Introduction

Adequate water is vital not only for the survival of fruit and vegetable crops in Missouri, but the precise timing and application of moisture can boost both the quality and quantity of these crops. Drip irrigation (also known as trickle irrigation, micro-irrigation, or low-volume irrigation) offers an ideal way to provide this moisture, because it requires 30-50 percent less water usage than conventional sprinkler systems, while reducing evaporation losses, weed pressures and plant disease potential, and allowing use of smaller, lower-cost pumps and pipes to deliver water at low pressure to the plants.

To be effective, however, drip irrigation systems (see Figure 1) require periodic maintenance. This paper will help explain the various aspects of system maintenance common to home and small commercial systems.

Before the Season Starts

Testing for Water Quality

Water for drip irrigation can come from wells, ponds, lakes, streams, rivers and municipal water systems. Quality of these water sources varies widely, with well and municipal water being the cleanest. No matter how clean the water looks, a water quality analysis should be completed to determine if precipitates or other contaminants are present that could affect operation of the irrigation system.

This water quality analysis should identify inorganic solids such as sand and silt; organic solids such as algae, bacteria, and slime; dissolved solids such as iron, manganese, sulfates, chlorides, and carbonates (calcium); and pH and hardness of the water. Water testing can be done by a number of laboratories in the state. The Soil and Plant Testing Laboratory at the University of Missouri-Columbia can test for most of these parameters for about $35. Contact your local University of Missouri Extension Center for a sample submission form. If the water also is to be used as a household drinking water source, a drinking water analysis test for coliform bacteria and nitrates should be done. Sampling kits for this test are available through your county Health Department. Cost of each test is currently $10.

If a review of your water test indicates factors that may cause plugging (Table 1), then special care in drip system maintenance needs to be practiced. High levels of certain parameter might not render a water source unsuitable for drip irrigation, but will make appropriate water treatment a necessity to avoid plugging the irrigation system.

Any surface water such as streams, ponds, lakes, and rivers will contain bacteria, algae, or other aquatic life. Therefore, a drilled well is the preferred water supply because algae and sediment problems will be minimal. Clear spring water is a good second choice.
Figure 1. Example Layout of Drip Irrigation System

Table 1. Criteria for Plugging Potential of Drip Irrigation System Water Sources

<table>
<thead>
<tr>
<th>Factor</th>
<th>Plugging Hazard</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slight</td>
<td>Moderate</td>
<td>Severe</td>
</tr>
<tr>
<td></td>
<td>in parts per million (ppm)* except pH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspended solids (filterable)</td>
<td>&lt; 50</td>
<td>50-100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Chemical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>&lt;7.0</td>
<td>7.0-7.5</td>
<td>&gt;7.5</td>
</tr>
<tr>
<td>Dissolved solids</td>
<td>&lt;500</td>
<td>500-2000</td>
<td>&gt;2000</td>
</tr>
<tr>
<td>Manganese</td>
<td>&lt;0.1</td>
<td>0.1-1.5</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>Iron</td>
<td>&lt;0.1</td>
<td>0.1-1.5</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>Hardness**</td>
<td>&lt;150</td>
<td>150-300</td>
<td>&gt;300</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>&lt;0.5</td>
<td>0.5-2.0</td>
<td>&gt;2.0</td>
</tr>
</tbody>
</table>

* Some water reports list results as milligrams per liter (mg/L), which is equal to parts per million (ppm).
** For hardness, divide ppm by 17 to get hardness in grains per gallon (gpg).

If a pond is used, a small settling basin built next to the pond can help reduce the fine sediment load created when water runoff goes into the pond. A coarse-screened, floating intake located one to two
feet below the water surface will help intercept algae and surface debris common to open basins. To slow algae formation, the sediment and nutrient flow into the pond must be minimized. This can be done by maintaining grassed buffer strips 50-100 feet wide above the pond. Regular treatment of the pond with a one part-per-million (ppm) dose of copper sulfate (2.7 lbs. per acre foot of water) will prevent algae formation and control bacterial slime.

Most well water in Missouri has a relatively high total hardness. The pH commonly ranges from an acidic 6.0 to an alkaline 8.0. Iron, manganese and hydrogen sulfide (which causes a “rotten egg” odor) can also be present, irrespective of topography. Therefore, the water quality analysis can be quite useful in identifying potential maintenance problems.

