table will occupy 1/3 (33 %) of the flat volume. Bilderback and Fonteno, 1987, discuss further information on how container dimensions influence substrate characteristics.

The physical properties of a substrate are also affected by amending the principle substrate with another ingredient. Amending pine bark with sand increases the amount of available water and bulk density but decreases unavailable water, total porosity and air space. Adding peat moss to pine bark also increases the amount of available water. The water-holding capacity of the substrate must be balanced with the air-filled pore space. Insufficient air-filled pore space in the substrate will promote root rot diseases. Conversely, the substrate should have sufficient water-holding capacity to keep plants well supplied with water and avoid excessive leaching. The desired balance between water-holding capacity and air-filled pore space in a substrate can vary with the plant species to be grown.

A substrate with a high proportion of coarse particles has a high air space and a relatively low water-holding capacity. Consequently, leaching of pesticides and nutrients is likely to occur. Always test the physical characteristics of the substrate and use the substrate initially on a trial basis.

Table 3. Recommended physical characteristics for container substrates*:

Physical Characteristic	Recommended Range
Total Porosity	50 to 85 %
Air Space	10 to 30 %
Container Capacity	45 to 65 %
Available Water Content	25 to 35 %
Unavailable Water content	25 to 35 %
Bulk Density	0.19–0.70 g/cc.

*Following irrigation & drainage as a % of volume

Fertilization

The cation exchange capacity (CEC) indicates how well a substrate holds positively charged ions (cations) such as ammonium, potassium, calcium and magnesium against leaching. Typical CEC values (in milliequivalents per 100 milliliters of substrate, meq/100 ml) for several container substrate components are: aged pine bark, 10.6; sphagnum peat moss, 11.9; vermiculite, 4.9; and sand, 0.5.

The role of the CEC in soil-less substrates as related to plant nutrient uptake and leaching continues to be important. The pH continues to influence nutrient availability as it does in field soils. The optimum release rates, however, occur at a lower pH than in mineral soils. Research has indicated optimal nutrient availability to occur between a pH of 4 and 5 in bark and peat/bark substrates as opposed to a pH of 6 and 7 in mineral soils (1). The ability to hold nutrients in the substrate is also necessary to maintain plant nutrition and reduce leaching. Research has shown that nitrogen and phosphorus leach readily from container substrates (3, 4). A partial solution to reduce leaching is to use of controlled-release fertilizers as a basis for fertility programs.

The container system requires frequent irrigations because of the limited water volume that can be held by the substrate. Consequently, irrigation is a predominate factor in controlling container substrate nutrient levels. Soluble fertilizers injected frequently through the irrigation system or controlled-release fertilizers are used to provide a continuous supply of nutrients at optimal levels, but in small quantities necessary to minimize nutrient loss due to leaching. Specific nutrient levels and pH required for container substrates are discussed in the section on Interpretation of Substrate Extract Levels.

Pre-Plant Substrate Amendments

Dolomitic Limestone

Dolomitic limestone supplies calcium (Ca) and magnesium (Mg) and neutralizes the acidity of the growth substrate. The quantity of dolomitic limestone added to the substrate depends on irrigation water alkalinity and Ca and Mg content, initial pH of growth substrate and the plant species grown. In mineral soils, hollies, azaleas and other ericaceous plants grow best in substrates from pH 4.5 to 5.5, while Nandina, junipers, boxwood and many flowering shrubs require a substrate pH of 5.5 to 6.5. In organic substrates, the nutrient availability curve is lower than that in a mineral soil and optimal uptake of nutrients occurs approximately 1 pH unit below that of mineral soils. Plants requiring a lower pH range (e.g. ericaceous) continue to perform well in the pH of 4.5 to 5.5 while non-acid loving plant material continues to do well at pH reading down to 5.5. The dolomitic limestone requirement will vary based on substrate components. Typically, a bark-based substrate will require less Dolomitic lime to correct pH imbalance than a peat-based substrate. The pH should be monitored to determine how well the substrate pH is being maintained through the growing season.

Micronutrients

Micronutrients are essential for plant growth, but only small quantities are required. There are several micronutrient fertilizers sold commercially. These fertilizers usually contain the essential micronutrients and are added to the container substrate as an amendment. Micronutrient amendments are usually effective for up to two growing seasons unless irrigation water alkalinity is high, in which case additional applications of micronutrients may be needed. Micronutrients are also available commercially as a component of the macronutrient fertilizers. If composted yard debris or composted biosolids are 10 % or greater by volume of the substrate, then micronutrient needs may be met by these components.

Superphosphate

Phosphorus leaches rapidly from a soilless container substrate. Complete controlled-release fertilizers applied during the growing season should supply adequate phosphorus. Superphosphate should not be added to the container substrates when controlled-release fertilizers are used.

