Florida Commercial Horticultural Production: Constraints Limiting Water and Nutrient Use Efficiency

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Abstract. Application of water and nutrients for horticultural production in Florida can be accomplished through use of many different methods. Often, the irrigation system that is utilized determines the potential use efficiency for both water and nutrients. Producers face many real and perceived constraints which affect their management decisions. This paper provides an overview of many of the encountered constraints with respect to commonly used irrigation systems and identifies the most effective management practices for overcoming these constraints. These constraints include those related to (i) irrigation system design and capabilities, (ii) soil factors, (iii) cultural practices, (iv) management intensity, and (v) economic and regulatory conditions. The ultimate goal of this discussion is to determine the critical issues on the horizon that may affect the Florida horticultural industry and outline future research needs.

Introduction

Any factor within a production system which inhibits, impairs, restricts or reduces the availability of applied water or nutrients can contribute to inefficient use of either of these inputs. It is essential to understand what these factors or constraints are and how they may be overcome in order to more effectively manage water and nutrient inputs in horticultural crop production as well as to minimize detrimental environmental consequences for Florida's natural soil and water resources. Certainly, the economic constraints inhibit the adoption of sustainable practices that may not be cost effective for producing certain crops. On the other hand, environmental concerns due to inefficient use of water and nutrients may overshadow economic constraints through imposed regulations. As a result, producers will have to comply with these regulatory constraints while still seeking to make an economic profit. While in many cases the physical constraints dominate, more often than not, the intensity of management and the use of best management practices (BMPs) are the keys to success in overcoming these constraints to ensure profitability.

The focus of this discussion is on the irrigation method and drainage constrains which affect water and nutrient application efficiency. Specifically, the constraints include: 1) irrigation systems and their operation and application characteristics; 2) the soil environment; 3) cultural management (i.e. mulch, raised beds, method of fertilization, etc); 4) operator management intensity; and 5) economic and regulatory constraints. The ultimate goal of this discussion is to determine what critical issues may be on the horizon that may affect the horticultural industry and where future research efforts should be focused.

1. Irrigation system operation and application characteristics

The type of irrigation system used determines the potential for subsequent water and nutrient use efficiency. While all irrigation system methods differ amongst each other in degree of efficiency of application (Smajstrla et al., 2002a), improper design of any system is the most critical factor that can significantly reduce water and nutrient use efficiency (Smajstrla et al., 2002c). Irrigation methods for horticultural crop production in Florida consist of subirrigation (seepage) using water table management, micro-irrigation (drip), micro-sprinkler, and overhead irrigation using large area application sprinklers. Each system has been evaluated for irrigation application efficiency (Smajstrla et al., 2002a) which takes into account the amount of applied water reaching the target crop root zone versus the total amount of water pumped. This irrigation application efficiency –together with the infiltration and soil water and nutrient holding characteristics, the ability to precisely manage applications, and the crop rooting characteristics–contribute to the effectiveness and efficiency of water and nutrient applications (Smajstrla et al., 2007). While an in-depth discussion of operation characteristics for each irrigation system can be found in Smajstrla et al. (2006b), there are inherent characteristics of each irrigation system that can affect water and nutrient use efficiency. For example, application coverage (gross area versus net cropped area) can contribute greatly to the efficiency of application. Application losses as a result of evaporation or surface runoff and subsurface water movement have very important impacts on both nutrient and water use efficiency. Another aspect of an irrigation system which can be very important is its ability to apply fertilizer in an efficient manner. The ability to schedule irrigation applications according to crop demands is very important (Haman and Smjstrla, 2002; Smajstrla et al. 2006a) and irrigation system choice can affect the degree to which this can be accomplished. Micro-irrigation and micro-sprinkler systems have the most potential to efficiently meet crop needs by nature of their design.

