

AGRICULTURAL ALTERNATIVES

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Drip Irrigation for Vegetable Production

Drip or trickle irrigation is a very efficient method of applying water and nutrients to crops. For many crops, the conversion from sprinkler to drip irrigation can reduce water use by 50 percent. Crop yields can increase through improved water and fertility management and reduced disease and weed pressure. When drip irrigation is used with polyethylene mulch, yields can increase even further.

These benefits are only possible when a drip irrigation system is properly designed, managed, and maintained. Irrigation system design is complex and is beyond the scope of this publication. You should consult with a qualified agricultural engineer or irrigation equipment dealer to design your drip irrigation system. However, by understanding the various design factors, you can help ensure that your drip irrigation system is properly designed and operated. System components, basic design principles, practical applications, and operating guidelines are discussed in this publication.

Advantages of drip irrigation

1. Lower-volume water sources can be used because trickle irrigation may require less than half of the water needed for sprinkler irrigation.
2. Lower operating pressures mean reduced energy costs for pumping.

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Drip irrigation of bell peppers

3. High levels of water-use efficiency are achieved because plants can be supplied with more precise amounts of water.
4. Disease pressure may be less because plant foliage remains dry.
5. Labor and operating costs are generally less, and extensive automation is possible.
6. Water applications are made directly to the plant root zone. No applications are made between rows or other nonproductive areas, resulting in better weed control and significant water savings.
7. Field operations, such as harvesting, can continue during irrigation because the areas between rows remain dry.

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8. Fertilizers can be applied efficiently through the drip system.
9. Irrigation can be done under a wide range of field conditions.
10. Compared to sprinkler irrigation, soil erosion and nutrient leaching can be reduced.

Disadvantages and limitations of drip irrigation

1. Initial investment costs per acre may be higher than those of other irrigation options.
2. Management requirements are somewhat higher. Delaying critical operation decisions may cause irreversible crop damage.
3. Frost protection is not possible with drip systems; if it is needed, sprinkler systems are necessary.
4. Rodent, insect, and human damage to drip lines are potential sources of leaks.
5. Water filtration is necessary to prevent clogging of the small emitter holes.
6. Compared to sprinkler irrigation, water distribution in the soil is restricted.

Because vegetables are usually planted in rows, drip tape with prepunched emitter holes is used to wet a continuous strip along the row. Most vegetables are grown for only one season, so thin-walled disposable tape (8 to 10 mil thick) is generally used for only one season. Less emphasis is placed on buried mainlines and sub-mainlines to allow the system to be dismantled and moved from season to season.

Costs may be high, so you should develop a functional system that allows for maximum production with minimal costs. You may purchase an entire system from a drip irrigation dealer or adapt your own components. Proper system design will help you avoid problems later.

Irrigation water may come from wells, ponds, lakes, rivers, streams, or municipal water suppliers. Groundwater is fairly clean and may only require a screen or disk filter to remove particles that can clog emitters. However, a water quality test should be conducted to check for precipitates or other contaminants before a drip system is installed. Surface water from streams and ponds contain bacteria, algae, and other aquatic life, making more expensive sand filters an absolute necessity. Municipal water suppliers will generally provide water quality test results, making it easier to spot potential problems. However, you can expect to pay a high price for this water.

Drip irrigation system components

A drip irrigation system has six major components:

1. Delivery system

Mainline distribution to field

Sub-mainline (header line)

Feeder tubes or connectors

Drip lines

2. Filters

Sand

Screen

Disk

3. Pressure regulators

Fixed outlet

Adjustable outlet

4. Valves or gauges

5. Chemical injectors

Positive displacement injectors

Pressure differential injectors

Water-powered injectors

6. Controllers

Manual

Computer

How these components are put together for your application, and which options you choose, will depend on the size of the system, the water source, the crop, and the degree of automation you desire.

Delivery system

Mainline distribution to field: Underground polyvinyl chloride (PVC) pipe or above-ground aluminum pipe is used to deliver water from its source (pump, filtration system, etc.) to the sub-mainline (header line).



