Drip Irrigation - An Overview

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Introduction

Drip irrigation is commonly used to water fruit crops in Saskatchewan and worldwide. The purpose of this guide is to provide an overview of current drip irrigation technology and a basic understanding of system design. In order to determine specific system requirements, a qualified irrigation system designer should be consulted. Note that currently, there are no guidelines relating native fruit production to irrigation rates and timing. Additionally, any reference made to manufacturers is for illustrative purposes only and is not meant as an endorsement.

Drip irrigation is a very efficient method of applying water to an orchard site. Drip systems apply controlled volumes of water directly to the orchard rows, which conserves water (especially in young plantings) and discourages weed growth between rows. Drip irrigation does not interfere with orchard operations such as pruning, harvesting, and spraying, and drip systems are easily automated. However, drip systems do not wet the crop canopy and therefore cannot provide frost protection nor retard blooming time.

Research in other fruit crops has shown that drip-irrigated orchards grow and yield as well as orchards watered by other methods of irrigation. Drip-irrigated orchards require more frequent watering than orchards using other types of irrigation, but soil moisture levels can be kept at near optimal levels.

The initial cost of a drip irrigation system ranges from $1,800 to $3,000 per hectare (not including the cost of equipment used to supply water to the site, or chemical injection equipment). A good quality drip system will last for many years if properly maintained.

It is a good idea to include the irrigation system in the initial planning stages of an orchard project. System components can then be matched to site characteristics. However, a drip system may be installed in virtually any established orchard site.

System Components

A basic drip irrigation system consists of a filter, pressure regulator, and a distribution network (mainline, submain/manifold lines and lateral lines), connected to a pressurized water supply (Figure 1). Collectively, the water supply, pump, filter and pressure regulator are

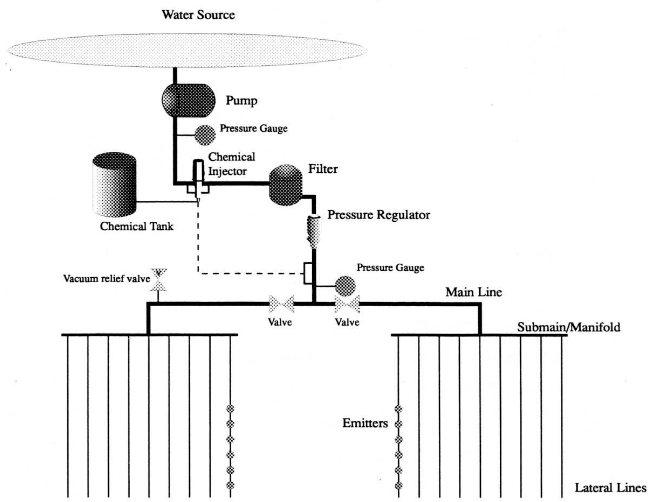

Figure 1. Components of a typical drip irrigation system (H. Tulloch1997)

called the system head. A chemical injector and water pressure gauge(s) may also be incorporated into the system head. Some systems may have more than one chemical injector and chemical injection points may vary. A back-flow prevention device is essential if chemicals are injected into the system. Vacuum relief valves should be installed at all high points in the system to avoid drawback of soil into the emitters when the system is shut off.

Filters

A filter is needed to prevent plugging of the irrigation system and is essential to maintain accurate control over emitter output. Filter requirements are dependent on system size, the type of emitters used, system flow rate and the characteristics of the irrigation water.

Particulate matter can be filtered from the water supply using screen filters. Mesh screen and grooved discs are two common types that are available. Mesh screens may be fabricated from either stainless steel or nylon. Steel screens are stronger but are considered to be more prone to debris buildup and corrosion than nylon screens. Stacks of grooved plastic discs are used in grooved disc filter elements. Disc filters are strong and are better for removing organic material such as algae but may require more frequent back-flushing than screens. Typical filter screens used in drip systems range in pore size from 100-200 mesh. The pore size of the filter is a function of emitter orifice size and system flow requirements. A supplier of drip-irrigation components will be able to determine filter specifications for specific situations.

