



Drip Irrigation Systems

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Introduction

Drip or trickle irrigation refers to the frequent application of small quantities of water at low flow rates and pressures. Rather than irrigating the entire field surface, as with sprinklers, drip irrigation is capable of delivering water precisely at the plant where nearly all of the water can be used for plant growth. The uniformity of application is not affected by wind because the water is applied at or below the ground surface. A well designed and maintained drip irrigation system is capable of an application efficiency of 90 percent. According to the Farm and Ranch Irrigation Survey conducted by USDA, 11,239 acres of agricultural lands in Oklahoma were under drip irrigation in 2007, out of which 81 percent was under SDI.

Irrigation Components

Drip irrigation systems can be arranged in a number of ways. The arrangement of components in Figure 1 represents a typical layout. Variations in pressure within the system due to changes in elevation and pressure loss within the pipes will affect the discharge of individual emitters. For a system to irrigate satisfactorily the application of water must be uniform. There should be no more than a 10 percent variation in discharge between the emitters with the lowest and highest output. To achieve this, pipes and tubing must be sized correctly. Laterals should run across slope, following contour lines, or run slightly downhill. Areas of a field at different elevations should operate as separate sub-units with separate pressure regulators.

Drip irrigation laterals can be divided into two categories: line source emitters and point source emitters.

Line Source Emitters

Line source emitters have built-in perforations where the volume of soil irrigated by each perforation overlaps with that of the perforation next to it, resulting in a long, narrow block of irrigated soil that surrounds the roots of the entire row crop. Line source emitters are used when plants are closely spaced within a row, with the rows separated several feet apart, as with row crops and most vegetable crops.

The typical line source emitter is a twin-wall tubing, with two pipe chambers. The larger, inner chamber is for water flow along the row length. The smaller outer chamber has the pressure dissipating emitting device. The emitting devices are typically spaced from 6 to 36 inches apart. The dual chamber design reduces the effect of pressure loss in the tubing, permitting a more uniform rate of discharge along the tube length. Typical operating pressures for drip tubing range from 6 psi to 12 psi. The maximum length of tubing that can be used satisfactorily depends upon the inlet pressure of the tubing, tubing diameter, emitter discharge rate, emitter spacing, and field slope. The limitation on length is imposed because of the need to maintain uniformity in water application. Maximum permissible lengths of run while maintaining a uniformity of 90 percent, and other pertinent operating characteristics for typical drip tubing are listed in Table 1.

The rate of water application from drip tubing depends upon the design discharge rate, emitter spacing, and the operating pressure. Manufacturers may express drip tubing

