

INNOVATIVE APPROACHES TO WATER QUALITY AND CONSERVATION IN THE GREENHOUSE INDUSTRY

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Abstract. Most greenhouse operations are inefficient in their use of water and fertilizer. As water conservation and prevention of fertilizer runoff become more important, growers may have to switch to alternative means of watering and fertilizing their plants. There is a variety of more efficient alternatives available. Some of these can be implemented in existing greenhouses with very little investment, while other methods require a significant capital investment. The advantages and disadvantages of the most common watering systems are addressed here. Some promising alternative irrigation methods for commercial greenhouses will be discussed. Because there is a wide variety of greenhouses in Georgia, not all these alternatives will be suitable for all growers. However, virtual all greenhouse operators should be able to reduce their water use and decrease the potential of fertilizer runoff using some of these techniques.

INTRODUCTION

The availability of affordable and clean water has become an important issue throughout Georgia. The rapid growth of the metro Atlanta area has led to a continuously increasing water demand in the Piedmont region of Georgia. The Florida aquifer, which supplies water to most of Southern Georgia, is threatened by salinization. These factors have led to an increased emphasis on water quality and availability throughout the state. Agriculture, as one of the largest water users, needs to be an integral part of any water conservation efforts in Georgia. Except for being a major water user, agriculture may also cause problems with water quality because of fertilizer and pesticide runoff, which can contaminate ground and surface water. The threat of fertilizer runoff from greenhouses is particularly significant, because fertilizer rates (per unit area) can be up to 100 times higher than in field crops. Current fertilization practices can lead to unacceptably high nitrogen levels ($>230 \text{ g m}^{-3}$) in the soil underlying commercial greenhouses (McAvoy, 1994).

The greenhouse industry is in a unique situation, because the crops are produced in an enclosed and controlled environment. This simplifies efforts to prevent or recapture runoff from greenhouses. Since inefficient use of water and fertilizer is an economic loss, more efficient utilization of these resources can be economically beneficial for growers. This emphasizes the importance of improving the efficiency of both water and fertilizer use in the greenhouse industry, while considering the economic consequences for growers.

WATERING AND FERTILIZING IN THE GREENHOUSE

Greenhouse crops are normally grown in potting mixes that do not contain any soil, but are a mixture of peat, perlite, vermiculite, and bark. Other organic or inorganic components can be added to improve water-holding capacity and/or pH of the mix. Unlike soil, these components do not contain appreciable amounts of available nutrients. Small amounts of fertilizer can be mixed in the growing medium, but the vast majority of nutrients has to be supplied by the grower. This is normally done by mixing water-soluble fertilizers with the irrigation water. To prevent build-up of fertilizer in the pots, it is often recommended to water plants until 20-30% of the applied water drains from the bottom of the pot. Since it is difficult to determine this leaching fraction accurately, much higher (50%) leaching fractions are probably not uncommon. This leachate can contain high levels of fertilizer and is normally not collected. There is some data available on the low efficiency of fertilizer use in greenhouses. Stewart *et al* (1981) estimated that only 5-8% of the applied nitrogen in the greenhouse production of privet (*Ligustrum japonicum*) was taken up by plants, while up to 50% of the nitrogen was lost in the leachate from the containers. In studies with seed geranium (*Pelargonium x hortorum*), 21 to 46% of the applied nitrogen was lost in the leachate, while 26 to 47% was used by the plants, depending on the nitrogen source (Cox, 1985). Since leaching through pots is a major cause of fertilizer run off, it is clear that runoff and watering efficiency are closely connected in the greenhouse industry.

Common Watering Systems

The method of irrigating greenhouse crops depends on the type of plants being grown. Bedding plants are most commonly watered by hand, although stationary overhead sprinklers or moving sprinkler booms are other alternatives. Potted plants are often watered by hand or with 'spaghetti' tubing (drip irrigation). All these systems have pros and cons but none make very efficient use of the applied water.

Hand Watering. Watering by hand is an extremely labor-intensive method, that is popular because of the extremely low initial investment. To leach out excess fertilizer and because it is difficult to apply similar amounts of water to all plants, it is common practice to water plants until water drains from the bottom of the pots. Much of the applied water can be lost because

of leaching and from moving the hose from pot to pot.