Centrifugal separators can also be used to remove suspended particles from irrigation water. Unlike screen filters, centrifugal separators remove suspended material from water on the basis of particle density rather than particle size. Only particles that are denser than water can be removed using centrifugal separators. This makes these filters unsuitable for the removal of biological contaminants such as bacteria.

Media filters remove unwanted material from the water supply by forcing water to pass through layered beds of media having varying pore sizes. Inert materials must be used in the media bed. Silica sand and inert gravel are commonly found in media filters.

Activated carbon may also be layered in the media bed, although this is not common in irrigation filters. Media filters are most effective at removing biological material such as bacteria and algae. These filters are much more expensive than screen filters but are usually essential with an open water supply.

Filters should be cleaned and inspected on a regular basis for signs of wear or damage. Holes in the filter screen can result in plugged emitters. Filters should be back-flushed regularly to keep them clean. Some filters are available with self-flushing mechanisms. These may be electronically or hydraulically activated. All hydraulic and some electronic automatic filters back-flush when the pressure differential between the inlet and outlet sides of the filter exceeds a certain level. Other electronic filters back-flush on a timed flushing cycle. Flushing timers are usually used with media filters and centrifugal separators.

Pressure Regulator

The pressure regulator reduces and stabilizes the water pressure to the operating range of the emitters. This is important so that emitter flow rates can be controlled and the volume of water applied to the crop can be predicted.

The Distribution Network

The main line, submains and lateral lines make up the distribution network which carries water to the crop. The size of the main and submain lines vary depending on the slope of the site, size of the irrigation system, the flow rate and number of emitters being operated.

The lateral lines carry water along the orchard rows and deposit water to the crop via emitters. Common types of lateral lines include porous tubing, drip tape and hard wall lateral lines. Porous tubing is relatively expensive and is not commonly used in large scale drip systems. Drip tape is more commonly used to irrigate annual crops but thick-walled drip tape is suitable in some orchard situations. One-half inch (inside diameter) polyethylene tubing is commonly used for hard wall lateral lines. This tubing is very durable and is recommended for long term use.

Head pressure decreases along the length of the lateral lines. This limits the maximum length of the lateral line to the point where there is less than a 10% change in emitter flow rate from the beginning of the lateral line to the end. The actual length of lateral line allowable is determined in the system design process and depends on the inside diameter of the lateral line, system pressure, emitter number and flow rate, and type of emitters used.

Emitter Technology

The purpose of emitters is to accurately regulate the flow of water and to deposit a small volume of water over a long period of time. There is a wide selection of emitters on the market. The required flow rate is dependent on many factors including the type of crop, soil texture, length of lateral line, and water analysis. Emitter spacing depends on crop spacing, soil texture and flow rate of the emitters. Additional devices (flaps, moving parts, elastic baffles) are sometimes incorporated into emitter designs to help regulate flow characteristics.

Hard wall lines are used in combination with some kind of emitter installed either in the line (in-line emitter), or through the wall of the line (on-line emitter). In-line emitters must be installed by the manufacturer and so emitter spacing options are limited. The main benefit of in-line emitters is that they are less likely to leak. On-line emitters can installed on site at any spacing required. One of the challenges of on-line emitter design is to integrate features into an emitter that is not bulky or prone to damage. In-line emitters can be larger and more elaborate than on-line emitters without actually protruding from the line.

There are many approaches used to regulate emitter flow rates. The main concern with emitter design is to maintain accurate flow rate and at the same time be resistant to plugging. Long path emitters force water to travel a long distance to control water flow. Microtube (laminar flow) and spiral path emitters are two examples of long path emitters. Turbulent flow and tortuous path emitters force water to travel a twisted path through the emitter passageways to restrict water flow. In constrast to reducing the orifice size this approach helps to reduce the risk of emitter blockages.