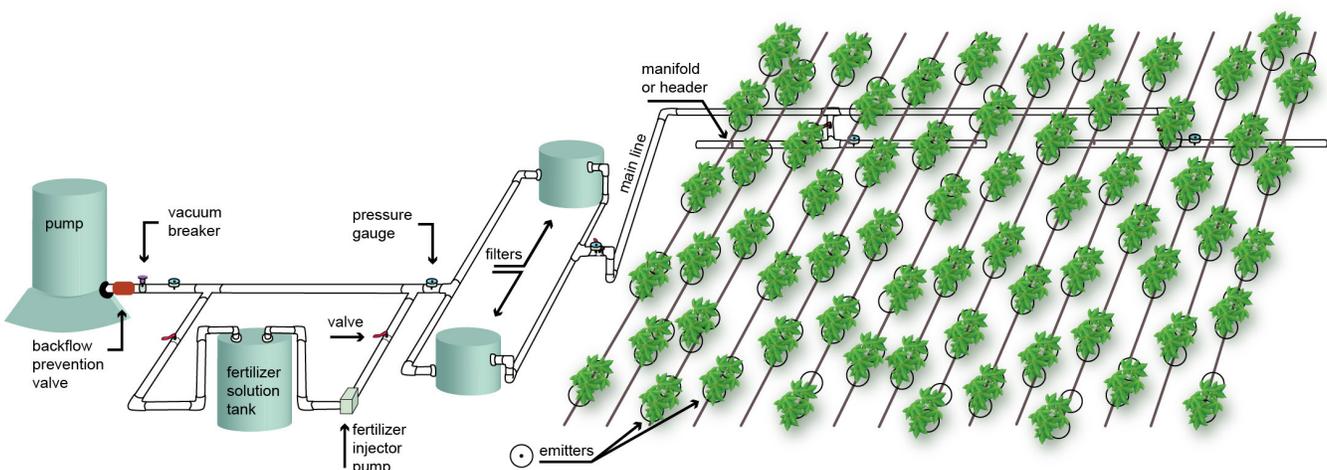


Figure 1. Typical drip irrigation system layout.

Table 1. Maximum Length of Drip Tubing Laterals. (8 psi inlet pressure, level field slope)

Emitter Spacing (inch)	Emitter Flow Rate (gph)	Emission Uniformity			
		90%		85%	
		Tubing Diameter		Tubing Diameter	
		5/8"	7/8"	5/8"	7/8"
12-inch	0.22	750 ft	1300 ft	1,000 ft	1,750 ft
	0.45	500 ft	900 ft	650 ft	1,150 ft
24-inch	0.34	672 ft	1203 ft	850 ft	1,521 ft
	0.50	519 ft	929 ft	657 ft	1,175 ft
36-inch	0.50	672 ft	1203 ft	850 ft	1,521 ft
	1.00	427 ft	765 ft	541 ft	967 ft

discharge in terms of gallons per minute per 100 feet of tubing, or in terms of gallons per hour per emitter. The emitter spacing that should be used depends largely upon the type of soil being irrigated. On coarse textured soils, water will not spread horizontally a great deal. It is necessary that the emitters in the drip tubing be relatively closely spaced to ensure a uniform line of water is discharged along the row length to promote even crop growth. More than one drip tubing may be needed to uniformly irrigate wide planting beds on coarse textured soils because of limited capillary action. On finer textured soils, the capillary action of the small soil pores will permit greater horizontal movement of the applied water from the point of emission. Water from each emitter could easily spread to cover three feet or more of row length and width on fine textured soil.

Recent developments in tubing manufacturing techniques now permit the production of drip tubing with turbulent flow properties in the outer chamber at reasonable costs. These devices are generally conceded to be superior to the original drip tubing with mechanical or laser drilled orifices. The advantages of turbulent drip tapes include larger openings at the same rate of discharge, which makes them less susceptible to blockages. They also exhibit improved pressure compensating characteristics, which permits their use on longer rows and irregular slopes.

Another type of line-source laterals that have been used widely is drip tape. Drip tape has thin walls (compared to drip tube), usually ranging from 5 to 15 mils, where 1,000 mils is equal to one inch. Drip tapes with thicker walls last longer and can be used multiple seasons, but they are pricier due to the more plastic used in manufacturing. The most common inner diameter of drip tape is 5/8 inches, but diameters as large as 14/16 inches are also available in the market. Drip tape is the preferred type for subsurface drip irrigation (SDI) of row crops.

Point Source Emitters

Point source emitters are used when widely spaced point sources of water are needed, as in the case of orchard crops where the trees are spaced several feet apart. In this type of system one or more emitting devices are attached to a pipeline at or near the base of the plant, irrigating a bulb of soil surrounding the root mass of the plant.

Emitting devices for widely spaced plants are normally attached onto polyethylene (PE) tubing. Most deliver either 1/2 gallon per hour (gph), 1 gph, 2 gph, or 4 gph at their design operating pressure. The maximum length of run for a single lateral depends upon the emitter design, emitter discharge

Table 2. Maximum Length of Level, Point Source Laterals

Nominal PE Tubing Diameter	Grapes 2-gph emitter/5 ft, $C_v=0.05, x=0.5$		Pecans 8 x 4-gph emitters/tree, 70-ft tree spacing, $C_v=0.05, x=0.5$	
	Lateral Inlet Pressure		Lateral Inlet Pressure	
	12 psi	15 psi	12 psi	15 psi
1/2-in	415 ft	475 ft	560 ft	630 ft
3/4-in	850 ft	980 ft	1,330 ft	1,400 ft
1-in	1,650 ft	1,800 ft	2,310 ft	2,590 ft

rate, emitter spacing, tubing diameter, lateral inlet pressure, and field slope. Maximum permissible length of laterals for two example crop layouts are given in Table 2. In both cases, the emitters are high quality (coefficient of variation = 0.05), non-pressure compensating emitters (emitter exponent = 0.5).

