An Overview of Drip Irrigation

Anne Carter and John Howell
Department of Plant and Soil Sciences,
University of Massachusetts

INTRODUCTION

Subsurface irrigation has been around since the 1860s, but drip irrigation was not a practical choice until Chapin developed lay-flat twin-wall drip tape in the late 1960s. Early problems with clogged lines, slime, and an inability to run nutrients through the lines have basically been solved as long as growers use a few precautionary tools to guard against problems.

A well designed drip irrigation system benefits the environment by conserving water and fertilizer. A properly installed drip system can save as much as 80% of the water normally used in other types of irrigation systems. Water is applied either on the surface, next to the plant, or subsurface, near the root zone. In dry years, fewer weed seeds germinate between rows because there is less water available beyond the plant root zone.

Another advantage to drip irrigation is that there is less evaporation from the soil, especially when drip irrigation is used with plastic mulch. Water is applied more evenly throughout the field, thus eliminating the need to run the irrigation longer to wet the whole field.

It requires some expertise to install and operate a drip system and consultation with a knowledgeable professional is wise. A less than adequate system can result in yield variability in the field due to areas of over-or under-watering and clogged lines. Pumps, filters and tape may not last as long. Trying to save money by cutting costs of initial equipment purchases will usually cost more money in the long run. Any or all of these problems can completely offset the potential cost savings from using drip.

This is by no means a comprehensive review of all materials used for drip irrigation. The references listed at the end of this article are useful resources to use in learning more about drip irrigation and in designing a system.

ON-FARM CONSIDERATIONS

The complexities of the system are related to the size of the farm, water quality, slope of the land, and the value of the crop. The system should be compatible with the grower's cultural practices, such as bed width, crop rotation, access to the field, unless he/she is willing to change them. The economic benefit of drip irrigation will only be realized if an increase in production potential or a decrease in operating costs outweighs the increased cost of setting up the system. If the cost of the system can be spread over multi-crops and uses, then the cost is easily justified. Thicker-walled drip tape can be used for three or more years, thus spreading the initial cost of tape over more than one year.

WATER SOURCE

The emitters in a drip system have small diameters that can easily become clogged if the wrong filters are used in the system. Therefore it is critical that a water test is taken prior to designing the system. Organic materials, such as plant materials, algae, small living organisms and inorganic sand, silt, and clay are the primary concern if the source of water is from surface water such as a pond or stream. Surface water might have contaminants from run-off. Inorganic materials such as salts are usually the primary concern if the water comes from groundwater.

WATER TEST

A water analysis should be done before the system is designed. Any reputable water testing lab will work as long as some specific tests are done. The water should be tested for at least the following: calcium, magnesium, pH, carbonates and bicarbonates, iron, living organisms, and size of the particulate matter. The test should be taken at a time that is representative of the poorest water quality in the growing season because the filter is chosen based on this analysis. If water will be pumped into a holding tank before it enters the field, then the water sample should be taken from the tank as it could add contaminants to those coming from the water source.

The results of the water test determine the type of filtration system used. The pH, calcium, and magnesium concentration will affect the solubility of certain fertilizers. Fertilizer can precipitate out and clog either the filter system or the emitters in the drip tape. A good rule of thumb is to premix a small amount of the fertilizer you plan to use in the water that will be used in the drip system, before adding it to the tank. If any precipitation occurs after 24 hours, then another fertilizer or a lesser concentration should be used. Further details about fertigation will be covered in another section.

SLOPE OF THE LAND

A slope of 2% or less is the ideal for drip irrigation. An elevation change of 2 ft can cause a 1 psi change in pressure. Very little land in New England fits this criteria. The length and number of lateral lines, the pump size, and pressure regulators are chosen based on the slope. Different emitter sizes or spacing between emitters can be adjusted to accommodate slopes.

SOIL

One of the advantages to drip irrigation is that it can be adapted to various soil types. The soil type determines the soil wetting patterns. Soil wetting patterns in turn influence depth of the drip tape and the distance between emitters. The duration and frequency of irrigation are also determined by the soil type. Over watering can move fertilizer away from the root zone. On sandy soils, the water never moves laterally more than 10 inches. In sandy soils, irrigate more frequently, but run the water for a lesser amount of time. In heavier soils, irrigate less often, but run the water for a longer duration. In both cases, this should lessen the chance of leaching fertilizers away from the root zone.

DESIGNING A SYSTEM

Before buying one roll of tape, pump, or filter, the entire system should be drawn out on paper. The main components of a typical drip system are the pump, flowmeters, main and sub-main lines, drip tape, pressure valves, filters, fertilizer injectors, and flushing manifolds. Before purchasing any component, a number of questions need to be answered:

1. Is the tape going to be laid on the surface or buried beneath the soil?
2. Is plastic going to be used with the tape?
3. What crop or crops will be planted/rotated in the field?
4. Will the tape be used to germinate seeds or will another irrigation method be used?
5. Will fertilizers be injected into the water?