Variations in the slope of an orchard site and long lateral lines can cause significant pressure differentials within irrigation lines. Some emitters are known as pressure-compensating. These emitters maintain a constant water flow even when there are variations in water pressure within the irrigation system (Figure 2). Pressure-compensating emitters can be operated at higher pressure and still maintain a specific flow rate. Lateral lines using pressure-compensating emitters can be longer than lateral lines using regular emitters.

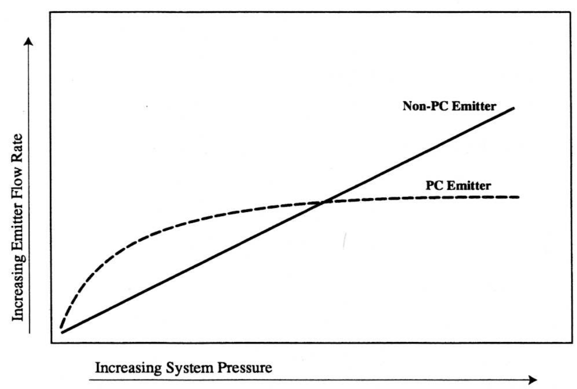

Figure 2. A comparison of the effect of increasing pressure on the flow rate of pressure-compensating (PC) and non-pressure-compensating (non-PC) emitters (H. Tulloch 1997)

Vortex emitters are not as sensitive to pressure changes as many emitter designs, and are less expensive than pressure-compensating emitters. In these emitters, incoming water spins around inside a vortex chamber creating

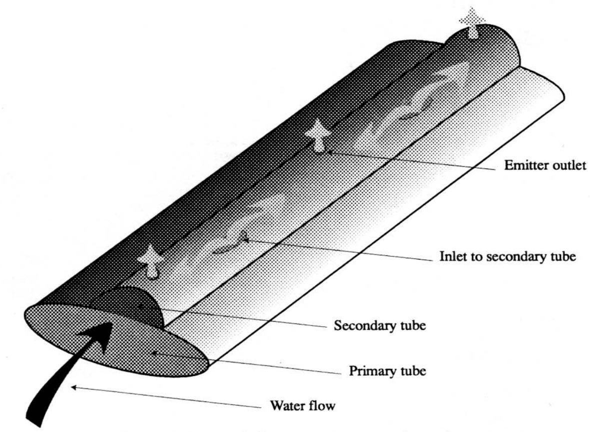

Figure 3. Bi-wall lateral lines use two chambers to regulate water flow. Flow volume is restricted in the secondary tube and water pressure is stabilized. The inner orifices distribute water to a fixed number of emitter holes. This provides uniform flow from the outlet holes at all points in the lateral line (H. Tulloch 1997).

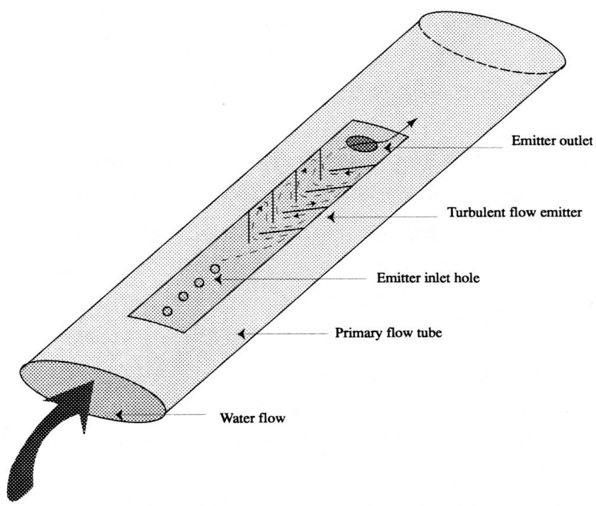

Figure 4. Cutaway view of turbulent flow drip irrigation tape. Water enters the emitter through a series of inlet holes and is forced to travel a twisted path to the emitter outlet. The flow rate in this type of emitter is regulated by flow path and not by orifice size. This reduces the chance of particles being caught in small passageways (H. Tulloch 1997).

a low pressure zone in the center where the water outlet is located. The pressure at the outlet remains fairly stable over a wide range of input pressures. Filtration requirements are higher than with turbulent flow emitters.

