



# The Basics of Micro Irrigation

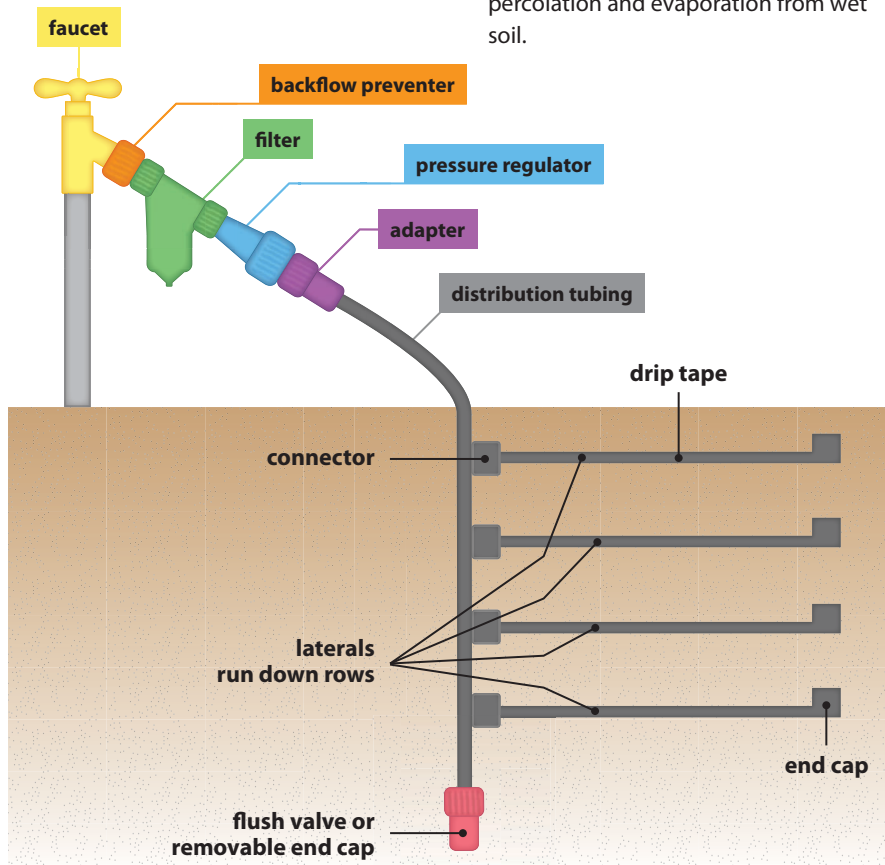
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A micro irrigation system consists of valves, pipes, tubing, and emitters that slowly dispense water near the plant root zone. There are several types of micro irrigation. Drip irrigation, also called *trickle irrigation*, delivers one water droplet at a time or a very small stream of water to plants. Micro spray irrigation delivers small amounts of water in a fine mist, in a stream of water, or by means of a micro sprinkler. Micro spray irrigation systems are often used in orchards to distribute water over a larger area of a tree's root zone than would a drip emitter. Micro irrigation can be used in greenhouses, orchards, vineyards, fields, lawns, and gardens.

Micro irrigation has many advantages over sprinkler irrigation:

- Water use can be reduced by 25 to 50% (Lamont, 2012; Simonne, 2015) because water is distributed to only the root zone of the target plants and not the area between rows, reducing losses by percolation and evaporation from wet soil.
- The plant foliage is not wetted, thus reducing the potential for foliar diseases.
- Since the area between rows isn't irrigated, fewer weeds grow, which can reduce herbicide use.
- Water is distributed more uniformly, with typically 90% or greater uniformity.
- Growers see reduced energy costs, because the system operates at lower pressure and less water is used.
- Water can be distributed on the soil surface (surface drip irrigation) or through lines buried in the plant root zone (subsurface drip irrigation), which will reduce damage to irrigation components by machinery.
- The drip irrigation system can be used to distribute water-soluble fertilizers. Fertigation allows fertilizer to be applied to the crop as needed during the growing season, reducing nutrient losses and leaching.
- Due to low water application rates, drip irrigation can be used on sloping ground without causing erosion or runoff.

FIGURE 1. Simple garden drip system.



There are also some drawbacks to drip irrigation:

- The initial cost of the system can be high (\$500 to \$2,000 per acre) relative to other types of irrigation systems, and there can be recurring costs if tubing is replaced annually.
- Emitter openings are very small, so all water must be filtered to prevent plugging. Depending on the source water quality, chlorination or acid rinsing the system may be necessary to prevent emitters from plugging.

