From Forest Nursery Notes, Winter 2011

200. Florida nursery best management practices: past, present, and future. Yeager, T., Million, J., Larsen, C., and Stamps, B. HortTechnology 20(1):82-88. 2010.

Florida Nursery Best Management Practices: Past, Present, and Future

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ADDITIONAL INDEX WORDS. container, fertilizer, irrigation water, ornamentals

SUMMARY. Florida container nurseries face the challenge of maintaining profitability while protecting the environment by improving the efficiency of water and fertilizer use. Best management practices (BMPs) provide irrigation and fertilization guidelines for meeting this challenge. BMPs are economically and technologically feasible to implement and they focus on the ground- and surface water quality issues of the state. However, increasing nursery participation in the statewide BMP program is crucial as the industry continues to expand and interface with urbanization.

The earliest reported ornamental plant production in Florida was 1881 at Reasoner's Nursery in Oneco (Pinardi, 1980). Approximately 70 years later, plant production in containers began and as the population of Florida increased, demand for plants escalated. Consequently, the number and acreage of nurseries increased. There are currently 7952 nurseries registered in Florida with the Division of Plant Industry (R. Wester, personal communication) of the Florida Department of Agriculture and Consumer Services (FDACS). In the most recent economic study conducted by Hodges and Haydu (2006) of the University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS), farm gate value of nursery plants was ≈\$3 billion with ≈59,000 acres of container production and 24,000 acres of field or in-ground production. Many container nurseries are located close to urban markets. Thorp (1995) conducted a survey of sustainable practices used at 113 container nurseries and found that ≈50% were within 1 mile of an urban center. This can result in land values exceeding profitable production, problems with some production operations that are not compatible with urbanization, and limited room for expansion. Some nurseries that needed larger land areas for expansion have relocated, particularly from southern Florida to south-central Florida. Migration of nurseries to a particular region or locale may also stimulate new nurseries to start in that locale.

The diversity of container nursery production is different from any other facet of agriculture. The sizes and shapes of plants and containers, number of plant species and cultivars, methods of irrigation delivery, fertilizer types and application methods, and number of plants per unit area make container production a very complex process. Despite production complexities, the container nursery industry in Florida continues to mature under the leadership of the Florida Nursery, Growers and Landscape Association (FNGLA). Political, regulatory, economic, and educational issues are very important to the industry. The FNGLA works cooperatively on many of these issues with the American Nursery and Landscape Association, a national nursery association, as well as the Southern Nursery Association (SNA), which represents 16 southern states.

The initial ornamental plant research and educational efforts conducted under the best management practice (BMP) umbrella in Florida began in the 1980s for the leatherleaf fern (*Rumohra adiantiformis*) industry. Those efforts resulted from elevated concentrations of nitrate–nitrogen (NO_3-N) in groundwater at a central Florida fernery. To address the issue of NO_3-N in groundwater and provide production guidance, a BMP guide for the leatherleaf fern industry entitled *Irrigation and Nutrient Management Practices for Commercial Leatherleaf Fern Production in Florida* was published (Stamps, 1995). Leatherleaf fern currently comprises ≈60% (6000 acres) of the cut, cultivated greens acreage.

In 1994, industry personnel from the southeastern United States met with regulatory and university personnel to discuss the need for compiling in written form the "best" practices used by the industry. This resulted in a regional BMP guide for container nurseries entitled *Best Management Practices: Guide for Producing Container-Grown Plants* published by SNA in 1997 (Yeager et al., 1997). As requested by the industry, the guide focused on irrigation and fertilization practices. The BMP guide was promoted in Florida by the Florida Department of Environmental Protection through a series of workshops; however, the BMPs were not specific to Florida.

Also in 1994, the Florida legislature passed "nitrate" legislation (Florida Legislature, 2008b) in response to finding elevated NO_3-N levels (greater than 10 $mg \cdot L^{-1}$ N) in groundwater in several citrus (*Citrus* spp.) production areas of the state. The legislation provided for a proactive approach for producers to implement management practices that were technologically and economically feasible and would minimize movement of NO_3-N to groundwater. In exchange for implementation

We thank the Florida Agricultural Experiment Station for providing funding.