Drip tape is a form of lateral line where emitters are integrated into the wall of the line. Two common types of drip tape used are bi-wall tubing and turbulent flow emitter tapes. Several manufacturers produce this material. Bi-wall tubing and turbulent flow tapes differ mainly in the methods used to reduce water flow rates from the emitter holes (Figures 3 & 4). There are many variations of these basic drip tape designs. This basic bi-wall design is not used anymore. Modern bi-wall tapes generally integrate turbulent flow technology into the design.

Burial Of Drip Lines

Lateral lines placed on the soil surface are exposed to large and sometimes rapid temperature fluctuations, sunlight, and field equipment. All of these factors have the potential to damage irrigation lines and to increase maintenance and repair costs. Day/night temperature changes cause the expansion and contraction of lateral lines which produces a snake-like movement of the lines and emitters away from their target areas. Burying lateral lines provides stable temperatures, avoids UV degradation from sunlight and places the lines out of reach of tractor tires and shallow tillage equipment.

The plugging of emitters from root penetration and inability to be seen are common concerns with buried lines.

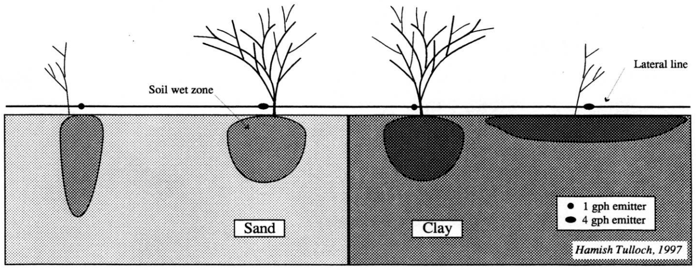

Figure 5.Soil texture and emitter flow rate influences water movement in the soil.

Frequently operating the system leaves a water-saturated zone around the emitter opening which is impermeable to roots and should prevent this type of plugging. Flushing with acid or herbicides is another method used to prevent this problem. Buried drip tapes should be operated during, or immediately after heavy rains to prevent permanent flattening of the line. Problems with buried lines are more difficult to detect and repair, but should occur less frequently assuming suitable materials are used.

Effects Of Soil Characteristics On System Design

Soil characteristics should be considered when designing a drip irrigation system. Soil texture influences water movement in the soil and water quality requirements. In sandy soils, water movement tends to be vertical whereas water movement in clay soil is relatively horizontal. It is possible to modify these wetting patterns by varying emitter discharge rates (Figure 5). Increasing water discharge increases the horizontal movement of water through the soil. In practice, low discharge emitters used in clay soil will promote deeper water movement. Applying irrigation water in short, pulsed applications is another method used to avoid ponding on the soil surface and to promote deeper water permeation.

Drip irrigation can be used to control salinity problems in some soils. Salts are carried at the perimeter of the water front which significantly reduces the salt load within the wetted zone. This allows for normal plant growth in this desalinized region of the soil. The high frequency watering schedules required with drip-irrigation further help to maintain soil salt concentration at levels which will not affect plant growth.

Effects Of Water Quality On System Design

The location of the water source, the volume of the water supply, and water quality must be considered when planning any irrigation system. The location of the water supply has a direct impact on the energy required to move water to the orchard site and on pump requirements. Vertical movement of water requires much more energy than horizontal movement and therefore has a greater impact on pumping costs.