## THE BASICS OF MICRO IRRIGATION

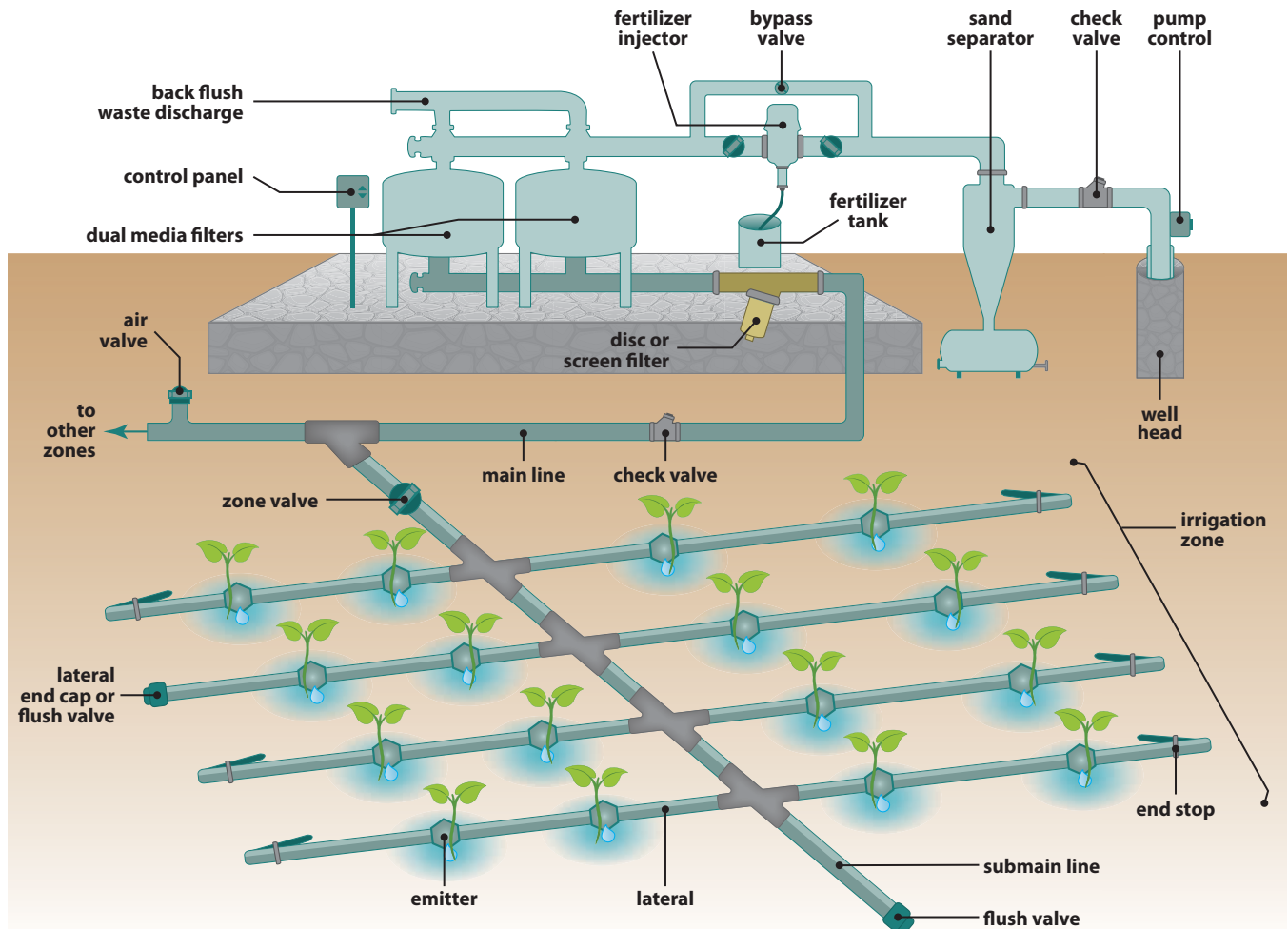
- A higher level of management is necessary to operate a drip system, because growers find it more difficult to judge the amount of water applied, which can result in under- or overwatering.
- Though drip irrigation reduces leaching, it can lead to high soil salinity or alkalinity over time because excess salts are not leached from the root zone. This can occur in soils that have a high clay content, high compaction, very high sodium content, or high water tables.
- Drip systems are also more prone to damage from machinery and wildlife, and at the end of the growing cycle there are cleanup costs to remove, recycle, or dispose of surface drip tape.
- In crops that could be damaged by frost during bloom, such as strawberries, a sprinkler irrigation system or floating row crop covers will be needed for frost control.

### System components

A basic drip irrigation system consists of a water supply, backflow prevention valve, fertilizer injector (optional), water filtration system, pressure regulator, a main line to transport water to the field, submains to distribute water within a field, laterals or poly tubes to distribute water down a row, and emitters to meter water to the plants. There may also be valves for zone control; various pipeline appurtenances such as vacuum relief valves, air relief valves, and pressure relief valves; flushing valves; pressure gauges; and system controllers.

For garden applications, this may be a very simple system, with a main line along the edge of the garden and laterals running down the rows all in one zone (figure 1) with manual water shutoff valves for individual rows. A large field may require multiple filtration systems, multiple zones, and a controller to automate irrigation of the zones sequentially. Figure 2 shows a water supply, a filtration system, and one zone of a multiple-zone, larger-scale drip irrigation system. When designing a new micro irrigation system, whether drip or micro spray, it is important to work from the field to the water source, or from the emitter or sprinkler to the water supply.

FIGURE 2. Components of a field-scale drip irrigation system.



## Piping and emitters

Three types of piping are used in drip irrigation systems:

- **Main line** pipe routes the water from the source to the edge of the field.
- **Submain** pipe distributes the water to zones in a field.
- **Lateral** pipe distributes the water to the plants.

In a small system, the main and submain pipes may be the same.

### Main lines

Main lines are typically made of aluminum, polyvinyl chloride (PVC), polyethylene (PE), or lay-flat tubing, (figures 3 and 4). They can be laid on top of the ground for seasonal use or buried for more permanent installations. The type of pipe will determine whether it can be buried. Some types of pipe, such as lay-flat tubing and thin-walled polyethylene, cannot be buried because they will collapse.

The pipe should be sized to minimize friction loss at the maximum expected flow rate and have a maximum flow velocity of less than 5 feet per second. For long runs, a larger pipe may be needed to reduce friction losses. The friction losses per hundred feet for different pipe materials and pipe sizes can be found in tables, such as the one published by the Irrigation Association in 2008 (see the reference section). Pipe fittings (e.g., elbows, tees, reducers) also need to be considered when

TABLE 1. Example of friction loss calculation.

Pipe size/type	Length of pipe	Friction loss (psi)/100 feet	Total friction loss
4-inch PVC pipe	200 feet	0.22	0.44 psi
3-inch PVC pipe	300 feet	0.74	2.22 psi
Fitting allowance	na	25% of total pipe	$2.66 \times 0.25 = 0.67$
<b>Total</b>			<b>3.33 psi</b>

calculating friction losses. A rule of thumb is to add 20% to the friction losses of your straight pipes to account for fittings.

Example: A system will require 750 feet of 2-inch PVC pipe, which has a friction loss of 1.37 pounds per square inch (psi) per 100 feet at a flow rate of 50 gallons per minute (gpm). The total friction loss is 10.3 psi for the pipe (750 feet  $\times$  1.37 psi/100 feet). The fittings are estimated to add an additional 20% in losses, or 2.0 psi (10.3 psi  $\times$  0.20). The estimated total friction losses for fittings and piping will therefore be 12.3 psi.

If the main or submain size is reduced along the pipe run (e.g., 200 feet of 4-inch pipe followed by 300 feet of 3-inch pipe), then the percentage to account for fittings is increased to 25%. If the pressure drop information for fittings is available from the manufacturer, it should be used instead of estimating.

Example: A system has 200 feet of 4-inch PVC pipe followed by 300 feet of 3-inch PVC pipe to the farthest field from the well at a flow rate of 100 gpm. Look up

the friction loss on the friction loss chart (see the third column of table 1). Calculate the pressure drop for each section of pipe (length  $\times$  pressure loss per 100 feet) (see fourth column of table 1). Calculate the allowance for fittings (total pressure drop for pipe  $\times$  25%). Add the pipe and fitting losses to estimate the total friction loss.

Pipes will need to be purged of water for the winter to prevent pipe breaks. For permanent installations, pipe slope and drain locations need to be considered during installation. Temporary or seasonally installed piping or permanent piping above ground needs to be protected from damage by vehicle traffic and field operations.