DRIP TAPE

Two goals for a drip irrigation system are to apply water uniformly over the field and to have the water running through the system only as long as necessary to properly wet the field. The uniformity of the water flow depends on the spacing and the type of emitters used with the tape. Drip tape should have a *coefficient of manufacturing variation* (CV) number which reveals how much variation in uniformity there is from one emitter to the next. A CV of 0.05 is considered excellent and a CV between 0.05 and 0.1 is acceptable. It is worth the initial expense of buying quality tape and emitters because of the reduced costs later on, such as the cost of pumping water.

The length of the drip lines is another important consideration. The length is determined by the pump size, the field size(s), and the slope of the land. Any one of these factors will influence wetting uniformity because the emitters will discharge water at different rates if there are changes in pressure along the line. Because of variation in water pressure, tape is rarely laid out longer than a length of 400 feet.

The choice of tape thickness, measured in millimeters (mils), is based on how long you want the tape to last and the expected highest water pressure in the lines. The longer the tape is in the ground, or the higher the pressure in the lines, the thicker the tape should be. Tape thickness is usually between 4 and 10 mil though thickness of up to 25 mil can be purchased. Tape life is usually 2 to 3 years depending on how well the system is managed in the field. Thicker tapes (15 mil or more) have been used in alfalfa fields where the tape may be in the ground up to 5 years.

PLACEMENT OF DRIP TAPE

There are three decisions to be made regarding placement of the drip tape:

1. the distance from the plant in the row,
2. whether to bury the tape or place it on the soil surface, and
3. the depth to bury the drip tape.

Whether the tape is laid on the surface or buried beneath the soil, there are a few general guidelines to follow. The tape should be placed as close to the plant as is practical for the specific crop. Twelve inches is the maximum distance away from the plant row - most tape is placed between 6 and 12 inches away. A little further away is possible in soils that have good lateral movement or when other means of irrigation is used to germinate seed or establish seedlings. The tape should be placed so that the emitters are pointed upward so that soil, silt and clay will settle away from the emitters after the water stops flowing.

Tape can be laid on the surface, especially if it is used in conjunction with black plastic. The advantages are that it is easy to install and to make repairs. The disadvantages are that there is greater evaporation in the initial stages of the crop's growth and the tape is more likely to be damaged by production practices, wind, and animals.

Drip tape is usually buried between 6 and 10 inches deep, though with some root crops, the tape can be buried a little deeper. Tape is buried 18 to 24 inches deep in some alfalfa fields. How deep the tape should be buried in a given field is determined by the crop, the soil type, the root pattern of the crop, soil wetting patterns, and the tilling practices used in the field. Water moves upward and laterally from the tape better in a loam soil than in a sandy soil, therefore, tape should be buried at shallower depths in sandy soils than loam soils.

PUMPS

The purpose of a pump is to deliver water evenly at the correct flowrate and pressure. There are usually two kinds of pumps sold - centrifugal pumps and deep well turbines.

The pump capacity needed and the discharge pressure should be determined prior to purchase. The capacity is determined by the crop's water requirements, the efficiency of the whole system, and the largest acreage to be irrigated by the pump at a given time. The discharge pressure is determined by the desired operating pressure through the drip tape, the pressure loss due to friction, and the various changes in elevation within the system. There is a rule of thumb that the larger the capacity of the pump, the more efficient it is. However, there is a point where efficiency levels off and more capacity does not bring any benefit.

FILTERS

As previously mentioned, the choice of filter is based on the quality of the water passing through the system. It is usually the greatest expense in a drip system. Growers may try to cut costs by buying a less than adequate filter for the worst case scenario on the farm. This usually leads to more costs down the road. If the water is loaded heavily with suspended solids, then a sedimentation tank is recommended. This would allow some of the coarse materials to settle out before it reaches the filter. However, a sedimentation tank should not be the only method of filtration for the system.

SAND SEPARATOR

If the sediment load is high, than it is a good idea to pre-filter the water with a vortex sand separator before running the water through another filter. A sand separator causes the water to swirl in a vortex. This forces sediments to drop to the bottom of the container. These separators can remove as much as 98% of the contaminants that would not pass through a 200 mesh screen, but are not as effective at removing organic materials.

SCREEN FILTER

Screen filters are inexpensive and easy to install. Mesh filters work well if there are moderate to low contaminants in the water such as those coming from a well.