Determining the Capacity and Pressure of the Water Supply

To determine the number of drip irrigation emitters that can be operated at once, the capacity of the water source must be measured. This is especially critical where the irrigation water source is also the water source for the household. Since nearly all underground water in southern Missouri is supplied by precipitation, extended dry weather can also negatively affect water quantity and quality of drilled wells, due to a drop in the underground water table.

A very simple and fairly accurate method to determine the household water demand is to count the fixtures in the home, such as toilets, sinks, tubs and hose bibs. The pumping needs for the home in gallons per minute (GPM) is equal to the fixture count. *MU Guide G1801 How to Size a Farm and Home Water System* gives more details on water flow rate requirements. A typical three-bedroom, two-bath home would require 12 GPM of pumping capacity. Any excess pump capacity is then available for irrigation purposes.

To check continuous pumping capacity, do the following procedure.

1. Attach a pipe (3/4” to 1-1/4” polyethylene or PVC) to the water supply. Keep the pipe as short as possible. Install a 0-30 psi pressure gauge and regulating valve as shown in Figure 2.
2. Completely open the water supply valve.
3. Gradually close the regulating valve until the pressure gauge reads 15 psi. Allow the water to run at 15 psi for five (5) minutes if on municipal water, or run for two (2) hours if drawing from a private well, before proceeding to Step 4. This is necessary to stabilize the water level in the well.
4. Collect the water from the pipe for one (1) minute (see note below). The amount of water collected, in gallons will give the capacity of the water system in gallons per minute (GPM).

   NOTE: If a private water supply is used for drip irrigation, two questions need to be answered before doing Step 4 above.

   First, is there enough pressure in the pressure tank with the water supply open? The pump should be able to maintain 20-25 psi at the tank. If it cannot, there will not be enough water pressure in the house while the system is operating. To increase the pressure at the tank, partially close the water supply valve and repeat Step 3 above.

   Second, is the pump running continuously? It should be. Most pump manufacturers do not recommend cycling a pump more than one time every 2-3 minutes because of possible damage to the motor and other electrical components. Pump cycling will cause pressure fluctuation in the system, requiring a pressure regulator.
5. The anticipated water flow from a public (municipal) water supply will be around 6-8 GPM. The anticipated water flow from private water supplies will range from 5-12 GPM using a 1/2 to 1 horsepower submersible pump. For private wells, contact a state-certified pump installer if water demand exceeds the existing pump's capacity. They can help determine whether installing a larger pump and pressure tank is feasible without exceeding the well's capacity to supply water.

6. There are many factors that will affect the flow from any water supply. Each water supply needs to be checked before the drip irrigation system is designed.

Figure 2. Measuring Water Source Capacity

Start-of-Season Tasks

Choosing a Filter System

A filter is the most critical component for proper operation of a drip irrigation system. The filter must be capable of removing sediment particles that are too large to pass through the emitters. Therefore, it should be checked to see that it is working properly according to the manufacturer's recommendations. Filters cannot remove dissolved minerals, algae cells, or bacteria. Filters are generally of three types--cartridges, screens, and sand filters.

Cartridge filters may be either disposable or washable, and are made of paper or a spun fiber. They work best for very small systems with a light sediment load. They should not be used if algae is present.

For wells or municipal water, a screen filter or disc filter can be used. Screen filters are made of slotted PVC, perforated or mesh stainless steel, or nylon mesh, and should have a 150-200 mesh screen. They come in sizes from 3/4-inch (used on fields up to a half-acre in size) to 6-inch (used with several acres). Disc filters consist of a stack of grooved wafers over which the water passes. These filters are sized based on the equivalent screen mesh filter size, and provide more filter surface area than screen filters of the same size. Although more expensive to purchase, they are reliable and easy to clean. Both screen and disc filters come in models that can be manually or automatically flushed as they build up with debris. Automatic back-flushing is preferred for acreages larger than 1/2 to 1 acre in size.
For any open or surface water sources, sand media filters are the preferred choice. For small systems, a swimming pool sand filter may be adequate. On larger acreages, the sand filter consists of pairs of sand-filled canisters and can be back-flushed to accomplish cleaning. Canisters from 14 inches (enough for two acres) to 48 inches in diameter are used, depending on the size of the system. They work best at flow rates of less than 20 gallons per minute per square foot of media surface. Install enough screen filters after the sand filter to match the water flow through it, to prevent accidentally-discharged sand from plugging the emitters.