Trade names and products are mentioned without endorsement nor discrimination of those not mentioned.

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
0.5933	lb/yard3	$kg \cdot m^{-3}$	1.6856
1.6093	mile(s)	km	0.6214
1	ppb	$\mu g \cdot L^{-1}$	1
1	ppm	$mg \cdot L^{-1}$	1

and keeping appropriate records, the producers would receive a waiver of state-imposed liability for recovery costs if NO_3-N contamination was subsequently found. The FNGLA and UF/IFAS developed, cooperatively, an interim measure (precursor to BMPs) for the Florida container plant producers as provided by the legislation. The interim measure was adopted by a statutory rule in 2003. Nursery operators implementing the practices of the interim measure were waived from state-imposed costs for cleanup of NO_3-N-contaminated groundwater. It is important to note that this legislation was applicable to NO_3-N in groundwater only. Subsequent legislation in 1999 (Florida Legislature, 2008a) provided the incentives for production agriculture in Florida to develop and adopt BMPs applicable to all surface and groundwater contaminants.

Just as NO_3-N contamination resulted in the BMP program for leatherleaf fern production, total phosphorus (TP) discharge to the Everglades resulted in the development of the BMP guide for Florida entitled *Water Quality/Quantity Best Management Practices for Florida Container Nurseries* (Yeager, 2007). The initiation of the BMP development process for container nurseries in Florida started in 2003 with the South Florida Water Management District asking the nursery industry in Broward County for their assistance in achieving a TP concentration of 10 $\mu g \cdot L^{-1}$ in water discharged from Canal 11 to the Everglades. Subsequently, the FDACS became involved in the process because the Office of Agricultural Water Policy of FDACS is responsible for developing BMPs that are adopted by rule with statutory authority. The FDACS BMPs must be economically and technically feasible and developed with grower input. The FDACS relies on technical input from university faculty to ensure the BMPs are research-based to the extent possible. Also, regulatory personnel of the state are involved in the BMP development process to ensure that BMPs provide the "backbone" for addressing water quality issues.

Industry representatives worked cooperatively with UF/IFAS to develop the BMP guide for Florida that was adopted by statutory rule in 2007. UF/IFAS faculty conducted workshops and demonstrations for growers about the use of BMPs. Cost share funds were made available and BMP implementation teams and mobile irrigation laboratory personnel assisted producers with BMP implementation.

Approximately 600 container nurseries representing 13,500 acres have registered with FDACS (H. Stone, personal communication) as BMP users by completing a notice of intent to implement BMPs. Our experience has been that most nurseries that have not registered with the state as BMP implementers actually use several BMPs as part of their standard practices. When nursery personnel are asked about nonregistration with the state BMP program, common responses include: complacency, skepticism of outside intervention, and general lack of trust of regulatory agencies. Any or all of these could be reasons for not signing on as official BMP practitioners.

Container crops comprise the largest amount of nursery plant production acreage in the state; however, in-ground production is increasing and represents ≈30% of the total acreage of nursery plant production. In-ground production typically requires less fertilizer and irrigation than container production. A BMP guide is currently being developed for producers of in-ground trees and shrubs. Caladium (*Caladium* spp.) production in native soils or muck will also be included.

Some benefits for nurseries implementing BMPs are: 1) protection from redundant regulations at the local level; 2) eligibility for U.S. Department of Agriculture, Natural Resources Conservation Service and possibly other cost share funds for retrofitting or implementing water-conserving irrigation systems and other conservation practices; 3) minimizing movement off-site of surface water contaminants such as phosphorus; 4) demonstrate that the nursery industry will exercise its ability to determine what are the "best" irrigation and fertilization cultural practices and management and voluntarily use these practices rather than be confronted with mandatory regulations; 5) improved production efficiency and reduced production costs; and 6) waiver of state-imposed liability for surface and groundwater cleanup and presumption of compliance with state water quality standards (Florida Legislature, 2008a).