### Submains

Submains are used to route water from the main line to zones in the field. The lateral tubing with emitters is connected to the submains and delivers water to individual plants. Submain piping can be PVC, PE, or lay-flat tubing. The laterals are connected to PE (figure 5) or lay-flat

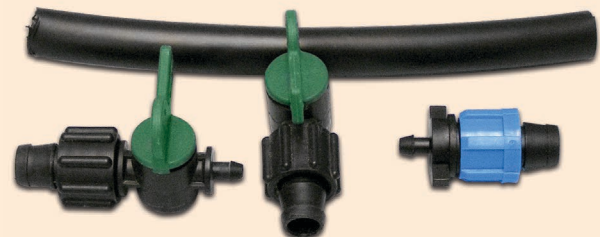
FIGURE 3. From left, aluminum, PVC, and lay-flat pipe materials.



FIGURE 4. Polyethylene tubing.



FIGURE 5. Drip tape barbed connector with and without valve.



**FIGURE 6.** Lay-flat tubing with adaptor for lateral.



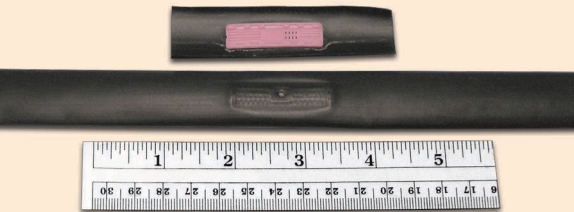
**FIGURE 7.** Drip tape barbed connector with grommet for PVC pipe.



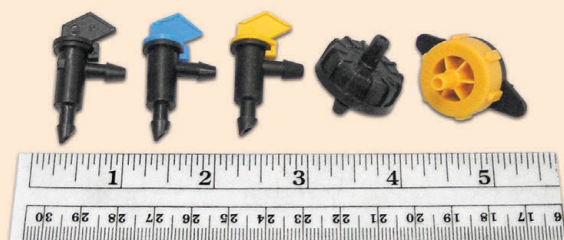
**FIGURE 8.** Different types of drip tubing emitter openings.



**FIGURE 9.** Cut-away view of drip tape emitter bonded to inside of tube (top) and external view (bottom).



**FIGURE 10.** Point source emitters.



tubing with barbed end connectors (figure 6), while PVC requires a gasket (figure 7), glue connector, or transfer tube. Fittings installed into PVC piping should be considered permanent.

Ultraviolet (UV) light from the sun degrades PVC. This causes PVC piping to become discolored and more brittle over time. If PVC piping is used above ground, it can be painted with a white water-based latex paint, wrapped with an opaque material, or purchased with UV protection. The UV-resistant PVC pipe is termed PVC UVR (UV-resistant). It still degrades over time but at a slower rate than it would without the protection. Most suppliers recommend painting the PVC pipe or using a thicker pipe rather than using PVC UVR pipe.

### Laterals and emitters

Drip tape, a thin-walled tubing with emitters incorporated at preset intervals, is the most common type of lateral used for row crops (figure 8). Drip tape comes in different wall thicknesses (4 to 15 mil) to meet various durability and pressure requirements. A thin-walled drip tape (4 or 5 mil) would be most economical for an annual crop. For a crop such as strawberries that will be grown for 3 to 4 years, a medium wall thickness (6 or 8 mil) will provide durability to last the crop cycle. If drip tape will be reused or moved for multiple seasons, a wall thickness of 10 mil is recommended. For permaculture (orchards, vineyards, or berries), or where there is more field traffic or where rodent damage is more likely, a heavy-walled tubing (12 or 15 mil) is available. The drip tape can remain in or on the ground over winter as the water will drain, so freezing will not damage it; however, it still can be damaged by rodents or equipment.

An emitter is a device that meters water out along a lateral. Typical flow rates for a drip emitter range from 0.4 to 2.0 gallons per hour (gph). The emitter opening can be a single point or a slit. Figure 9 shows the external view of the emitter and a cut-away of the internal part of the emitter that is bonded to the inside of the plastic tubing. Emitter spacing can range from 4 to 24 inches; 8 to 16 inches is common for vegetable crops. A closer spacing

would be used for sandy soils, while a wider spacing could be used for soils with higher clay content due to the difference in lateral water movement within the soil. Crops with large in-row spacing, such as tomatoes or pumpkins, can have emitter spacing that matches the plant spacing. Closer spacing in row crops reduces the variation in water distribution between emitters. Typically, a 12-inch spacing works well for most soils.

Another type of emitter is a point source emitter (figure 10). This type can be used in greenhouses or nurseries for potted plants and in orchards or vineyards. For orchards and vineyards, multiple emitters may be required per tree or vine. One advantage of point source emitters in orchards and vineyards is that you can insert them at any spacing needed—just punch a hole and insert the barbed end. They are available in pressure-compensating or non-compensating types. Pressure-compensating emitters (figure 10, two emitters on the right) are designed to maintain uniform water flow over a range of pressures. Typically they have a diaphragm to regulate the pressure. They help to maintain uniform water flow when there are elevation differences in a system or long pipe runs.

Spray emitters, misters, and micro sprinklers (figure 11) are other types of emitters and are typically used in orchards, landscape applications, or greenhouses.

**FIGURE 11.** Micro sprinklers on stakes or risers.



**FIGURE 12. Heavy-walled drip tubing for surface or sub-surface applications.**



They can distribute water across a large area of the root zone of a plant or tree. These emitters can cover areas from about 5 to 30 feet in diameter depending on orifice size, distribution pattern, and water pressure. The water flow rates range from 5 to 20 gph. The micro sprinklers are typically attached to a 1- to 3-foot-long stake with spaghetti tubing (small diameter tubing) connecting the sprinkler to the lateral. These are typically used in orchards with full-size or semi-dwarf trees. Micro sprinklers or misters may also be useful for frost control for strawberries and other early-flowering crops. These types of sprinklers have the disadvantage of higher evaporative losses and may increase canopy humidity levels, increasing conditions favorable for fungal diseases. Traditionally, drip tape is placed on top of the soil surface or under plastic mulch, which can expose the drip tape to damage. When tape is placed on top of the soil, some evaporation will occur due to the wet soil surface. For subsurface drip irrigation (SSDI), the emitter is

**FIGURE 13. Drip tubing supported on wire in vineyard about 1 foot above the ground.**



**TABLE 2. Recommended subsurface drip tubing spacing and depth.**

Crop	Depth (inches)	Drip line spacing
Fruit trees and grapes	> 16	Same as rows
Blueberries, raspberries	> 8	Same as rows
Row crops—corn, asparagus	> 12	Maximum of 60 inches
Raised beds—single row (tomatoes, cucumbers)	2–4	One drip line offset 4 to 6 inches from center of bed
Raised beds—double row (eggplant, peppers, strawberries)	2–4	One drip line in center of bed
Raised beds—double row (bed width greater than 30 inches)	3–6	Two drip lines spaced half the bed width apart

Adapted from Van der Gulik, 1999 (table 6.1).

placed in the root zone. This reduces the exposure of wetted soil to evaporation. For deep-rooted crops the SSDI lines are installed permanently below the tillage zone, but for shallow-rooted crops the tubing may be removed after the crop rotation. Subsurface installation can reduce the cost over the long run but has a higher initial cost because installation is more complex, requiring a thick-walled emitter line and trenching equipment. Subsurface drip tubing can be knifed in, but submain piping must be trenched in at the ends of the field or zone. Typically, tubing has an 8 to 15 mil wall thickness, but piping is available up to 60 mil (figure 12). Thicker-walled tubing is used with higher system

pressures and in rough (rocky) terrain. Very thin-walled tubing (4 to 6 mil) should not be used for permanent subsurface drip irrigation applications because it will collapse. Drip tubing should be pressurized shortly after burying to prevent crushing of the tubing as the ground settles.