Emitters for trees should be located to provide balanced root development. While a single, small capacity emitter may be sufficient during the early years of plant development, a higher flow rate will be needed as the tree matures. This large flow should be divided between several emitters, spaced around the trunk within the canopy dripline. The dripline is simply the line marking the extent of the tree canopy coverage on the ground surface.

Pressure Regulators

Since drip irrigation systems operate at relatively low pressures, even small variations in pressure can have a significant effect on how uniformly the system applies water to the crop. For this reason, pressure regulators should be used, especially on fields where the elevation varies considerably. For every 2.31 feet of elevation fall the pressure on water in a pipe will increase one pound per square inch (psi). If a field has a variation of 10 feet in elevation from the highest to the lowest point, the emitters at the lowest point will be operating at a pressure more than 4 psi greater than the highest emitter. In a system which may have a design operating pressure of only 8 psi, that is an extremely large variation.

Variations in pressure due to elevation change can be handled by using pressure regulators, or pressure compensating emitters. Regulators are devices that maintain an outlet pressure that is virtually constant as long as they are driven by an input pressure higher than their output pressure. There are two common types of regulators used in drip systems. There are adjustable regulators where the output pressure is set by the irrigator, and preset regulators that have a fixed output pressure to match the pressure requirements of the emitting devices. Preset regulators are generally less expensive than adjustable regulators.

Fields with elevation variations must be broken into sections with only slight variations of elevation within each section. A pressure regulator would be placed at the inlet to each section, and the delivery system pressurized to maintain adequate pressure to the regulator in the section with the highest elevation. All sections with lower elevations would have their increased pressure reduced by the regulators and a reasonably uniform application of water would result.

Pressure compensating emitters are emitting devices that maintain a virtually constant discharge as long as their operating pressure stays within a certain range. Most pressure

compensating emitters maintain an acceptable uniformity of discharge in the operating range of 10 psi to 30 psi. Pressure compensating emitters require no pressure regulator, but are substantially more expensive to purchase than ordinary emitters. On undulating fields where it is impossible to create zones of uniform elevation pressure compensating emitters are the only way to design a drip irrigation system with satisfactory uniformity.

Water Quality and Filtration

Water quality and filtration are probably the most serious concerns when considering drip irrigation. In order to discharge very low flow rates, the diameter of the emitter orifices must be very small. This results in the emitters being blocked very easily by even the smallest contaminants in the water supply. Of particular concern are suspended solids, such as silt and sand, minerals that precipitate out of solution, such as iron or calcium, and algae that may grow in the water. Virtually every drip irrigation system must include a filtration system adequate to prevent plugging of the emitters. A system with poor quality water and poor filtration simply will not function reliably enough to warrant the maintenance requirements needed to keep it in operation.

Manufacturers typically rate emitters with regard to the degree of filtration required to prevent plugging by particles. This can be expressed in terms of a screen mesh number, or as the diameter of the width of the maximum filter opening. The relationship between the two sizing methods is given in Table 3.

Filters may be constructed of stainless steel or plastic screens that are reusable and require periodic cleaning. They may also use disposable fiber cartridges. For water that has a heavy load of large contaminants, a separator, which uses centrifugal force to remove most of the particles, may be used. Moderately dirty water can be filtered by disk filters. These units have a large number of thin plastic disks with grooves of precise dimensions cut into them. They are relatively easy to flush and reuse and are moderately expensive. Water with large amounts of fine silt and clay in suspension will normally require filtration with a media filter. Media filters use graded layers of fine sand to remove sediment. They are effective filters, capable of handling very large flow rates, but are relatively expensive to purchase and maintain. Suspended solids will normally be less of a problem when ground water is used for irrigation than when surface water is used.

