Survey of Irrigation Best Management Practices in Alabama Container Production Nurseries

by

Caitlin Morgan Carter

A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science.

Auburn, Alabama
December 14, 2019

Approved by

Adam Newby, Chair, Assistant Professor of Horticulture
Jeremy Pickens, Assistant Research Professor & Horticulture Extension Specialist I
Carolyn Robinson, Associate Professor of Horticulture

Abstract

For over 100 years, nursery crop production in the United States has been well established and has become one of the most dominant, fastest growing sectors within agriculture. The green industry, specifically horticulture, is highly diversified in terms of practices and materials grown, with over 390 genera of ornamentals produced (Bilderback et al., 2013). It is estimated that the total production acreage in the United States alone is 981,625 and container production currently represents about 60% of the industry (Bilderback et al., 2013). However, within any industry, problems and concerns arise about production techniques and methods. Environmental impacts are always of concern within our industry and how it affects not only the materials produced, but the general public as well. To regulate these concerns, Best Management Practices (BMPs) were introduced in the late 1980's. Even with the introduction of BMPs, the adoptions of BMPs have been limited, and growers are still struggling with many problems that arise during production or ornamental crops. The adoption of irrigation BMPs has significant potential for improvement while also providing the greatest impact of environmental and economic sustainability for the container nursery industry. The primary goal of this work is to identify the current irrigation practices, BMP implementation, water usage and water use efficiency across nurseries in Alabama. Analysis and summaries of this data will allow researchers and Extension efforts to better target specific needs while providing the greatest impacts for the Alabama nursery industry.

Acknowledgments

First and foremost, I would like to thank and dedicate this work to my Heavenly Father, for without him, none of this would have been possible. Because of His love and guidance, I can say that I am proud of this work and my time spent towards attaining this graduate degree.

I would like to thank Dr. Adam Newby for serving as my major advisor and giving me the opportunity to work on this project. I would also like to thank Dr. Carolyn Robinson and Dr. Jeremy Pickens for their generosity, advice, and leadership during my research. I truly am thankful for the opportunities and guidance that you all, as well as the Horticulture Department and graduate students, have given me during my time at Auburn University.

Lastly, I would like to express my deepest appreciation and love to my parents, grandparents, brother, and my fiancé, Thomas Reeves. Mom and Dad: thank you for being my rock, biggest supporters, and loving me unconditionally through these last two years. Granddaddy and Nana: Thank you for supporting me financially over the last 7 years and allowing me to get the best education. I would not have made it this far without both of your help. Covin: thank you for being the best brother, protector, and roommate this last year we have spent together at Auburn. Thomas: thank you for encouraging and loving me every day since we met, and patiently waiting for me while I earn this degree. I love you all and am *eternally* grateful for everything you have done.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

BMPs	Best Management Practices
CWA	Clean Water Act
DU	Distribution Uniformity
SNA	Southern Nursery Association
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency

CHAPTER I: INTRODUCTION

The ornamental horticulture industry is highly diversified in terms of practices and materials grown with over 390 genera of ornamental plants produced (Bilderback et al., 2013). Nursery, greenhouse, floriculture, and sod crops in the U.S. reached $16.2 Billion in sales in 2017 (USDA, 2019). Nursery stock crops (ornamentals, shrubs, shade trees, flowering trees, evergreens, live Christmas trees, fruit and nut trees and plants, vines, palms, ornamental grasses, and bare root herbaceous perennials) accounted for $5.9 Billion or 36% of those sales (USDA, 2019). Alabama had $92.9 Million in nursery stock sales in 2017 from 224 farms (USDA, 2019). Container nursery stock production is a relatively new and important sector of horticulture crops within the United States. In 2014, nursery stock produced in containers accounted for 63% of all nursery stock sold (USDA, 2015). While the average sales per acre of all U.S. agricultural products was $432 in 2017, nursery crop sales were on average $17,073 per acre (USDA, 2019). Achieving such a high production value requires intensive production practices and inputs including frequent irrigation and fertilization.

Container Production of Nursery Stock

The two types of systems commonly used in nursery production are field production (in-ground growing) and container plant production (Newman, 2014). Field-produced nursery stock is grown directly in the ground and harvested by hand or machine as bare root plants or balled-and-burlapped plants in which a soil mass remains attached around the root zone. Container plants are produced by various methods, such as direct seeding/sticking of cuttings into containers, transplanted rooted cuttings (liners) into containers, and transplanting field grow stock into containers (Newman, 2014). Plants produced in containers can be harvested and shipped any time of year, while plants produced in-ground must be harvested when plants are dormant. Typically, container production requires less acreage than field-grown nursery stock and has higher economic returns per acre (Newman, 2014). Although containers use less space than field-grown nurseries, container production nurseries require more intense management. Containerized plants are commonly subjected to moisture loss, temperature extremes, circling roots, as well as wind gusts that blow over containers (Newman, 2014). Labor required for container production is generally constant and more intensive than field production operations. Soilless growing medias such as pine bark and peat, are used to produce plants in containers. These soilless growing medias are lightweight which keeps shipping costs down (Newman, 2014).

Most nursery plants were field-produced until the 1960s and 1970s when many growers began to transition to container production (Newman, 2014). New developments at the time facilitated that transition. Plants grown in containers can be transported at any time, while field-grown plants could only be transported when dormant (Newman, 2014). The development of plastic films changed designs for greenhouse structures, while also catalyzing a reaction that led to the development of irrigation systems. Plants in containers have limited water supply and must be irrigated frequently. New plastic technology allowed the development of new irrigation systems that could deliver large volumes of water to containerized plants more easily (Biernbaum, 1992). New plastic technology also allowed the production of inexpensive plastic containers. Until the 1970's, virtually all containers were recycled food cans (Avent, 2003). Metal cans were durable and affordable; however they had many disadvantages. Early metal cans had straight sides which made storage difficult because the cans did not nest into one another. Additionally, the cans had to be cut down the side in order to remove mature plant root balls. They were eventually manufactured with tapered sides for stacking and easier removal of root balls; however the heavy weight was still a major disadvantage. Punching holes in the bottom of metals cans for drainage was a time-consuming and hazardous activity (Avent, 2003). Plastic containers were first introduced as an alternative to metal cans in the 1950s (FHCP Manual, 2007). Manufacturers of food began producing plastic containers for the nursery industry. As a result, the dimensions of the first “trade gallon” plastic containers were based on #10 food cans rather than dimensions that were optimal for root development (FHCP Manual, 2007).

While early irrigation systems allowed large volumes of water to be applied to containerized plants and reduced labor-intensive hand-watering, growers had less control over the volume of water applied to individual containers. Early irrigation systems did not apply water uniformly (Biernbaum, 1992). As a result, irrigation was applied until the containers receiving the least irrigation volume received adequate water, while excessive irrigation was applied to other containers (Biernbaum, 1992). Although technology existed in the 1960s and 1970s to automate irrigation using tensiometers, scales, or light levels, growers chose to use clocks to schedule irrigation events or to manually turn on irrigation systems (Biernbaum, 1992). Today, most container nursery operators continue to use these methods.

Applying large volumes of water to containerized plants can lead to excessive leaching of nutrients. The use of controlled-release fertilizers (CRF) in nursery production began in the 1970s (Sharma, 1979). CRFs are coated fertilizers that release nutrients gradually at a predictable rate (Gregorich et al., 2001). The use of CRFs in place of water-soluble fertilizer reduces the volume of nutrients leached by soilless substrates in containers (Rathier and Frink, 1989; Sharma, 1979).

Best Management Practices

In order to further prevent and reduce the discharge of pollutants such as nutrients from nurseries, researchers from several southern universities developed a guide of best management practices (BMPs) which was first published by the Southern Nursery Association in 1997 (Yeager et al., 1997). It was one of the first BMP guides published for any agricultural industry (Bilderback, 2001). The BMP guide was developed to help nursery stock producers "produce plants with minimal environmental impact" (Yeager et al., 2007). Best Management Practices, BMPs, are defined as "schedules of activities, prohibitions, maintenance procedures, and structural or other management practices found to be the most effective and practicable to prevent or reduce the discharge of pollutants to the air or waters of the U.S." (Bilderback et al., 2013). BMPs of container nursery production include grouping similar plants by water requirement, use of vegetative buffers near retention ponds, cyclic irrigation systems, monitoring distribution uniformity (DU), and many others. Best Management Practices guide and aim towards helping eliminate problems with irrigation, fertilization, applications of chemicals, or other issues that growers encounter.

Water Conservation

One of the main concerns with industry growers is the conservation, reuse and quality of irrigation water. The Clean Water Act (CWA) of 1972, establishes the basis structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters (USDA, 2019). Under the CWA, the EPA implemented Total Maximum Daily Loads (TMDLs) that each state must follow, and report specified bodies of water that pose concerns of exceeding the water quality standards of a particular pollutant. Growers should be aware of the possibility of negative environmental impacts that can result from nursery and greenhouse production practices, and the potential for future regulations that could impact crop production and profitability (USDA, 2019).