Subsurface drip irrigation installed permanently in a field or orchard typically will have a longer life if thicker-walled tubing is used, and it can last 20 years or more if properly installed and maintained. The biggest disadvantage of subsurface irrigation is the difficulty of monitoring the water applied and being aware of problems such as plugged emitters or damaged tubing. Using water meters on each zone and on each field can help identify problems by making it possible to compare current flow rates with those observed at installation. The use of soil moisture monitoring sensors can help determine when water is needed. Subsurface drip irrigation won't wet the soil near the surface so other means of applying water may be needed during germination if the weather is dry; however, this is typically not a problem in Wisconsin.

**Drip line spacing and depth**

The spacing and depth of subsurface irrigation piping varies greatly with the type of plant. The installation depth for fruit trees and grapes will be the deepest, while the installation depth for crops like strawberries and tomatoes will be shallow. Raised beds may require multiple drip lines, depending on the bed width. Table 2 provides guidance on the depth and spacing to use for various crops.

**Emitter spacing**

The number and type of emitters varies with the crop type and spacing. See table 3 for guidelines.

Drip tape should be placed as close to the crop row as possible with consideration given to avoiding damage during field operations (e.g., cultivation, hoeing, pruning). If drip tape is placed under plastic, the location is important so that the drip line is not damaged during planting. For grapes and berries, the drip line can be buried (subsurface) or suspended from a trellis wire (figure 13). A suspended line should be high enough not to impede mowing or tillage operations. When suspended, the drip line will sag, causing water to drip from the lowest point. Increasing support of the drip line will help to direct water to the intended location. If using point source emitters, install them on the underside of the pipe to drop water directly to the ground where desired.

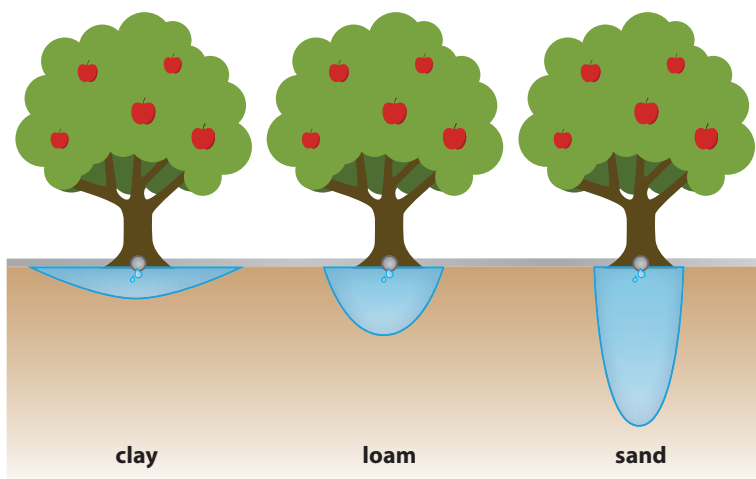
As water is emitted, it enters the soil and may spread horizontally beneath the soil surface, depending on the soil texture (figure 14). This will affect the wetted volume of soil, width of the wetted root zone, and possibly the number and spacing of laterals needed. Table 4 provides a rough estimate of the lateral movement of the water away from the drip emitter in different soil textures. Growers will need to dig holes, take soil core samples, or use a soil moisture sensor to determine the extent of lateral movement in their soils.

**TABLE 3. Guide for number of emitters per plant.**

Crop type	Minimum number of emitters
Vegetables (single row)	Drip tape—orifice spacing not greater than 1.5 times plant spacing
Vegetables (double row)	Drip tape—orifice spacing not to exceed plant spacing
Grapes	Point source or drip line—2 emitters per plant
Strawberries	Drip tape—12-inch spacing recommended
Raspberries	Point source—spaced every other plant Drip line—1 emitter per plant
Blueberries	Point source—1 per plant, match plant spacing
Fruit trees (spacing 6 feet or less)	Point source—halfway between trees Drip line—2 emitters per tree
Fruit trees (about 8 feet apart—dwarf)	Point source or drip line—2 per tree spaced 2 feet from tree trunk Spray or micro sprinkler—spaced halfway between trees with 360° head or 2 spray emitters at tree base with 180° or 270° heads
Fruit trees (greater than 8-foot spacing)	Point source or drip line—2 per tree spaced 2.5 feet from tree trunk, spacing greater than 15 feet use 3 or more emitters per tree Spray emitters—2 at tree base with 180° heads discharging away from tree
Container plants	Spray or point source—2 emitters per pot to ensure plants get water should one orifice plug; large pots can benefit from spray to distribute water

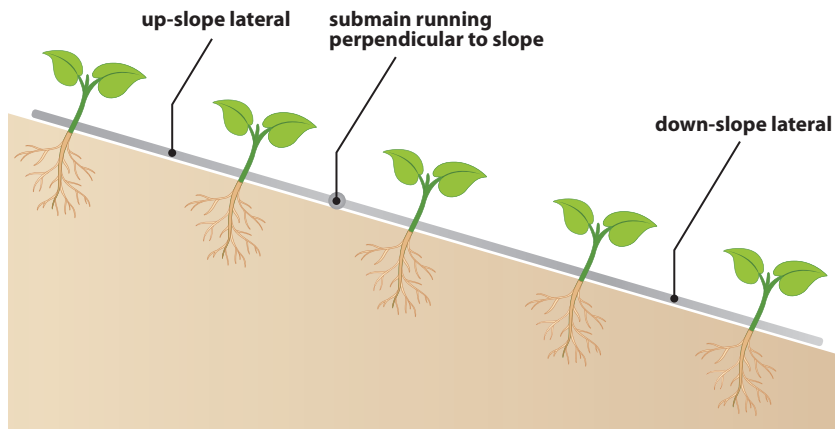
Adapted from Van der Gulik, 1999 (table 5.4).

