ENVIRONMENTALLY COMPATIBLE CONTAINER PLANT PRODUCTION PRACTICES

T.E. Bilderback
Department of Horticultural Science
North Carolina State University
Raleigh, N.C. 27695-7609 USA

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Abstract

Environmentally compatible production practices are conscious efforts to design and retrofit nursery container growing areas to improve irrigation and nutrient efficiency and reduce exposure of ground and surface water supplies to contaminated effluent. Irrigation of ornamental crops in containers can be a very inefficient, using large quantities of water and fertilizer. Irrigation and fertilizer efficiencies are directly related. Even with controlled release fertilizers, improving irrigation efficiency improves nutrient efficiency and reduces water volume and nutrients leaving production beds.

Increasing efficiency can be accomplished in many ways. Grouping plant species and container sizes into blocks with similar water requirements improves efficiency. Re-designing overhead sprinkler systems to accomplish uniform distribution across growing beds or replacing worn nozzle orifices can significantly improve irrigation. Low volume / low pressure systems distribute water directly into containers and apply less water in a specific amount of time than overhead sprinkler application and therefore conserves water. Applying irrigation in short cycles rather than long cycles improves wetting in substrates and conserves electrical energy, water and reduces nutrient leaching from containers. Creating microclimates in nurseries to optimize light or reduce container temperatures, disease pressure and crop stress can improve water and nutrient efficacy. Flow of runoff from nursery growing areas must be engineered to slow velocity, filter and contain effluent. Strategies are site specific. Capture, containment and re-cycling of irrigation water has been a common practice in many nurseries in the U.S., as a means to provide adequate water supplies. In areas with sandy soils, some nurseries have developed closed systems where drainage channels and collection basins are lined to prevent nitrogen movement from runoff into shallow ground water. Vegetative filter strips adjacent to beds and containment basins have been installed at nurseries as "best management practices" for reducing contaminants in effluent before water enters recycle irrigation supplies. Routing runoff into wetland plant production areas to mitigate nutrients before recycling irrigation has been implemented in some nurseries. In North Carolina, new rules for the Neuse River Basin, a nutrient sensitive watershed, mandate that agricultural businesses in the watershed develop plans to reduce nitrogen loading into the river by 30% within the next five years. Nurseries and greenhouses will be required to implement best management practices or maintain 15 m riparian buffer zones adjacent to streams and rivers. The North Carolina nursery industry will employ the Southern Nursery Associations Best Management Practices Guide as a format for reducing nitrogen loss from nurseries.

1. Introduction

Growing plants in containers is a unique production system when compared to growing plants in soil. Container plants are usually grown in soil-less substrates

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containing primarily organic and inert components such as sphagnum peat moss, pine bark, sand, perlite or composts containing yard wastes, animal wastes or kitchen wastes. Soil-less container substrates have been developed through engineering and testing ratios of components so that optimum air and water characteristics produce rapid growth of crops. However, soil-less potting substrates are generally considered to contain deficient nutrient content for plant production without supplementing with fertilizers. Substrates containing composts may provide adequate content of some nutrients for plant growth while other nutrients are usually supplemented. Therefore, nutrients essential for plant growth are routinely incorporated, surface applied or supplied in irrigation to soil-less potting substrates. In contrast to soils, organic and inert potting components have very limited cation-ion exchange and retention characteristics and almost no anion retention. Consequently nutrients must be re-applied or the nutrient products are designed to become available throughout the growing season due to long term release characteristics related to particle size, solubility, or controlled release coatings of commercial fertilizers.

The system is designed for maximum growth of crops. Container plant production systems are totally integrated variables of substrates, irrigation and nutrient supplies. Nutrients are available for plant uptake only when they are soluble and dissolved in the container solution. This nutrient laden container solution is very susceptible to being leached from the container during irrigation. Nutrients released to public watersheds and ground water are threatening drinking water supplies and upsetting natural population dynamics in watersheds around the world. Therefore, it is the responsibility of container plant production facilities to plan and design site specific "best management practices" (BMP'S) that prevent or reduce discharges of pollutants. BMP's can be defined as schedules of activities, maintenance procedures, grading, vegetation and structural land modification or other management practices found to be effective and practical to prevent or reduce the discharge of pollutants. BMP's can conserve and protect water resources from adverse environmental impacts that might result from cultural practices used to produce plants.