Current irrigation practices used in container nurseries

Irrigation water is usually applied with overhead sprinklers if containers are less than 7 gal. Larger containers are irrigated using low-volume microirrigation (e.g., drip tube irrigation or microspray stake irrigation) (Garber et al., 2002; Yeager et al., 2007). The nurseries surveyed by Thorp (1995) had ≈79% of the production area irrigated with overhead sprinkler irrigation and 12% with low-volume microirrigation. Overhead sprinkler irrigation in most regions of Florida is restricted to nighttime watering and ≈0.3 to 0.6 inch of irrigation water is applied per application. Unlike overhead irrigation, microirrigation is not restricted by amount or time of day. Approximately 3 to 5 gal per 1 inch of trunk caliper per day are applied to 1- to 3-year-old trees during times of peak demand with water needs increasing with plant size. Most container crops are irrigated daily as a result of the limited substrate volume for retaining water. Cyclic irrigation scheduling, which supplies water in several short cycles instead of one long cycle, can improve water retention in containers and is being used by many growers, particularly for microirrigated plants (Schoene et al., 2006). Subjective decision-making based on personal observation and experience is still the key factor used by growers in determining when and how long to irrigate. For example, from the surveys of 58 nurseries in west-central Florida (Schoene et al., 2006), it was determined that more than 70% relied on visual observation to determine when to irrigate (Table 1). The primary objective of irrigation decision-making is to apply enough water

Table 1. Factors aiding nursery operators with the determination of irrigation frequency in west-central Florida (Schoene et al., 2006).

Determination of irrigation frequency	Nurseries (%)
Indicator plant	9
Visual observation	74
Sensor	9
Fixed schedule	59

so plant growth is not restricted. Minimizing leaching by monitoring container drainage and adjusting irrigation scheduling accordingly is not the primary objective for most growers at this time. Few growers are using BMPs such as evapotranspiration (ET) -based irrigation scheduling, tensiometers, or other systems of objective irrigation scheduling.

Besides irrigation scheduling, container spacing can play a major role in irrigation efficiency and runoff. Beeson and Knox (1991) reported that irrigation efficiency was 37% when containers were adjacent to each other but only 25% when plants were spaced 7.6 cm (3 inches) apart. Million et al. (2007a) found that spacing containers at planting instead of midseason increased total runoff 9% compared with nonspaced containers. Fortunately, most growers place containers adjacent to each other during early stages of production, minimizing the amounts of overhead water that fall unintercepted between containers. As plants grow, containers are spaced to allow more sunlight penetration and improve plant quality. The larger canopy can often help capture water that might normally fall between containers. This canopy effect, which depends on plant species, canopy characteristics, and container size and container spacing (Beeson and Yeager, 2003), is not considered by most growers when scheduling irrigation and grouping plants in the nursery. Regardless of the infrastructure specifics for producing container crops, the objective should be to maximize irrigation efficiency and to minimize leaching and associated loss of nutrients. Educating producers and getting them to conduct leaching tests would be an important BMP to conserve water and fertilizer. Irrigation BMPs adopted by nurseries in west-central Florida that used overhead sprinkler and microirrigation are listed in Table 2.

Table 2. Best management practices (BMPs) adopted by container nurseries with overhead and microirrigation systems in west-central Florida (Schoene et al., 2006).

BMPs	Nurseries (%)
Collect irrigation or rain runoff	34
Know water-holding capacity of substrate	9
Group plants by irrigation requirements	74
Group container sizes by irrigation requirements	69
Use any other grouping for irrigation requirement	26
Monitor amount of water applied each irrigation	34
Monitor the application pressure in irrigation	45
Use automatic rain shutoff	29

Most research has shown that ≈10% to 40% of overhead irrigation water is captured by containers (Beeson and Knox, 1991; Weatherspoon and Harrell, 1980). Limitations to efficiency include overwatering to compensate for nonuniformity of water delivery or nonuniformity of plant water demand within the irrigation zone (i.e., different container sizes, species, and stage of growth), lack of knowledge about exactly how much water is needed and how the canopy affects irrigation water capture, variable wind conditions, and wide container spacing arrangements. By improving irrigation delivery to more closely match the capturing capabilities of the container-plant, growers could reduce application amount and fertilizer leaching.