The water source must be able to supply enough water to meet crop demands. For the purpose of estimating water supply requirements, the

Saskatchewan Water Corporation estimates crop water use as 74 cm of precipitation per hectare per season. The actual amount of water used will vary depending on the crop, crop age and the season.

Water quality is determined by the amount and type of dissolved salt. Salt concentration of water is measured as total dissolved solids (TDS) or by electrical conductivity (EC). Runoff water is generally low in dissolved salts and is suitable for irrigation purposes. For details on digging a dugout and using runoff water for irrigation purposes, contact your local PFRA or Sask-atchewan Water Corporation office. Ground-water is sometimes used for irrigation but it is more difficult to obtain government approval for such use. The salt level, and in particular, the sodium concentration of well water is often too high for irrigation use. Sodium salts tend to breakdown soil structure and often cause crusting problems. The sodium adsorption ratio (SAR) measures the proportion of sodium relative to magnesium and calcium. Carbonates and bicarbonates can effect calcium and magnesium levels of the water. A more accurate measure of the sodium hazard is the adjusted sodium adsorption ratio (adj.RNa) which takes the carbonate and bicarbonate effects into account. The effect of sodium in irrigation water varies, depending on soil texture (Table 1). Excessive calcium, sulfur and iron levels in well water can cause plugging of emitters. Some ground water supplies cannot be used for irrigation because of toxic levels of micronutrients such as boron.

Assuming that the quality of the well water is adequate, a temporary permit for irrigation use may be granted but water levels in the aquifer must be monitored to show that other users are not affected by the irrigation project. If the well density in an area is high, temporary permits for irrigation use of well water are usually not granted. The additional monitoring costs and the risk of shut down generally prohibit the use of well water for large scale irrigation projects.

Research has shown that more saline water can be used when drip-irrigating crops than by using other methods. Since the water is not applied to leaf surfaces, leaf burn will not occur. High frequency watering minimizes salt accumulation between waterings. Salts are also continually being washed to the perimeter of the emitter's moisture zone. Brackish water has been used successfully with some crops but this practice is not recommended.

Maximum Sodium Salt Levels For Irrigation Water For Various Soil Types

Soil Texture	Maximum Sodium Adsorption Ratio (SAR)
Silty clay	8
Clay	8
Heavy clay	8
Sandy clay loam	10
Silty clay loam	10
Clay loam	10

Silt	10
Sandy clay	10
Loam	12
Silty loam	12
Sand	16
Loamy sand	16
Sandy loam	16

*Adapted from: Understanding Your Soil Water Report. Saskatchewan Water Corporation, 1989.

Chemical Injection

Chemical injection equipment can be used to inject chemical solutions such as fertilizers, pesticides and cleaning solutions into the irrigation system. A back-flow prevention device must be installed upstream from the injection point to prevent contamination of the water supply. Chemical solutions can be injected into an irrigation system using a chemical pump or with some type of pressure differential delivery system. Ideally, a drip system should have two chemical injection points, one before and one after the filter. This may require more than one injector, depending on the type of chemical injection system used. The pre-filter injection point should only be used if the chemical solution presents a risk of clogging. The post-filter injection point is important so that very corrosive materials can bypass the system head.

Chemical Pumps

Chemical pumps may be powered by an external power source or by the system's water pressure (hydraulic pumps). Chemical pumps are very precise, once calibrated, and easy to control but are expensive. With the exception of hydraulic pumps, all chemical pumps inject solutions into the irrigation system under pressure. These injectors are known as positive injection pumps. Gas or diesel engines, electric motors, and tractor PTO units are potential sources of pump power. Electric pumps can be connected to automatic controllers but electricity is not always available.

Piston pumps and diaphragm pumps are usually used to inject chemical solutions. It is important to make sure that pump materials are compatible with chemical solutions. Pumps with fewer metal components, such as diaphragm pumps are better suited for use with corrosive materials. Other parts in the irrigation system must also be considered in terms of susceptibility to corrosion. Injection rates can be adjusted by varying chemical solution concentration or by modifying pump flow. Pump flow can be regulated by changing drive pulleys, modifying piston stroke, or by varying pumping speed (variable speed motors). System flow rates must be known in order to calibrate positive injection pumps.