The objective of this article is to review widely adaptable BMP's that are currently suggested as practices which can reduce or prevent nutrients from leaving container nursery and greenhouse operations specifically in the Southeastern United States and in general, to all container plant production operations in the U.S. (Yeager *et al*., 1997). A second objective is to cite published studies that provide validation of selected BMP's.

2.1. Overhead irrigation systems

Implementing irrigation and irrigation runoff best management practices are critical for environmentally conscious production of container crops. Irrigation efficiency can be related to three aspects of water application including: uniformity of application; amount of water retained within the substrate compared to the amount of water applied; or for overhead irrigation, the amount of water that enters the container compared to that which falls between containers (Yeager *et al*., 1997). Uniformity of application of overhead irrigation systems in container nurseries is greatly influenced by the design of the irrigation system and growing bed layout. Water distribution pattern and uniformity are influenced by nozzle spacing, system hydraulics (pressure and elevation), wind speed and duration, plant canopy density and many other factors. Irrigation pumps, main lines and distribution lines must be designed specifically for the volume of water available, topography and distance of water sources from production areas. Pressure loss in an irrigation line increases with pipe length (friction loss), therefore it is important to design systems so that the end of the line has adequate pressure. Irrigation zones must be designed so that the pressure and water demand are not exceed by the capacity of the pump, distribution lines or nozzles. "Poorly designed irrigation systems can have as much as 300% variability in the amount of water applied with in an irrigation zone" (Niemiera, 1994).

There are many overhead nozzle types including impact, spinner and fixed head nozzles. Nozzle selection depends on water volume, size of bed area and available pressure. Overhead systems are generally used for small containers (17 l or less) that are jammed together or with relatively short distances between containers (Yeager, *et al.*,1997). Since a significant portion of the applied water falls between containers and in aisles, overhead irrigation is inefficient related to the amount of water that enters containers compared to that applied. The amount of water entering containers depends the percentage of bed surface area covered by containers.

In situations where impact nozzles are used for large container beds, a square design where risers are equally distanced down and across beds will provide the best uniformity for overhead irrigation systems. In a square irrigation pattern, water is applied from nozzles in an overlapping distribution pattern. Height of irrigation nozzles should exceed the height of the crop canopy. Distribution angles for corner nozzles is 90 ^{o} while middle nozzles distribute water 180 ^{o} where the arc of distribution reaches adjacent and opposite risers. Nozzles with 90 ^{o} distribution arcs are fitted with orifices that apply one-half of the water applied by 180 ^{o} patterns. For many locations, bed widths may be limited to distances of 11-12 m (36 to 40 ft). Irrigation uniformity and distribution can be tested by placing rain gauges or straight sided cups of uniform size on a grid pattern on a container bed. At the end of a typical irrigation cycle record the amount of water in each gauge. Excessive amounts of water are need to irrigate crops when a system has poor uniformity. Inspecting and changing worn nozzles will frequently improve uniformity.

3. Low volume / Low pressure irrigation systems

Where economically feasible, microirrigation (low volume/low pressure) systems usually have better irrigation efficiency than over head systems. Flow rates are usually milliliters or gallons per hour compared to liters or gallons per minute. Also in contrast, microirrigation systems to small beds or individual containers. Irrigating containers with low volume irrigation systems can result in 80% less water applied compared to overhead irrigation (Ross, 1994). However low volume/low pressure systems may have higher initial costs and require more maintenance.