Water is a finite resource, and its availability is increasingly becoming more and more limited. In agriculture alone, water used for irrigation accounts for nearly 65% of the world's freshwater withdrawals, excluding thermoelectric power (Hutson et al., 2004). Irrigation is not only used to water crops, but total irrigation usage also accounts for pre-irrigation, frost protection, application of chemicals, and crop cooling. The most common types of irrigation methods in container production of nursery crops are overhead, micro irrigation, surface, and flood irrigation. Each method of irrigation should be evaluated by growers to decide what is most effective for their operations.

Problems with Runoff

Container grown nursery crops rely on soilless substrates to provide high porosity; however, this requires frequent use of irrigation. One half to two inches of water per acre per day are required with overhead irrigation, which is equivalent to approximately 12,000 to 50,000 gal of water per day per acre (Halcomb et al., 2010). Most nursery crops are grown in containers up to 5 gal and are irrigated with overhead irrigation. With this, problems tend to arise. Poorly designed overhead irrigation can have as much as 300% variability in the amount of water applied within an irrigation zone (Fare et al., 1994). This can be resolved by re-designing the layout of overhead sprinkler irrigation, but the most efficient system for many nurseries is the square irrigation design with 90^{o} and 180^{o} nozzle patterns. This design provides the most coverage when used. (Bilderback, 2002). Low pressure irrigation, or microirrigation, is another method of efficiently applying water. These systems distribute water directly into containers and apply less water in a given amount of time than overhead sprinklers, thereby conserving water (Bilderback, 2002). When irrigation is not managed appropriately, leaching of applied fertilizer elements can occur. Nutrient-rich leachate can percolate through the soil and eventually reach the water table, or it can contribute to runoff and end up in surface water (Fare et al., 1994). Contaminants (such as fertilizers, agri- chemicals, and sediment) that leave an operation via runoff water from agricultural production sites are considered nonpoint source pollution and can contribute to the impairment of waterways downstream. (Majsztrik and Lea-Cox, 2013). Nonpoint source water pollution can be mitigated by the use of BMPs. Reducing irrigation water to a specific plant's needs could save time, effort, money, and the depletion of our freshwater reserves. There are many suggested BMPs that cover water related topics that arise for nurseries.

Collection ponds

Drainage of crops and other irrigated areas is an important factor to consider when designing plans for a nursery. Large volumes of water are applied during the growing seasons, and growers must account for the water that does not fall into the container (Davidson et al., 1988). If sites are not well drained, they should be graded and have a drainage system developed (Davidson et al., 1988). Options for drainage systems include holding ponds or "French" drains to capture the runoff (Davidson et al., 1988). Runoff that is recaptured in holding ponds should be analyzed for pH or soluble salt content, before it is used again as an irrigation source. A case study of mid-Atlantic ornamental operations surveyed growers about their investments to capture and recycle irrigation runoff. All eight nurseries surveyed captured rainfall and irrigation runoff in collection basins, or ponds (Ferraro et al., 2017). After determining the annual estimates of recycling irrigation runoff, total cost savings from recycling ranged from $694 to more than $1.2

million per year (Ferraro et al., 2017). The largest cost items for implementing capture and recycling were regrading production areas and digging for recycling ponds, however, with the results from this study, it could be suggested that many nurseries in the Mid-Atlantic region could reduce costs by adopting recycling (Ferraro et al., 2017).

Cyclic Irrigation

Container grown landscape ornamentals are commonly irrigated with overhead systems in the United States. Overhead irrigation is common for production; however, it is a very inefficient method to irrigate plants. Another method of best management practices adaptation, cyclic irrigation has proven to be a very practical way of managing irrigation in container nurseries. Cyclic irrigation is defined as applying a daily quantity of water in several sub-volumes throughout the day (Beeson, 1995). Growers have been encouraged for the last few decades to practice techniques for increasing irrigation application efficiency [(water volume applied-water volume leached)/ water volume applied]. Studies have proven that dividing irrigation events into two or more events throughout the day, rather than one single application reduces leachate in plants. Fare et al., (1994) demonstrated this by testing the effects of cyclic irrigation reducing container leachate. The two experiments in this study found that container leachate volume was reduced by 34% when 13mm of water was applied in three cycles, rather than one continuous irrigation cycle. Testing the differences between 8mm and 13mm of water applied, total effluent (container leachate and irrigation runoff) was reduced by 28% (Fare et al., 1994). This research shows that quality plants can be grown with lower irrigation volumes than those traditionally applied. This can also result in container leachate volume reduction with results in less nitrate leachate.

Irrigation Application Efficiency

Irrigation management and efficiency is a key factor in the role of implementing best management practices. Management of irrigation requires focus in areas of water quantity, quality, treatment, runoff, etc. (Bilderback, 2013). Irrigation efficiency is defined as the fraction of irrigation that is held in the soil of a container or root zone of a field-grown plant, divided by the total volume of irrigation pumped (Bilderback, 2013). Some irrigation systems may be more efficient than others, however, it is important to understand that poor management or scheduling run times can reduce efficacy in operations. Leaching fraction, irrigation systems, distribution uniformity, and other factors are all important areas to pay close attention to when evaluating efficacy of irrigation systems. Soilless substrates have a relatively high porosity and low holding water capacity when compared to soils, which allow growers to apply heavy and frequent irrigation. However, over application of irrigation water can lead to further issues.

Leaching Fraction

Leaching fraction is a measured loss of water and water-soluble minerals from the substrates of container grown plants due to known amounts of irrigation and can be calculated as the ratio of water volume that leaches from a container to the volume of water applied by irrigation (Owen et al., 2019). Although growers typically apply heavy irrigation and consider the risks to be minimal, overwatering crops can result in nutrients leaching from containers, as well as potential pesticides or plant growth regulators (Owen et al., 2019). Also, leaching fractions can help monitor and manage salt levels in container substrate. Leaching is necessary to flush water from the container that has accumulated salts (Owen et al., 2019).
Monitoring leachate can be a helpful tool for growers to schedule irrigation, and help growers determine if irrigation run times need to be adjusted to apply the desired volume.

Overhead Irrigation and Micro-irrigation

Two of the most commonly used irrigation application methods are overhead irrigation systems and micro irrigation systems. Overhead irrigation systems apply water from above the canopy by sprinklers or emitters. Typically, overhead irrigation systems are most efficient for irrigating containers smaller than 7-gal and that are space closely together, so most of the water is captured by the plant and does not fall between containers (Owen et al., 2016). Overhead irrigation systems should be designed to have head-to-head coverage, where the spray radius is equal to the distance between the sprinklers (Owen et al., 2016). Typically, overhead irrigation systems are relatively permanent infrastructure (pipes, risers, etc.) With time, overhead sprinkler nozzles wear, and can result in decreased efficiency, so growers need to be constantly evaluating irrigation equipment to make repairs or adjustments. Advantages of overhead irrigation are that it supplies large production areas with water fairly cheap for growers, it is easier to set up compared to microirrigation, it is low maintenance, and does not clog as easily as microirrigation systems (Yeary et al., 2016). Disadvantages of overhead irrigation can be challenging for some growers. Overhead sprinkler systems are extremely inefficient, and depending on plant spacing and canopy size, large amounts of water will not reach the root zone (Yeary et al., 2016). University of Tennessee Extension's study of nursery irrigation showed that only 25-40% of irrigation water applied to azalea and pittosporum was captured by containers, even when placed pot-to-pot (Yeary et al., 2016).

Microirrigation systems are the other common sprinkler design that growers can install. Although the initial startup costs for installing microirrigation systems deter many growers, they are very effective in most nursery and greenhouse operations. Unlike overhead irrigation, these systems apply water at or near the rootzone of a plant with higher interception efficiency and higher uniformity (Majsztrik et al., 2011). Compared to overhead systems, microirrigation systems use lower water pressure and have lower horsepower and energy requirements, and also make efficient use of water labor costs associated with irrigation scheduling, since they are automated systems (Majsztrik et al., 2011). Disadvantages of microirrigation systems are the higher initial infrastructure costs and increased labor time to place emitters in containers (Majsztrik et al., 2011). Also, drip lines are susceptible to rodent, pest, and even worker damage that can easily dislodge stakes, as well as clogging from substrate (Yeary et al., 2016).

Distribution Uniformity

The greatest limitation to efficient overhead irrigation systems is the lack of distribution uniformity within an irrigated zone (Bilderback et al., 2013). Irrigation DU should be monitored regularly, as excessive amounts of water are needed to irrigate crops when a system has poor uniformity. Irrigation DU should be greater than 80%, but a DU $\leq$ 80% would warrant an irrigation system audit to solve problems (Haman et al., 2003). Distribution uniformity is defined as DU= average of lowest volume quartile/ average volume x 100 (Mathers et al., 2005). Fare et al., 1992 monitored six container nurseries in Alabama to determine amounts and distribution of irrigation water applied to nursery grown crops. When growers were asked how much irrigation is applied, they responded that they normally watered for about 1 h, applying about 1 inch (2.5 cmh^{-1}) of water (Fare et al., 1992). Majority of the nurseries had varying distribution uniformities over the sampling times. One specific nursery collected 0.9 inch (2.2 cm) in June, but only collected 0.4 inch (1 cm) in November, both during a 1-h irrigation (Fare et al., 1992). Most other nurseries had similar discrepancies between sampling times and DU levels, demonstrating that uniform distribution can be achieved, and careful monitoring of systems can minimize water runoff (Fare et al., 1992).

