NC STATE EXTENSION

Critical Management Issues for SDI Systems in North Carolina

Subsurface Drip Irrigation

Although subsurface drip irrigation (SDI) is in its infancy in North Carolina, it is becoming more popular as growers learn of its many benefits, which include increased irrigation efficiency. Proper management is imperative with an SDI system.

Some management areas, such as water management (irrigation scheduling) and chemigation management (applying chemicals and fertilizers through your irrigation system), are similar to above ground drip systems. But other management practices are especially important or unique to SDI. Many components of an SDI system are underground; therefore, you must carefully monitor pressure and flow rates to ensure that the system is operating properly. This publication addresses water management, chemigation, system management and maintenance, and system evaluation.

Water Management

Water management, often referred to as irrigation scheduling, is the process of determining when and how much to irrigate. Factors influencing your decision to irrigate include weather, crop, soils, system design, and management criteria (yield goal, labor, convenience, water supply, etc.). Irrigation scheduling techniques provide information on how much to irrigate, or when to irrigate, or both.

Techniques that determine how much to irrigate are typically called water balance or checkbook methods. They are based upon replacing water that has been lost to soil evaporation and plant transpiration, often lumped together and called evapotranspiration (ET). You may also lose water to deep percolation (drainage) and runoff. Inputs of water to the soil system are irrigation and rainfall. Water balance methods try to balance incoming and outgoing soil water so that water is available for crop growth.

Techniques that determine when to irrigate typically measure stress points in soil or plants, and require additional soil and crop information to determine how much to irrigate.

An SDI system can apply water in relatively small amounts and can be operated to replace the water several times a day as it is used by the crop. Multiple small irrigations per day are more appropriate for high value vegetable crops.

Water Balance Scheduling Methods

The water balance or checkbook method requires that you estimate evapotranspiration, measure rainfall, and record irrigation amounts. Irrigation and rainfall replace water lost to ET. Irrigation and rainfall in excess of what the soil can hold are lost as deep percolation or runoff and are not credited towards replacing ET. The amount of water a soil can hold is called field capacity. Evapotranspiration is determined from what is called reference evapotranspiration (ET0) and crop information. Reference evapotranspiration is also sometimes referred to as potential evapotranspiration. Weather data, specifically air temperature, relative humidity, solar radiation, and wind, are collected and used to estimate ET0. Reference evapotranspiration and rainfall are available for several sites from the State Climate Office of North Carolina.

The estimated evapotranspiration of the crop (Etc) is determined by multiplying ET0 by a crop coefficient (kc). The kc is dependent on the type of crop, stage of growth and management factors. Crop coefficients are often site specific, and are usually associated with the equation used to predict ET0.

One of the simpler methods of estimating daily ET is by measuring evaporation from a free-water surface, since a correlation exists between ET and evaporation from free water. The standard water surface commonly used is the National Weather Service Class A evaporation pan surrounded by well-watered short grass. The ratio of ETo to evaporation from a well-maintained evaporation pan is typically assumed to be about 0.8 in North Carolina. You must use crop coefficients developed for pan evaporation if you use this method to estimate ETc. Pan coefficients developed in the Southeast for several crops may be found at *Irrigation Scheduling Methods*.

Rainfall information may be available in local newspapers, but it is a good idea to measure rainfall with a rain gauge near your field for use in the water balance method, since rainfall amounts are highly variable in North Carolina.

Measure irrigation amounts with a flow meter, or use the rated discharge of the dripline at the pressure the dripline is operated, and the time the system is operated. If the dripline you are using is drip tape, the rating for the product is usually expressed in gallons per minute per 100 feet of drip tape operated at a pressure of 8 psi. To use the checkbook method, you will need to convert the irrigation volume applied to a depth. If you operate your dripline zones at a pressure near 8 psi, you can use the following equation to obtain irrigation depth in inches:

Depth Applied (inches) = [Dripline Rating (gpm/100 ft) x Operating Time (minutes)] ÷ (Dripline Spacing (ft) x 62.3)

*Soil-Based Scheduling Methods*You may choose to replace the water lost to ET daily or irrigate only at a predetermined soil-water level that prevents drought stress. More information on the checkbook irrigation scheduling method can be found at *Irrigation Scheduling to Improve Water and Energy-Use Efficiency*.