Fertilizer Applications

The preferred nutrient ratio for fertilization of container-grown plants during the growing season is approximately 3:1:2 ($N:P_2O_5:K_2O$). Fertilizer can be applied with one or more applications of a controlled-release fertilizer (CRF) or with a fertilizer solution through the irrigation system (fertigation).

Controlled-release fertilizers supply essential plant nutrients for an extended period of time (months). Fertilizers are available that contain different mechanisms of nutrient release and contain various components. CRF’s can be applied to the substrate surface or incorporated into the substrate prior to potting. High temperatures can result in excessively high soluble salt levels, so monitoring is important. If the CRF is incorporated, be sure to use it within a few days to prevent excessive soluble salt build-up. Avoid broadcasting CRF fertilizer on spaced containers.

Liquid fertilization should be applied at the frequency of application dependent on nutrient concentration in the substrate solution. When fertilizer is injected in the overhead irrigation system it will be necessary to take steps to capture the nutrient loaded runoff water so it will remain on-site. Fertilizing through the irrigation water is appropriate for low-volume irrigation systems in which irrigation water is delivered into the container. Even then, care should be taken to minimize leaching from the container to prevent nutrient laden runoff from entering surface or ground water.

Fertilizer Application Rate

The goal of a fertilizer program is to apply the least amount of fertilizer for the desired growth so that nutrient leaching is minimized. Fertilizer application rates will vary from product to product but will also depend on species and container size.

As a general rule, one should apply CRF’s at the manufacturer's recommended rate. Reapplication of a fertilizer should occur when substrate solution nutrient status is below desirable levels (see section on Monitor Container Substrate Nutrient Status).

Studies have shown that plant growth using 75% of the recommended rate of CRF are not significantly different than full CRF rates. Rates of CRF at 50% of the recommended rate combined with low rate fertigation have resulted in increased growth rates. Even when using lower rates of CRF, there remains the need to capture nutrient-rich runoff water for re-use.

Monitoring Container Substrates for Nutrient Status

To ensure adequate nutrient levels in the growth substrate, nursery operators should monitor the container substrate nutrient status and use the results to determine fertilizer reapplication frequency. Periodic monitoring is important because plant growth will be reduced when excessive or inadequate nutritional levels are present. Many times, this reduced growth may not be expressed by visual symptoms.

High concentrations of soluble salts can result from substrate components, inadequate irrigation frequency and duration, water source and/or fertilizer materials and application methods. Container substrate soluble salt levels may also accumulate during the overwintering of plants in polyhouses when fertilized with CRF's. Excessive nutrient concentrations injure roots, ultimately restricting water and nutrient uptake. That combination ultimately compounds the problem because the plant will remove fewer nutrients from the substrate. Conversely, rainfall and excessive irrigation can leach nutrients from the container substrate resulting in inadequate nutritional levels and threaten water quality.

How Often to Monitor

Substrate used for long-term crops should be tested at least monthly. Biweekly monitoring during the summer may be necessary to track fluctuations in electrical conductivity (EC). The EC level is a measurement of soluble salts in the substrate and is used as a relative indicator of the nutritional status. Even when controlled-release fertilizers are used, substrate nutritional levels will gradually fall during the growing season to levels that may not support optimal growth.

High temperatures in overwintering structures can result in nutrient release from controlled-release fertilizers. Monitor substrate electrical conductivity two or three times during the winter to ensure levels are not toxic.

Nutrients may accumulate in specific locations in substrate due to irrigation patterns and fertilization methods. Therefore, one isolated sample will not give an accurate representation of the nutrient status of the substrate.

Substrate Sampling Methods for Nutrient Extraction

Several procedures have been used to extract the nutrient solution from the container substrate. The liquid extracted or sample of liquid extracted is needed for nutritional analyses. The Virginia Tech Extraction Method (VTEM, also referred to as the pour-through or leachate collection method) enables rapid sample collection.

The Virginia Tech Extraction Method should be conducted about an hour or two after irrigation (so that the growth substrate has drained). Uniform moisture levels are critical for obtaining consistent results with time. The container is then placed in a collection pan with the bottom of container elevated above bottom of the pan.

The bottom or sides of the container do not need to be wiped before collecting leachate. The elevated container does not allow the container to come in contact with the liquid collected in the pan and thereby avoids contaminating the liquid. Apply water (in a circular motion) to the substrate surface to yield about 50 ml (1.5 oz) of leachate (liquid) from the container. Leachate should be collected from five to ten containers per production bed or area to obtain an average value for the five to ten individual samples. This average value should be representative of the growth substrate nutritional status. This method of leachate collection allows for nursery operators to make quick determinations of leachate electrical conductivity and pH. For additional analyses, samples can be sent to a laboratory for determination of elemental concentrations. All laboratories do not use the same procedures, so test results can differ between laboratories. Consequently, interpretation of results by the testing lab is very important.