The precipitation of minerals in irrigation water is usually a problem only with groundwater sources. Dissolved minerals may come out of solution with a change of pH or temperature or when aeration occurs. If calcium is the problem, injecting acid into the water to lower the pH will prevent precipitates from forming. Sometimes there is not sufficient calcium to precipitate out of solution, but enough to form a "lime" crust over

Table 3. Filter Size Conversions.

Mesh Size	Maximum Opening Width	
	(inch)	(microns)
40	0.0150	380
60	0.0100	260
80	0.0070	180
100	0.0060	140
140	0.0041	105
200	0.0029	74
400	0.0011	27

the openings of emitters after the system is shut off and the components dry. If this situation causes frequent blockage of emitters, injection of acid into the system for the final few minutes of operation before shutdown should eliminate the problem.

If iron is the problem, oxidizing the iron by chlorination or aeration and then filtering the water will be necessary. Injection of chemicals such as fertilizers or pesticides into the water may cause precipitation of minerals. Consequently, any filtration should take place after chemical injection has been done. Occasional flushing of the system by opening the ends of the lateral lines to discharge accumulated sediment and precipitates is recommended.

Growth of algae within the irrigation system is seldom a problem, since most algae require sunlight to grow, and virtually all system components are made of opaque materials. However, if surface water is used to irrigate, algae quite often exist in the water supply. Pumping unfiltered water from an algae laden source will result in frequent blockage problems, so adequate filtration is important. Treatment of ponds with algae problems by the addition of copper sulfate will greatly reduce the filtration load if the pond is used for drip irrigation.

A bacterial slime may develop in systems where the water has considerable organic matter. Routine use of a 2 ppm chlorine rinse at the end of each irrigation set will normally prevent slime development. If a slime problem does develop, a 30 ppm chlorine treatment will clean the system.

The use of high quality water and an adequate filtration system cannot be over emphasized. Use of poor quality irrigation water in a drip irrigation system can result in so many maintenance problems related to emitter plugging that any labor savings you would expect relative to other irrigation methods will be eliminated. Maintaining the filtration system satisfactorily, chemically treating the water if necessary, and frequent flushing of the system will go a long way toward eliminating these problems.

Backflow Prevention

The water in drip irrigation pipes and tubes is contaminated with numerous chemicals, whether from direct injection or from contact with soil water where fertilizers, pesticides and herbicides have been applied. Thus, it is important to prevent the water in drip systems from flowing back to and contaminating water resources (surface or ground). This can be accomplished by including a device to break the vacuum and prevent water from flowing back. Such devices are usually installed between the injection point and the water source.

System Capacity

The hours of operation needed to meet the irrigation requirement will depend upon the flow rate of the emitting device, the irrigation interval, and the rate of consumptive water use by the crop. In no case should the total system be designed to operate more than 18 hours per day. This allows time for system maintenance, and excess capacity for catch-up in case of breakdowns. Nor should any zone be irrigated for more than 16 hours continuously, to allow some time for aeration of the crop root zone.

When computing the daily water requirement, the calculations are based only on the area of the field that is actually covered by vegetation. This is possible because only the vegetated area is irrigated with drip irrigation systems. For example, if tomatoes are planted in rows that are five feet apart but the vegetation is only three feet wide, 100 feet of row length would have an area of 300 square feet, not 500

square feet. It is assumed that the unvegetated strip between rows uses no water and is not irrigated. If the tomatoes were estimated to require 0.25 inch of water per day, the daily water requirement would be 52.5 gallons per day per 100 feet of row length. This answer is given by:

$$Q = 0.7 W L D$$

where

Q = daily water requirement, gallons

W = row width of vegetation, feet

L = length of row, feet

D = depth of water use by crop, inch/day

0.7 = constant (includes 90% efficiency)