Irrigation challenges and best management practices

Producing plants in containers provides some unique challenges to growers. The confined substrate volume, even when the substrate has excellent water-holding properties, provides little buffer against under- or overwatering. It is not surprising to observe that many growers err on the side of caution and apply more water than is needed—preferring the risk of increased leaching losses rather than the consequences of underwatering. By weighing plants and measuring daily water loss, it is known that water need is relatively low during early stages of growth and increases as the plant canopy develops (Beeson, 2004). Therefore, grouping plants within irrigation zones based on stage of growth and container size is very important if precise amounts of water are to be applied. Unfortunately, in most nurseries, a wide range of crop species, container sizes, and stages of growth exist and although grouping of plants by water needs and container size is acknowledged by growers as important, grouping is often impractical based on space availability and/or labor availability and associated moving costs.

We also know that at any given stage of growth, container ET is highly dependent on the weather, particularly solar radiation. ET-based irrigation scheduling relies on models to help growers adjust irrigation rates according to daily weather (Beeson, 1997, 2005, 2006; Irmak, 2005; Schuch and Burger, 1997). Additional soil moisture-sensing technologies such as suction tensiometers (Bacci et al., 2008) and time domain refractometer probes (Bergeron et al., 2004; Charpentier et al., 2004) can be used to trigger irrigation when substrate moisture content falls below a critical level. These devices require special management expertise and as yet have not been widely adopted. However, they provide an objective method of irrigation scheduling and their use should increase as water conservation demands increase. Another BMP that can save growers both water and leaching is the automatic rain shutoff sensor. However, its use is limited by the fact that many nurseries do not have automated irrigation systems to control irrigation (Schoene et al., 2006).

Precise irrigation designed to apply enough water to recharge substrate without excessive leaching requires excellent management (Mathers et al., 2005). This is particularly important with overhead irrigation because irrigation application efficiencies are low. Growers can maximize irrigation efficiency by implementing BMPs listed subsequently (Yeager, 2007): 1) install and maintain uniform irrigation delivery systems; 2) install and maintain windbreaks around the perimeter of production areas; 3) group plants according to water requirements; 4) measure water content of substrate or use ET models and adjust irrigation amounts; 5) use leachate volumes to adjust irrigation amounts; 6) adjust amount of water applied based on the water-holding capacity of substrate; 7) plants are consolidated to avoid open areas receiving irrigation; 8) use rain shutoff devices; 9) collect and reuse rain and irrigation water; 10) use cyclic irrigation to minimize water and nutrient loss from containers; and 11) use substrate moisture sensors for initializing irrigation rather than using a fixed schedule.

Current fertilization practices used in container nurseries

Plant nutrients are most often supplied with controlled-release fertilizers (CRFs) incorporated at nitrogen (N) rates of 2 to 3 lb/yard^3 of substrate before potting. Approximately 82% of the nurseries surveyed by Thorp (1995) used CRF. In some situations such as repotting or correcting a deficiency problem, CRF can be placed on the substrate surface, although this method may lead to significant fertilizer loss through spillage if containers are overturned. Injection of soluble fertilizers into overhead irrigation water has traditionally been a common method of fertilizing foliage crops watered with overhead irrigation. However, use of CRFs can greatly reduce N leaching in these container production systems (Yeager and Henley, 2004).

Many growers monitor substrate nutrition by using the pourthrough or suction lysimeter techniques (Yeager, 2003). Published guidelines for electrical conductivity and nutrient concentrations of solutions obtained with these tests are used by producers to determine if nutrition is adequate or excessive (Yeager, 2003). Although tissue testing can be used to confirm deficiencies, the high cost of nutrient analyses prevents its routine use by most growers. Thorp (1995) indicated that 56% of nurseries surveyed tested the substrate, whereas only 18% conducted tissue analyses.