Irrigation scheduling based on replacing lost soil water can also be done by measuring the soil water content using the feel method or by using sensors or other devices. As with the checkbook method, water lost to ET is replaced by irrigation and rain. The feel method is done by sampling the soil in the root zone using a push probe, auger, or shovel and feeling the soil to determine the amount of plant-available water remaining in the soil or conversely the amount of water depleted from field capacity. When using the feel method with SDI systems, be careful not to puncture driplines that may be located near your sampling location. The amount of irrigation added using the feel method will vary from user to user because of the judgments made by each user.

Tensiometers and electronic soil-water sensors can be used to measure soil moisture. Tensiometers and granular matrix sensors measure soil-water tension (suction) that the plant has to overcome to uptake soil water. A popular type of granular matrix sensor is the Watermark sensor. To convert centibars to plant-available water, you will need a conversion table or chart. Most manufacturers supply charts that categorize the relationship between soil water tension and plant available water by soil type (e.g., sand, loam, clay). Other electronic-based sensors register total soil water content (not plant available) in percent water by volume (volumetric water content). To convert total soil water content in percent to inches of water per foot of soil, multiply by 12. A rule of thumb is that a soil's plant-available water holding capacity is about half of the total amount of water the soil holds at field capacity. No matter which soil-based method is used, be sure not to apply more water than the soil can hold at field capacity. If you are using a tensiometer or Watermark sensor, field capacity will be at about 5 centibars for a sandy soil and about 30 for a clay soil. You can estimate the total water content at field capacity by using a sensor that registers in volumetric water content a day or two after a soaking rain.

Soil water sensors are also used to help decide when to irrigate. A certain tension (tensiometer or Watermark sensor) or soil water content (dielectric sensor) can be used as a trigger point to initiate irrigations.

Sensor Number and Placement

Soil water sensors are particularly effective in helping to schedule irrigations in North Carolina, where hard-to-predict rainfall can make it difficult to plan irrigation. Always place more than one sensor per field to allow for possible sensor malfunction and field variability. When using sensors in SDI-irrigated fields, it is particularly important to use more than one sensor per location. It can be helpful to sensors at least two depths and at two distances form the dripline to monitor water movement from your SDI system.

Sensor placement depends on crop type. For instance, placing a soil water sensor greater than 2 feet in the soil for peanut may not be as important as placing the sensor in the pod zone (2 to 6 inches). Also, placing the sensor too close to the dripline's emitters may not be wise. For an SDI system with a 36-inch row spacing and emitters spaced at 18 inches and buried 12 inches deep, the driest part of the field would be half way between the drip laterals (18 inches), half way between emitters (9 inches), and at the soil surface. Place sensors in the active part of the root zone to monitor water uptake and far enough from emitters to show fairly precise measurement. For the peanut crop in this example, place crop sensors about half way between emitters, about six inches deep, and about 10 to 14 inches from the drip lateral. If possible, also place sensors deeper to monitor water movement. An increase in water content at these deeper soil depths would indicate overirrigation with water draining to the lower soil depths. If the water content decreases, then not enough water is being applied and drought stress may occur.

Application Frequency

Once you have determined when and how much to irrigate, you must decide how to apply the water. With SDI you may apply water once a day or multiple times during the day. Watering once per day could potentially leach nutrients or pesticides below the root zone. Watering multiple times a day may keep small amounts of water in the root zone throughout the day. The SDI system controller may not be able to apply water at multiple times. Other hardware design criteria must be taken into consideration to make the choice of one or multiple irrigations per day. At the time of this writing, there is no research available with SDI to show any benefit of irrigating multiple times per day versus once per day.