Overhead Sprinklers. Sprinkler irrigation is a relatively inexpensive method to automate watering in greenhouses. Unfortunately, it is difficult to get an even water distribution throughout the greenhouse using overhead sprinklers. Some overlap between sprinklers is normal to assure complete coverage. This leads to uneven watering and the crop is normally watered so that all plants receive enough water for healthy growth. As a consequence some plants will be over watered. Generally, sprinkler systems are not very water-efficient. This is especially important in the case of potted plants, where there is considerable space between pots. For example, 6" pots are commonly spaced 4" apart, which means that 72% of the ground area is not covered by pots. Sprinkler irrigation is not well-suited for potted plants because it can cause excessive run off (Morey, 1987; Neal and Henley, 1992). It is best suited for bedding plants, where practically the entire ground surface is occupied by plants.

Spaghetti Tubing (Drip Irrigation). The most common watering system for potted plants is spaghetti tubing. Plants receive water through small diameter plastic tubes, which are connected to a larger supply line. The tubes are normally held in the pots by a lead weight or a wire and the water flows directly into the pots. A problem with spaghetti tubes is that pots are often watered too fast to allow for a good water distribution in the pots. Water often starts draining from the bottom before all the growing medium is thoroughly watered. Another disadvantage of spaghetti tubing is that it does not give the grower a lot of flexibility in plant spacing, since it is impractical to change the spacing of the plants (and tubing) during the growing season. The terms spaghetti tubing and drip irrigation are often used interchangeably. However, since the flow rate can be as high as 15 mL s^{-1} , spaghetti tubing is more appropriate than drip irrigation.

Improved Watering Systems

Growers in many other states and countries have faced water availability and quality problems in the past and have dramatically increased the efficiency of their watering systems. Some of these methods are simple adaptations of old systems, while some new watering techniques have been developed. Most growers in Georgia could reduce water and fertilizer runoff from their greenhouses by implementing some of these techniques.

Drip emitters Pressure-compensated emitters can be attached to the end of the spaghetti tubing. This greatly decreases the flow rate, allowing a better water distribution within the containers. Pressure compensation also has the benefit that flow rates to all the plants are fairly equal, allowing for more uniform watering. Most drip emitters also have the advantage that individual emitters can be turned on and off. This is a simple and fairly cheap adaptation of traditional spaghetti tubing.

Pulse watering is another improved method of spaghetti tube irrigation. Instead of watering plants once or twice a day with a large amount of water, plants are watered more frequently with small amounts of water. This allows the water to be redistributed within the pots between waterings, resulting in a more uniform

water distribution within the pots. That makes it possible to thoroughly wet the growing medium without much leaching. Pulse watering systems need to be designed more carefully than regular spaghetti tubing. In regular spaghetti tube systems, it is not uncommon that tubes on one end of a bench start dripping 10-15 seconds before tubes at the other end emit water. This may not be significant if the plants are watered for several minutes. However, with pulse irrigation, plants are watered up to ten times per day for short periods and the system needs to be designed so that all pots receive similar amounts of water.

Capillary Mat. Benches can be covered with a water-absorbing, porous mat. The mat is kept moist with water or fertilizer solution as needed and the pots absorb the water and nutrients through holes in their bottom. It is essential that the pots are in close contact with the mat to allow for water flow between the mat and pots. The mats also have to be kept moist at all times because it can be difficult to rewet a dry mat. To prevent excessive algae growth on the mat, it is normally covered with black polyethylene with many tiny slits to allow water flow. A properly managed capillary mat can reduce run off to almost zero, but it requires some experience to determine how much water the mats need. The mats can be watered by hand or with drip tubes, which allows for automation. Because there are no tubes to the individual pots, it is easy to change the spacing of the plants on the mats. This allows the grower to adjust plant density throughout the growing cycle and make optimal use of the available greenhouse space.

Capillary mats may be a practical alternative for many growers, because it can easily be installed in existing greenhouses without a large investment in new benches or other equipment.