Surveys on BMP and Irrigation Management

Due to concerns and issues presented by the industry, many studies have been conducted to answer the questions of how to improve irrigation application efficiency. Florida growers were surveyed as part of a series of workshops titled "Improving Irrigation Application Efficiency" that were open to the commercial container nursery operators during 1999-2002 (Schoene et al., 2006). In the 2-d workshops, presentations about irrigation needs, water efficiency saving techniques, container plant water needs, and hands-on activities to determine substrate physical properties were demonstrated to the growers as a way of informing. Surveys were completed by one participant representing each nursery operation and were completely voluntary.

Representing two different counties, there were 58 respondents total. Results for series one showed that 37 nurseries used overhead irrigation systems and 16 of those also used micro irrigation systems, and two used only micro irrigation. Series two results showed that 17 nurseries used overhead, 13 of those also using micro irrigation and only 2 exclusively using micro irrigation. Of the nurseries that responded, only 35% were able to affirmatively respond that they monitored their overhead irrigation uniformity, while 69% of micro irrigation nurseries monitored their uniformity. Methods used to determine of when to irrigate were reported by the nurseries. Visual observation was the primary method, and only a few used sensors or fixed schedules. Among those using a fixed schedule, only 29% used an automatic rain shutoff (Schoene et al., 2006). It is reasonable to assume that BMPs are not practiced as a standard across Florida nursery growers, as well as many other places. Water supplies could be limited in the future due to population increases and climate change. However, educational programs can prepare nursery growers for the possible impacts.

Plants should be grouped by container size, substrate type, plant water needs, or other criteria (Bilderback, 2002). Not only does grouping plants by species improve the growth of crops and conserve water, but it can save growers money and resources when operating nurseries. Irrigation shutoff devices are suggestions to be installed, so that irrigation systems can minimize nutrient runoff. Rain override sensors can be installed on irrigation controllers to skip irrigation cycles if significant amounts of rainfall have occurred in the last few hours (Bilderback, 2002).

A BMP survey was carried out in Georgia to observe irrigation practices with container nurseries (Garber et al., 2002). The state of Georgia has four of the top 100 container nurseries in the U.S. and the state supplies plant material throughout the U.S (Garber et al., 2002). Unlike traditional row-crop agriculture, container production is based majorly on the foundation of using soilless growing systems. With this comes the requirement of frequent irrigation. However, irrigation practices and the amount of irrigation water used are better documented for row crops than for container nursery crops (Bilderback et al., 2013). In this study, Garber's main objectives were to evaluate: 1) irrigation practices of container nurseries and the value of product grown, 2) adoption of industry BMPs, 3) application methods for irrigation water, and 4) practices adopted by container nurseries to reduce water use and improve quality of water leaving the nursery.

Of the 102 container nurseries surveyed, respondents used overhead irrigation and direct, or drip, irrigation. When surveying BMPs, roughly 48% of Georgia nurseries collected runoff water in a basin; in contrast where only 34% of nurseries in West-Central Florida collected rain or irrigation runoff. The results demonstrate that about half of the irrigation water used by Georgia container nurseries comes from ground water while the other half is surface sources such as recaptured irrigation water or rain water (Garber et al., 2002).) Recycling water can reduce the need for potable water across the industry. When wanting to produce consistently high-quality products, it is important to check quality of different variables within a program, especially water quality. When asked about the frequency of monitoring alkalinity, roughly half of the respondents (45.8%) monitored water alkalinity once a year, while 25% never checked water alkalinity (Garber et al., 2002). Only measuring once a year would not allow nurseries to determine a baseline or level of peak nutrient loss. Not checking quality of irrigation water, and recycled water collected from runoff and basins warrants the risk for incorporating unknown elements and quantity of nutrients in irrigation water in production systems. Results reported that ~44% of growers practiced cyclic irrigation when watering crops, an encouraged BMP. Besides the type of irrigation, the timing is important as well. Georgia growers reported that 92% of the time, crops are irrigated in early morning hours if possible. Also, early morning tends to be time of lower winds and reduced evaporation.

In Virginia, Mack et al (2017) conducted a BMP survey with goals of finding the reasons behind BMP barrier implementation. Cost was the most cited barrier to BMP adoption for all BMPs. When asked the reasoning for BMP use for water, fertilizer, and runoff management, environmental/resource savings was the most cited reason among Virginia growers. Out of the 60 growers, runoff retention was 77%, higher than the rates in other Southeastern states such as Florida, Georgia, and Alabama. Mack speculates that this high rate of retention was due to a recent drought in the area that led growers to become more aware of the importance of water retention and recycling of irrigation water. An interesting aspect of this study was BMP education. Eighty-one percent of respondents reported that their source of BMP information was learned on their own. Efforts should be used to increase BMP use with the sources cited, such as industry personnel, extension publications, BMP manuals, and other avenues (Mack et al., 2017).

Water Management

Bilderback (2002) argued that water management is the key in reducing nutrient runoff in container nurseries. Unlike conventional agriculture, nutrient management strategies are not feasible for container plant production. The amount of fertilizer applied per unit area is dependent on spacing, container size, species produced, method of fertilizer, season, and the number of crops produced yearly (Bilderback, 2002). To reduce these environmental impacts of nutrient leaching, Bilderback suggests that irrigation and runoff management strategies will best eliminate these problems. Single daily overhead irrigation event cycles have been the standard practice of many nursery container growers. However, studies have shown that cyclic irrigation, where multiple irrigation events are applied rather than one single irrigation event, improves irrigation and nutrient efficiency. Groves et al., 1998a found that irrigation efficiency for cyclic irrigation varied depending on the amount of irrigation volume applied and the crop grown. Irrigation efficiencies averaged over an entire growing season with daily applications of 6.8, 13.5, 27.1, and 40.6 fl oz. (200, 400, 800, and 1200 mL) for ‘Skogholm’ cotoneaster (Cotoneaster dammeri) were 95%, 84%, 62%, and 48% while ‘Goldstrum’ coneflower (Rudbeckia fulgida) was 100%, 90%, 72%, and 51% respectively. As irrigation increased, nutrient concentrations in container solution decreased with all of the three controlled release fertilizer products tested. Studies further reported that 90% of maximum growth could be achieved with 40% reduction of irrigation applied (Groves et al., 1998a).

Relevance to Nursery Industry

With increased pressure on agriculture to reduce water use and runoff contamination, the amount for water permitted for irrigation use by horticulture container nurseries will likely decrease. A detailed analysis of current irrigation and fertilization practices would increase our knowledge of current practices in the Alabama nursery industry and can help demonstrate to growers where improvements need to be made to preserve our natural resources. In Alabama's last survey, (Fain et al., 2000) data was solely collected by use of interviews and questionnaires, but no measurements of irrigation application were measured.

The main objectives of this study were to survey Alabama nursery and greenhouse growers to determine knowledge of BMPs and the most widely used BMPs, as outlined in Best Management Practices Guide for Producing Container-Grown Plants published by the Southern Nursery Association. Results will answer if the location of growers throughout the state has any correlation with BMP knowledge. BMP knowledge will be tested to determine any correlations with current usage of the suggested BMPs, such as DU, cyclic irrigation, usage of collection ponds, etc. Findings will be communicated to nursery and greenhouse growers via Extension and trade publications with the goal of increasing grower awareness and the adaptation of BMPs.

Literature Cited

Avent, Tony. 2003. So You Want to Start a Nursery. Timber Press, Portland, Oregon.

Beeson Jr., R. C. and J. Haydu. 1995. Cyclic microirrigation in container-grown landscape plants improves plant growth and water conservation. J. of Env. Hort. 13:6-11.

Biernbaum, J. A. 1992. Root-zone Management of Greenhouse Container-grown Crops to Control Water and Fertilizer. HortTechnology 2:127–132.

Bilderback, T. E. 2001. Environmentally compatible container plant production practices. Acta Hort. 548:311–318.

Bilderback, T. E. 2002. Water management is key in reducing nutrient runoff from container nurseries. HortTechnology 12:541-544.

Bilderback, T., C. Boyer, M. Chappell, G. Fain, D. Fare, B.E. Jackson, J. Lea-Cox, A.V. LeBude, A. Niemiera, J. Owen, J. Ruter, K. Tilt, S. Warren, S. White, T. Whitwell, R. Wright, and T. Yeager. 2013. Best management practices: Guide for producing nursery crops. 3rd ed. S. Nur. Assoc., Acworth, GA.