Hydraulic injection pumps are very useful if an external power source is not available. Hydraulic pumps use system pressure to drive the chemical mixing and delivery mechanism. Piston, diaphragm, or impeller designs are common variations of hydraulic pumps. These pumps can provide very accurate proportioning of the chemical solutions even if input pressure fluctuates. Some hydraulic injectors are designed to proportion chemical solutions at variable rates. This eliminates the need to adjust solution concentration or to modify the pump every time a different chemical or a new dosage is applied.

The most common type of pressure differential chemical delivery system is the venturi injector. Venturi injectors are very simple (Figure 6), reasonably priced, and are accurate as long as system pressure and solution viscosity remain constant for the duration of the injection period.

Venturi injectors are safer then positive injection pumps since the chemical solution is drawn into the system by vacuum rather then forced under pressure. This reduces the risk of chemical leakage which could result in injury, crop damage, or environmental contamination.

Fertigation

Drip irrigation produces a localized wetting pattern in the soil which limits root development and the area that the plant has for nutrient uptake. To ensure that applied nutrients are readily available to the plants, most sources recommend that fertilizers be applied through the irrigation system (fertigation). One of the advantages of drip irrigation is the ability to accurately place and time fertilizer applications. Unfortunately the response of native fruit species to fertilization is not very well understood. Only moderate amounts of fertilizer should be applied initially until accurate recommendations are available.

Fertilizer solutions can be injected using chemical injection equipment but care must be taken to avoid blockages from precipitates and microbial growth. It is important that the irrigation system be fully charged before injection begins, otherwise the dosage from each emitter will vary. Flush the system for one hour after fertigating to avoid the build-up of bacteria and algae and to discourage root penetration into the emitters. Fertilizer solutions are salt solutions and solid salts may form (salting out) if crystallization temperatures are reached. Salting out can occur in the solution holding tank if there is a significant drop in temperature from the mixing temperature, or inside the irrigation system if the water supply is very cold.

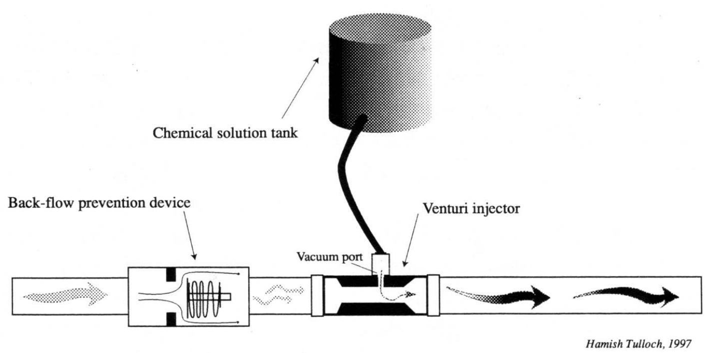

Figure 6. Venturi injector for a drip irrigation system.

Phosphorus

Most of the phosphorus in the soil is unavailable to plants and is tightly bound to soil particles. It is most practical to apply phosphorus (preferably using deep placement equipment) to the orchard site before planting. Since phosphorus is bound to soil particles, a long term reservoir can be established before the site is planted. Over-fertilization can lead to problems with salinity and inhibited uptake of certain nutrients, such as zinc.

If phosphorus deficiencies occur once an orchard is established, it is not practical to apply phosphorus to the soil surface and often it is difficult to side band fertilizers in an orchard. Phosphorus can be successfully applied through drip lines if certain precautions are taken. Studies have demonstrated significant phosphorus movement through the soil profile from drip fertigation relative to other methods of irrigation-applied phosphorus. The concentration of phosphorus in the wetted zone saturates the sites in the soil where phosphorus is bound and allows for greater movement of phosphorus outside of this zone.