Interpretation of Substrate Extract Levels

Container substrate nutritional levels in Table 2 may be used for interpreting levels obtained with the Virginia Tech Extraction Method. If nutritional levels that result from application of controlled-release fertilizers should drop below desirable levels during periods of active plant growth, then re-application should be considered to maintain optimal levels. Most fertilizers (except urea) are salts and when fertilizers are in solution they conduct electricity. Thus, the electrical conductivity of a substrate solution is indicative of the fertilizer level that is available to plant roots.

- Desirable container substrate electrical conductivity levels are 0.5 – 1.0 mmhos/cm for solution fertilizer only, controlled-release fertilizers or the combined use of controlled-release and solution fertilizer. Ranges given in Table 2 correspond to most container-grown landscape plants. However, adjustments must be made for plants known to be sensitive to fertilizer additions.
- Plants with a low nutrient requirement (Appendix 2) may grow adequately with nutrient levels lower than those given in Table 2.
- Measure the irrigation water electrical conductivity. The irrigation water electrical conductivity will allow you to know the contribution of your water to the extracted liquid or leachate electrical conductivity and this should be considered when interpreting the substrate electrical conductivity.

Table 4: Desirable nutritional substrate levels for container plants with high nutritional requirements. (Levels are for interpretation of the Virginia Tech Extraction Method when fertilizing with solution or liquid fertilizer alone or in combination with controlled-release (CR) fertilizer or using only controlled-release fertilizer.)

Analysis	Desirable levels	
	Solution only or CR and solution	CR fertilizer only
pH	5.0 to 6.0	5.0 to 6.0
Electrical conductivity, dS/m (mmhos/cm)	0.5 to 1.0	0.2 to 0.5
Nitrate-N, NO_3–N mg/L (ppm)	50 to 100	15 to 25
Phosphorus, P mg/L	10 to 15	5 to 10
Potassium, K mg/L	30 to 50	10 to 20
Calcium, Ca mg/L	20 to 40	20 to 40
Magnesium, Mg mg/L	15 to 20	15 to 20
Manganese, Mn mg/L	0.3	0.3
Iron, Fe mg/L	0.5	0.5
Zinc, Zn mg/L	0.2	0.2
Copper, Cu mg/L	0.02	0.02
Boron, B mg/L	0.05	0.05
Levels should not drop below these during periods of active growth. Plants with low nutritional requirements may grow adequately with lower nutrient levels. See Appendix 2 for various plant nutritional requirements.		

Supplemental Fertilization

When nutritional monitoring indicates the need for additional fertilizer, apply supplemental fertilizer to return the desired nutritional levels. The two application options are to apply fertilizer by injecting fertilizer into irrigation water or placing fertilizer on the surface of container substrate. When injected fertilizer is applied through an overhead irrigation system, runoff water will have a nutrient load and should be collected in an impoundment for reuse. It is recommended that one inject an individual element or a combination of elements in concentrations slightly less than desirable levels to be maintained in the growth substrate (Table 3).

Surface-applied fertilizer should be applied to specific blocks or groups of plants, thus minimizing nutrient loss and nutrient loading of runoff water. Broadcast fertilizer applications should be avoided whenever possible unless containers are closely spaced.

It is important to record all fertilizer applications. Good current and past records are valuable to help identify production problems. They also to help identify why things went better than expected and can be used to help fine-tune an already good program. Record as much information as possible. At a minimum, information should include fertilizer product name and analysis, date and location applied, and general notes about plant and environmental conditions. See Appendix 4 for a sample record sheet of fertilizer applications.

Foliar Analyses

Foliar analyses may be used to verify or diagnose deficiencies or toxicities during the growing season. They are also used to determine the elemental status of plant tissue in fall or winter prior to spring flush of growth. Where a problem exists, it is typically necessary to sample a “good” plant as well as a “bad” plant for basis of comparison. It is important to maintain good records of foliar analyses. Ideally, photographs of sampled plants should also be included. That will help form a database of desired nutritional levels for future plant production. A well-designed fertility program can eliminate the need for tissue testing.

Tissue Sampling Considerations

Generally, plants grown under similar conditions can be treated as a group when sampling, although samples from different species or cultivars should not be mixed. A tissue sample must be representative of plants sampled. An acre of plants of the same species that had been treated similarly would require only one to three composite samples while plants of the same species that have been grown under different cultural or environmental conditions, should be sampled separately.