Chemigation

Chemigation is a term used to describe the process of applying chemicals through irrigation systems. SDI can efficiently and safely apply chemicals, such as pesticides and fertilizers (fertigation). Other chemicals may be applied to protect the dripline from rodents, insects, root intrusion, chemical precipitates, and biological slime. Regardless of the chemical you are using, always follow manufacturers' labels closely to ensure effective application, proper use, and extended life of the system. Make sure your system has been designed in accordance with the State of North Carolina guidelines on chemigation and fertigation, and that it has the required backflow prevention devices.

Operation of Chemical Injection Devices

SDI systems use the same type of chemical injection devices as other drip systems. Injection of chemicals can be accomplished with Venturi injectors, positive displacement pumps, water-driven pumps or diaphragm pumps. For all of these units, you need to adjust the injection rates and chemical stock solution concentrations to reach the desired concentration in the irrigation water. If your system has been designed properly, your injection device has the capacity to inject an adequate amount of stock solution for its various functions. Electric-driven positive displacement pumps will deliver a constant flow, so if your irrigation pumping rate changes you will either need to adjust the stock solution concentration or the pump's stroke or frequency (if adjustable) to maintain the same concentration in the irrigation water. Water-driven pumps use a portion of the irrigation water flow to drive a water motor that mixes the chemical stock solution inside a mixing chamber that then flows back into the main irrigation line. The water-driven motor operates at a speed proportional to the flow driving it (motive flow), so a constant output concentration is maintained.

Diaphragm pumps are normally driven by an electric motor. A combination of stroke length and stroke speed is used to adjust the injection rate. These types of pumps will come with a nominal rating (gallons injected per day) at the rated pressure. Many diaphragm pumps will have greatly reduced injection rates at pressures over the rated pressure. You may have to reduce pressure in the irrigation main line at the injection point to achieve the necessary injection rate if your injection pump's pressure rating is marginal. The pressure that the diaphragm pump has to pump against (backpressure) can change as different zones are irrigated or as pumping water levels change.

Control of Root Intrusion

Root intrusion is a common problem with SDI; several methods have been tried to deal with it. A mechanical solution is to use small emitter orifices to discourage root hairs from trying to penetrate, but other impurities or dirt in the water may clog the smaller orifice. Some drip tape products have tiny flaps over the emitters that are designed to provide a physical barrier to root intrusion.

Chemical control methods are also available to kill the root hair as it tries to grow into the emitter. The chemical trifluralin (TFN), also known by the brand name Treflan, may be injected into irrigation systems to kill roots near the emitters. Label directions have changed over the years, so be sure to follow label guidelines if you use this method. Some manufacturers have incorporated TFN into the emitter, where it is released slowly. This product has a trade name of ROOTGUARD. Another method for applying TFN is to use a filter with the chemical incorporated. The concentration of TFN in the water depends on the flow rate.

Another technology uses a copper product in the emitter that kills roots on contact and thus discourages the roots from penetrating into the emitter. Sulfuric, phosphoric, and other acids have also been used to stop root intrusion. Always follow label directions for mixing and injection these chemicals into the drip tube. These acids are highly corrosive and can damage some components of the drip system, especially metals and some plastics. Once the acid has been injected, be sure to flush the system with clean water.

Fertigation

Plant nutrients can be applied through the SDI system to reach the deeper plant roots. Depending on the installation depth of the drip line, young plants with shallow roots will not get water or nutrients from the surface drip irrigation line. Crop nutrient feeding is best done later in the growing season when the roots reach the depth of the SDI driplines.

Emitter and Filter Clogging

Clogging problems are always a concern with drip systems because the emitters are small. In an SDI system, take extra precautions to maintain the cleanliness of the water and thus prevent clogging. Treatment methods include acid injection and chlorination. Problems with mineral deposits like calcium and magnesium carbonates and iron oxides can be treated with acid to keep those in solution. Regular flushing of your SDI system is also important in preventing clogging.

Chlorine is used to kill and dissolve algae and bacteria and prevent their growth. Chlorine will also oxidize ferrous iron to form iron oxide that will precipitate out of the solution and must be trapped in a filter. Fresh water algae require light for growth, so they do not live inside buried pipes. However, colonies of algae can form a large enough mass to cause clogging in emitters and also may clog the filter that is intended to remove them. Chlorine is used to kill the algae and dissolve them before they clog the filter or emitters.