Ebb-and-Flow was initially developed in Western Europe to prevent fertilizer runoff from greenhouses. Water is pumped from a holding tank onto watertight benches until there is approximately an inch of water on the bench (the water level can be adjusted by the grower). The water subsequently starts draining back into the holding tank. The growing medium absorbs the water through the holes in the bottom of the pots. Although it is possible to use ebb-and-flow just for watering, water-soluble fertilizer is almost always added to the holding tank. Unfortunately, complete ebb-and-flow systems are expensive. Although labor savings, lower amounts of water and fertilizer, and improved plant quality make ebb-and-flow systems economically attractive (Josko, 1991), the initial investment is an important barrier to widespread implementation of these systems.

A newer application is the use of precision-leveled concrete floors for ebb-and-flow irrigation. This allows for the irrigation of an entire greenhouse at a time, and makes investment in benches unnecessary. Since the fertilizer solution is recirculated in ebb-and-flow systems, runoff is completely eliminated.

Ebb-and-flow systems are normally fully automated, resulting in significant savings on labor costs. Ebb-and-flow can be used with almost any type of greenhouse crop (potted plants, bedding plants) and crops with similar water and fertilizer requirements can be grown in the same irrigation section. It is simple to change plant spacing during the growing season, allowing the grower to adjust plant density as needed.

Trough Irrigation. Like ebb-and-flow, trough irrigation was

developed to prevent nutrient runoff from greenhouses. Troughs are placed in the greenhouse at a slope of 1:25 to 1:100 (0.5 - 2.5° from horizontal) and water is pumped into the high end of the trough. Pots are placed in the troughs and absorb the water as it flows down. The excess water is collected at the bottom of the trough and recycled into the nutrient solution tank. Since it is a closed system, it can be used without any runoff. It is important that the size of the troughs and pots are matched, because if the pots are too small, the water can channel past the pots without wetting the growing mix. This greatly reduces the flexibility of these systems, since a grower needs different sets of troughs to grow plants in different pot sizes.

Trough irrigation systems are considerably cheaper than ebb-and-flow benches, making it an attractive alternative for growers who specialize in potted plants.

Whole Firm Recirculation. It is possible to construct new greenhouses so that all the runoff is collected in a retention pond. A concrete floor with gutters, or plastic liner underneath the greenhouse can be very efficient. This option is less suitable for existing greenhouses, because they are difficult and expensive to retrofit.

It may be necessary to treat the water from the retention pond and to test it for nutrient levels. The fertilizer level can be adjusted as needed and the water reused.

Problems with Low or Zero Runoff Systems

Systems that drastically reduce runoff bring some new challenges for growers. Growers normally apply excess water to leach out salts that build up in the growing mix. To minimize runoff it is important that leaching is kept to a minimum. Since the build-up of salts is normally caused by excessive fertilizer applications, leaching would not be necessary if less fertilizer was applied. However, if fertilizer rates are too low, this can cause a decrease in growth and it is important for a grower to apply the right amount of fertilizer. Fertilizer rates in the growing mix can be monitored by measuring the electrical conductivity (EC) of the bulk solution in the growing mix. A continuously low EC reading (< 1 dSiemens/meter) indicates a low concentration of nutrients in the growing mix and higher fertilizer rates may be needed. If EC readings keep increasing throughout the growing cycle of the crop, fertilizer rates are too high and should be decreased. Growth of many plants can be adversely affected if the EC becomes higher than 3 dS/m.

EC monitoring allows a grower to better adjust fertilizer rates to the needs of a specific crop. Fertilizer rate affects plant growth and quality (Poole and Conover, 1992) and it may be possible to reduce the total amount of fertilizer and improve growth and quality of the plants. Unfortunately, there are no good guidelines to determine optimal EC levels for the many different crops that greenhouse growers produce. Research is needed to generate knowledge on the interactions between fertilizer rates, EC levels, growth, and plant quality. This type of information will make it more feasible for growers to implement production strategies that conserve water and reduce fertilizer runoff.

CONCLUSIONS

There is great opportunity in Georgia's greenhouse industry to use water more efficiently, thereby decreasing both water demand and fertilizer runoff from greenhouses. Although a variety of approaches are available, few of these are currently being implemented by greenhouse operators in Georgia. The main obstacles for implementation of more efficient irrigation systems appear to be a lack of knowledge about possible improvements and high initial investment costs associated with some of these systems.

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