**FIGURE 14. Wetted root zone pattern by soil type.**



**TABLE 4. Lateral water movement from point emitter.**

Soil type	Lateral movement (feet)
Coarse sand	0.5–1.5
Fine sand	1.0–3.0
Loam	3.0–4.5
Heavy clay	4.0–6.0

**FIGURE 15. Split slope lateral layout.****Lateral layout**

The layout of the laterals or drip tape needs to minimize the effects of elevation changes to maintain high water distribution uniformity. Whenever possible the laterals should lie along the contour of slopes in order to minimize elevation pressure losses or gains. If that is not possible you may compensate by regulating the pressure at the lateral manifold or submain, by using pressure-compensating emitters, or by splitting the field so that the lateral going up the slope is shorter than that going down the slope (figure 15). The split is to balance the elevation effect so that pressures at the emitters are more uniform.

A variety of nominal sizes of lateral pipe and drip tape are available. Most manufacturers offer drip tapes from ½ to 1¾ inches in diameter. The ¾-inch tubing is sufficient for most fields, costs less, and is available in a wide range of emitter spacings and flow rates. The larger 7⁄8-inch tubing can be used in longer runs and will still maintain high uniformity. It will also possibly require fewer submains, which could reduce the number of obstacles you will need to maneuver around during field operations. Although 7⁄8-inch tubing and fittings cost more than ¾-inch tubing, the possibility of needing fewer submains may reduce the overall system cost. Drip tape sizes of 1½ and 1¾ inches in diameter permit higher flow rates and longer runs, but are not commonly used.

The maximum drip tape length will depend on the distribution uniformity required, the slope of the field, the flow rate, the inlet pressure, and the diameter of the drip tape. On a flat field, the lateral length can be 1,000 feet or more, but an uphill slope can reduce the maximum length by 15 to 60% depending on inlet pressure and slope. Drip tape manufacturers publish tables or charts indicating the maximum length of run based on operating pressure, flow rate per 100 feet, percent slope, emitter spacing, and uniformity.

**Design**

All pipes in the drip irrigation system must be sized to match the flow rates and pressure losses in each section of the system. This process starts with laying out and sizing the laterals or drip tubing in the field, then working backward to the submains, then to the main lines. There are three excellent handbooks listed in the reference section to help with the layout and sizing of all system components: *RO-Drip User Manual*, *B.C. Trickle Irrigation Manual*, and *Drip and Micro Irrigation Design and Management for Trees, Vines and Field Crops*.

**Controls**

Drip irrigation can be controlled manually, with a timer, or by using a sophisticated controller that interacts with sensors that determine soil moisture levels and turn on the irrigation when the moisture level reaches a predetermined value. In larger systems controllers can be used to sequence zones by activating multiple valves. Figure 16 shows a valve bank with an automated controller in a vineyard.

**Water supply**

Water sources for drip irrigation can be surface water, groundwater, or a public water utility. A groundwater or public water source is usually best because it typically provides cleaner water. If a surface water source is used, additional filtration will be required to remove biological materials (debris, algae, bug larva, etc.) to prevent emitter plugging.

When considering a drip irrigation system, remember it is important to have an adequate water supply for the irrigated area during a drought period. If the water source cannot supply enough water for the system to function efficiently during a drought period, then installing an irrigation system may not result in sufficient additional yield or crop quality to pay for the investment.

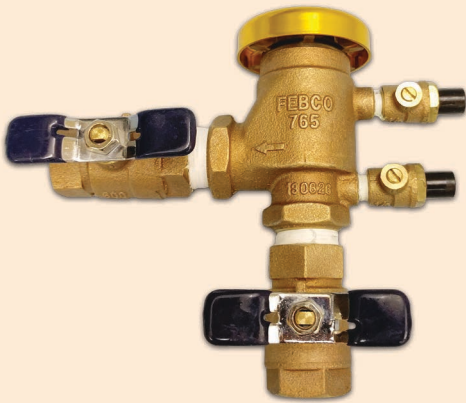
In Wisconsin the peak growing season evapotranspiration, or plant water use, is about 0.30 inches per day.

**FIGURE 16. Valve bank with an automated controller in a vineyard.**

**FIGURE 17.** Backflow preventer for hose.



**FIGURE 18.** Anti-siphon vacuum breaker.



**FIGURE 19.** Inline screen filter.



The recommended maximum water application time is 12 hours per day (Van der Gulik, 1999), which means a minimum water flow rate of 6 gallons per minute per irrigated acre. Converting the plant water use into gallons of water per acre results in a requirement of 8,146 gallons per acre per day before irrigation system losses are considered. Drip irrigation typically reduces the total water volume needed by reducing deep percolation and surface evaporation, and by only watering the crop root zone and not the aisle between the rows. It can also reduce weed growth due to the dry soil surface. The total amount of water the plants use will remain the same but there should be less unused water if the system is managed effectively.

Water quality is an important consideration when using drip irrigation. The amount and size of suspended solids in the water is important in selecting the type of filtration system to use to prevent emitters from plugging. Measures of water quality include Total Dissolved Solids (TDS), which is a measure of the concentration of soluble salts, and Sodium Absorption Ratio (SAR), which is a ratio of sodium to calcium and magnesium. If total dissolved solids are high, they can become a problem if they precipitate out of the water and plug the very small openings of the emitters. Sometimes water treatment is needed to control TDS.

## Backflow prevention valve

A backflow prevention valve is required to prevent contaminated water from being drawn back into a well or public water system. It is basically a check valve and a vacuum relief valve in one unit that will allow the water to flow in only one direction, but will also allow air into the pipeline to replace the water draining from the system. For a small system it consists of a small valve that attaches to a garden hose (figure 17). A large system will use a vacuum breaker that is permanently installed in the water supply line (figure 18).

## Filtration

Drip irrigation emitters have very small openings that can plug from biological particulates (e.g., algae, bug larvae) or chemical particulates (e.g., iron, calcium). It is imperative that the water be free of any debris in order to reduce emitter clogging and to maintain uniform distribution. Most systems will need a 120- to 150-mesh filtration screen, but some will require 200-mesh filtration to keep emitters from plugging. Manufacturers of drip tape and emitters will provide a specification sheet with recommended filtration levels measured in microns or mesh. There are four types of filtration systems: screens, disks, media (sand), and separators. Often more than one type of filter will be used in series in a system. A simple drip irrigation system for a small area such as a garden may include a screen or disk filter; a system serving a larger area will often include a media filter for primary filtration in combination with a screen or disk filter.

**Screen filters** have a fine screen to remove debris from the water (figure 19). They are used in small systems that have clean water supplies or as secondary filters after a media filter. Regular maintenance is required to remove any debris on the screen. If the screen is allowed to become clogged, the water force can push debris through the screen or rupture it. Screens can be cleaned by reversing the water flow to dislodge debris either manually or by using a flushing valve. The screen should be cleaned after the pressure drop across the filter reaches 4 to 5 psi.