**Flushing and Leak-Checking the System**

Before using the drip irrigation system for the season, it should be flushed. This will remove any pump oil, precipitates or fertilizer residues that have coated the pipes.

If the sand filter was not drained when put away for the off-season, now is the time to unclog it. Pour 2-3 quarts of chlorine (laundry) bleach into the filter, fill it with water and let it sit for 24 hours. Then backflush the filter until the water runs clear.

To flush the pipes, flush the mainlines (see Figure 1) for 20 minutes first, with all the manifold valves closed. Then flush each manifold one-at-a-time for 5-10 minutes. Finally, flush the laterals, opening only as many ends at a time that will sustain adequate pressure for flushing. In all cases, flush long enough to observe clear water running out of the ends of the pipes. Table 2 lists the recommended water flow rates for effective flushing.

<table>
<thead>
<tr>
<th>PVC Pipe Diameter (inches)</th>
<th>Velocity (feet/second)</th>
<th>Flow Rate (gallons/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>1/2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3/4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3/4</td>
<td>4</td>
<td>8.5</td>
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<tr>
<td>1</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>1 1/4</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>1 1/2</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>47</td>
</tr>
</tbody>
</table>

Once the system is turned on, let it run for about 20 minutes so any air in the system has a chance to work its way out. Next, check the pressure throughout the system, starting at the filter and proceeding to the manifolds. Operating pressure in the laterals depends on the type of emitters that are used. Thin-wall “tape” usually operates best at 4-8 psi. Non-pressure-compensating emitters perform well at 8-15 psi. Pressure-compensating emitters installed in polyethylene tubing work best at 10-30 psi. One design criteria for drip irrigation is to try to develop a system which will not have more than 20 percent (+10%) variation in flowrate throughout the block of plants being irrigated.

Walk through each block to check wetting patterns. Any plumbing leaks or tears will appear after 30 minutes of operating time. The appropriate splices should then be made.

If any fertilizers or chemicals are applied through the irrigation system, be sure a backflow prevention valve is installed and working properly to ensure no contamination of the water source can happen.
Throughout-the-Season Tasks

Flushing Physical Contaminants

The filter on the drip irrigation system should be checked during or after each operating period, and cleaned if necessary. Cleaning frequency can be determined by installing a pressure gauge on the inlet and outlet sides of the filter. When the pressure loss through the filter exceeds 5-7 psi, it is time to clean the filter. A clogged cartridge filter should be replaced. A clogged screen or disc filter can be cleaned with a stiff-bristle brush or by soaking in water. Sand filters need to be back-flushed according to manufacturer's recommendations.

Since normal filtration only traps larger particles, fine silt and clay particles entering a drip irrigation system will settle as the water velocity decreases at the ends of the manifolds and laterals. Periodic flushing will remove this buildup, which would otherwise clog the emitters. Provide a flow rate of at least four (4) feet per second (see Table 2) in mainlines and manifolds (about 14 GPM flow in a 1" pipe) and one (1) foot per second in laterals (about 2 GPM flow in a 3/4" pipe). Flush the mainlines first, with all the manifold valves closed. Then flush each manifold one-at-a-time. Finally, flush the laterals, opening only as many ends at a time that will sustain adequate pressure for flushing. In all cases, flush long enough to observe clear water running out of the ends of the pipes for at least two minutes.

Intervals between flushings may be extended by leaving a 10-20 foot length of lateral past the last emitter in each plant row. This will allow a "catch area" for sediment that might otherwise plug emitters. This pipe end can then be capped or folded and tied. Installing an air-relief valve on the high point of each zone of laterals will also help prevent suction of sediment into the upslope emitters as the downhill emitters drain after the water flow is shut off at each irrigation cycle.

Periodically check drip irrigation lines for excessive leaking. A large wet area in the field indicates a leaking drip tube or defective emitter that should be replaced.

Removing Chemical Contaminants

Filtration alone is not always adequate to solve all water quality problems. Chemical treatment is often required to prevent emitter plugging due to microbial growth and/or mineral precipitation. An injection pump is used to introduce the chemicals into the water stream.