Screen filters have a limited ability to store contaminants. Thus, if the water comes from a river or a holding pond, the screens will have to be flushed often. This could result in considerable down time in the system. Clean water must be used to clean the system!

Mesh screen sizes are between 20 and 200 mesh. The larger the number, the smaller the particle the screen will filter out. The screens are made from stainless steel, nylon, or polyester. The maximum flow rate through a screen is 200 gpm/sq. ft. of screen.

SAND FILTER

Sand filters are more effective than screen filters if the contaminant load is moderate to heavy or there are sources of heavy inorganic or chemical substances in the water. A sand filter can run longer than a screen filter before it needs to be cleaned. There is less down time in the system. The filters can be set up in pairs so that clean water from one filter is used to flush the other filter.

The correct filter size is critical to the failure or success of the system. Under-sizing will increase pressure loss and there is considerable down time for cleaning. It is better to be too big than too small. For most systems the average size filter is 20 gpm/sq. ft.

The type of sand filter used in the system is based on how much the water needs tobe cleaned. It is made up of crushed, sharp edged silica or granite. The sand never needs replacing unless it is contaminated by oil or other chemicals. Sand filters can remove particles smaller than those that can be removed from a 200 mesh screen filter.

DISC FILTER

Another popular type of filter is a *disc filter*. It consists of a series of disks that are stacked on top of each other. The disks are made up of microscopic grooves that serve as the filters. Equivalent mesh sizes are between 40 and 600 mesh. They require less water for cleaning than do sand filters.

CARTRIDGE FILTER

Cartridge filters are used if contaminant concentrations are less than 5 ppm and there is low flow volume through the system. The filters are usually replaced rather than cleaned. The filters are made out of paper, cotton, fiberglass, or other synthetic material. Paper will deteriorate over time and may clog the system. Cartridge filters, though inexpensive and popular, are not recommended for drip irrigation.

FLOWMETERS

The main reason for properly managing a drip irrigation system is so that the water is not wasted and fertilizer does not leach. Managing the system requires that

1. the operator knows how much water the crop used since the last irrigation or rainfall event and
2. the operator applies a specific amount of water during any one irrigation.

A flowmeter measures the volume of water passing through the system. The system can be programmed to shut down as soon as the flow meter registers that a pre-determined volume of water has passed through it. This saves water over the long run and decreases the likelihood of nutrients leaching from the root zone. The flow volume for a single irrigation event is determined by the needs of the crop and the size and efficiency of the system.

PROPELLER METER

There are several types of flowmeters. The most commonly used flowmeter is the propeller meter. It requires installation in a straight section of pipe and for the pipe to flow at full capacity in order to register accurately. Propeller meters can become clogged if there is debris in the water. Variation in water pressure will alter the amount of water registered on the meter.

MAGNETIC FLOWMETER

Magnetic flowmeters do not have an obstruction in the pipe so there is no opportunity for debris to get clogged in the meter. Also, there is no pressure loss as the water flows through it. Magnetic meters remain accurate for a longer time than propeller meters. The initial cost is higher and they require an external power supply. The need for an external power supply to run the meter is a disadvantage since flowmeters are usually placed right in the field and not always within easy access of a power supply.

PIPE/MAINLINES

Mainlines are made of either PVC pipe or lay-flat hose. Their purpose is to deliver water to the submains and laterals. The diameter of the pipe is determined by the distance the water needs to travel and the pressure requirements of the system. The wider the diameter of the pipe, the more expensive it is. The longer the pipe and the more elbows or junctions, the more loss due to friction, which then causes a gradual loss in pressure. A design engineer will help determine the appropriate pipe size for the system.

Care showed be taken when laying the pipe to prevent soil or debris from getting into the system and clogging the lines. The lines should be flushed before the tapes is connected to flush out any dirt that got into the lines during installation. It is a good idea to bury the lines at least deep enough to allow equipment to roll over them with out damaging the pipe.

CHECK VALVES AND PRESSURE REGULATORS

Valves control the direction of water flow. They are used to prevent water from flowing backward into a well after the system is shut off. Pressure regulators help maintain a constant pressure as the water flows through the system. Pressure relief valves prevent sudden changes in pressure from damaging pipes or tape. Vacuum-relief valves are installed to prevent soil from being sucked into the emitters when a vacuum is created after the system is shut-off.

RUNNING THE SYSTEM

Once the system has been properly designed, the next most important step is to operate the system correctly. No matter how well the system is built, if it is used improperly, then the cost of the system will be greater than the benefit.

Every crop requires different amounts of water to grow. The amount of water the crop needs for optimal production depends on the crop, the region of the country the crop is grown in, and the weather patterns for the growing season. Calculating how much water to apply depends on the evapotranspiration rate of the crop and the soil moisture content.