**TABLE 5. Media type and filtration range.**

Sand media type and designation	Mesh range	Mean effective size (mm)
#8 crushed granite	100–140	1.50
#12 silica sand	130–140	1.20
#11 crushed granite*	140–180	0.78
#16 silica sand	150–200	0.70
#20 silica sand*†	200–250	0.47

\* Widely used media types.

† Use a base layer of garnet media (effective media size greater than 1.0 mm) in bottom of tank. Fill to 6 inches above underdrain.

Source: Van der Gulik, 1999; Burt and Styles, 2011.

**FIGURE 20. Media filter.**

(Courtesy of EurodripUSA.)

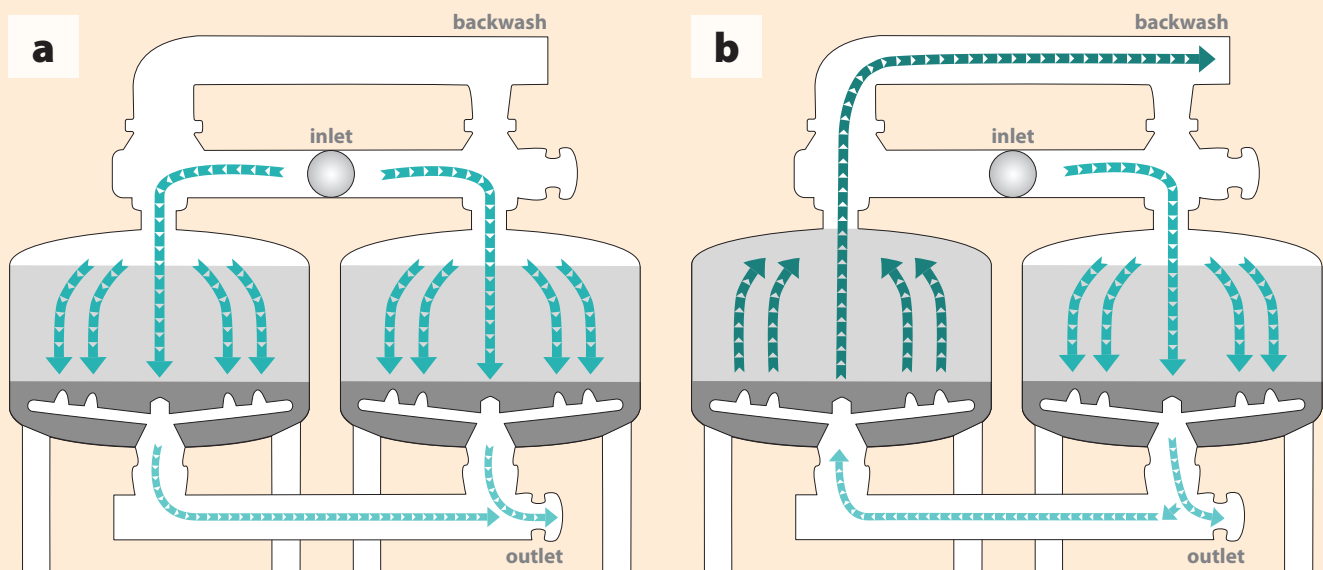


**Media filters** (also called *sand filters*), similar to swimming pool filters, are effective for removal of suspended particulate matter in the water supply. They use sand or crushed rock as a media and are capable of trapping large quantities of suspended solids while still maintaining rated flow rates (figure 20). The media type selected will affect the filtration mesh range. Table 5 lists different types of media and the effective mesh range.

Media filters can be easily cleaned by backflushing to remove the trapped particles. During backflushing water is routed backwards through the media to dislodge trapped particles and discharge them to a waste drain (figure 21). With proper controls, backflushing can be programmed to occur automatically at a fixed time interval or based on the pressure difference between the incoming and outgoing flow. To provide continuous water flow for irrigation, at least two filters are needed so that at least

one is filtering while the second filter is being backflushed. Three-filter systems are often used so two are filtering while one is backflushing. The filter should be backflushed for 3 to 5 minutes or until the drain water runs clear. The frequency of backflushing will depend on the amount of particulates in the source water. The recommendation is to backflush every 2 to 4 hours of operation or, if differential pressure is used, when pressure loss across the filter (compared with clean sand) is 5 to 7 psi.

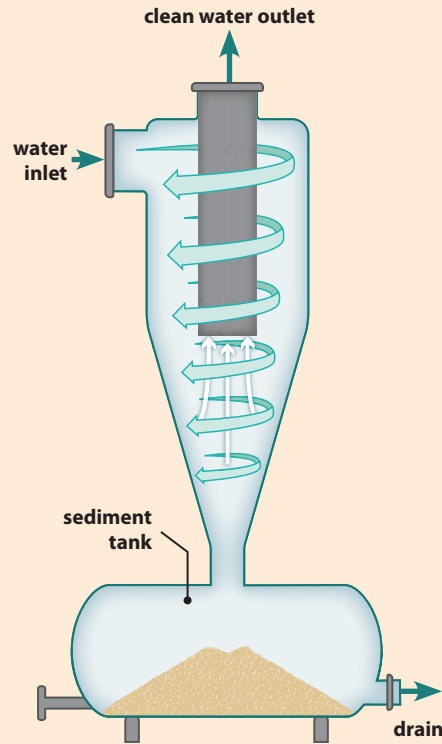
**FIGURE 21. Backwashing of a media filter: (a) both vessels in filtration mode; (b) one vessel in backwash mode and one vessel in filtration mode.**



**FIGURE 22. Separator/cyclone filter.**  
(Courtesy of Netafim USA.)



**FIGURE 23. Separator flows.**



**FIGURE 24. Disk filter.**



**FIGURE 25. Disk filter element assembly.**



**Separator filters** make use of centrifugal force to separate particles from the water (figure 22). They work well for removal of sand and particles that are heavier than water. They are not effective for removing organic matter and particles that are less dense than water. The water flow enters the top of the cone-shaped separation vessel tangential to the vessel wall. As the water flows circularly, the heavier particles move towards the vessel wall and settle to the bottom while the water flows out the top center of the cone (figure 23). The accumulated particles are removed as required, either manually or automatically. This type of filter has the advantage of low pressure drop because the debris is separated out without obstructing the flow path.

**Disk filters** use a stack of thin doughnut-shaped filter material (figures 24 and 25). These are often used to remove organic matter and small particles after the water goes through a media or separator filter, but they can also be used on small systems to avoid the expense of a media filter. Multiple disk filters can be used in parallel in large systems to provide greater volume. They have greater capacity than screen filters of similar size and are easy to clean without scrubbing. Mesh sizes range from 40 to 200 microns and they can be cleaned by backflushing or reversing water flow to remove debris. This can be done either automatically with a controller and valves or manually. Backflushing scheduling can be based on time or on inflow/outflow pressure differential.