Several commercial solutions are available that contain a mixture of ingredients to deal with pH, iron and other water problems. These commercial products come with instructions on dilution concentrations for daily maintenance or "shock" treatment to unclog plugged water lines. Small producers just getting started with drip irrigation should consider using these products.

Chlorine is the primary chemical used to kill microbial activity, to decompose organic materials, and to oxidize soluble minerals, which causes them to precipitate out of solution. Acid treatments are used to lower the water pH and either maintain solubility or dissolve manganese, iron, and calcium precipitates that clog emitters or orifices.

Bacteria and Slime

Bacteria can grow in the absence of light within the irrigation system or in a contaminated well. The bacteria can live on iron or sulfur and produce slime that clogs filters and emitters. Reddish-brown filamentous slime or particles near the emitters indicates bacteria feeding on iron. White stringy masses of slime near emitters indicate bacteria feeding on sulfur.
Chlorination with 5.25% sodium hypochlorite household bleach is effective at killing this bacteria and controlling slime growth. Powdered 65-75% calcium hypochlorite, also called High Test Hypochlorite (HTH), is not recommended for injection into drip irrigation systems since it can produce precipitates that can plug emitters, especially at high pH levels. Treat to provide a continuous residual rate of 1-2 ppm of free available chlorine measured at the most distant end of the piping system from the water source. An alternate method is to intermittently charge the system with a 10-20 ppm chlorine rate for 30-60 minutes. Treatment may be required at the end of each irrigation cycle for problem water sources or after every 10-20 hours of irrigation for cleaner water sources.

The amount of chlorine needed to obtain the necessary residual will depend on contact time, water temperature, water pH and turbidity (cloudiness). More chlorine is needed as contact time and temperature decrease, and as pH and turbidity increase. Inexpensive kits to measure chlorine residual are available wherever swimming pool supplies are sold. The kit should specify it measures the free chlorine residual and not the total chlorine, or overestimation of chlorine residual will result. The test is done by looking for a color change in the water sample after the test chemical is added.

Wells that are contaminated with bacteria can be shock-chlorinated by injecting chlorine at a rate of 200-250 ppm into the well. This translates to one (1) pint of 5.25% sodium hypochlorite laundry bleach for each 25 feet of water in a 6-inch diameter well. Deeper wells (over 300-400 feet deep) can be treated more effectively using 1/2 pound of 65-75% calcium hypochlorite swimming pool chlorine per 150 feet of water depth in the well. Rates and disinfection procedures for various diameters of wells can be found in MU Guide WQ102 Bacteria in Drinking Water.

Calcium Deposits

Many wells in southern Missouri are drilled through limestone, so the water is high in calcium carbonates with a total hardness of 240-680 parts per million, or ppm (14-40 grains per gallon, or gpg). Water pH (a measure of acidity/alkalinity) commonly ranges from 7.0-8.0 on a 0-14 scale. As the pH and/or the temperature of the water is raised above a certain point, calcium precipitates and forms a scale that sticks tightly to the inside walls of pipes. This hard water scale builds up slowly, and can eventually block water lines and clog emitters.

One defense against this problem is to bury or mulch laterals whenever possible to reduce the temperature rise of the water in the laterals, especially under no-flow conditions in hot weather.

Another solution is to keep the pH down below 7.0 by using a chemical metering pump or venturi to inject an acid, such as sulfuric, hydrochloric (muriatic) or phosphoric acid, into the irrigation system. Use of sulfuric or hydrochloric acid is preferred over phosphoric acid, because they do not cause precipitation of calcium carbonate. Plan to control the pH in water if it is over 300 ppm (18 gpg) of hardness. For 150-300 ppm (9-18 gpg) water, operate for a year, then cut out and examine a few sections of lateral and the narrow passageways in emitters. If calcium carbonate accumulations are visible, flush the system out with acid and begin a pH control program. Water with less than 150 ppm (9 gpg) hardness, should not cause a carbonate precipitate problem.