Irrigation mainline with screen filter, pressure regulator, pressure gauge, and water meter connected to sub-main

Sub-mainline (header): It is common to use vinyl “lay flat” hose (polyethylene pipe) as the sub-mainline (header line). This hose is durable and long lasting, and it lies flat when not in use so that equipment can be driven over it. The lay flat hose, connectors, and feeder tubes are retrieved after each growing season and stored until the following year. Since polyethylene pipe is somewhat rigid, it is not easily rolled up at the end of the season.



Vinyl lay flat hose with connector and drip tape

Connectors/couplings: Plastic connectors or couplings are used to connect the drip line to the sub-main.



Drip tape and wetting pattern

Drip lines: Two basic types of drip lines are used for commercial vegetable production, with turbulent flow drip tape most commonly used. This polyethylene product is thin-walled, collapses when not pressurized, and has emitters formed into its seam during manufacturing. Drip tapes are operated at pressures ranging from 6 to 15 psi. Drip tubes with internally attached emitters are an alternative to turbulent flow drip tapes. Products with in-line or internally attached emitters tend to be more expensive, but they often have better water distribution uniformity and better clogging resistance.

Understanding the water flow rate, emitter spacing, wall thickness, diameter, and pressure compensation ability of the drip line you choose is very important. Water flow rate is typically specified in gallons per minute per 100 feet of tape (gpm/100 ft) or by the emission rate of a single emitter in gallons per hour (gph). Tape flow rates typically range from 0.2 to 1.0 gpm per 100 ft. For vegetable production, tapes with flow rates around 0.5 gpm are often used. Maturing vegetables grown in the northeastern United States require about two to three hours of irrigation during hot summer days when a 0.5 gpm per 100 ft tape is used.

Emitter spacing refers to the distance between emitters along the drip line. For vegetables, emitter spacings of 8 to 16 inches are common. On very sandy soils, a closer spacing may be required to ensure adequate water distribution. However, closer emitter spacings translate to higher emission rates. Higher emission rates increase the system flow rate and require a larger pump and pipe size, leading to a higher overall system cost. A 12-inch emitter spacing works well on many soils and is very common in the northeastern United States.

Wall thickness of drip tapes is specified in mils (1 mil = 1/1000th of an inch). Manufacturers produce drip tapes with wall thickness ranging from 4 to 25 mil. Wall thickness selection should be based on user experience, the number of seasons a product will be used, and the potential for damage by insects, animals, and machinery. Inexperienced users needing a single-season product should begin with a 10 mil tape to minimize the stretching and breaking commonly experienced when installation procedures are first being learned. Experienced users of single-season tapes often prefer 8 mil products. Tape cost is influenced by wall thickness, so thin-walled tapes cost less than thicker tapes.

A drip line installed on the soil surface is much more likely to be damaged by birds, animals, and insects than one buried 1 to 3 inches in a bed covered with plastic mulch.

Buried lines will also not move around on the bed. Drip lines laid on the soil surface can move, as a result of wind and the expansion and contraction of the polyethylene. Drip lines on the soil surface are also prone to damage by tractors and foot traffic. Although drip tubes can be reused, commercial vegetable growers rarely reuse them. Reusing drip tape is an ecologically sound practice, but the cost of retrieval, storage, and repair is high.

Diameter of the drip tape is important to consider in system design and is chosen based on row length. Row length directly affects both the flow rate through the tape and pressure loss in the tape. A tape diameter of 5/8 inch is the industry standard and is common where rows range from 300 to 600 feet. For rows ranging from 600 to 1,500 feet, 7/8-inch-diameter tape is available. As with wall thickness, the cost of tape is proportional to tape diameter.

Pressure compensation refers to a drip line’s ability to maintain a specified emission rate over a range of pressures. A pressure compensating line emits water at the same flow

rate over a range of pressures. A non-pressure compensating line emits water at a rate that increases linearly with pressure. Commonly used drip lines fall somewhere in the middle and are called partially pressure compensating. For example, many drip lines will experience a 10 percent increase in emission rate when pressure is increased 20 percent. Drip tubes with internally attached emitters are fully pressure compensating, but they are more complicated to manufacture and are more expensive.