Bacteria can live in pipelines and may cause clogging. Some bacteria come from wells, where they may have lived on sulfur or iron; these can continue to multiply in the irrigation lines and cause problems downstream of the filter. These iron or sulfur bacteria form bacterial slime around clay particles that then bind together to clog emitters and filters.

Continuous chlorine injection is sometimes used to prevent growth in the SDI system. More commonly, a larger dose of chlorine is injected at intervals to kill and oxidize the organic matter.

Chlorine is available as a dry material, liquid formulation, and as a gas. The dry material is calcium hypochlorite, which is commonly used in treating swimming pools. Calcium hypochlorite is usually not recommended for use with irrigation water of high alkalinity since it tends to form scales. Liquid sodium hypochlorite is relatively easy to handle. It is available in supermarkets as household bleach in a 5.25 percent chlorine form. Some swimming pool companies carry a 10 percent chlorine solution, and agricultural suppliers typically carry stock in 10 percent and 15 percent concentrations. Chlorine gas is used by larger operations because a tank of compressed gas lasts a long time and is the cheapest form of chlorine. Special injection meters are used, which reduces the hazard of handling the gaseous form. Chlorine gas is very poisonous and must be handled with extreme care.

When chlorine is injected, some of it reacts with bacteria, algae, or other organic matter (as it destroys the organic matter by oxidation). This “reacted” chlorine is chemically bound and is no longer active. Chlorine that has not reacted is “free residual chlorine” and is avail- able to react to treat parts of the system downstream.

To be effective, maintain 1 or 3 parts per million (ppm) free chlorine in the system for 30 to 60 minutes to kill all bacteria and algae. If the initial organic load is not very heavy, adjust your stock solution and/or injection rate to a concentration of 5 to 6 ppm in the irrigation water and test the water at the flush outlets of the system for chlorine presence. Adjust the injection rate as required to achieve 1 or 2 ppm active chlorine at the end of the system. A swimming pool test kit can be used to check the chlorine activity. More information on chemigation for maintenance of drip-type systems can be found at *Maintenance Guide for Microirrigation Systems in the Southern Region*.

Preventative Maintenance and System Management

Proper system maintenance and management are critical to system performance and the longevity of your SDI system. Most performance problems are the result of inadequate system maintenance and/or management. Once a problem develops, it is often impossible to correct, especially if the problem occurs in the buried tubing resulting in expensive repairs or system replacement costs. Preventative maintenance is paramount for long-term satisfactory performance of the system. You must test the quality of the water supply, routinely flush and clean the system, and monitor system flow and pressure to identify developing problems before they become irreversible.

Water Quality Sampling

Your irrigation water quality can vary seasonally, especially if you depend on a surface water supply. You may want to check your water quality for the first few seasons to help you develop a maintenance program that works for your system. The North Carolina Department of Agriculture & Consumer Services analyzes irrigation water (called a solution analysis) for a very reasonable price.

Flushing

Flushing moves the dirt or other debris out of the system so it is not picked up by the flow of water and carried into the emitters. You may need to flush the irrigation system until all foreign debris has exited the system when the system is first operated. After that, start by flushing the system at least weekly. The flushing frequency can be reduced if problems are not encountered. Take samples of the flush water and examine them for sediment. It is recommended that the flush water exceed 1 foot per second velocity in the main line, sub-mainline, and dripline to help remove sediments. If your system is designed to allow flushing of half a zone, you may need to use that option to sustain the pressure and flow rate required for adequate flushing.

The length of time it takes for water to move from the water source to the flush point should be known so a proper flush can be completed. One way to determine this length of time is to add a chemical amendment that has an odor, such as chlorine. That odor will allow the operator to know when clean water has reached the flush point. In addition to an odor, the chlorine will aid in cleaning the system of algae. Also, several drip tape manufacturers have software that helps you determine required flushing times.

Another consideration is the fate of the flush water when flushing the irrigation system. It is important that discharged flush water not go directly into drainages or waterways. Always mix and keep chemical amendments safe distances from well heads and open waterways.