When precipitating chemicals must be used, inject them upstream from the filtration system and route the treated water through at least two elbows to create turbulence for complete mixing and formation of any precipitates, so the filter can remove them. Use extreme care when handling acids and always add acid to water—never water to acid. Acid can react with hypochlorite to produce chlorine gas and heat, so be sure to inject acid at least two feet upstream of the chlorine to allow the acid to mix with water first. Stop injection an hour or so before the end of the irrigation cycle to allow the water to flush the chemicals out of the irrigation system.
Fertilizer Injection

One of the advantages of drip irrigation systems is the ability to apply fertilizer to the root zone of the plants while irrigating. To do this, only 100% water-soluble fertilizer should be used. Fertilizer formulations vary considerably in their ability to dissolve in water, as indicated in Table 3. Hot water increases solubility and makes dissolving fertilizer (especially dry fertilizer) easier and quicker. Because solubility is reduced when water cools, it is not a good practice to heat water in order to dissolve "extra" fertilizer (more than is soluble at normal temperatures). As the solution cools, this extra fertilizer will come out of solution (precipitate or "salt out") and possibly clog drip emitters.

<table>
<thead>
<tr>
<th>Fertilizer Formulation</th>
<th>Solubility (lb/gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium nitrate</td>
<td>9.8</td>
</tr>
<tr>
<td>Calcium nitrate</td>
<td>8.5</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>2.3</td>
</tr>
<tr>
<td>Potassium nitrate</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Table 3. Solubility of Selected Fertilizers in Pure Water

If two or more fertilizers are to be mixed in the same solution, test their combined solubility by mixing them in one to five gallons of water (mix precise amounts so the concentrations will be the same as the concentrations desired in the stock solution). If the fertilizers dissolve completely in this test, proceed with making the planned stock solution. If the fertilizers do not dissolve, consider making a less concentrated solution or possibly using some other fertilizer(s) to make the stock solution.

Most phosphate fertilizers react with the calcium in hard water and form a precipitate. When applying phosphorus fertilizer through a drip irrigation system, a food-grade (white) phosphoric acid will cause less precipitates than the "green" phosphoric acid.

Like chemical treatments, fertilizers should always be injected before the filters so any undissolved particles can be filtered out.

Animal Damage

Animals, such as deer, raccoons, rabbits, opossum and mice can cause damage to the piping in drip irrigation systems. The animals seem to "sense" the water moving through the pipes and emitters and will attempt to chew through them for a drink. Thin-wall hose and polyethylene pipe up to 3/8" diameter are most susceptible to chewing damage.

Switching to heavier-wall piping is one way to reduce this damage. In the case of deer, an 8-foot high plastic mesh fence, or 5-foot high slanted wire fence installed around the field perimeter may be a cost-effective solution.

End-of-Season Tasks

The first step in shutting down the season for winter is to turn off the main water control valve. This stops water from flowing to the system. Then open any manual drains at low points in the system to allow gravity to remove the water. On flat ground where gravity won't work to flush the system, use a portable air tank or compressor to blow the pipelines clear of water. An air valve (similar to that found on a car tire) installed at the manifold or solenoid valve simplifies this process. All pipe openings should then be sealed to prevent debris from entering the system.

If the system is equipped with a timer, it should be unplugged. It's best to store filters and pressure regulators inside over winter. The sand filter should be drained to prevent algae or other biological material from clogging it during the off-season.
For small plots using surface-run laterals with closely-spaced emitters, the laterals can be rolled up and stored inside. For buried laterals, or those with emitters spaced more than four feet apart, removal and storage of the drip system laterals is not recommended as it would be difficult to realign the emitters with the plants in the spring. All pipelines should be protected from freezing. This can be accomplished by burying mainlines and manifolds below the frost line. Frost line depth ranges from 24-30 inches deep in southern Missouri to 36-48 inches deep in northern Missouri.

Summary

A well-designed drip irrigation system is an extremely efficient method of precisely dosing nutrients to growing plants. A water quality analysis will help identify the various physical, biological and chemical factors that could prevent the irrigation system from working as desired. Testing the water supply capacity will ensure that sufficient water is available to the plants during shortages of rainfall. Matching the filter to the field size and water source is vital to preventing plugging problems within the irrigation system plumbing. Good maintenance practices, which include periodic flushing and occasional treatment with chemicals, will reduce downtime and overall labor costs to help you make the most of your irrigation system investment.

References

- Drip Chemigation: Injecting Fertilizer, Acid and Chlorine, Bulletin 1130, University of Georgia Cooperative Extension Service, 1996
- Drip Irrigation for Vegetables, MF-1090, Kansas State University Cooperative Extension Service, 1996