The cost of drip lines varies with diameter, wall thickness, emitter design, and pressure compensation capability. Turbulent flow tapes (5/8-inch diameter) with a wall thickness of 8 mil cost \$1.50 to \$2.50 per 100 ft (about \$175 to \$250 per acre). Tubes with internally attached emitters and a wall thickness of 8 mil cost from \$2.50 to \$4.00 per 100 ft.

Filters

Filters are essential to the operation of a drip system. Many devices and management techniques are available for cleaning irrigation water. Depending on the water source, settling ponds, self-cleaning suction devices, sand separators, media filters, screen filters, and disk filters are used with drip irrigation systems. Keeping a drip system free of debris is critical because most clogs will irreparably disable a system.

Media, screen, and disk filters are characterized by the size of the holes the water passes through in the filter element. The size of the openings is specified by the filter's mesh size. Mesh size is inversely related to the size of the filter openings. For example, a 200-mesh filter will capture smaller particles than a 100-mesh filter. For most drip tapes, 150 to 200 mesh filtration is required. For clog-resistant tubes with internally attached emitters, 100-mesh filtration is sufficient.

Settling ponds use gravity to allow particulate matter to settle to the bottom of the pond. However, other techniques are more suitable and practical, since settling is not efficient for removing suspended matter. Although sand-sized particles will settle in seconds, silt- and clay-sized particles can take hours, weeks, or months to settle. Ponds also support aquatic life that often contributes to clogging problems. Media, screen, or disk filters are preferred for removing physical material from water.

The location of the suction inlet is an important decision as it affects the quality of the water entering the filtration system. Ideally, the inlet should be located some distance from the edge of the pond, 1 to 2 feet below the pond surface. Attaching the inlet of the suction pipe to the bottom of a sealed, partially water-filled 55-gallon drum can serve as a self-adjusting inlet depth regulator. However, it is often impractical to locate the inlet away from the shoreline. Near the pond edge, weeds and algae are often drawn into the inlet. A self-cleaning suction device can reduce the amounts of weeds and algae drawn into the system. This device has a screened, barrel-shaped rotating basket around the inlet of the suction pipe. A pressurized water return line from the irrigation system sprays water against the inside of the

screen basket, cleaning the basket and forcing weeds and algae away from the inlet.

Sand separators are sometimes used in front of media, disk, or screen filters. These devices separate sand and heavy particulate matter by swirling the water passing through them. Sand separators must be sized according to the flow rate to operate properly and will not remove silt- or clay-sized material.

Media filters are the most common filters used in commercial vegetable production. Ranging from 14 to 48 inches in diameter, they are usually installed in pairs. Media filters are expensive, heavy, and large, but they can clean poor-quality water at high flow rates. In a media filter, 12 to 16 inches of media (sand or crushed rock) act as a three-dimensional filtering agent, trapping particles within the top inch or two of media. As the media fills with particulate matter, the pressure drop across the media tank increases, forcing water through smaller and fewer channels. This will eventually disable a media filter, requiring that clean water from one tank be routed backwards through the dirty tank to clean the media. This "backwashing" requires exact flow rates to make the media "dance" and be thoroughly cleaned. Large, commercial-sized filters require electronic controls and hydraulic valves to route the water. Typically, the pressure drop across a clean media tank is 2 to 3 psi. When the pressure differential across the media filters reaches a given level, typically 5 to 8 psi higher than when the tanks are clean, it is time to backflush the filters.



Sand filter, pump, and fertigation unit

Screen filters are used widely in commercial vegetable production and are the most common irrigation filter used by small operations if the water source is relatively clean. Screen filters can remove debris efficiently like a media filter, but they are not capable of removing as much debris as a media filter before cleaning is required. Compared to media filters, screen filters are often oversized because they only have a relatively small, two-dimensional cleaning surface. Screen filters are sometimes used as secondary filters, located downstream from media filters.

Regular cleaning of screen filters is very important. If they are neglected, a portion of the screening element will become caked and clogged, forcing water through a smaller area. This can push debris through the screening element and under extreme conditions rupture it. Upstream and downstream pressure gauges can help you judge when a filter requires cleaning. A pressure drop of 1 to 3 psi is normal for a screen filter. Screen filters should be cleaned when the pressure drop is 5 to 8 psi compared to when the filter is clean. Many screen filters contain a flushing valve, making it extremely easy to clean the filter.