An important point to remember with drip irrigation is that the water is applied near the plant and that there is very little available moisture outside of the root zone. The root zone of a specific crop is much closer to the plant under a drip system than with other types or irrigation or where there is significant rainfall during the growing season. Soil moisture should be measured in the root zone, not in the furrows away from the plant. During periods of warm weather, the moisture in the root zone can be rapidly depleted even though there is sufficient moisture next to the plant.

One of the reasons for using drip irrigation is to decrease the amount of water applied to the field. This aids in weed control and decreases surface run-off. But you must still apply enough water for the crop's needs. This factor never changes. The way to measure the amount of water that a plant has used is to measure the evapotranspiration rate, also called crop water use. Either term means the amount of water used by the crop in a given period of time. This includes the amount of water that has evaporated from the soil surface and the amount of water that had transpired (like perspiration in humans) from the leaf's surface. Yields are limited if the plant receives less water than required for optimum growth.

SOIL MOISTURE

If no reliable evapotranspiration data is available, then monitoring the soil moisture is the next best way to determine how much water is required for the next irrigation event. It is also useful to monitor soil moisture to determine if the field overall is getting too wet or too dry, both indications that the irrigation system is not functioning properly. The usual devices for measuring soil moisture are tensiometers or gypsum blocks.

TENSIOMETER

A tensiometer is the most common tool used by growers. A tensiometer is a plastic pipe with a ceramic cup at one end and a vacuum gauge at the other. They can be purchased through several field equipment suppliers. The cup is wetted to saturation; then the pipe is filled with water. The pipe is inserted into the ground at the root zone. A rule of thumb is to place the tensiometer about six inches from the drip tape at a depth of one-third the entre root zone.

As the soil becomes wet or dry through irrigation or rain, the change in the water level of the pipe is registered on the gauge. The higher the reading on the tensiometer, the drier the soil. If the tensiometer reading is getting higher as the season progresses, then the soil is too dry; if the reading is decreasing as the season progresses, then the soil is too wet.

GYPSUM BLOCK

A gypsum block is less commonly used by growers. It measures the soil moisture by measuring electrical resistance. After the gypsum is saturated with water, it is embedded in the soil. Soil water moves in and out of the gypsum block as the soil is wetted or dried through irrigation or rain. The gypsum dissolves and moves with the water. As the concentration of the gypsum changes, the electrical resistance changes. The block needs to be replaced after all the gypsum dissolves.

FREQUENCY OF IRRIGATION

The soil should be irrigated often enough to keep the soil moisture level at a constant level. Some water all the time is better than putting the plant through a water stress-no water stress cycle. Generally, the plant should never be water stressed. Irrigation is more frequent under drip irrigation than more conventional irrigation because the roots remain close to the emitters. An irrigation schedule is based on the climate, the plant, and the soil. The table below shows the rule of thumb for irrigation.

FERTIGATION

Fertigation is the word used to describe the injection of chemical fertilizer into irrigation water. Nitrogen and potassium, are available in liquid or soluble solid form and can be applied through a drip system, though phosphorus is usually broadcast at the beginning of the season.

Anything injected into the water must go into solution or the system can become plugged. As mentioned earlier, a water test is a critical component of a properly designed system. Injection should always occur upstream of the main filters so that undissolved materials can be screened out.

Fertilizer should be injected into the system during the last phase of a scheduled irrigation event with three quarters of an hour to an hour of water with no fertilizer after that. This is to insure that all the fertilizer is applied and none remains in the tubing. Fertilizer in the tubing can encourage the growth of algae and other organisms.

There are several ways to inject chemicals into the system and there are advantages and disadvantages to each method. The five main types of injectors are: Chemical injection pumps, venturi applicators, pressure differential tanks, gravity injectors and bladder tanks. It is best to consult with an irrigation specialist to determine the right type for your operation.

Table 1. Factors influencing irrigation scheduling. Adapted from Drip Irrigation for Row Crops. University of California, Davis. P. 102

	More irrigation	Less irrigation
Climate	hot, dry, windy (high evaporative demand)	calm, cool, humid conditions (low evaporative demand)
Plants	shallow-rooted; damaged roots; complete ground cover	deep-rooted; healthy plants; incomplete ground cover
Soil	shallow, coarse textured	deep, fine textured

REFERENCES

Chapin Watermatics, Inc.

Hansen, B., L. Schwankl, S.R. Gattan, and T. Prichard. 1994. *Drip Irrigation for Row Crops*. University of California Irrigation Program, University of California, Davis.

Yardney Water Management Systems. Riverside, CA.

information in this fact sheet if it is in conflict with the label.

University of Massachusetts Extension
VegSF 1-00

First printed Feb 2000