Taking Tissue Samples

Take samples just before new flush of growth develops. Each sample should be composed of 20 – 30 uppermost mature leaves (or shoot tips) selected randomly from the group of plants. Only one or two leaves for broadleaf evergreens or one or two shoot tips (1-inch long) for narrow-leaved evergreens should be removed from a single plant to obtain a sample of green tissue that weighs from 10 to 30 grams (approximately one ounce). When sampling for diagnostic purposes, collect three samples of tissue that are the same age from abnormal or problem tissue and three samples of "normal tissue." Samples that represent different stages of the problem should be obtained to determine whether tissue elemental content changes as the problem progresses. Collect tissue samples in brown paper bags (not plastic lined) and mark with appropriate identification and sampling date.

Interpretation of Tissue Analyses

Elemental ranges for uppermost mature leaves of woody ornamental plants are given in Table 4. Compare the magnitude of Table 4 values with test results as well as the ratio between elements. Seldom are all elemental test values within the ranges given in Table 4, but these values are intended to be guidelines. Maintain tissue test records for they are valuable aids when making fertility management decisions and you will be able to refine the guidelines in Table 4 based on your experience and for your crops and growing conditions.

Table 5. Elemental ranges for uppermost mature leaves of woody ornamentals.

Element	Percent*	Element	Parts Per Million (ppm)
Nitrogen	2.0–2.5	Iron	100–200
Phosphorus	0.2–0.4	Manganese	50–100
Potassium	1.5–2.0	Zinc	20–75
Calcium	0.5–1.0	Copper	5–10
Magnesium	0.3–0.8	Boron	20–30
* Percent of leaf dry weight		Molybdenum	0.1–1.0

Pest Management

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 (herbicides, fungicides or insecticides) applications. Current pest control involves scouting for pests on a regular basis, identifying the pest and selecting appropriate chemicals that are environmentally friendly and target existing pest problems. Other good management practices include using low volume applicators and maintaining proper sprayer calibration and nozzle adjustments.

Rules and Regulations

- Pesticide Use Certification Program
  - All agricultural businesses that use pesticides must possess a pesticide applicator license. If the business applies pesticide only for their own business they should have a private license.
    - To receive a license, one must pass a test administered by the New Jersey Department of Environmental Protection (NJDEP).
    - Licenses are good for five years but need to be renewed annually. During the five-year license period one is expected to receive eight (8) credits of core and sixteen (16) credits of category recertification training.
- Employee requirements
  - Employees may apply pesticides as a “handler”. Annual training is required. A roster of trained handlers must be maintained.
  - Employees are required to have received EPA-approved Worker Protection Safety training every five years and have a current verification card in their possession.
- Reporting
  - Businesses need to inventory stored pesticides annually and submit a copy to the local fire company by May 1.

  - It is required that an annual use report be submitted to the NJDEP Pesticide Control Program office.
- A complete set of rules and regulations can be found on the Internet at: http://www.nj.gov/dep/enforcement/pcp/pcp-regs.htm.

Nursery Pest Management (NPM)

Pest management strategies should be used to minimize the amount of pesticides applied. That entails the application of pesticides based on need and requires monitoring to make that determination. In addition, pesticides should be applied efficiently and at times when runoff losses are unlikely.

Use of NPM strategies is a key element of pesticide management. NPM strategies follow many of the practices established by integrated pest management programs. The significant difference is that nursery stock is governed by a zero threshold requirement. That requirement is necessary to meet laws established for shipment of nursery plant material. The following is a list of NPM strategies:

- Apply insecticides and fungicides based on need. A scouting program to monitor pest problems is a necessary component of a NPM program. Only apply in anticipation of a pest problem when established environmental factors are present that predicts an outbreak. The major exception is that some disease pathogens require preventative sprays on susceptible crops.
- Use regular scouting to determine pest problems. Scouting can include direct observation or trapping with sticky cards or pheromone traps. Trained employees or professional pest control advisors should do scouting. Records of scouting results should be maintained, and there should be a designated person for making pest management decisions.
- Use effective pesticides, but choose those that are less environmentally persistent, toxic, or mobile.
- Maintain records on past pest problems, pesticide use, environmental and other information for treatment areas.
- Use control options that help maintain pest predators. Use pesticides that affect only target organisms and apply pesticides only to affected plant species or areas.
- Evaluate the use of pheromones:
  - For monitoring populations
  - For mass trapping
  - For disrupting mating or other behaviors of pests
  - To attract predators/parasites
- Destroy pest breeding, refuge and overwintering sites. Remove plant debris and keep them in a sealed container until disposal. Inspect and quarantine newly introduced plant material. When possible, choose plant species or cultivars that are known to be more resistant to common pests and diseases.
- Use spreader/stickers with fungicides and insecticidal sprays to increase efficiency and reduce losses due to rain or irrigation.