Disk filters are devices that possess traits of both media and screen filters. The screening element of a disk filter consists of stacks of thin, doughnut-shaped, grooved disks. The stack of disks forms a cylinder where water moves from the outside of the cylinder to its core. Like a media filter, the action of the disk filter is three dimensional. Debris is trapped on the cylinder's surface while also moving a short distance into the cylinder, increasing the capacity of the disk filter. Cleaning a disk filter requires removing the disk cylinder, expanding the cylinder to loosen the disks, and using pressurized water to spray the disks clean. Although disk filters have a cleaning capacity between media and screen filters, disk filters are not recommended where organic matter load is high.

Both disk and screen filters can be configured with electronic controls, hydraulic valves, and special devices to operate as self-cleaning filters. With these attachments, self-cleaning disk and screen filters can be used in place of media filters if the organic matter load is not high. These devices have the advantage of being smaller and lighter but cost about the same as media filters.



Disk filters

Pressure regulators

Pressure regulators reduce the water pressure in the irrigation system manifold (the pipeline feeding the drip lines) to the working pressure of the drip lines. Both fixed outlet and adjustable outlet pressure devices are available for a wide range of flow rates. Globe valves regulate pressure by constricting the water flow path. However, they are not

recommended because any change in the system flow rate or operating pressure also affects downstream pressure. This could happen when water is routed to a different zone or when a system begins to experience some clogging. The danger in having an unreliable pressure regulator is that the system could become over-pressured. Drip tape may deform or burst at pressures as low as 30 psi.

Valves or gauges



Screen filters, pressure regulators, and pressure gauges

Watering several fields or sections of fields from one water source can be accomplished by using automatic or manually operated valves to open and close various zones. Either hand-operated valves (gate or ball type) or automated electric solenoid valves (using a time clock, water need sensor, or automatic computer controller box) can be used to control irrigation zones. It is also recommended that a water meter be installed to monitor total water usage and flow rate in the system. A backflow/anti-siphon valve is also necessary if you use a well or municipal water source or when injecting fertilizers or chemicals into the system.

Chemigation

Chemigation is the practice of injecting and applying fertilizers, pesticides, and anticlogging agents with a drip irrigation system. Fertilizers are routinely injected; the ability to "spoon-feed" nutrients is partially responsible for the yield increases resulting from drip irrigation. Systemic pesticides are also frequently injected into a drip irrigation system to control insects and protect plants from disease. Chemicals that prevent or repair clogging problems can also be injected. Chlorine is used to kill algae, and acids are used to modify water pH and dissolve certain precipitate clogs.



Water meter

The type of chemical being injected is a key consideration in determining the appropriate chemical injector. For fertilizers, maintaining an accurate injection rate is not critical, unless fertilizer is injected on a continuous basis. The most important feature of a fertilizer injector is that it has a high-enough injection rate to complete the injection cycle in a reasonable period. An injector with a capacity of 1 gpm is likely to be sufficient for injecting fertilizer into irrigation zones of less than 10 acres.

In contrast, injecting chemicals to prevent clogging requires an accurate and very low injection rate. Since these materials are usually injected continuously at concentration rates of 1 to 10 ppm, a separate injector is often used. Pesticide injection is similar to fertilizer injection, but the volume of material required is usually small compared to the volume of fertilizer required. For this reason, most pesticides can use injectors suited to either fertilizers (high injection rate/low accuracy) or clogging prevention (low injection rate/high accuracy).

The type of power available at the injection site will affect your choice of injectors. Injectors can be powered by gasoline engines, the PTO shaft of a tractor, electric motors, or the water pressure of the irrigation system.

Positive displacement, pressure differential, and water-powered injectors make up the majority of injectors used for chemigation. Externally powered diaphragm, piston, gear, lobe, and roller (peristaltic) pumps are all positive displacement injectors. These injectors are typically powered by gas, diesel, or electric, have a high chemical resistance, and are medium to high in cost. The injection rate of diaphragm pumps can be adjusted, but piston pumps must be stopped to adjust the injection rate. A piston pump is more chemically resistant than a diaphragm pump, and its injection rate is less affected by downstream pressure. Many growers purchase an expensive, high-quality diaphragm or piston pump for injecting fertilizers. With the higher cost comes reliability, durability, and peace of mind.