Tillage/Traffic Operations

Soil compaction can occur in any field especially when there is excess soil moisture after rainfall or irrigation events. When soil is wet, curtail traffic. Heavy equipment can also flatten drip tubing. Traffic on wet soil will increase soil compaction resulting in problems with root growth, water movement, and inevitably crop yield.

There is little research available on best tillage practices for subsurface drip irrigation systems. However, it is felt that tillage/traffic that is detrimental to field conditions with overhead irrigation will probably also be detrimental with subsurface drip irrigation.

Insect and Rodent Damage Prevention

Damage to the drip tubing by insects and rodents is a documented problem that cannot always be rectified. Not many pesticides that are labeled for the use through drip irrigation for the control or prevention of insects or rodents. Manufacturers of drip tubing have published recommendations for their product. However, you must read and follow all label instructions for the pesticide used. You cannot assume that you are allowed to use a chemical just because an SDI manufacturer recommends it. Any misuse of chemicals is in violation of the pesticide regulations.

Winterization and Spring Startup

Proper maintenance is as important during the off-season as it is during the growing season. When winterizing the SDI system, flush the system with clean water. Remove algae and other contaminants by using a high rate of chlorine of about 20 ppm, which is called a shock treatment. A general rule of thumb is that the chlorine solution be in contact with algae for at least 30 minutes. The time needed to shock the system will depend on the size of the zone and the length of time needed for the chlorine to get from the injection point to the last emitter on the system plus 30 minutes. After the shock treatment with chlorine, flush the system, especially susceptible irrigation components, with clean water. Once the system has been flushed, drain all components above the freeze line. This would include filters, pumps, valves, pipes, and other components where water could collect and freeze and break components.

The procedure of flush-shock-flush should be used in the spring to prepare the system for the irrigation season. Chlorine and other acids and chemicals can be added throughout the growing season to maintain the system.

Figure 1. Regular flushing using a flushing riser assembly as shown here is important to prevent emitter clogging.

System Evaluation

Because working components of an SDI system are underground, it is important to document performance while the system is relatively new, which establishes your system's baseline performance. Then monitor and record flow rate and operating pressure in each zone of your system regularly. A decline in operating performance can often help you diagnose the problem by comparing current performance against the base- line performance.

For example, if the pressure suddenly decreases and the flow rate increases, you likely have a leak in your system (holes in dripline, broken fittings, etc). On the other hand, high pressure and low flow rates point to emitter clogging or collapsed driplines.

Low flow in a zone soon after the system is installed is an indicator that one or more laterals may have collapsed after installation. Collapsed driplines may also cause a drought-stressed area of a field, especially if the soils are not droughty in that area. Flow meter data can also be used to compare uniformity between zones. A gradual decline in flow is an indicator that emitters are gradually clogging. A sudden increase in flow rate indicates an acute line failure and leak, while gradual increases in flow likely result from emitter wear.

Permanently installed flow meters are more convenient than temporary ones, but they add to the initial cost of the system. If permanent installations are too expensive, installation of quick connects to allow temporary flow meter installation for periodic measurements is an option.

For more thorough diagnostics, you may have to expose several emitters by digging pits at several locations along the lateral or within a zone to expose emitters. Once the emitter is exposed, collect flow from individual emitters in a jar, and time the collection with a watch to evaluate emitter performance.

Figure 2. Monitoring pressure at several key locations is critical for SDI system evaluation.

Conclusion

To get your money's worth from any irrigation system, good management is essential. Proper management of an SDI system is especially important since most of the system is buried. Proper flushing schedules and chemical treatment to prevent emitter clogging and root intrusion will help ensure that your system performs as designed. Routine monitoring of flow rates and pressures will help identify any problems. Tillage operations and associated traffic may need to be modified for SDI systems. With proper management and preventative maintenance your SDI system should perform well for a number of years.

For more information, see other publications in the Subsurface Drip Irrigation series:

- *SDI Considerations for North Carolina Growers and Producers*
- *Site Selection for Subsurface Drip Irrigation in North Carolina*
- *Design and Installation of SDI Systems in North Carolina*

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