Pesticide Applications

When pesticide applications are necessary, growers should identify and evaluate pesticide options. Growers should develop a schedule that provides a rotation between pesticide classes to help reduce pest resistance to the controls. Where a choice of registered materials exists, producers are encouraged to choose the most environmentally benign pesticide products. Consider the persistence, toxicity, runoff and leaching potential of products along with other factors.

Growers should be licensed to use pesticides and meet the requirements of federal and state laws that regulate use of pesticides. Users must apply pesticides in accordance with the instructions on the label of each pesticide product and wear appropriate protective equipment. Farm-worker safety requirements should also be reviewed and met. A checklist of some pesticide safety needs follows:

- Calibrate pesticide spray equipment annually.
- Use backflow protection devices on hoses used for filling tank mixtures.
- Evaluate the soil and physical characteristics of the site. Locate mixing, loading and storage in areas that have a low potential leaching or runoff of pesticides. In situations where the potential for pesticide loss is high, emphasis should be given to practices and/or management practices that will minimize these potential losses. Recognize physical characteristics that may be impacted by pesticide movement and take steps to reduce the risk of an incident occurring.
    - Proximity to surface water
    - Runoff potential
    - Wind erosion and prevailing wind direction
    - Highly erodible soils
    - Highly permeable soils
    - Shallow aquifers
    - Wellhead protection areas
    - Proximity to dwellings
- When possible, use pesticides with a low solubility in water or a low potential risk for leaching.
- Use pesticides with a short half-life to reduce the persistence of the pesticide in the soil and thus the opportunity for leaching.
- Time the pesticide application as far in advance as possible of irrigation and unfavorable weather conditions. The interval between pesticide application and irrigation or rain is closely related to the amount of pesticide runoff and leaching loss. It also relates to pesticide efficacy against the pest.
- Use efficient application methods, e.g., banding of pesticides or applying chemicals when containers are jammed (containers spaced pot-to-pot), or stagger applications.

Operation and Maintenance of Pesticide Application Equipment

All pesticide application equipment should be maintained in good working condition and have known replacement, repair and wear items identified. Calibration of equipment should be conducted prior to the mixing and loading of pesticides, and at a minimum, prior to each season of application or when a change in pesticide application is made. All sprayer tanks should be locked when not in use to avoid possible contamination of spray materials. Even small quantities of herbicides in a spray tank not intended to contain those products can result in significant plant damage.

Storage

Chemical storage facilities must be designed or located such that weather conditions or accidental spills or leakage will not impact soil, water, air or plants. Chemical storage facilities should be posted with adequate safety warning signs and chemicals in storage must be reported to the local fire department annually. Store pesticides 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. Designs for chemical storage and handling facilities can be obtained through Rutgers Cooperative Extension or through your local Natural Resources Conservation Service office.

Mixing and Rinsing Stations

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

To protect against ground water contamination, mixing, loading and cleaning operations should be done on an impervious surface covered with a roof and surrounded by impervious curbing. Wash water and waste products used in cleaning of pesticide application equipment should be disposed of in a safe manner. 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 laws and regulations, it should be performed avoiding high runoff and leaching areas such as: ponds, lakes, streams and other water bodies. Disposal of empty pesticide containers should follow instructions provided on the container.

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-siphoning devices should always be used to prevent backflow into the well.

Other Pesticide Considerations

- Follow label guidelines:

  Pesticide applicators need to follow recommended rates, use recommended methods of container disposal and follow all other instructions (re-entry interval, worker protection standards, etc.) as indicated on the pesticide label.

- Mix only the amount of pesticide needed:

  Plan ahead and mix only the amount of pesticide needed. Disposal of excess pesticides often presents water quality problems.

- Comply with Worker Protection Standards:

  Worker Protection Standards training sessions need to be conducted (and documented) 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 necessary information in a central location.

- Stagger herbicide applications whenever possible:

  Since the major herbicide runoff from container nurseries occurs in the first 6 irrigations after application, staggering the herbicide applications over small areas should reduce peak loading of the system. Staggering applications would be preferable to one application over a large area.

- Apply pesticides to containers that are spaced optimally. Excessively wide spacing wastes pesticides and raises the potential for runoff.
- Avoid injecting pesticides into the overhead irrigation system.
- Select pesticides with lower water solubility.
- Participate in pesticide recycling programs.

System Integration: Grouping Plants

The content of this document is a review of recommended practices for production of container nursery plant material. It has been divided into the major categories of water management, nutrient management and pest management and it is recommended to group plants based on those categories for optimal efficiency.

There will always be reasons to modify grouping schemes within each category. As an example, when using controlled-release fertilizer for basal plant needs it may be more important to group according to the need for supplemental fertilization. It becomes increasingly important if the supplemental fertilizer is injected in irrigation water.