4. Irrigation and nutrient efficiency

Since the volume of water required to maximize growth of containerized plants is poorly understood, growers often utilize high volumes of irrigation resulting in low irrigation efficiency [irrigation efficiency = water applied - water leached ÷ water applied] and reduce nutrient concentration in the substrate solution. The plants response to nutrient application is not a direct response to concentration in the substrate solution but to total nutrient supply (concentration x volume of solution) (Wright and Niemiera, 1987). Manipulation of the volume and frequency of irrigation can be tailored to increase water and nutrient efficacy. Several studies have reported that cyclic irrigation where daily irrigation is applied in separate cycles rather than one irrigation application improves irrigation and nutrient efficiency (Fare *et al.*, 1994; Groves *et al.*, 1998a &1998b; Lamack and Niemiera, 1993; Tyler *et al.*, 1996a & 1996b). Groves *et al*. (1998b) found that irrigation efficiency for cyclic irrigation compared to a single irrigation varied with the amount of irrigation volume applied and crop grown. Irrigation efficiencies averaged over an entire growing season with applications of 200 ml (0.3 in), 400 ml (0.6 in), 800 ml (1.1 in, and 1200 ml (1.7 in) for *Cotoneaster dammeri* 'Skogholm' were 95%, 84%, 62% and 48% while *Rudbeckia fulgida* 'Goldstrum' was 100%, 90%, 72% and 51%, respectively. Nutrient concentrations in container solution decreased with increasing irrigation volume with all of the three controlled release fertilizer products tested. Groves *et al.* (1998a) further reported that 90% of maximum growth could be achieved with 40% reduction of irrigation applied. Fare (1993) reported that leachate volumes were reduced 54% with overhead cyclic irrigation compared to one overhead irrigation interval. Fare also found that 63% of 6.0 g N applied as Osmocote 17N-3.0-10K (17-7-12) was lost as NO_3 in the effluent with a single irrigation application compared to 46% for cycled irrigation. Lamack and Niemiera (1993) reported that irrigation application efficiency with individual spray stakes applying irrigation to the substrate surface increased with increasing number of cycles. Tyler *et al.* (1996a) using spray stakes did not improve efficiency with 2, 3 or 6 irrigation cycles but had 38% improvement in irrigation efficiency with cycled irrigation compared to a single application. Tyler *et al*. (1996b) reported that when cyclic irrigation leaching fraction (volume of irrigation applied) was reduced by 44% the volume of effluent lost from containers decreased 63% (Tyler *et al*., 1996b). Nutrients leached are also directly related to irrigation application. With 44% less irrigation volume applied NO_3, NH_4, and P content in the effluent decreased by 66%, 62% and 57% respectively. The 44% reduction of water application did result in 10% decrease in plant dry weight.

5. Management strategies for water conservation

Plants should be grouped by container size, substrate type and plant water needs. Grouping plants by species which have similar water needs frequently will improve growth of crops as well as conserve water. A table with many ornamental crops listed by water requirement is printed in the Southern Nursery Association Best Management Practices Guide for Producing Container Grown Plants pages 16-17 (Yeager *et al*. 1997). Plants that require large amounts of water and fertilizer need to be located at the farthest point in the production area from any body of water; whether a stream or drainage channel to decrease the risk of polluting adjacent or nearby by water bodies.

Irrigation shutoff devices can be installed for irrigation systems to minimize nutrient runoff. Rain override sensors can be installed on irrigation controllers to skip irrigation cycles if significant amounts of rainfall has occurred within the previous few hours. When beds are unoccupied after containers have been shipped, cut off valves or individual risers conserve water supplies and reduce runoff volumes.

Close spacing of containers not only increases irrigation efficiency due to greater space occupied by plants, but also substrate temperatures are reduced which reduces transpiration and evaporative water losses from containers. Placing small containers into larger containers (double pots) or using light colored containers reduces root zone temperatures.

Creating growing areas with unique microclimates can reduce plant stress and irrigation needs. Crops such as *Prunus laurocerasus* 'Otto Luyken' cherry laurel are desirable and perform well as landscape plants. As a nursery crop ‘Otto Luyken’ cherry laurel is easily stressed, grows slowly and has significant problems with shothole fungus, which leaves black necrotic-edged holes in the leaves. Severe cases result in defoliation. The disease seems to be enhanced by wetting the foliage with overhead irrigation and growing in full sun. Fungicide sprays are generally ineffective in controlling the necrotic foliar problems. The key for success in producing the crop has been to reduce heat, light and water stress. One successful nursery created a production area under natural pine shade. A double-pot systems with spray stakes placed below the canopy to avoid wetting foliage was developed, then the tops of containers were mulched with 7.5 cm (3 in) of pine straw. Under natural shade, double pots and moisture-conserving mulch, containers are irrigated infrequently. Fungicide applications for the crop ranges from none to a few times per growing season (Bilderback, 1999).