Davidson, H., R. Mecklenburg, and C. Peterson. 1988. Nursery Management: Administration and Culture. 2nd ed. Prentice Hall, Englewood Cliffs, N.J.

Dickey, R. D., E. W. McElwee, C. A. Conover, and J. N. Joiner. 1978. Container Growing of Woody Ornamental Nursery Plants in Florida. Bulletin 793:33-34.

Fain, G. B., C.H. Gilliam, K.M. Tilt, J.W. Olive, and B. Wallace. 2000. Survey of Best Management Practices in Container Production Nurseries. J. Environ. Hort. 18:142–144.

Fare, D.C., C.H. Gilliam, and G.J. Keever. 1992. Monitoring Irrigation at Container Nurseries. HortTechnology 2:75-78.

Fare, D.C., C. Gilliam, and G. Keever. 1994. Cyclic irrigation reduces container leachate nitrate-nitrogen concentration. HortScience 29:1514–1517.

Ferraro, N., D. Bosch, and J. Pease,. 2017. Costs of Capturing and Recycling Irrigation Water in Container Nurseries. HortScience 52:258-263.

FCHP Manual. 2007. FNGLA Certified Horticulture Professional Program. Florida Nursery, Growers & Landscape Association.

Garber, M.P., J.M. Ruter, J.T. Midcap, and K. Bondari. 2002. Survey of container nursery irrigation practices in Georgia. HortTechnology 12:727-731.

Gregorich, E.G., L. W. Turchenek, M.R. Carter, and D.A. Angers. 2001. Soil and Environmental Science Dictionary. CRC Press. p. 132.

Groves K.M., S.L. Warren, and T.E. Bilderback. 1998. Irrigation volume, application, and controlled-release fertilizers: I. Effect on plant growth and mineral nutrient content in containerized plant production. J. Environ. Hort. 16:176-181.

Halcomb, M. and D. Fare. 2009. Conventional container production. Univ. of Tennessee Extension, Knoxville, TN.

Haman, D.Z. and T.H. Yeager. 2003. Field evaluation of container nursery irrigation systems: Measuring uniformity of water application in microirrigation systems. Univ. Fla. Ext. Fact Sheet 98-1.

Hutson, S.S., N.L. Barber, J.F. Kenny, K.S. Linsey, D.S. Lumia, and M.A. Maupin. 2004. Estimated Use of Water in the United States in 2000. USGS Circular 1268.

Mack, R., J.S. Owen, A.X. Niemiera, and J. Latimer. 2017. Virginia Nursery and Greenhouse Grower Survey of Best Management Practices. HortTechnology 27:386–392.

Majsztrik, J.C. and J.D. Lea-Cox. 2013. Water quality regulations in the Chesapeake Bay: Working to more precisely estimate nutrient loading rates and incentivize best management practices in the industry and greenhouse industry. HortScience 48:1097-1102.

Majsztrik, J.C., A.G. Ristvey, and J.D. Lea-Cox. 2011. Water and Nutrient Management in the Production of Container-Grown Ornamentals. Hort. Reviews 38:253-297.

Mathers, H. M., T.H. Yeager, and L.T. Case. 2005. Improving Irrigation Water Use in Container Nurseries. HortTechnology 15:8-12.

Newman, J. P. (Ed.). 2014. Container Nursery Production and Business Management Manual (Vol. 3540). UCANR Publications.

Owen, J.S., Jr., A.V. LeBude, and M.Chappell. 2016. Advanced Irrigation Management for Container-Grown Ornamental Crop Production. Virginia/North Carolina Coop. Ext. Publ. HORT-218P.

Owen, J. S., Jr., A.V. LeBude, A. Fulcher, J. Stanley, and L.R. Oki. 2019. Leaching Fraction: A Tool to Schedule Irrigation for Container-Grown Nursery Crops. Virginia/North Carolina Coop. Ext. Publ. SPES-128/AG-855.

Rathier, T.M. and C.R. Frink. 1989. Nitrate in runoff water from container grown juniper and alberta spruce under different irrigation and N fertilization. J. Environ. Hort. 7:32-35.

Schoene, G., T. Yeager, and D. Haman. 2006. Survey of container nursery irrigation practices in west-central Florida: An educational opportunity. HortTechnology 4:682–685.

Sharma, G.C. 1979. Controlled-release fertilizers and horticultural applications. J. Amer. Soc. Hort. Sci 118:107-29.

U.S. Department of Agriculture. 2015. 2014 Census of Horticultural Specialties. National Agricultural Statistics Serv., Washington, D.C.

U.S. Department of Agriculture. 2019. 2017 Census of Agriculture. National Agricultural Statistics Serv., Washington, D.C.

Yeager, T., C. Gilliam, T. Bilderback, D. Fare, A. Niemiera, and K. Tilt. 1997. Best management practices: Guide for producing container-grown plants. S. Nur. Assoc., Marietta, Ga.

Yeary, W., A. Fulcher, and B. Leib. 2016. Nursery Irrigation: A Guide for Reducing Risk and Improving Production. Univ. of Tennessee. PB 1836.

CHAPTER II: A SURVEY OF IRRIGATION BEST MANAGEMENT PRACTICES IN ALABAMA CONTAINER PRODUCTION NURSERIES

Abstract

Nursery and greenhouse growers have an important role conserving resources during operating and production of ornamental plants. Many new technologies are available to help growers produce quality crops while practicing conservation. However, many within the industry do not adapt these practices. Best Management Practices (BMPs) were introduced as a way to improve the quality of crops grown, while providing the greatest impact of environmental and economic sustainability for the container nursery industry. This survey observes BMP adaptation of twenty-four nurseries producing container-grown plants across Alabama. Fifty-four percent of growers surveyed were not familiar with the BMP guide published by the SNA. Cyclic irrigation was reported to be used by twenty percent of growers, and thirty-seven percent used collection pond(s) to capture irrigation runoff. These and additional findings suggest the need for BMP education to be communicated to growers via extension and trade publications.

Introduction

Nursery crop production in the United States has become one of the fastest growing sectors within agriculture. The green industry is highly diversified in terms of practices and materials grown. Nursery, greenhouse, floriculture, and sod crops in the U.S. reached $16.2 billion in sales in 2017, with Alabama reporting $92.9 million in nursery stock sales in 2017 from 224 farms (USDA, 2019). Container nurseries operate differently conventional agriculture, as crops are grown in artificial substrates, rather than mineral soil. Container nurseries are also heavily dependent on large volumes of irrigation. Development of Best Management Practices (BMPs) for the nursery industry began in the late 1980s with efforts to improve water quality of nursery effluent. An issue with industry growers across the nation is the capture, reuse and quality of irrigation water. The Clean Water Act (CWA) of 1972 established the regulation of discharges and pollutants into waters of the United States, and regulating quality standards for surface waters (U.S. EPA, 2003). The CWA helps nursery growers understand how to efficiently reduce contaminated runoff into nearby water sources. In Agriculture alone, water used for irrigation accounts for nearly 65% of the worlds' freshwater withdrawals (U.S. EPA, 2003). Irrigation usage accounts for watering crops, pre- irrigation, frost protection, application of chemicals, crop cooling, and other uses. The most common types of irrigation used in Alabama are overhead irrigation systems, micro irrigation systems, and flood irrigation. Each method of irrigation has its own set of problems unique to each grower; however, there are solutions that growers can implement themselves to correct irrigation issues.

Growers in the southeastern United States are advantageous over others due to ample yearly rainfall to irrigate crops. In Alabama, the average rainfall is 58 inches yearly (ADECA, 2016). There are still many growers that do not understand the risks and problems associated with over-irrigating. Overhead irrigation is most common in container plant production; however, it is a very inefficient method to irrigate plants. Growers tend to over irrigate crops, which can ultimately lead to nutrient deficiency, disease, pests, etc. (Groves et al., 1998a). Cyclic irrigation is a common BMP that has been suggested to growers over the last decade and is defined as applying a daily quantity of water in several sub-volumes throughout the day (Beeson, 1995).

Garber et al. (2002) reported that 44% of Georgia nurseries practiced cyclic irrigation. Evaluating irrigation practices, adoption of industry BMPs, and other similar criteria, Garber surveyed 102 nurseries, four of which are within the top 100 container nurseries in the United States. Growers used mixed methods of irrigation application techniques, but still had low rates of BMP adaptation. Only 21% checked the quality of runoff water once per year, and 25% never checked water alkalinity (Garber et al., 2002). However, Georgia growers reported that 92% of the time, crops are irrigated in early morning hours if possible (Garber et al., 2002).

Growers in Florida were evaluated by researchers during 1999-2002 by methods of a 2-d workshop to educate growers and distribute surveys to determine BMP practices (Schoene et al., 2006). With 58 respondents from two counties, only 35 were able to affirm that they monitored their overhead irrigation uniformity (Schoene et al., 2006). Visual observation was the primary method, and among those growers using a fixed schedule, only 29% used an automatic rain shutoff procedure (Schoene et al.,2006).