The larger challenge for growers is to balance the grouping needs between the water management, nutrient management and pest management categories. As an example, there will be often be times when grouping based on water will not be the best when considering either pesticide use or fertilization requirements. There is not just “one way” of doing things. Growing plants is a series of compromises.

As a grower, one must look for the best workable option. The ability to group plants based on all three management categories is highly improbable if not nearly impossible. One will need to develop a prioritized listing of critical needs. The management area that is most critical for optimal plant growth should be rated highest and should generally form the basis of one’s management program. As an example, if a plant is susceptible to root rots, watering may be the critical management area since plants will die if over-watered.

As a final thought, an agricultural management plan is a series of tools. It is the grower’s responsibility to choose the best tools for success in the nursery business. There is a combination that will maximize profitability while minimizing environmental impact for your business.

Glossary

Absorption - to take in through pores or membranes (such as water) or to hold within.

Acid - a substance that tends to give up protons (hydrogen ions) to some other substance.

Acidity - hydrogen ion activity measured and expressed as a pH value. A substance is considered acidic if the pH is less than 7.

Adsorption - the attraction of ions or compounds to the surface. Substrate particles can adsorb large amounts of ions and water.

Air space - the percentage of container volume occupied by air-filled large pores from which water drains following irrigation.

Alkalinity - concentration of bases often expressed as carbonate or bicarbonate equivalents. An alkaline substrate will have a pH greater than 7.

AMP - the Agricultural Management Practices (AMP's) include schedules of activities, prohibitions, maintenance procedures and structural or other management practices found to be the most effective and practicable methods to prevent or reduce the discharge of pollutants to the air or waters of the United States. Practices also include operating procedures and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Anion exchange capacity – the sum total exchangeable anions (negatively charged particles) that a soil or substrate can adsorb. Anionic compounds include sources of phosphorus (PO_4^{3-}), nitrogen (NO_3^-), and sulfur (S^- and SO_4^{2-}).

Base - a substance that tends to accept protons (hydrogen ions) from some other substance. Soil or water is considered basic if the pH is greater than 7.

Bicarbonate/carbonate - salts of carbonic acid that formed when carbon dioxide dissolves in water. In combination with sodium, calcium, and magnesium ($NaHCO_3$, $CaCO_3$ and $MgCO_3$), they have an alkalizing effect.

Biofilter – a living system of plants, including natural and constructed wetlands, located within a watercourse that uses nutrients in runoff water, captures sediment, and degrades other chemicals, thereby enhancing water quality.

Bulk density - the weight of dry substrate per unit volume of substrate (expressed in grams per cubic centimeter, g/cc).

Carbonate - see bicarbonate.

Cation Exchange Capacity (CEC) - total of exchangeable cations (positively charged ions) that a substrate can adsorb. Some cations of interest include ammonium (NH_4^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), all of which serve as plant nutrients, and hydrogen ions (H+) that cause soil acidity.

Collection basin (pond) – an enclosed body of water to collect excess water from irrigation or storm events.

Constructed wetland - a shallow bed filled with selected vegetation, such as cattails, into which runoff water is diverted and which serve as a biological filter for removing chemicals from the water. Constructed wetlands are designed to slow moving water, allowing time for treatment, and can use a variety of substrates, from native soil to sand or gravel. They can be designed to have the water level above the substrate surface or so that the water is kept below the surface.

Container capacity - the maximum volume of water that a substrate can retain following irrigation and drainage. It is a measure of the water reservoir in the container.

Controlled-release fertilizer (CRF) - a formulation of fertilizer where release time is controlled by the thickness of the coating (i.e. resin) or the amount of the release agent in the coating that dissolves in water to form pores in the coating (i.e. plastic). CRFs have the advantage over granular fertilizers of slowly but continually feeding crops and not exposing plants to a large dose of salt at one time.

Cyclic irrigation –an irrigation schedule in which a plant's daily water allotment is divided up and applied in a series of irrigation and rest intervals throughout the day.

Deionization - a technique used to remove ions (charged particles) from irrigation water. Systems are available that combine pre-filtration, mixed-bed resins, activated carbon and final filtration.

Electrical conductivity (EC) - the measure of salt content of water based on the flow of electrical current. When the salt content increases, there is greater the flow of electrical current. EC is measured in mmhos/ cm or deciSiemens/m (dSm), which are numerically equivalent.

Emitter - a device used to apply water in the form of spray or drops to the substrate surface. It is a general term that can be applied to drip stakes, micro-sprinklers, misters, etc.

Half-life - the time required for a substance to degrade by one-half. Pesticides with a long half-life are considered persistent.

Leachate - solution that drains from container substrate during and after irrigation and may contain nutrients and pesticides from the substrate solution.

Nematode - very small worms abundant in many soils and important because they may attack and destroy plant roots or infest foliar portions of the plant.