Pressurized mixing tanks and venturi injectors are two common pressure differential injectors. These devices often have no moving parts and tend to be very simple because they use the difference in pressure between two different locations on an irrigation system to power the injection process. Pressure tanks are the simplest types of injectors and work well for fertilizers because delivery accuracy is not critical. The venturi injector is more efficient and more accurate than a pressurized mixing tank. Both require that the injector be plumbed parallel to the irrigation mainline and that a constriction be placed in the mainline between the line delivering water to the injector and the line returning to the mainline. Venturi injectors can deliver chemicals very accurately and can be sized for a particular injection rate. They can be used either for injecting fertilizers or for anti-clogging agents.

Water-powered injectors are driven by the pressure of the irrigation system. Thus, their principal advantage is they

do not require an external power source. Both piston and diaphragm types are available. Their injection rate is either proportional to the system pressure or to the flow rate through the injector. Proportional injectors insert chemicals in proportion to the flow rate. They are particularly useful where chemicals are injected for clogging prevention and a fixed concentration of chemical is required. Changing the system flow rate (for example, by switching from one zone to the next) does not change the concentration of material injected with proportional injectors.



Fertilizer injector

Water management

Irrigation scheduling is the process of determining how often to irrigate and how much water to apply. The appropriate irrigation frequency depends on the rate at which crops use water and on the water-holding capacity of the soil. The amount of water to apply for each irrigation application can be calculated from known soil and plant characteristics.



Drip wetting pattern with plastic mulch

Soil in the root zone acts as a reservoir for water. Soil texture is the primary factor influencing the amount of water stored. Available water is defined as the amount of water that plants can easily withdraw from the soil and use (Table 1).

Fine-textured soils, such as clays, silt loams, and loams, hold much more water than coarse-textured soils. Thus, coarse-textured soils must be irrigated more frequently. For most crops, an appropriate goal is to irrigate when 50 percent of the available water is depleted.

Table 1. Available water-holding capacity for different soil textures.

Soil texture	Available water holding capacity (inches of water per foot of soil)
Sand	0.25–1.00
Loamy sand	0.75–1.50
Sandy loam	1.25–1.75
Loam and silt loam	2.00–2.75
Clay loam	1.75–2.50
Clay	1.50–2.25

C. A. Storlie, 1995.

Water-storage capacity is influenced by soil depth. Nearly all irrigated vegetable and agronomic crops extract water from the top two feet of the soil profile, even though the roots may extend much deeper. In fact, 75 to 95 percent of most plant roots are in the top 12 to 18 inches of the soil profile. Proper irrigation results in this plant root zone being refilled, but not overfilled. Filling the root zone beyond its capacity results in leaching. The proper duration can be calculated from the plant root zone depth, soil texture, and water flow rate.



Tensiometer

Tensiometers indicate available soil moisture by measuring soil tension (also referred to as soil suction or vacuum). Soil tension indicates how tightly water is held by the soil and increases as moisture in the soil is depleted. This force draws water out of a tensiometer through its porous tip, creating a vacuum inside the tensiometer. This negative pressure, or tension, is registered on a vacuum gauge. However, tensiometers do not work well in fine-textured soils and require constant maintenance. Because of this, most vegetable growers rely on their experience to determine critical periods of plant water demand and proper irrigation.

System maintenance

Clogging is the most serious threat to a drip irrigation system and arises from physical, biological, and chemical contaminants. Filtration can remove physical contaminants, and chemical water treatment is often necessary to eliminate or remove biological and chemical contaminants. Tapes buried under plastic mulches are much less apt to become clogged from mineral deposits.

Bacteria, algae, and slime in irrigation lines can be removed with chlorine or commercial bacterial control agents injected through the fertilizer injection system. A 2-ppm chlorine daily rinse at the end of the irrigation cycle or a 30-ppm “shock treatment” can be used if slime becomes a problem in the system. Consult your irrigation system dealer for dilution rates for commercial cleaning products.