If the tomatoes are to be irrigated every two days by a drip tubing that emits 0.5 gpm per 100 feet of length, the operating time for the system would be 210 minutes (3.5 hours) per irrigation. This is determined from the equation:

$$T = \frac{Q I}{R}$$

where

T = operating time, minutes/irrigation

Q = water requirement, gallons/day/100 feet of row

I = interval between irrigations, days

R = application rate of tubing, gpm/100 feet

Making the calculations based upon a unit row length of 100 feet makes computations for a larger system simple. For every 100 feet of row length added in this system, another 0.5 gpm of flow is needed from the water supply. Once the maximum capacity of the water supply is reached, the system must be divided into sub-units. Each sub-unit operates independently, in this case requiring 3.5 hours to apply sufficient water for a two day period and is then shut off while another sub-unit is irrigated. For example, if the tomatoes to be irrigated were in a plot with 24 rows, each 240 feet long, the total row length would be 5,760 feet. At 0.5 gpm per 100 feet, the total flow rate required from the water supply would be 28.8 gpm. If your water supply is capable of delivering only 10 gpm, not all of the system can be operated at once. If the plot is irrigated in three sub-units, each with eight rows, only 9.6 gpm is needed at one time. After the first sub-unit is irrigated for the required 3.5 hours, it is switched off and the next sub-unit is irrigated for 3.5 hours and so on until all the sub-units have been irrigated. As long as there is sufficient time to cover all of the sub-units in the field before the interval between irrigations (2 days in this case) has elapsed, the water supply will be adequate for the entire field. In this example, the system could irrigate up to 10 sub-units in two days without operating longer than 18 hours per day.

For widely spaced plants, such as orchard trees, water requirements are best determined on a "per plant" basis. For example, if a peach tree has a canopy that is 12 feet in diameter and uses water at a rate of 0.24 inches per day, drip irrigation must replace 18.8 gallons of water per day. This figure is computed by the equation:

$$Q = 0.544 d^2 D$$

where

Q = water requirement, gal/day

d = tree diameter, ft

D = water use rate, in/day

0.544 = constant (includes 90% efficiency)

Each tree will require 18.8 gallons of water per day at this stage of development. While a single 1 gph emitter could provide this amount of water, proper root system development would be better promoted by dividing this flow among three or four emitters. The emitters should be placed out near the canopy dripline, equally spaced around the tree.

The required operation time per irrigation will be given by:

$$T = \frac{Q}{N R}$$

where

T = Time of operation, hours/day

Q = Water requirement, gal/tree-day

N = Number of emitters per tree

R = Emitter flow rate, gal/hour

For example, with four emitters of 2 gph flow capacity, the required 18.8 gallons would be applied in 2.4 hours.

If the irrigation interval is longer than one day, the time of operation per irrigation will be multiplied by the number of days that elapse between irrigations. If the trees in the example above were to be irrigated every seven days, the system would need to operate 16.5 hours per irrigation.

In the case of home gardening irrigation, maximum system capacity is limited by water system flow rate. A standard outside hydrant has a maximum capacity of about 5 gpm, and can operate a maximum of 1000 feet of drip tubing with 0.30 gph emitters on a 12 inch emitter spacing (0.5 gpm per 100 feet of tubing length), or about 300 1-gph point source emitters.

Summary

Drip irrigation can stretch a limited water supply to cover up to 25 percent more acreage than a typical sprinkler system. It can reduce the incidence of many fungal diseases by reducing humidity in the crop canopy and keeping foliage dry. It allows automation of the irrigation system, reducing labor requirements. It delays the onset of salinity problems when irrigation water of marginal quality must be used.

Drip irrigation requires careful water treatment to prevent emitter blockage problems. Frequent inspection of the system is necessary to insure it is functioning properly. Improper design and component sizing can result in a system with poor uniformity of application and a much lower than expected application efficiency.

A properly designed and installed drip irrigation system will normally be substantially more expensive than a sprinkler irrigation system initially. However, the lower operating cost and higher efficiency of the drip system can justify the added expense very quickly in many horticultural production systems.

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