Pathogen - a causal agent of disease. The term can refer to funguses, bacteria, viruses or other disease-causing organisms.

Perched water table – in container production, a saturated zone of water above the bottom of a container.

Permeability - the capacity of porous rock, sediment or soil to transmit water.

Pesticides - any form of chemical or substance used to control pests. Pesticides include fungicides, herbicides and insecticides.

pH - a measurement, ranging from 0 to 14, of the concentration of hydrogen ions (H+) in a solution. A pH of 7 is neutral, a pH below 7 is acidic and a pH above 7 is alkaline or basic.

Reverse osmosis - process where water is forced under pressure through a semi-permeable membrane to remove dissolved and suspended constituents.

Rhizosphere - the vicinity of the roots.

Runoff - the portion of precipitation or irrigation on an area that is discharged from the area. Runoff which is lost without entering the soil is called surface runoff and that which enters the soil is called ground water runoff or seepage flow. Managing excess irrigation water and rainfall is critical in the nursery industry because it can carry sediment, fertilizers, pesticides and other pollutants to surface water bodies or groundwater.

Sedimentation - particles settling out from suspension.

Sodium Adsorption Ratio (SAR) - the concentrations of calcium and magnesium relative to that of sodium. Sodium is often responsible for salinity problems when linked to chloride (Cl^-) or sulfate (SO_4^{2-}). The SAR can be determined for irrigation water or in soils. The following formulation is used to calculate the adsorption ratio:

$$SAR = \frac{Na}{\sqrt{\frac{(Ca + Mg)}{2}}}$$

Soluble salts - see electrical conductivity.

Substrate - organic and inorganic materials, often bark, peat, and sand, used as substrate components in a container to support the plant and contain the root system.

Total porosity - total volume of pore space in a substrate.

Transpiration – the loss of water vapor from plants, mostly through stomata (a pore in the epidermis of a leaf or young stem) and lenticels (an opening in the cork of roots and stems).

Virginia Tech Extraction Method (VTEM) - a technique used to monitor container nutrient status.

Water-holding capacity - the amount of water a substrate can hold after being fully wetted and allowed to drain. In containers, the term *container capacity* is also used. Because some water will be held too tightly by the substrate for plants to use, the term *available water capacity* is used to designate the amount water a substrate can hold that can be used by plants. An understanding of the water-holding capacity of your containers is important because it determines how frequently you should irrigate and how much water should be applied.

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Appendix 1:

A partial list of container-grown plants with low, medium, or high water requirements.

LOW WATER REQUIREMENT
Arctostaphylos spp., Bearberry
Berberis thunbergii, Japanese Barberry
Cornus spp., Dogwood
Cytisus scoparius, Scotch Broom
Euonymus japonicus 'Albo-Marginata'
Hedera helix, English Ivy
Juniperus chinensis 'Blue Vase'
Juniperus chinensis 'Parsonii'
Juniperus chinensis 'Torulosa'
Juniperus conferta, Shore Juniper
Juniperus horizontalis Blue Rug (`Wiltonii')
Leucophyllum frutescens, Texas Sage
Mahonia fortunei, Fortune's Mahonia
Tilia spp., Linden

MEDIUM WATER REQUIREMENT
Abelia X *grandiflora*, Glossy Abelia
Buxus microphylla, Japanese Boxwood
Callistemon spp., Bottlebrush
Camellia japonica, Camellia
Chaenomeles speciosa, Flowering Quince
Cortaderia selloana, Pampas Grass
Crataegus spp., Hawthorn
Forsythia spp.
Gardenia jasminoides, Gardenia
Hemerocallis spp., Daylily
Hibiscus syriacus, Shrub Althaea
Ilex X *attenuata*, East Palatka Holly
Ilex cornuta 'Burfordii Compacta', Dwarf Burford Holly
Ilex crenata, Japanese Holly
Ilex crenata 'Compacta'
Ilex crenata 'Helleri'
Ilex vomitoria, Dwarf Yaupon Holly
Ilex vomitoria 'Schelling's Dwarf'
Illicium parviflorum, Anise
Juniperus chinensis var. sargentii
Lantana montevidensis, Trailing Lantana
Ligustrum japonicum, Wax-Leaf Ligustrum
Ligustrum sinense, Japanese Privet
Liriope muscari, Lilyturf
Liriope 'Evergreen Giant'
Magnolia grandiflora, Southern Magnolia
Malus spp., Crab Apple
Myrica cerifera, Waxmyrtle
Nandina domestica, Heavenly Bamboo
Pennisetum setaceum, Red Fountain Grass
Philadelphus coronarius, Mock Orange
Photinia X *fraseri*, Fraser's Photinia
Pittosporum tobira, Pittosporum
Platanus spp., Plane Tree
Platycladus spp., Arborvitae
Podocarpus macrophyllus, Podocarpus
Pyrus spp., Pear
Quercus laurifolia, Laurel Oak
Quercus virginiana, Live Oak
Rhododendron spp., Kurume Azalea
Spiraea spp.
Ulmus parvifolia, Chinese Elm
Zelkova spp., Japanese Zelkova