2. Soil Environment Constraints

Any soil factor which contributes to the inefficiency of water and nutrient use can be considered a constraint that needs to be overcome. Soil physical and chemical properties are major factors which affect water and nutrient use efficiency (Haman and Izuno, 2003). These factors include texture or the particle size distribution for a soil and the cation exchange capacity (CEC) which defines the ability of the soil to chemically bind nutrients in the soil profile. As Florida's soils are quite diverse in characteristics (very sandy mineral soils to organic soils), the constraints associated with them are also diverse. Generally, most soil-related constraints are associated with sandy soils and the discussion of this paper will concentrate on these. Sandy soils with low water and nutrient holding capacity provide little room for inefficiencies of irrigation or fertilizer application. Many soils used for horticultural production in Florida are very sandy in nature and are typically low in organic matter, which contributes to a low CEC. These soil characteristics result in a growing environment, especially when large amounts of dry fertilizer are applied at one time, that can be very vulnerable to leaching losses from inefficient irrigation or after heavy rainfall events. Management of these soils to overcome these constraints is benefitted by synchronizing water and nutrients use with crop needs at any one time although this may require multiple daily applications if the irrigation system allows. Because heavy rainfall events in Florida are not uncommon, drainage characteristics of production areas is critical. The ability to drain a field when needed is greatly affected by topography and presence of (or lack of) a high naturally occurring water table. Drainage can contribute to reducing or enhancing water and nutrient use efficiency depending upon design and management.

3. Cultural management factors

There are many cultural factors inherent with irrigation system and the soil environment which can contribute to overcoming these constraints. For example, the use of bedded culture versus non-bedded culture can protect a root zone during heavy rainfall periods. Further, the use of plastic mulch can protect applied fertilizer from leaching during the same periods as well as reduce evaporation and facilitate weed and other pest control. These two factors alone have become the norm for many high value horticultural crops. While options for fertilization procedures are greatly affected by irrigation system, this cultural management decision can be critical for reducing nutrient losses and optimizing nutrient use efficiency. The use of coated fertilizer materials which provides for controlled release of nutrients is an option when dry fertilizer application is necessary. Regardless of type of fertilizer used or the method it is applied, recommendations based on plant requirements (Simmone and Hochmuth, 2007) as to the quantity of fertilizer needed to grow a crop can be viewed as a constraint by producers. The decision as to how much fertilizer should be applied initially determines the potential nutrient losses that can happen as a result of the applied amounts not being utilized by the crop for production. In some instances, excessive fertilizer amounts can be viewed by producers as justified to provide "insurance" to protect the investment they have made in their crop. Even under these circumstances, management practices such as double-cropping or cover-cropping to use residual nutrients can minimize nutrient losses to groundwater and surface water resources.

4. Intensity of Management Constraints

Probably, the most under-considered yet most important constraint to water and nutrient use efficiency is that which concerns the producer and the intensity of management to overcome any physical constraints of production system. One can have the most efficient irrigation system and still experience water and nutrient losses if it is not managed properly. Decisions with respect to scheduling water and nutrient applications, system maintenance and repair can greatly affect efficient water and nutrient use. Many types of water and nutrient BMP's have been developed over the years to give producers options to achieve production goals while maintaining efficient water and nutrient use, but implementation of such practices, to a large degree, is still up to the manager himself.

5. Other Constraints

Other factors affecting water and nutrient use efficiency which producers may view as constraints include regulatory and economic factors. While this discussion will not dwell on these, they are often perceived by producers as real barriers to reaching production goals. Methods and systems that maximize water and nutrient use efficiency may exist, but the economic cost may be seen as unjustified. Regulatory requirements, while necessary, are constantly becoming more stringent to protect natural resources and they can be viewed as an imposition by the producers if they inhibit or force change from normal operating procedures.

For the remainder of this discussion, we will concentrate on addressing two specific questions regarding these constraints and how they relate to different irrigation systems for achieving water and nutrient use efficiency with their use.

<u>Question 1</u>. What are the constraints that limit water and nutrient use efficiency when using the following irrigation methods: seepage subirrigation, micro-irrigation (drip), micro-sprinkler, and overhead?

Seepage Sub-irrigation

Seepage subirrigation utilizes field water table management to provide water for crop production (Smajstrla et al., 2006b). This system requires three components to be successful: (i) readily available source of large quantities of water, (ii) a soil which has a naturally high water table level, and (iii) a soil with physical characteristics that allow both rapid infiltration and drainage. This system is typically used on Flatwoods soils with a spodozolic layer which are very sandy and have a naturally-occurring high water table level (typically < 1m from soil surface). Water is typically conveyed within the field by surface furrows or buried perforated pipe. For plastic-mulched field production of row crops, this system requires dry fertilizer to be applied in concentrated bands on top of raised beds, slowly coming into the soil solution as upward capillary movement of water results from the elevated water table position below the bed. This system inherently can result in water applications 2-3 times beyond plant water use requirements simply because such large quantities are needed just to maintain the water table level itself due to surface and subsurface losses. Because this process affords little control other than the target water table level, traditionally as much as 2-2.5 times the UF-IFAS recommended rate of fertilizer has been applied as insurance against leaching losses, which may occur as a result of heavy rainfall periods where the water table may be elevated to the surface. Since many crops which are grown with this system are very high value crops and require large investments (>$20,000 per ha) just to establish the crop, therefore, excessive fertilization and irrigation have been considered "cheap insurance" to protect the investments.