Virginia researchers distributed a similar study in 2017 with goals of finding reasons to BMP barrier adaptations, and the current practices of Virginia Nursery and Greenhouse growers. Out of the 60 responses, 45% reported usage of overhead irrigation systems and 77% reported collecting retention runoff at their operations (Mack et al., 2017). The main water source reported was well water irrigation (50%). Retention rates were higher than the other southern states, such as Florida, Georgia and Alabama, possibly as a result from recent drought activity in the Chesapeake area (Mack et al., 2017). Eighty-one percent of respondents reported that they learned BMP information on their own, and cost was the most cited barrier for adoption of all BMPs. BMPs were practiced by 100% of growers, indicating that BMPs are of common practice in the Virginia industry (Mack et al., 2017).

Many growers have had success with implementing BMPs and have seen many benefits from them. In one success story from J. Frank Schmidt and Son Nursery in Oregon, they solely relied on overhead irrigation for field grown liners. Between the inefficiency of overhead irrigation systems, wage increases, and safety concerns of moving heavy equipment, they began to consider drip irrigation. Reports were made and shown to investment owners that a job that previously required 16 people, could now be done by 3 workers and would decrease water use by 30% (Yeary et al., 2016). With moisture sensors that provided real-time measurements, Sam Doane, Production Horticulturist at J Frank Schmidt and Son Nursery, was able to monitor trends of volumetric water content (VWC) easier and faster. Previously, the nursery had switched from broadcast to banded fertilizer applications to conserve fertilizer but was presented a challenge when converting to drip irrigation. However, drip irrigation systems allow growers to directly inject fertilizer to the root zone, reducing their overall fertilizer use by 30% (Yeary et al., 2016).

In another success story, Saunders Brothers Nursery saw firsthand how efficient use of water can positively affect a nursery's bottom line. Saunders Brothers set out to restructure their irrigation schedules by measuring leaching fractions, or leachate fraction-based irrigation (LF-based). When they reduced irrigation to the desired leachate fraction, they learned of having to cut fertilizer rates on most crops, so to not have high EC levels, and noticed some herbicides lasting longer. As a result of this seemingly simple decision, Saunders Brothers Nursery decreased their water usage by 54% over the three-year course, and the length of time between herbicide application increased (Saunders, 2014). In the estimated savings between labor, plant quality, and fertilizer, the total annual savings for their nursery was $33,764-$75,764 (Saunders, 2014).

In collaboration with the University of Georgia, Transplant Nursery in Lavonia, GA, began trials on automated irrigation systems based on container substrate moisture level (Yeary et al., 2016). Plants were produced with either the sensor-based automated irrigation, or conventional irrigation practices, such as hand operating irrigation valves based on weather and experience. The set point to operate automated irrigation was at 27-28% volumetric water content (Yeary et al., 2016). Different plant species were grown outdoors with impact sprinklers and across the species, the automated system did not reduce plant size or quality compared to the nursery's traditional irrigation practices. The automated system did result in reduced water consumption by 48% over 2.5 months, roughly 56,990 gallons (Yeary et al., 2016).

While larger growers and operations have successfully implemented many BMPs, there is still little information concerning the industry wide adaptation of BMPs. The objective of this study was to survey nurseries across Alabama to determine the extent of BMPs implementation to develop irrigation management training workshops, targeted on educating how to reduce resource inputs such as water, fertilizer, and pesticides.

Materials and Methods

The Alabama Department of Agriculture and Industries collaborated with researchers at Auburn University to conduct an assessment of irrigation practices at container nurseries across Alabama. Of 400 licensed growers in Alabama roughly half of growers supplied an email address. Survey questions were derived from multiple sources, such as the SNA BMP Manual, (Bilderback,2013) the questionnaire from Fain et al., 2000. The questions were formatted into a survey that would be dispersed to our audience via email (Appendix A). The survey divided Alabama into 7 regions to cover statewide nursery production.

A Qualtrics survey (Qualtrics, Provo, UT) was dispersed via email to 208 container nursery growers that provided email addresses in April 2018. The Alabama Nursery & Landscape Association supported and advertised the survey for additional responses. The survey had a 45% open rate and 16% of growers clicked on the survey link. In September 2018, phone calls were made in attempts to reach more growers, resulting in 4 additional survey completions. It was estimated that our sample could be approximately 100 or less container production nurseries, due to meeting the criteria of being a true container production nursery. Completed surveys were received from 24 growers, making for a 24% response rate of container nurseries. Data were tabulated and analysis of responses were conducted using IBM SPSS Statistics (Version 23.0). Data was recorded in Qualtrics Software and analyzed in SPSS producing frequencies and descriptives. Cross tabulations and Chi square tests were run to determine if any of the variables had an influence on each other. An $\alpha = .05$ significance level was used for all statistical tests.

Results and Discussion

Participation varied from regions across Alabama (Figure 2.1). Regions 1 and 3 had 4.2% of growers respond, region 4 had a 20.8% grower response, region 5 had 8.3% of growers respond, region 6 with 45.8% response, and region 7 with 16.7% response. Region 6 covers Mobile and Baldwin counties, which have the larger operations in our state (Figure 2.1). The nurseries' acres under irrigation ranged from 0 to 110 acres, with 20.8% of growers having 2 acre of container beds under irrigation. As this study's goal was to determine BMP adaptation and use, results determined that 54% of our sample were not familiar with the SNA BMP Guide, nor had they implemented any of the recommended practices, whereas only 46% had heard of

BMPs for Nursery Crop Production (Table 2.2). Of those that had heard of the BMP guide, only 25% used some guidelines, 4.2% used no guidelines, and 16.7% used many of the guidelines.

Irrigation Practices

Although overhead sprinklers are the most common method to irrigate container grown plants, it can be highly inefficient to irrigate this way. When nurseries were questioned about irrigation systems used, many growers combined systems. Growers indicated the use of overhead sprinklers (79%) and micro irrigation (58%). This is likely due to crop type and species. Majority of growers (70%) had #5 or smaller containers under overhead irrigation, while 12% of nurseries used micro irrigation for the same size containers. Thirty-three percent of growers use overhead irrigation for #7 or larger containers, and 33% reported use of drip or microirrigation for #7 or larger containers. Others indicted that they used #15 containers that were irrigated via overhead and micro irrigation, 30-40 gal containers via drip irrigation, and field operations that used drip irrigation. As discussed before, cyclic irrigation is a very critical and important BMP that the industry is encouraging growers to adapt to their everyday practices. Almost 80% of growers watered crops by single irrigation events, while only 20% practiced cyclic irrigation. When prompted to choose a reason for watering only once a day, 75% of respondents saw no benefit to watering more than once per day, while 83% selected that scheduling irrigation run times would be too complicated. Roughly 4 participating nurseries watered more than once per day to keep up with the water demand of their crops, (16.7%) while 4% of participants practiced cyclic irrigation to reduce root temperatures or to reduce leaching (4%). No participants indicated the reason they water more than once per day was because it was a more efficient use of water.

Growers were surveyed on usage of BMPs at their nursery. Grouping plants by water requirements is a recommended BMP. Fifty percent (50%) of nursery growers grouped their crops by water requirements, 33% did not group, and 16.7% grouped plants sometimes. Twenty-nine percent of growers monitored volume of irrigation applied, while 41.7% never checked and 29% sometimes checked irrigation volume applied. Checking the DU of irrigation systems is important, since excessive amounts of water can be used when a system has poor uniformity. When asked how often DU of overhead irrigation systems are measured, only 17% regularly monitored distribution uniformity, 38% sometimes checked, while 33% never checked it.

Leaching fraction can be used to determine irrigation run times. Sixty-seven responded that they never checked the leaching fraction to determine how long to irrigate, 29% of growers measured leaching fractions sometimes, while only 4.2% regularly checked. Other factors are used to help growers determine when to irrigate such as container weight, sensors, or timed clocks. The most used aid selected was visual observation (88%). Some growers selected feeling the weight of the container (54%), while, 20% used irrigation clocks and 13% used sensors to determine when and how much to irrigate.

Runoff Retention

Collection structures are great tools to help minimize the amount of irrigation runoff leaves a site and can be designed to retain almost 90% of daily irrigated water applied (Bilderback et al., 2013). When asked if growers use collection pond(s) to capture irrigation runoff, 38% had collection ponds, while 63% did not use ponds. Thirteen percent of growers had ponds maintained by wells as their main irrigation source, 21% had irrigation ponds maintained by runoff recapture, and 4.2% had irrigation ponds maintained by a surrounding watershed. Vegetative zones are considered to be a runoff collection structure, by helping slow the flow of water and trap soil or substrate particles, thereby extending the life of vegetative zones

(Bilderback et al., 2013). Thirty-three percent of growers incorporated the use of vegetative buffers for runoff, while 67% did not use these buffers.