A screen or disk filter should be installed after a media or separator filter to remove any particles that were not removed by the initial device.

## Pressure regulators

Drip irrigation systems operate at pressures from 6 to 60 psi at the field lateral. A field lateral is piping that supplies water to the drip tape or piping that contains the emitters. The pressure needed will depend on the elevation change along the pipe length, length of the pipe, water flow rate, distribution uniformity required, and type of emitter system used. Most drip tape has an operating pressure range of 6 to 15 psi with a general recommended range of 8 to 10 psi (refer to manufacturer's literature for individual product recommendations). The recommended operating pressure for micro sprinklers or misters will vary depending on the type and can range from 20 to 60 psi. Higher pressures result in larger wetted diameters and fewer emitters per lateral. When selecting a pressure regulator, the desired pressure and flow rate need to be matched to the device. Pressure regulators can have a fixed pressure setting (figure 26) or can be adjustable (figure 27).

Since a drip irrigation system can operate at lower pressure than other types of irrigation systems, it can utilize gravity-pressurized flow, given that the pressure provided by gravity is sufficient to operate the system. The lower recommended operating pressure range for most drip tape is 4 psi. A filter should be used in the system and this may cause a pressure drop

of 2 psi, depending on the water flow rate and the number of emitters being supplied at one time. Assuming negligible pressure drop between the reservoir and the drip line, the total pressure required would be 6 psi. It requires 2.31 feet of elevation to produce 1 psi of pressure, so to achieve the 6 psi would require the water supply to be elevated about 14 feet above the field ( $2.31 \text{ feet/psi} \times 6 \text{ psi}$ ). A system might be operated on less pressure, but the length of run may need to be reduced or the water distribution uniformity may be lower. See manufacturer's data for recommended pressures and length of runs.

## Flushing

Drip irrigation systems need to be flushed periodically to remove sediment, precipitated minerals, and particles that could plug the emitters. Even when the filtration system is well designed and well managed, flushing is essential. Systems should always be flushed before the first use after installation and at the beginning and end of each growing season. Where water quality issues exist, flushing may also be needed during the growing season. Flushing involves opening the terminated ends of the submains and laterals and allowing water to freely flow for a period of time. The flow rate needs to be sufficient to maintain a velocity of at least 1 foot per second in the pipes to suspend particles

for removal. This will require higher pressure and water flow rates, so zoning the system is important in order to be able to flush portions of the system one at a time to achieve enough water velocity.

If the irrigation water contains high amounts of dissolved solids, algae, or bacteria, it may require frequent chlorination or the addition of algaecides or acid to remove these materials and keep them from plugging the emitters. Refer to the *B.C. Trickle Irrigation Manual* or *Drip and Micro Irrigation Design and Management for Trees, Vines and Field Crops* in the reference section for more information on source water treatment options.

**FIGURE 26.** Pressure regulator for small system with fixed pressure setting.



**FIGURE 27.** Adjustable pressure regulator.



## Fertigation

The drip irrigation system can be used to apply water-soluble fertilizers and systemic pesticides. This is done using an injector or dosing system to meter the chemical into the irrigation water. A drip irrigation system that has high distribution uniformity for irrigation water will also have high distribution uniformity for fertilizers and pesticides if managed correctly.

The injector should be installed before the filtration unit. A backflow preventer **must** be installed between the injector and a well or public water source. There are several different types of injection units: venturi (figure 28), proportional injector, or injector pump (electrically or water-powered) (figure 29). For small systems

a venturi or proportional injector are the least expensive methods but may require that the chemical or fertilizer be diluted with water so the proper concentration will be distributed across the field. Refer to the *B.C. Trickle Irrigation Manual or Fertigation* in the reference section for more information on equipment and process for fertilization through a drip irrigation system.

## Irrigation scheduling

The amount of water to apply to a crop will depend on the stage of growth, daily evapotranspiration (ET), soil moisture, water volume, and area to be irrigated. The first step is to estimate the wetted root zone volume using table 4 to consider lateral water movement, the emitter

spacing, and the managed root zone depth. Refer to UW-Extension bulletins *Irrigation Management in Wisconsin* (A3600-01) and *Methods to Monitor Soil Moisture* (A3600-02) for suggested root zone depth for different crops. Overlap between emitters must be taken into account when estimating the wetted root zone volume.

The following example demonstrates how to determine the amount of irrigation water to apply and the interval between irrigation events.

FIGURE 28. Venturi injector.



FIGURE 29. Water-powered fertilizer injector.



## Example calculation of water requirements

### Crop: Strawberry

Plants are 1 foot apart in rows 4 feet apart with row lengths of 200 feet. The root depth is assumed to be 1 foot (table 2 in *Methods to Monitor Soil Moisture* (A3600-02)).

**Irrigation system:**  $\frac{5}{8}$ -inch drip tubing with 12-inch emitter spacing and a flow rate of 0.22 gallons per minute (gpm)/100 feet at 8 psi.

**Soil type:** Silt loam with 2.5 inches of available water per foot (refer to *Irrigation Management in Wisconsin* (A3600-01)) and 3 feet of lateral movement (table 3).

**Average crop ET:** 0.18 inches per day. Reference ET  $\times$  crop coefficient ( $K_c$ )  $\times$  non-uniformity factor (1.1–1.2).

**Allowable depletion**, amount of water removed from managed root zone before irrigating: 50%.

#### 1. Calculate soil volume.

The lateral movement of the water can be up to 3 feet but the roots of the strawberries will be about as wide as they are deep. Therefore the soil volume will be 1 foot deep  $\times$  2 feet wide (1 foot diameter around each plant)  $\times$  200 feet, or 400 cubic feet (see figure 30).

#### 2. Calculate the water-holding capacity of the soil.

The given water available water-holding capacity of the soil is 2.5 inches per foot of depth. The water volume is 2.5 inches  $\times$  12 inches  $\times$  12 inches = 360 cubic inches of water per cubic foot of soil.

Converted to gallons,  $360 \div 231$  cubic inches/gallon = 1.56 gallons/cubic foot.

So in the 200-foot row the soil can hold 1.56 gallons/cubic foot  $\times$  400 cubic feet = 624 gallons.

With a 50% allowable depletion, irrigation would occur when the water volume had decreased by 50%, or 312 gallons.