A modified design of the ditch-conveyed seepage system (Stanley and Clark, 1991; Stanley, 2004), the fully-enclosed subirrigation system (FES), using micro-irrigation tubing buried below the tillage zone has shown to be very effective in reducing water application amounts while still maintaining the target water table level. This is because much of the inefficiency of the seepage system attributed to surface runoff losses from the irrigation furrows is eliminated with the FES system since there is no surface water present. However, the use of banded dry fertilizer with FES remains the same as ditch-conveyed seepage subirrigation.

Much research and extension effort has been devoted to helping commercial producers overcome the obvious inefficiencies which can be associated with use the seepage subirrigation system. Probably the most difficult constraint is the legacy of this system in that it has been the traditional method used for much of the vegetable production for decades. It is a very effective irrigation system since the optimum environment provided for crop growth with respect to availability of water and nutrients is hard to match with other systems. In addition, it is a relatively low cost system and requires minimal management intensity. But because of its inefficiencies, the potential for over-application of water and nutrient losses has become great concern for environmental regulatory agencies.

Micro-irrigation

The design and operation of the seepage subirrigation system is in stark contrast to the micro-irrigation system which through its design (Haman and Smajstrla, 2003) has the ability to precisely apply water and nutrients directly into the root zone of the crop (Clark and Haman, 2003; Clark et al., 2002) and, manually or through automation, to schedule these applications to minimize water and nutrient losses (Haman and Smajstrla, 2002). Efficiency of application is enhanced by microirrigation by the ability of only irrigating the soil areas where roots are present, thus reducing the net area irrigated. Sandy soil constraints such as low water and nutrient holding capacities can be overcome through multiple daily irrigations so that only the daily required amounts of water and fertilizer are applied at a time, and the susceptibility of nutrient losses is minimized. The use of microirrigation on the very sandy soils of Florida does require some other irrigation method (such as subirrigation) to enable preparation of the land (bed formation, fumigation, transplant establishment) for crop production. It is imperative that the design of a microirrigation system results in uniform distribution of water throughout the cropped area (Smajstrla et al., 2002a). If the distribution system isn't sized properly, or length of run of individual microirrigation lines is too long, inconsistent applications of both nutrients and water can result.

While micro-irrigation provides the highest potential for efficient water and nutrient application, a lack of high management intensity can negate that advantage quickly. Mismanaged micro-irrigation can leach more nutrients than other systems if the scheduling allows application amounts greater than the soil's ability to maintain those nutrients in the rooting zone or when nutrients are applied followed by an extensive period of continued irrigation.

Constraints associated with micro-irrigation systems primarily deal with the high cost of installation and operation and the management intensity required to be successful. This system has large investment costs associated with specific components needed for filtration, chemical injection, automated control, as well as seasonal tube replacement. In addition, the training and experience that is necessary for successful micro-irrigation can be viewed as a constraint. This system requires a completely different mindset compared to seepage irrigation since a higher degree of attention to its management is necessary. If this constraint is not overcome, failure is sure to follow.

Overhead Irrigation

Traditional overhead irrigation of crops with wide area sprinklers can include solid set (permanently installed) systems, temporary moveable impact sprinkler systems, or self propelled wide area systems such as center pivot or lateral move systems. These systems are designed to apply water to the gross growing area and efficiencies are affected by evaporation losses and irrigation of non-cropped areas. Since the gross area is irrigated, inherent losses by irrigating non-cropped areas is evident. Fertilization through overhead systems can be very risky for the same reason. For example in citrus production, the use of surface applied inorganic fertilizers near individual trees is a common practice. Because the fertilizer is exposed to potentially high rainfall events, it is vulnerable to leaching. This constraint can be reduced when applications are split during the production year, thus reducing the amount of fertilizer present in the field at any one time. Even so, this split amount of fertilizer may be vulnerable to leaching. The use of controlled-release fertilizer to overcome this problem is an option, but the application costs are much higher.