Periodic flushing of the mainline, sub-mainline, and drip tape is an excellent maintenance practice. Adapters are available for the ends of each drip tape to automatically flush lines at the end of each irrigation cycle, or they can be manually opened to allow a few gallons of water to flush from the end. This will prevent any buildup of particles or slime at the end of the drip line.

Routine maintenance includes:

- Checking filters daily and cleaning if necessary. A clogged screen filter can be cleaned with a stiff bristle brush or by soaking in water.
- Backwashing sand filters to remove particulates and organic contaminants.
- Checking drip lines for leakage. A large, wet area in the field indicates a leaking drip line. Leaking lines can be repaired by splicing with an inline connector or bypassed with a short piece of feeder tube.
- Using water treatment chemicals to dissolve excessive mineral deposits and remove buildup of organic contaminants in water supply lines.

Drip irrigation as part of a plasticulture system

Drip irrigation works well with plastic mulch in an efficient production system that helps retain moisture for the crop and control weeds. Water and nutrients can be placed into the crop root zone very efficiently with little loss. The cost for irrigating 20 acres with drip irrigation in conjunction with plastic mulch is presented in Table 2. More information on drip irrigation and plasticulture can be found on the Penn State Center for Plasticulture website (extension.psu.edu/plasticulture).

Table 2. Component list for a one-acre plastic mulch drip irrigation system.*

Component description	Total price (\$)
Engine and pump (5.5-hp engine and pump)	\$2,450
24-inch stainless steel media filter (2) and fertilizer injector	\$5,750
Lay flat, header pipe 2"	\$150
Drip tape (7,500 ft/roll)	\$150
Plastic mulch (1.0 mil black)	\$300
Valves (pressure regulation, gauges, and air release)	\$800
Miscellaneous connectors, adapters, clamps, etc.	\$50
Lay flat connectors and hole punch	\$200
Total	\$9,850

*Only plastic mulch and drip irrigation components are included. The field is assumed to be level with an adjacent surface water supply (pond). The filters designed in this system are capable of irrigating one acre at one time. The system contains media filters, a venturi injector, and a 5.5-hp engine and pump. Additional equipment to consider includes water meters. Although the base equipment used in this example will sufficiently handle more than one acre, carefully consider the number of zones and the time required to irrigate additional zones before purchasing equipment. No sales tax, freight, or field labor was included in these estimates.



Laying plastic mulch and drip tape

For more information

Granberry, D. M., K. A. Harrison, and W. T. Kelley. "Drip Chemigation-Injecting Fertilizer, Acid and Chlorine." Cooperative Extension Service, University of Georgia, Bulletin 1130, 1996.

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Storlie, C. "Irrigation Scheduling with Tensiometers." Rutgers Cooperative Extension Service Factsheet FS657, 1995.

Storlie, C. "Treating Drip Irrigation Systems with Chlorine." Rutgers Cooperative Extension Service Factsheet FS795, 1995.

Selected Web Resources

"Basics of Vegetable Crop Irrigation," Alabama Cooperative Extension System (<https://store.aces.edu/ItemDetail.aspx?ProductID=13806>)

Center for Plasticulture, The Pennsylvania State University, Department of Horticulture (extension.psu.edu/plasticulture)

"Drip-Irrigation Systems for Small Conventional Vegetable Farms and Organic Vegetable Farms," University of Florida (<http://edis.ifas.ufl.edu/hs388>)

"Drip or Trickle Irrigation Systems: An Operations and Troubleshooting Checklist" (www.ces.ncsu.edu/depts/hort/hil/hil-33-b.html)

"Introduction to Micro-irrigation," North Dakota State University Extension Service (www.ag.ndsu.edu/pubs/ageng/irrigate/ae1243w.htm)

"Irrigation in Ohio: Eight Major Factors," Ohio State University Extension (ohioline.ag.ohio-state.edu/aex-fact/0370.html)

"Planning To Irrigate...A Checklist" (www.ag.ndsu.edu/pubs/ageng/irrigate/ae92w.htm)

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