#### 3. Calculate volume of water to replenish daily ET losses.

The crop ET is 0.18 inches per day, so we need to determine how long the irrigation needs to run per day to replace the water used. The amount of water per cubic foot of the managed root zone will be equal to 0.18 inch/day  $\times$  144 square inches at the surface/cubic feet of soil  $\div$  231 cubic inches/gallon

= 0.112 gallon of water/cubic foot of soil per day used by plants and evaporation

= 0.112 gallon of water/cubic foot of soil  $\times$  400 cubic feet of soil = 44.9 gallons water used per day.

#### 4. Calculate the days between irrigation events (assuming no rainfall).

They will equal  $312 \text{ gallons} \div 45 \text{ gallons/day} = 6.9$  days. Based on the water-holding capacity of the soil, the crop would need to be irrigated every 6 or 7 days. (Note that this does not account for the potential lateral movement of water.)

#### 5. Calculate the hours of irrigation.

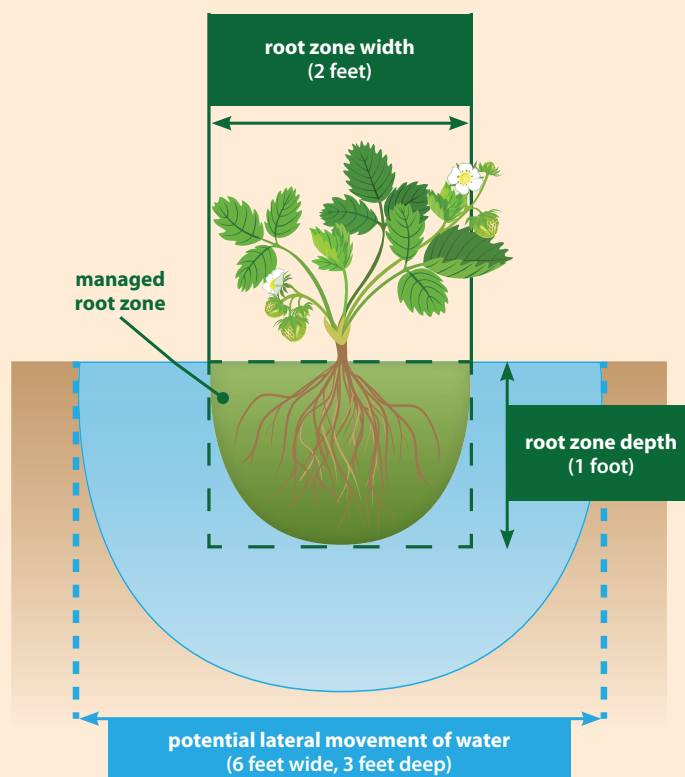
The irrigation rate for the 200-foot row is  $0.22 \text{ gpm}/100 \text{ feet} \times 200 \text{ feet row} = 0.44 \text{ gpm}$ .

To apply 312 gallons of water will require  $312 \text{ gallons} \div 0.44 \text{ gpm} \div 60 \text{ minutes/hour} = 11.8$  hours.

Because the water may spread laterally up to 3 feet, irrigation should be done more frequently for shorter durations to keep the applied water within the root zone where the plant can access it. It will be better to apply water every 2 to 3 days than every 6 to 7 days; only experience will help determine the appropriate frequency and timing. A soil moisture probe could be used to verify water movement in the soil to determine the appropriate irrigation frequency. If the water was going to be applied every 2 days, the application time would be calculated by multiplying the daily evapotranspiration amount for the row by the number of days (to determine the water volume) and dividing by the water application rate.

In this example,  $44.9 \text{ gallons of water use per day} \times 2 \text{ days} \div (0.44 \text{ gpm} \times 60 \text{ minutes/hour}) = 3.5$  hours.

**FIGURE 30. Plant root zone versus water movement.**

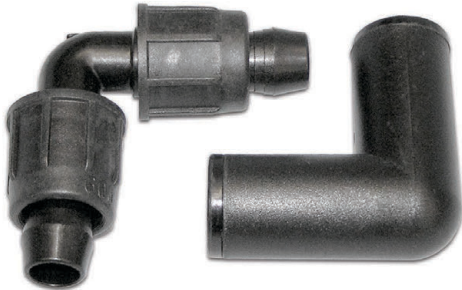


## Drip irrigation fittings and tools

**FIGURE 31. Tee connector**—Used for adding a branch in a drip tape line.



**FIGURE 32. Elbow connector**—Used for making a sharp bend in a drip tape without kinking.



**FIGURE 33. Coupler**—Used to connect two sections of drip tape or rigid polyethylene tubing. They are available with valves for zone control.



**FIGURE 34. End plug**—Used at the end of drip tape to terminate the line. Some have a cap that can be removed for flushing the line. Others just hold the tubing in a folded-over position.



**FIGURE 35. Goof plug**—Used to plug an unneeded hole in the sub or main polyethylene tubing.



**FIGURE 36. Drip tape and barb connector**—Used to connect drip tape to a submain line.



**FIGURE 37. Spray/sprinkler emitter**—Used to cover a wider area such as the root zone of a fruit tree.



**FIGURE 38. Zone control valve**—Electrically operated (solenoid) valve used with a controller to turn water to a zone on and off.



**FIGURE 39. Punch tools**—Used to punch a hole in polyethylene tubing for inserting a drip tape and barb connector.



**FIGURE 40. Controller**—Used to turn on and off the water flow to a system or to a zone. This can be a manual valve, timer (pictured below), or a programmable controller that uses sensors to determine when soil moisture is needed.



## Recycling

Drip tubing is typically made from polyethylene plastic that can be recycled. Some drip tubing manufacturers offer recycling of tubing, hose, or tape. There are also independent companies that will recycle drip tubing along with other agricultural plastics. Refer to the UW-Extension crop irrigation website for a list of companies that offer recycling (<http://fyi.uwex.edu/cropirrigation/drip-irrigation/>).

## Equipment manufacturers

A list of manufacturers who distribute irrigation equipment in Wisconsin for the agricultural market is available at <https://fyi.uwex.edu/cropirrigation/drip-irrigation/>.

### Design software for layout and pipe sizing

- Aqua-Flow Design Assist software from Toro.
- Drip Hydraulics Calculator, Irrigation Training and Research Center, California Polytechnic State University, San Luis Obispo, CA. (Comes with the book *Drip and Micro Irrigation Design and Management for Trees, Vines, and Field Crops*).
- HydroCalc software from NetaFim.

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### Websites

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*Irrigation in the Pacific Northwest*, irrigation calculator tools and tools for determining pipe sizes, irrigation timing, drip line rates, among many others. <http://irrigation.wsu.edu/Content/Select-Calculators.php>

*Understanding Crop Irrigation*, UW-Extension resource for all types of irrigation and irrigation management tools for Wisconsin. <https://fyi.uwex.edu/cropirrigation/>



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*This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2011-38640-30539 through the North Central Region SARE program. USDA is an equal opportunity employer and service provider. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.*

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