Irrigation Source and Fertilizer Management

As a main irrigation water source, 63% of respondents reported using a well. Regularly measuring and maintaining water irrigation water pH and soluble salts is important, however 50% of growers reported that they never monitor pH or soluble salts of irrigation water, 37% sometimes check, while 13% regularly checked. Additionally, 42% never checked their crop pH and fertilizer salt levels, while 37% sometimes checked and 21% regularly check crop pH and salt levels. We asked growers what types of fertilizers they apply to container crops. Eighty-three percent, or 20 growers, used controlled release fertilizers (CRFs), three growers (12%) used liquid fertilizer through overhead irrigation, four (16%) used liquid fertilizer through microirrigation, and three growers (12%) used field grade fertilizers.

Comparisons of Grower BMP Knowledge

Chi Square tests were used to test for significant interactions between variables. It was tested to see if there were significant interactions between: 1) location and BMP knowledge, 2) BMP knowledge and use of collection ponds to capture irrigation runoff, 3) grouping of plants by water requirement and single versus cyclic irrigation, 4) BMP knowledge and measuring DU. When testing location versus BMP knowledge, we found that these two variables are independent of each other, X2= (5, N=24) = 5.892 , p=.317, thus accepting that location has no significant effect on knowledge of BMPs (Table 2.2, Figure 2.2). Based off the data, it appeared that majority of the growers who used collection ponds had heard of BMPs in some form but may or may not have adopted it as a practice. According to the test and Table 2.3, X2= (1, N=24) = 6.172 , p=.013, there are correlations between grower BMP knowledge and use of collection ponds. This could suggest that the usage of collection ponds to capture irrigation runoff is directly related to knowledge of BMPs. Testing cyclic irrigation effects of grouping of plants, Table 2.4, Chi Square results reported $X2= (2, N=24) = 6.589$, $p=.037$, determining that there are correlations between cyclic irrigation use and grouping of plants. This could be due to the reason that many respondents answered that they saw no use in watering more than once per day and setting up fixed irrigation schedules would be too complicated. Lastly, testing between variables BMP knowledge and measuring DU, Table 2.5 shows the Chi Square results were $X2= (3, N=24) = .284$, $p=.963$. There were no detectable significant differences or associations between BMP knowledge and measuring of DU. This means that growers did not practice measuring distribution uniformity because of their knowledge of BMPs.

BMP Scores

Growers were given a BMP score based on their answer choices for BMP specific questions. This was done so we could observe how many growers were actually practicing BMPs willingly or unknowingly. There were 9 BMP specific questions relating to cyclic irrigation, plant groupings, monitoring leachate and DU, collection ponds, vegetative buffers, and other BMPs. Scoring ranged from 1-9 and were grouped into three categories. Scores ranging from 0-3 were assigned to group 'low', scores 4-6 were assigned to group 'medium', and scores 7-9 were assigned to group 'high'. Group 'low' had 8 growers and accounted for 33% of our sample, group 'medium' represented 12 growers with 50% of our sample, and group 'high' accounted for 17% of the sample with 4 growers.

The low group scores reported 37% of growers used single irrigation and 20% practiced cyclic irrigation. When grouping plants by water requirement, 16.7% of 'low' growers practiced this BMP, while 50% sometimes grouped and 50% never grouped plants. When monitoring volume of applied irrigation, no one in group ‘low’ regularly monitored irrigation applied, 14% sometimes monitored, and 70% never monitored volume applied. Collection ponds to capture irrigation runoff were used by 33% of growers in this group and zero people used grass filters or vegetative buffers in their operation. Only 11% sometimes checked pH of irrigation water, and 20% regularly monitored the pH and soluble salts of their crops. Distribution Uniformity monitoring was low within this group, as no one regularly monitored DU, while 11% sometimes monitored. Sixty-three percent of the ‘low’ group never monitored their DU of irrigation systems. Fifty percent of the ‘low’ group never measured leaching fraction of plants.

The ‘medium’ group reported 47% of growers practiced single irrigation events, while 60% practiced cyclic irrigation. Fifty-eight percent of ‘medium’ growers grouped plants by water requirements, 50% sometimes grouped, and 25% never grouped plants. Growers in group “medium” monitored volume of irrigation applied at 71%, 57% monitored sometimes, and 30% never monitored. When measuring DU, 50% of growers regularly measured DU, while 67% did sometimes, and 38% never checked. Fifty-seven percent of the medium group sometimes checked leachate, and 44% never checked leachate of their containers.

Only four growers had a BMP score of 7 or higher, which is why the group ‘high’ is smaller than the other two. Among these growers in group ‘high’, three growers (16%) practiced single irrigation events, while only one grower (20%) practiced cyclic irrigation. Three growers (25%) in group ‘high’ said they did group plants by water requirements, while one (25%) grower sometimes grouped. When monitoring the volume of irrigation water applied, growers in the ‘high’ group regularly and sometimes monitored this volume at 29% consecutively. Two growers (50%) measured the DU in this group regularly and two growers (22%) sometimes measured DU. Three growers (43%) selected they sometimes measure the leaching fraction and

1 grower reported they never checked. Four growers in the ‘high’ group all used collection ponds to capture irrigation runoff, and the incorporation of vegetative buffers was used by half of growers. All growers additionally reported they sometimes tested pH of irrigation water and crops, as well as fertilizer salt levels.

Literature Cited

Alabama Department of Economic and Community Affairs. 2016. Floodplain Management. Montgomery, AL.

Beeson Jr., R.C., and Haydu, J. 1995. Cyclic microirrigation in container-grown landscape plants improves plant growth and water conservation. Journal of Environmental Horticulture 13:6-11.

Bilderback, T., C. Boyer, M. Chappell, G. Fain, D. Fare, B.E. Jackson, J. Lea-Cox, A.V. LeBude, A. Niemiera, J. Owen, J. Ruter, K. Tilt, S. Warren, S. White, T. Whitwell, R. Wright, and T. Yeager. 2013. Best management practices: Guide for producing nursery crops. 3rd ed. S. Nur. Assoc., Acworth, GA.

Fain, G. B., C.H. Gilliam, K.M. Tilt, J.W. Olive, and B. Wallace. 2000. Survey of Best Management Practices in Container Production Nurseries. J. Environ. Hort. 18:142–144.

Garber, M.P., J.M. Ruter, J.T. Midcap, and K. Bondari. 2002. Survey of container nursery irrigation practices in Georgia. HortTechnology 12:727-731.

Groves K.M., S.L. Warren, and T.E. Bilderback. 1998a. Irrigation volume, application, and controlled-release fertilizers: I. Effect on plant growth and mineral nutrient content in containerized plant production. J. Environ. Hort. 16:176–181.

Saunders, T. 2014. An Irrigation Evolution©. In Proceedings of the 2014 Annual Meeting of the International Plant Propagators Society 1085: 309-313.

U.S. Department of Agriculture. 2019. 2017 Census of Agriculture. National Agricultural Statistics Serv., Washington, D.C.

U.S. Department of Environmental Protection Agency. 2003. Section 404 of the Clean Water Act. National Statistics Serv., Washington, D.C.

Yeary, W., A. Fulcher, and B. Leib. 2016. Nursery Irrigation: A Guide for Reducing Risk and Improving Production. Univ. of Tennessee. PB 1836

.

Table 2.1 Number of nursery growers that participated in the Best Management Practices Survey from each region in Alabama based on survey responses in 2018.

Region 1	1
Region 2	0
Region 3	1
Region 4	5
Region 5	2
Region 6	11
Region 7	4
Total	24

[z] For region location, see Figure 2.1.

Table 2.2 Crosstabulation of Alabama nursery growers' knowledge of Best Management Practices for container plant growth and region of location within Alabama based on survey responses in 2018.

Location by Region	BMP Knowledge		χ^2	Asymptotic Sig.	*df*
	Yes	No			
Region 1	1	0	5.892[z]	0.189	5
	(0.5)	(0.5)			
Region 3	0	1			
	(0.5)	(0.5)			
Region 4	3	2			
	(2.3)	(2.7)			
Region 5	2	0			
	(0.9)	(1.1)			
Region 6	4	7			
	(5)	(6)			
Region 7	1	3			
	(1.8)	(2.2)			

[z] 10 cells (83.3%) have expected count less than 5. The minimum expected count is .46.

Table 2.3 Crosstabulation of Alabama nursery growers' knowledge of Best Management Practices for container plant growth and use of collection ponds in Alabama based on survey responses in 2018.

Collection Pond Use	BMP Knowledge No	BMP Knowledge Yes	χ^2	Asymptotic Sig	*df*
			5.919[z]	0.013	1
Yes	2	7			
	(4.9)	(4.1)			
No	11	4			
	(8.1)	(6.9)			

[z] 2 cells (50%) have expected count less than 5. The minimum expected count is 4.13.

Table 2.4 Crosstabulation of Alabama nursery growers that group plants by water requirement and their use of single or cyclic irrigation based on survey responses in 2018.