Fertilizer challenges and best management practices

Supplying adequate nutrients for producing plants in containers poses interesting challenges to the grower. Young plants with immature root systems require relatively high concentrations of nutrients to maintain optimal growth, although the total amount of nutrients taken up is low. As root systems develop, nutrient uptake by plants is more efficient and less sensitive to fluctuations in nutrient release from CRF. During rapid growth stages, fast-growing plants require relatively high amounts of nutrients. Because CRFs must supply, in one application, enough plant nutrients to support season-long growth of the crop, matching nutrient release with plant requirements is a major challenge for both growers and CRF manufacturers. Coating technologies of CRFs, which impart the slow-release properties of these fertilizers, have not changed significantly in the past 20 years. The environmental factor primarily affecting nutrient release from most polymer-coated CRFs is substrate temperature (Lamont et al., 1987), which may not be related to plant growth. For example, late spring and summer plantings may cause undesirably high release rates during early stages of growth. Furthermore, temperatures in containers can be significantly increased from solar radiation exposure if plants are small and/or containers are widely spaced (Ingram et al., 1988; Million et al., 2007a). This can lead to undesirably fast release rates and leaching losses (Million et al., 2007a). By varying coating thicknesses, manufacturers offer CRFs with different longevities but with similarly shaped release curves. Some control over nutrient release patterns has been accomplished by mixing CRFs with different longevities into one product. For example, a CRF that consists of a combination of 3- to 4-month product with 8- to 9-month product can provide quicker nutrient release during early stages of growth than would be possible with 8- to 9-month product alone. Some CRFs have a significant portion of "imperfectly coated" product that essentially behaves as soluble fertilizer. Also, coatings may be cracked or broken during handling. This provides for initially high concentrations of nutrients needed for young transplants, but if the "imperfectly coated" amounts are excessive, it could cause too much leaching early in production (Huett, 1997; Million et al., 2007a), even during initial watering in of transplants (Million et al., 2007b). In this regard, some studies have shown that zeolites, gels, and other active compounds can be used as substrate amendments to retain soluble nutrients such as NO_3-N and orthophosphorus within the container (Broschat, 2001; Chen et al., 2000). Successful research in this area, particularly in regard to NO_3-N retention, could help buffer against rapid loss of nutrients under these circumstances. However, reductions in fertilizer leaching may be limited in areas with significant rainfall even when precise irrigation practices are used. Leaching of applied nutrients in container production is usually reported to be 10% to 30% of that applied in CRF (Million et al., 2007a, 2007b; Ristvey et al., 2001). Chen et al. (2001) noted that up to 50% of applied fertilizer may leach out of containers. A working knowledge of plant N requirements, fertilizer release properties, and expected temperatures will provide the best opportunity to apply CRFs most efficiently during container production, especially when combined with precision irrigation scheduling designed to minimize leaching of released nutrients from containers.

Another challenge preventing efficient fertilizer use is the "one size fits all" practice. Because of the wide variability in crop species and container sizes found within a given nursery and the common practice of buying premixed substrate amended with fertilizer, it is not uncommon for nurseries to use the same substrate amended with fertilizer for different types of production. This requires much less management than custom mixing fertilizer into substrates used for different crops. For example, where an N rate of 3 lb/yard^3 may be judicious for a shrub grown in 3-gal container for 1 year, this would likely be excessive for producing a shrub that takes only 4 to 5 months when grown in a 1-gal container. Like with water, growers tend to err on the side of applying too much fertilizer rather than risk an inferior crop from underfertilization. The added costs of applying additional fertilizer provide a measure of insurance against producing underfertilized plants of inferior quality and allows for extended growth during times when crops cannot be sold. Quality plays a major role in consumer preference for ornamental crops and high fertilizer rates produce dark green foliage that is desirable for many ornamentals. These factors help to explain why growers are reluctant to reduce application rates to those found by researchers to produce optimal growth.

Precision application of both water and fertilizer to match plant requirements provides the best opportunity for conserving water and nutrient resources in the container nursery. Plants require a significant pool of available N in the substrate to grow well and because rainfall will likely occur, leaching of applied fertilizer nutrients will result regardless of whether irrigation water is precisely applied. Nonetheless, it is essential for nutrient monitoring BMPs to be in place to provide an objective basis for irrigation and fertilization decision-making to maximize conservation of these resources.

By periodically monitoring substrate nutrition, an objective assessment can be made of how well the fertilizer program is working and provides valuable insight into the release pattern of the fertilizer used. Adjustments in fertilizer type or application rate made to bring substrate nutrition into recommended ranges can help to maintain optimal plant growth while minimizing the potential for loss of excessively applied nutrients. In some cases, this is more management than growers have been accustomed to providing.