HIGH WATER REQUIREMENT
Acer rubrum, Red Maple
Betula spp., Birch
Buddleia davidii, Butterfly-Bush
Cercis spp., Redbud
Cotoneaster spp.
Hibiscus rosa-sinensis, Hibiscus
Hydrangea macrophylla, Hydrangea
Juniperus chinensis var. procumbens
Juniperus chinensis 'San Jose'
Juniperus horizontalis 'Plumosa Compacta'
Juniperus virginiana 'Grey Owl' Eastern Redcedar
Lagerstroemia indica, Crape Myrtle
Pyracantha spp., Pyracantha
Rhododendron spp., Indica Azalea
Salix spp., Willow
Spiraea spp.
Viburnum odoratissimum, Sweet Viburnum
Viburnum plicatum var. tomentosum 'Shasta', Doublefile Viburnum
Vitex agnus-castus, Chastetree

Plant water requirements will vary depending on growth rate desired and cultural conditions.

Appendix 2:

A partial list of plants with low, medium, or high nutritional requirements when container-grown.

LOW NUTRIENT REQUIREMENT

Camellia japonica, Camellia
Camellia sasanqua, Sasanqua Camellia
Cortaderia selloana, Pampas Grass
Hydrangea macrophylla, Hydrangea
Lantana montevidensis, Trailing Lantana
Leucophyllum frutescens, Texas Sage
Liriope spp. `Evergreen Giant'
Myrica cerifera, Waxmyrtle
Pennisetum setaceum, Red Fountain Grass
Pinus spp., Pine
Prunus caroliniana, Cherry Laurel
Rhododendron spp., Azalea, Rhododendron
Rhododendron austrinum, Florida Flame Azalea
Rhododendron canescens, Pinxter Azalea
Taxodium distichum, Bald Cypress

MEDIUM NUTRIENT REQUIREMENT

Abelia X *grandiflora*, Glossy Abelia
Acer rubrum, Red Maple
Buxus microphylla, Japanese Boxwood
Dietes vegeta, African Iris
Gardenia jasminoides, Gardenia
Hedera helix, English Ivy
Hemerocallis spp. Daylily
Ilex X *attenuata*, East Palatka Holly
Illicium parviflorum, Anise
Juniperus chinensis `Blue Vase'
Juniperus chinensis `Parsonii'
Juniperus chinensis `Torulosa'
Lagerstroemia indica, Crape Myrtle
Liriope muscari, Lilyturf
Magnolia grandiflora, Southern Magnolia
Mahonia fortunei, Fortune's Mahonia
Nandina domestica, Heavenly Bamboo
Photinia X *fraseri*, Fraser's Photinia
Pittosporum tobira, Pittosporum
Podocarpus macrophyllus, Podocarpus
Quercus laurifolia, Laurel Oak
Quercus virginia, Live Oak
Ulmus parvifolia, Chinese Elm
Washingtonia robusta, Washington Palm
Zamia floridana, Coontie

HIGH NUTRIENT REQUIREMENT

Buxus sp. `Wintergreen' Boxwood
Callistemon spp., Bottlebrush
Euonymus spp., Euonymus
Hibiscus rosa-sinensis, Hibiscus
Hibiscus syriacus, Shrub Althaea
Ilex cornuta `Burfordii Compacta' Dwarf Burford Holly
Ilex crenata, Japanese Holly
Ilex vomitoria, Dwarf Yaupon Holly
Ligustrum japonicum, Wax-Leaf Ligustrum
Lonicera spp., Honeysuckle
Spiraea spp., Spiraea

Plant requirement will vary depending on growth rate desired and cultural conditions.

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Appendix 3:

Fertilizer Application Record Sheet

Date	Field Location	Fertilizer Analysis	Brand Name	Amount Applied	Plant Name	Container Size	Environmental Conditions

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Appendix 4: Fertilizante Aplicación Tablero

Fecha	Area	Análisis de fertilizante	Nombre del Producto	Cantidad total usada	Planta	Volumen de Maceta	Condiciones Ambiental

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Appendix 5: Pesticide Application Record Sheet

Date	Location	Plant	Wind	Product Name	Pounds per Section	Total Used	Length of Control	Pests Not Controlled	General Plant Health

Appendix 6: Peste Aplicación Tablero

Fecha	Area	Planta	Viento	Nombre del Producto	Libras por la sección	Cantidad total usada	Longitud del Control	Pestes (Plagas) no controladas	Salud de Planta General