Group Plants	Single Irrigation	Cyclic Irrigation	χ^2	Asymptotic Sig	*df*
Yes	11	1	6.316[z]	0.037	2
	(9.5)	(2.5)			
No	4	4			
	(6.3)	(1.7)			
Sometimes	4	0			
	(3.2)	(0.8)			

[z] 4 cells (66.7%) have expected count less than 5. The minimum expected count is .83.

Table 2.5. Crosstabulations of Alabama nursery growers' knowledge of Best Management Practices for container plant growth and their use of measuring distribution uniformity based on responses from 2018 survey.

Measure DU	BMP Knowledge		χ^2	Asymptotic Sig	*df*
	Yes	No	.280[z]	0.963	3
Regularly	2	2			
	1.8	2.2			
Sometimes	4	5			
	4.1	4.9			
Never	4	4			
	3.7	4.3			
Don't use overhead irrigation	1	2			
	1.4	1.6			

[z] 8 cells (100%) have expected count less than 5. The minimum expected count is 1.38.

Figure 2.1. Map of Alabama region included in survey.

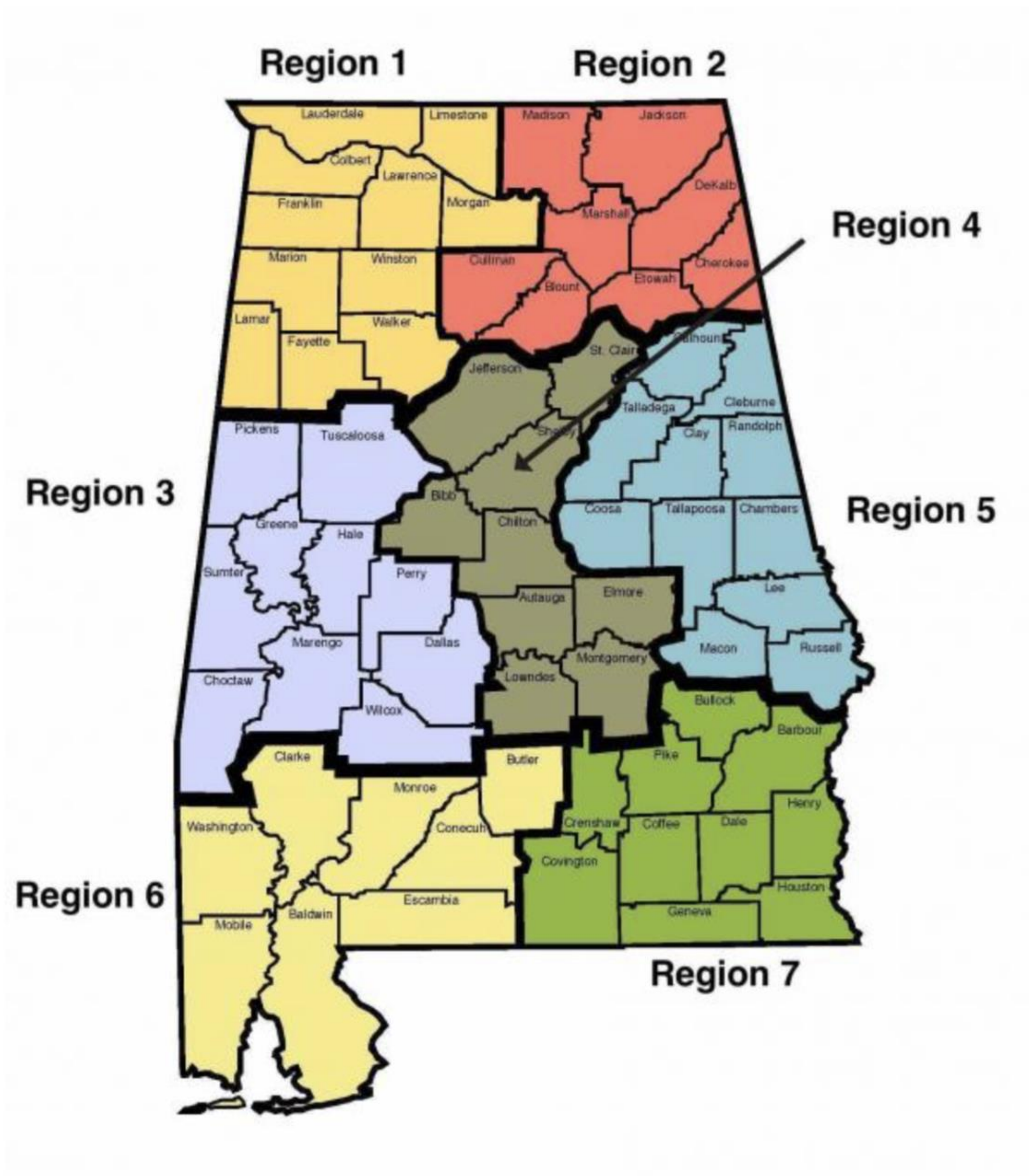
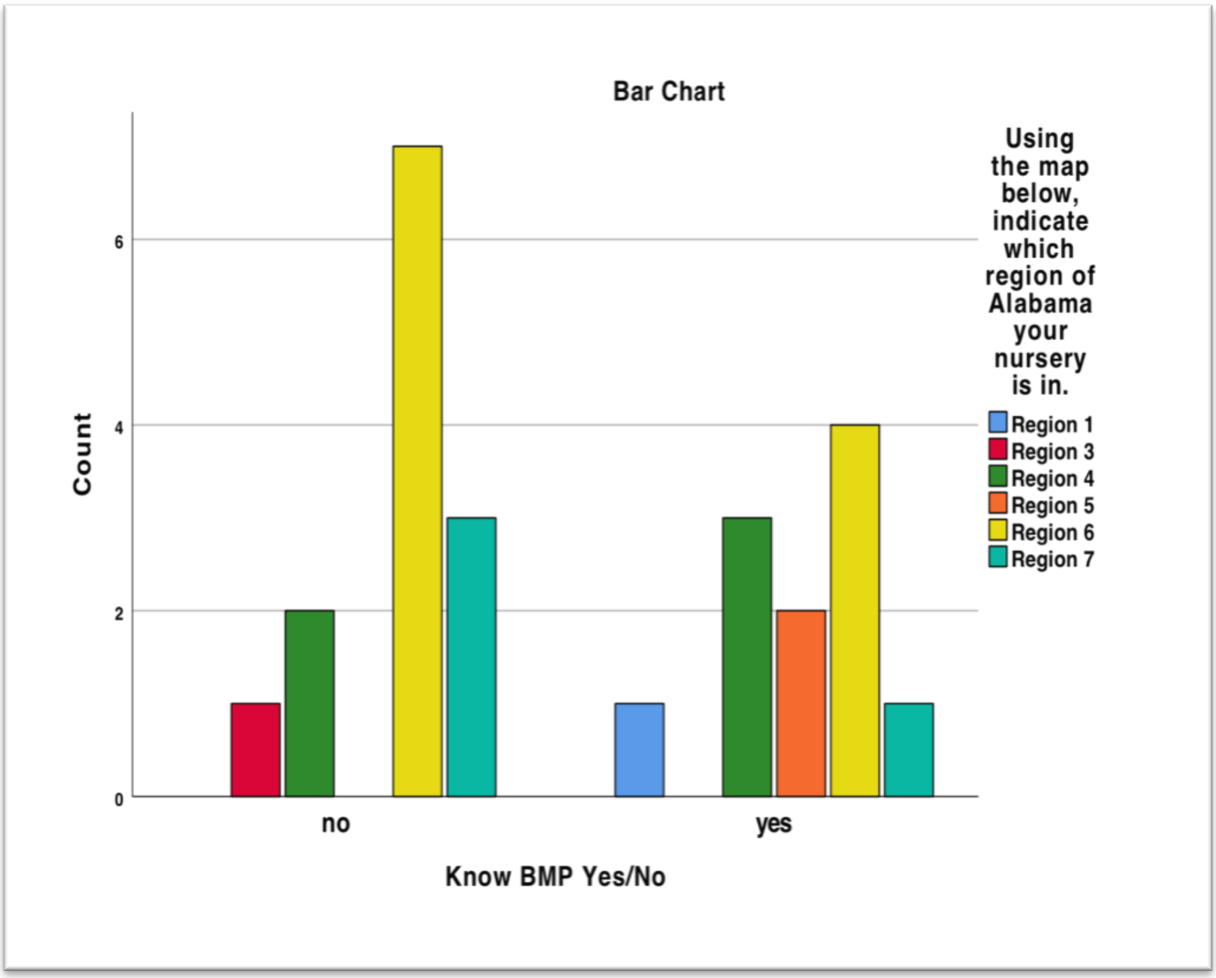


Figure 2.2. Bar chart of BMP knowledge based on region selected.