Some fertilizer-related BMPs that are important in Florida include (Yeager, 2007): 1) use of CRFs with release patterns that match expected crop requirements; 2) adjust fertilization rates for time of year; 3) collect irrigation runoff and reuse if fertilizer is applied in overhead irrigation water; 4) amended substrates with CRF if containers are likely to overturn; 5) broadcast fertilizer on nonspaced containers only; 6) monitor substrate nutrition to maintain desirable nutrition levels; 7) keep records to help follow trends and to troubleshoot unforeseen nutritional problems; 8) cover substrate storage areas to prevent leaching and runoff of nutrients; 9) use substrate immediately (within 1 week) if amended with fertilizer; and 10) use a ratio of phosphorus pentoxide (P_2O_5) to N in fertilizers of 1:3 or less.

Water discharged from container nurseries

Zero discharge production systems are often used in greenhouses in conjunction with subirrigation. Benches designed to capture runoff from containers provide an infrastructure needed to recycle water. Irrigation water runoff from outdoor production areas is often recycled, but zero discharge from the property is unlikely because storm events often force water to leave the property. Recycling of water from production beds is greatly improved by lining beds with impervious plastic and providing ditching to channel water efficiently to containment structures.

The volume capacity of a containment structure is generally sized to contain at least 90% of the applied water from an irrigation event (Yeager et al., 2007). The containment system should also include a structural buffer zone capable of containing runoff from a 0.5-inch rain before the next irrigation event. Entry of runoff into containment structures may be accomplished with pipes or channels with open conveyance. Provisions should be made within containment structures to minimize erosion of sidewalls, especially where water enters. Sidewall areas above the high water mark should be stabilized with stone, synthetic materials, or natural vegetation (Yeager, 2008).

Drought and excessive rain will result in wide variations in the volume of water contained in the structure. Evaporation varies with ambient conditions, but generally in Florida, 1 inch of evaporation per week can be anticipated. Thus, 1 month without rain will result in a 4- to 5-inch decrease in the amount of water in containment without considering runoff volume. Also, no more than $\approx$50% of the irrigation water will run off to containment structures. Additionally, the volume in containment during a drought is diminished as a result of lack of runoff from rain on the production surface. Conversely, there should be the capability to discharge water from containment structures as a result of excessive rain.

Storm events can result in movement or a surge of sediments and nutrients transported in runoff. Generally, the first 0.5 inch of a storm event must be retained on the nursery; rainfall in excess of the 0.5 inch may be discharged. However, the specific amount that must be retained on-site may vary with state and local laws and ordinances. The first flush of storm water is usually contained in collection structures and separated from subsequent storm water by the use of retaining walls with overflow capability.

Another approach to retaining storm water is to maximize capacity of the water storage to minimize discharge. This can be important if the nursery depends on storm water for irrigation. Surface runoff resulting from 4 to 5 inches of rain would supply approximately four or five irrigation events for container plants (3-gal container or smaller) grown in the production area from which the runoff flowed.

Discharge from containment is best accomplished with open channel conveyance with provisions to minimize erosion. Overflow areas with concrete surfaces and concrete runways or runways with synthetic liners are often used to minimize erosion. Water discharged from the containment should be subjected to remediation before release from the property.

Remediation may be accomplished in several ways. Depending on the amount of land available, discharge from one collection structure may flow to another structure or several structures in series before ultimately leaving the property. Discharge from a single containment structure may traverse wetlands or grass areas for sediment filtering and flocculation. Remediation may also involve biological processing such as that provided by NO_3-N bioreactors and denitrification walls (Schipper et al., 2005).

Vision for the future

Plant selection within the gene pool could offer potential for plants with enhanced drought tolerance and efficient uptake capabilities. However, the plant palette or diversity of plants produced by the industry can change rapidly in response to market demand, making it unlikely, at least in the short term, that genetics or breeding of plants will result in more efficient use of water and fertilizer. Thus, the major improvements in water and nutrient use will likely be achieved by improving infrastructure or adopting management BMPs.