Micro-sprinkler Irrigation

An alternative to overhead systems (for perennial crops) is the micro-sprinkler system. Much like micro-irrigation, the system is designed to apply water to specific areas only when desired and eliminates irrigation of non-cropped areas in contrast to overhead systems. Micro-sprinkler systems have the ability to apply nutrients as often as irrigation is scheduled, thus controlling the amount of fertilizer present in the soil at one time and reducing the leaching potential.

As with micro-irrigation, the associated costs for this system are higher since similar components are needed for operation and maintenance. A similar higher level of management intensity is needed also to ensure that the system is operating properly and that problems with malfunctioning micro-sprinklers (breakage or clogging) are attended to.

***Question 2.* How do drainage practices used by producers affect water and nutrient-use efficiency for the following irrigation systems: Seepage sub-irrigation, drip, micro-sprinkler, and overhead irrigation?**

Drainage during times of heavy rainfall is critical for crop survival to minimize exposure time of roots to low soil oxygen concentrations in the crop rooting zone. How this is achieved and the degree to which it occurs with respect to the irrigation system used can be important when trying to minimize water and nutrient losses. This is primarily driven by the soil characteristics and is magnified on soils with a naturally high water table where seepage irrigation is used. Since in this case the water table has been elevated even more for irrigation purposes, as soon as rainfall begins, the irrigation distribution system becomes a drainage system. If allowed to excessively drain, nutrients in solution may be leached quickly as the water table is lowered for drainage. In contrast, under the same circumstances but using drip irrigation with injected fertilizer, the water table is lower initially and only nutrients which have been recently been applied (typically one day's requirement) are vulnerable to leaching. A similar situation exists with overhead irrigation compared to micro-sprinkler irrigation when soils are excessively drained and is also due to the fertilization method (daily injection versus dry application) that is used.

The capture and reuse of runoff water for irrigation is a method where increased water use efficiency can be realized and to some degree nutrients if they are present in the water can be reused. This system can be effective since less water would be necessary to be applied from other well or surface sources, but a large storage structure is needed and often water treatment is necessary if reused for drip, overhead and micro-sprinkler systems. For the most part drainage practices can contribute to the efficient use of water and nutrients, but the degree to which drainage is managed is the constraint which must be overcome.

Questions to consider as we move forward:

1) Vision: what does the industry need to do better?

Some commodity groups in Florida have embraced the use of more efficient BMPs to a greater degree as a whole than other groups. In some cases it has occurred because of necessity, but also there have been those commodity groups that could see potential economic advantages that existed to make the change. Increased communication of examples of success among and within commodity groups is needed. Regardless, horticultural producers should be encouraged to pay more attention to management of whatever practices they are using, consider all options when making management decisions, be aware of all the resources that are available to improve the efficiency of operation.

2) Where should the future research efforts be focused?

Certainly new technologies will be developed and as they are, evaluation and refinement should be a focus of future research. A component of communicating effectiveness of current and new BMP's requires field validation to gain the confidence of producers that what may be recommended in the future will benefit their operation. Also, as continued land use changes occur with population growth, more effort should be concentrated on the impacts of these land use changes on water quality, especially on natural resources such as drinking water sources or bays and estuaries for coastal Florida.

3) What are the critical issues on the horizon that may affect the industry?

Coping with increased regulations for water quantity and quality management are major issues that the industry faces now and will continue to face. As increased competition for these resources continues and stronger policies to protect these resources are imposed, producers will have to determine whether or not they can survive under such an environment. However, these are not the only issues the industries continue to cope with - labor, foreign competition, invasive and new pest problems are among a few. It is essential that research and extension efforts are focused on ensuring a viable and growing industry in light of the many issues that are present.

In summary, horticultural producers face many constraints which can affect how efficiently they use water and nutrients. These constraints can be a result of the environmental, physical and cultural growing conditions, but also can include economic and regulatory issues. While many of these constraints can be overcome with the use of the effective BMP's, success is a direct function of producer management decisions and the intensity to which they are implemented. Our focus must be on the future, demonstrating to producers, that current technologies are effective in achieving water and nutrient use efficiency, developing and evaluating new technologies that will improve efficiency even further and being aware as land use change continue to occur, our focus may shift to more agricultural/urban fringe issues that may involve even more urban landscape management of water quality.

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