CHAPTER III: CONCLUSION

The ornamental horticulture industry is highly diversified in terms of practices and materials grown. Growers see daily the problems that arise within the green industry, which is why BMPs were introduced. The survey described in Chapter 2 provides researchers and extension specialists a snapshot of BMP adoptions in Alabama nurseries. Unfortunately, Alabama growers seem reluctant to adopt many BMPs.

Region 6 in Southwest Alabama of our survey accounted for 46% of our respondents. Best Management Practices were used by 46% of survey respondents, indicating that they are in use by Alabama nursery operations. In comparison with neighboring states Georgia and Florida, Alabama's overall cyclic irrigation rate was at 20%, compared to Florida's 42% and Georgia's 44% usage rate (Garber et al., 2002, Schoene et al., 2006).Growers measured distribution uniformity at an average rate of 17%, while Florida growers were at 35% (Schoene et al., 2006). Many of the operations we surveyed (70%) used #5 containers or smaller with overhead irrigation.

Comparison to Fain et al., 2000 Survey

The last statewide survey in Alabama was in 1998, surveying 24 container production nurseries in South Alabama (Fain et al., 2000). The survey divided nurseries into three categories by acres of production: small, medium, and large nurseries. Survey questions were similar as the current study. To make comparisons between new and old data, our sample was categorized similarly into the small, medium and large groups like Fain et al. We categorized nurseries with

20 or less acres under production as small, nurseries having 21-69 acres as medium, and nurseries with acreage greater than 70 acres as large. In 1998, cyclic irrigation was used by small, medium, and large nurseries at 38%, 25%, and 0% consecutively (Fain et al., 2000). In our survey, 40% of small and 40% of large growers reported using cyclic irrigation, while 20% of medium sized growers reported using cyclic irrigation. One noticeable find was that 73% of small nurseries group plants by water requirements, while 50% of large and medium nurseries reported grouping plants by water requirements. Many of the large nurseries in our survey and the survey conducted by Fain et al. in 1998 did not utilize cyclic irrigation. The reason is most likely due to difficulty in managing irrigation schedules and labor demands (Fain et al., 2000).

In 1998, 50% of the nurseries surveyed by Fain et al. monitored distribution uniformity compared to 57% of medium nurseries. The numbers are relatively the same today. In our survey, 50% of small and medium nurseries reported monitoring DU regularly. However, 88% of large nurseries never check distribution uniformity.

The percentage of respondents who reported using collection ponds was smaller in our survey compared to that of Fain et al. In 1998, 63% of small nurseries, 75% of medium, and 100% of large nurseries had collection ponds for capturing runoff. Now, 45% of small and medium growers use collection ponds to capture runoff, while only one large nursery with 70+ acres reported using collection ponds.

In regard to grass filters or vegetative buffers, the percentages of small nurseries incorporating this BMP did not change over the duration between our survey and Fain et al. Sixty-three percent of small nurseries reported incorporating grass filters. Medium nurseries reported less use of grass filters for the current survey, dropping from 75% in 1998 to 38% in

2018. No large nurseries reported using grass filters in our survey, while 63% of large nurseries reported using grass strips in the 1998 survey.

The most common fertilizer used in small nurseries were controlled release fertilizers (CRF) representing twelve growers (63%). Medium and large nurseries used liquid fertilizer through drip irrigation (33%). Field grade fertilizer was used by 3 growers from each size category.

BMPs can help growers increase their profits by mitigating loss of nutrients through overwatering, as well as control runoff (Saunders, 2014). In addition, growers can make more efficient use of scheduling irrigation times, cyclic irrigation, and grouping of plants, with increased BMP use, while conserving water and reducing runoff (Mathers et al., 2005). Further research is needed to determine what barriers, financial or economical, are hindering growers from adopting BMPs. With increasing demands of water and land resources, growers should strive to consider both environmental and production goals when making changes in practices.

Literature Cited

Fain, G. B., C.H. Gilliam, K.M. Tilt, J.W. Olive, and B. Wallace. 2000. Survey of Best Management Practices in Container Production Nurseries. J. Environ. Hort. 18:142–144.

Garber, M.P., J.M. Ruter, J.T. Midcap, and K. Bondari. 2002. Survey of container nursery irrigation practices in Georgia. HortTechnology 12:727-731.

Mathers, H. M., T.H. Yeager, and L.T. Case. 2005. Improving Irrigation Water Use in Container Nurseries. HortTechnology 15:8-12.

Saunders, T. 2014. An Irrigation Evolution©. In Proceedings of the 2014 Annual Meeting of the International Plant Propagators Society 1085: 309-313.

Schoene, G., T. Yeager, and D. Haman. 2006. Survey of container nursery irrigation practices in west-central Florida: An educational opportunity. HortTechnology 4:682–685.

APPENDIX A

Survey of Irrigation Practices in Alabama Container Production Nurseries

Q1 How many acres of container beds under irrigation does your nursery have?

____

Q2 Using the map below, indicate which region of Alabama your nursery is in:

- ○ Region 1
- ○ Region 2
- ○ Region 3
- ○ Region 4
- ○ Region 5
- ○ Region 6
- ○ Region

Q3 Are you familiar with Best Management Practices Guide for Producing Nursery Crops published by the Southern Nursery Association? If so, have you implemented any of the recommended practices?

- ○ No, I'm not familiar with it.
- ○ Yes, but I have NOT implemented any of the recommended BMPs
- ○ Yes, and I have implemented SOME of the recommended BMPs
- ○ Yes, and I have implemented MANY of the recommended BMPs

Q4 What type(s) of irrigation system(s) are used in your nursery? (Select all that apply.)

- ☐ Overhead (sprinklers)
- ☐ Drip/micro (irrigation applied directly into container)
- ☐ Ebb and Flow
- ☐ Other ____

Q5 What size containers are in production and how are they irrigated? (Select all that apply.)

- ☐ #5 or smaller containers, overhead irrigation
- ☐ #5 or smaller containers, drip/micro irrigation
- ☐ #7 or larger containers, overhead irrigation
- ☐ #7 or larger containers, drip/micro irrigation
- ☐ Other ____

Q6 Do you water the same crop once in a day (single irrigation) or multiple times in a day (cyclic irrigation)?

- ○ Once a day (single irrigation)
- ○ Multiple times a day (cyclic irrigation)

Q7 Breaking up irrigation into 2 or more applications per day is a recommended Best Management Practice. Why do you water once per day? (Select all that apply.)

- ☐ I see no benefit to watering more than once per day.
- ☐ Scheduling irrigation run times would be too complicated.
- ☐ Other (explain) ____

Q7 Why do you water the same crop more than once per day? (Select all that apply.)

- ☐ Water demand of the crop.
- ☐ To reduce root temperatures.
- ☐ It's a more efficient use of water.
- ☐ To reduce leaching.
- ☐ Other (explain) ____

Q8 Do you group plants by water requirements?

- ◯ Yes
- ◯ No
- ◯ Sometimes

Q9 Do you monitor the volume of irrigation applied during irrigation events (i.e. using rain gauges)?

- ◯ Regularly
- ◯ Sometimes
- ◯ Never

Q10 Do you measure the distribution uniformity of overhead irrigation systems (uniformity of applied irrigation throughout container area)?

- ◯ Regularly
- ◯ Sometimes
- ◯ Never
- ◯ I don't use overhead irrigation.

Q11 Do you measure the leaching fraction to determine how long to irrigate (percentage of applied irrigation that leaches from holes in bottom)?

- ◯ Regularly
- ◯ Sometimes
- ◯ Never

Q12 What factors do you use to aid in determining when and how much to irrigate? (Select all that apply.)

- ☐ Visual observation
- ☐ Feel weight of container
- ☐ Fixed irrigation times (irrigation clocks)
- ☐ Sensors
- ☐ Other (explain) ____

Q13 Do you use collection pond(s) to capture irrigation runoff?

- ○ Yes
- ○ No

Q14 What is your irrigation water source? (Select all that apply.)

- ☐ Well
- ☐ River/creek/stream or lake
- ☐ Municipal (city)
- ☐ Pond- maintained by well
- ☐ Pond- maintained by runoff recapture
- ☐ Pond- maintained by surrounding watershed
- ☐ Other ____

Q15 Does your nursery incorporate the use of grass filters, erosion strips, or constructed wetlands for runoff?

- ◯ Yes
- ◯ No

Q16 Do you test the pH and/or soluble salts of the irrigation water?

- ◯ Regularly
- ◯ Sometimes
- ◯ Never

Q17 Do you test your crop pH and/or fertilizer salt levels?

- ◯ Regularly
- ◯ Sometimes
- ◯ Never

Q18 What type(s) of fertilizer do you apply to container crops? (Select all that apply.)

- ☐ Controlled release fertilizer (CRF)
- ☐ Liquid fertilizer through overhead irrigation
- ☐ Liquid fertilizer through drip/micro irrigation
- ☐ Field grade fertilizer
- ☐ Other ____

Q19 Please list any questions, issues, or concerns you have about irrigation or fertilizer management? Is there any irrigation management issue on which you would like to see more research or extension information?