There is tremendous potential for container nurseries to become more efficient with water and fertilizer use. Research-based irrigation management strategies currently exist that could be implemented to increase irrigation efficiency and reduce environmental impacts (Fare et al., 1994). Many have been described in this article. However, to date, efforts to get producers to adopt in earnest irrigation management BMPs have not been as successful as we would have liked. There is the need to investigate further why adoption has been slow and develop strategies to improve this. With regard to nutrient management, adopting precision irrigation management practices will go a long way toward decreasing nutrient losses from containers and the nursery. Although CRFs are used by most growers, there is the need to develop new CRFs with release patterns that more closely match plant requirements. Unfortunately, developing new nutrient release technologies is costly and exacerbated by the recent rise in oil prices, slow economic growth, and low value of the dollar. Yet the appreciation for the attributes of ornamental plants and the impacts of these plants on our lives is stronger now than at any time in history. Our passion for plants will strengthen if the time-tested model of our European roots continues to grow. Our obligation is to master the environmental challenges of production inherent with a nonagrarian society. The research, teaching, and extension missions of the land grant universities are vital to meeting these challenges.

We believe that BMPs—past, present, and future—can be categorically expressed as: 1) BMPs that are not widely used; 2) BMPs that are widely used; and 3) BMPs that need to be developed. The inherent pros and cons of these categories will direct the future of BMPs, particularly the impact on BMP research and extension efforts. Some examples to stimulate thought are included subsequently.

Best management practices that are not widely used. BMPs such as monitoring substrate nutrition, use of environmental or substrate moisture sensors, and checking irrigation uniformity yearly have low adoption. In addition, only 8% (23% of land area) of container nurseries in Florida have signed the notice of intent to implement BMPs. Why are the adoption and commitment low despite receiving a waiver of liability and many other benefits? Perhaps this question is worthy of investigation to determine if our communication and educational efforts are on target and appropriate.

Best management practices that are widely used. The use of CRFs and grouping plants by irrigation needs are examples of extensively used BMPs. To a lesser extent, collection structures are used to contain runoff on the property. However, questions remain regarding the efficacy of some BMPs, particularly collection structures and covered substrate storage areas. The efficacy of these BMPs in minimizing movement of nutrients in discharge or surface water has not been definitively documented by research. In addition, large capital expenditures are required to install collection structures and covered substrate storage areas. Verification by research would ensure the capabilities of these costly BMPs and may also provide the impetus for nursery personnel to promote these BMPs to other nurseries. Similarly, the efficacy of BMPs that have a low cost of adoption should be verified by research. For example, cyclic irrigation for overhead sprinkler systems is not costly to adopt, but its performance has not been verified by research.

Best management practics that need to be developed. Future BMPs will likely capitalize on technology or precision agriculture. Examples might include a CRF with programmable release more in tune with plant nutrient needs, containers that are self-cooling so plants have less stress, technologies or plants engineered to indicate water and nutrient stress, repeatable and communicative criteria for categorizing plant water and fertilizer needs, or decision support systems to simulate the use of BMPs in complex production systems without conducting physical experiments. Simulation models would use local weather to help growers with BMP decision-making, including irrigation and nutrient scheduling. The simulation of BMP implementation could be linked to economic or profit criteria so the BMPs selected to implement are truly economically and technologically feasible.

In conclusion, the container nursery industry in Florida has grown rapidly as urbanization has increased in most areas of the state. Consequently, the industry is challenged to maintain profitability while protecting the quality of natural waters. The BMPs focused on irrigation and fertilization practices that protect water quality provide a waiver from state-imposed liability for producers that commit to FDACS that they will use BMPs for production of container plants and keep appropriate records about BMPs. Growers voluntarily choose the BMPs for their nursery from the lists in *Water Quality/ Quantity Protection for Florida Container Nurseries*. Many BMPs such as monitoring the substrate nutrition have been researched extensively, but research is lacking for some BMPs such as the use of a water-impermeable cover for storage of substrate amended with fertilizer.

Future challenges for container nursery plant producers will focus on greater efficiency of irrigation and fertilization. However, an increase in the number of producers implementing BMPs that address these efficiencies is needed so that environmental challenges are conquered voluntarily without future regulation.

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