6. Runoff management

The goal for container plant production operations should be that no irrigation water leaves the property. To the maximum extent possible, all irrigation runoff should be recirculated with no discharge to public waters. Many nurseries recapture and recycle water and would not have adequate irrigation supplies without recycling. Some businesses however, apply collected runoff to other agronomic crops or non-cropped areas.

Collection basins should be constructed with clay-like materials with good sealing properties or be lined to provide an impervious bottom. Where rainwater is allowed to discharge from the property, it must be considered in the design of the water collection basin. Collection basins should be designed to hold all of the irrigation water runoff which can drain back to the basin from irrigated growing areas. In planning storage capacities about 90% of the water applied should be calculated for storage capacity. Growing beds and drainage channels in sandy soil areas with seasonal or perennial shallow water tables should be lined with plastic or covered with plastic to prevent runoff and nutrient loss to shallow ground water. In clay soils, impervious bed preparation and lined drainage returns reduces silt and increases the percentage of water returned to capture basins from irrigation events. Concrete of plastic lined waterways or drainage channels reduce erosion adjacent to growing areas but can increase the velocity of runoff water. Where lined sections are not on steep slopes, use of rip rap and / or vegetation in channels can slow water movement, allowing sediment and dissolved substances to settle or be filtered out of returning water. Drainage channels can be established with permanent vegetation such as fescue grass or even aquatic plants. Permanent vegetation in drainage channels slow water velocity, reduce erosion, and decrease movement of sediment and nutrients in runoff water. Permanent vegetation located at outlets of drainage channels also trap organic material, solids, soil, nutrients and other dissolved pollutants and serve as very scrubbers before runoff water returns to irrigation supplies.

Grassed waterways are channel-shaped or graded areas where vegetation can act as a stable conveyance for runoff across the area. One of the primary functions of a grassed waterway is to reduce velocity of runoff water. Grass waterways are frequently located between growing areas or growing areas and catch basins. Grass waterways should be designed such that water enters and leaves in a sheet flow or drainage channels have adequate vegetation to resist development of erosion channels. Vegetation may act as a filter in removing some of the sediment delivered to the waterway, although this is not the primary function of a grass waterway. Grassed waterway should not be used as travel lanes which might create ruts and damage vegetation.

Filter strips are vegetated buffer strips that many container plant producers install as pervious strips adjacent in locations such as along a shoreline which can accept sheet flow from developed areas and help minimize adverse impacts of untreated storm water before it enters water supplies. Often filter strips do not filter out soluble materials. Filter strips are often difficult to maintain since they remain wet. Like grassed waterways, traffic should not be permitted over filter strips.

In addition to handling irrigation runoff water, most container growing operations must also plan how stormwater runoff immediately following a rainstorm will be managed. Whenever possible, stormwater management should take advantage of the contour and topography of a site. Stormwater should be routed over long distances and grading developed to reduce water velocity, usually directing water through grass waterways, wetlands, vegetated buffers or other areas design for overland flow. Considerable planning and design for large storage and overflow outlets are required if stormwater is directed to irrigation runoff catch basins.

6.1. Watershed legislation in North Carolina

In North Carolina, law makers have mandated the development of a plan to reduce nutrient loading by 30% for one troubled watershed, the Neuse river. Watershed plans are also being developed for the 16 other watersheds in North Carolina (Bilderback 1998).

The best one management practice for all watersheds in North Carolina is deemed to be maintenance or development of 15 m (50 ft) riparian buffers along all natural conveyances including streams, rivers and esturaries. City stormwater, new construction and agriculture are required to maintain existing buffers and are exempt from other nutrient management requirements if buffers are established where they do not currently exist in riparian areas and all buffers are maintained free of erosion and nutrient application. Where this is not possible nursery and greenhouse business will need to implement and exhibit best management practices such as those described in this article.

7. Management practices for fertilizer application

Fertilizer application of container grown crops is accomplished by one or more applications of controlled release fertilizers (CRF's) during a growing season or multiple applications of fertilizer solution through the irrigation system. When fertilizer is injected in the overhead irrigation system, best management practices require total capture of nutrient runoff with no runoff leaving nursery property. Much of the irrigation water falls between containers, so large quantities of runoff water contain nutrient levels sufficient for growing crops. For this reason, several best management practices related to handling and recycling runoff are required. Fertilizing through irrigation is much more efficient in low volume irrigation systems where the nutrient solution is delivered directly to the container.

Studies have been conducted to determine whether incorporating or surface application of CRF's produces larger plants (Eakes *et al*.,1990, Yeager *et al*.,1989, Warren *et al.*1997). The SNA BMP manual recommends amending the potting substrate with CRF's rather than surface applying fertilizer if containers are subject to blow over (Yeager *et al*.,1997). Warren *et al*.(1997) compared surface application and incorporation of two CRF' s for leachate nutrient losses. Results illustrated that method of fertilizer application does affect nutrient losses in irrigation effluent. Incorporating CRF's increased NO_3 and P losses in irrigation an average of 171% and 58%, respectively. Plants were larger with surface applied Meister fertilizer than incorporated and the reverse was true for Nutricote.

8. Monitoring container leachates using the VTEM pour through method

Environmental conditions influence the longevity of controlled release fertilizers. Therefore periodic monitoring is important to determine if excessive or inadequate nutritional levels are present in container nutrient solution. Hot weather may increase the release of some controlled release fertilizers. In hot weather, growers may irrigate frequently and heavily. Without monitoring container leachate levels, it is difficult to know if high or inadequate levels exist in containers. Monitoring container leachates can help growers take preventive steps to reduce possible damage to roots due to high electrical conductivity before visual symptoms occur. Checking leachates of containers across irrigation blocks frequently can be used to diagnose poor uniformity of irrigation.

Containers close to irrigation nozzles that receive more water may have low electrical conductivity while containers in dry zones further away from nozzles may have high electrical conductivity. The Southern Nursery Association BMP manual recommends that growers monitor electrical conductivity at least once a month. Several procedures have been used to extract nutrient solution from container substrates. In the Southeastern U.S. most growers and ornamental university faculty use the Virginia Tech Extraction Method (VTEM) (Wright, *et al*.,1986). This method is also referred to as the pour-through or leachate collection method. Collection of the container substrate solution is accomplished by placing containers to be sampled in a pan shortly(30 min to 2 h) after irrigation and collecting drainage or pouring through a small amount of water to purge the container of leachate (a small amount is equivalent to approximately 120 ml / 3.8 l container at container capacity). Minimal levels for electrical conductivity should range from 0.2 to 0.5 dS/m for controlled release fertilizers and 0.5 to 1.0 dS/m for liquid feed or combinations of CRF's and liquid. Maximum levels for most pine bark based substrates should not exceed 2.0 dS/m. Desirable nutrient levels are published in the Southern Nursery Association Best Management Practices Guide (Yeager *et al*.,1997).

9. Conclusions

For most agronomic crops, annual fertilizer application rates are based upon expected realistic yield and soil characteristics which in turn dictate reasonable fertilizer application rates used to produce crops. Such nutrient management strategies are not possible for container plant production since the amount of fertilizer applied per hectare (acre) is dependent upon container population density (spacing), container size, crops produced, method of fertilizer application (complete liquid feed; incorporation of controlled release fertilizer; or surface application of controlled release fertilizers), season of potting and number of crops produced yearly in an area. In addition, nutrient absorption occurs only when nutrients are soluble in solution in containers and are highly subject to leaching during irrigation. Therefore, methods directed to reducing environmental impacts for ornamental container crops are irrigation and runoff management strategies.

Environmental consciousness of society and concern for safe drinking water makes it necessary for the container plant production industry to understand impacts of management practices and fertilization programs on water resources. In North Carolina, greenhouse and nursery businesses are mandated to do their part in reducing nutrient levels in the states public waters. These business will do their part by implementing best management practices. The Southern Nursery Associations Best Management Practices Guide is one of the first BMP guides for any agricultural industry. Practices highlighted here are given greater explanation in this manual.

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