Phosphorus can react with calcium and magnesium in the water supply to form an insoluble precipitate which can plug emitters. To avoid this problem, it is necessary to acidify the phosphorus stock solution or to inject an acid solution immediately following the injection of phosphorus. Sulfuric acid and hydrochloric acid are usually used for this.

Triple super phosphate (0-45-0) should not used in phosphorus solutions because calcium phosphate readily precipitates from this solution. Ammonium phosphates such as ammonium phosphate sulfate (16-20-0), monoammonium phosphate (11-48-0), and diammonium phosphate (16-46-0) can be applied safely in solution through the drip system. Phosphoric acid solutions are also used for phosphorus injection.

Since phosphorus does not leach from the soil, it will not need to be applied very often. Phosphorus levels should be tested in the spring and a single adjustment can be made at this time.

Nitrogen

There are a variety of fertilizer sources that can be used to apply nitrogen through drip irrigation lines. Once in the soil, nitrogen is usually taken up by plants in the form of nitrate ions (NO^{3-}) or less frequently, ammonium ions (NH^{4+}). All forms of nitrogen fertilizer are eventually converted to the nitrate form. Nitrate is mobile in the soil, whereas ammonium ions bind to the surface of soil particles. Most ammonium salts, except ammonium phosphate, are readily dissolved in water and should not cause plugging. However, it is not as easy to control the placement of solutions having a high concentration of the ammonium form of nitrogen. Dry urea is very soluble in water and is also completely mobile in the soil. With a urea-based nitrogen solution, placement is simply a matter of controlling water placement. Urea is often mixed with ammonium nitrate in commercial liquid fertilizer blends. Some nitrogen fertilizers, such as aqua and anhydrous ammonia, can increase water pH and may cause calcium and magnesium precipitates to form.

Nitrogen in solution is pushed to the perimeter of the wet zone in the soil out of reach of most of a plant's root system. Therefore, it is most efficient to make several nitrogen applications throughout the growing season. It is not advisable to make any fertilizer applications late in the season, because this can delay the winter hardening processes.

Potassium

In general, Saskatchewan soils already contain high levels of potassium and therefore will not need to be supplemented in most cases. If a deficiency does occur, potassium chloride, potassium sulfate and potassium nitrate dissolve readily in water and should not increase the risks of clogging.

Preventing Blockages

Clogging will eventually occur in any drip irrigation system. Clogging may be caused by debris, chemical sedimentation, or by the build-up of bacteria, algae and even insects.

Debris such as clay and silt may accumulate inside filters or form aggregates in the irrigation lines and emitters which may prevent or restrict the water flow. This type of blockage can be avoided with regular flushing of the irrigation lines and backflushing of the filter. The amount of debris naturally found in the water supply should be considered when determining filtration needs. Initial reductions in drip irrigation flow rates are usually the result of debris blockages which often lead to other types of blockages. It is important to routinely monitor the water flow through the irrigation system and to correct problems as they occur.

Emitters can also be clogged by salt deposits left behind as water evaporates from emitters. This type of blockage may need to be cleaned out manually but can often be cleared by injecting acid into the irrigation line. To clear salt blockages, the pH of the water needs to be lowered to between 1 and 2. Sulfuric or hydrochloric acid can be used to lower the pH.

Insects can inhabit emitters and plug them; these need to be removed manually. Bacteria and algae blockages can be cleared with a biocide such as chlorine gas or a hypochlorite solution. The chlorine concentration of the irrigation water should be 1 mg of free chloride (Cl^2) per liter of water which should be applied for 30 minutes. Calcium and sodium hypochlorite (laundry bleach) solutions are recommended since they are effective and relatively safe. Chlorine gas is also used to clear biological blockages but it is much more difficult to handle safely.

Chlorination can cause manganese and iron to precipitate out of irrigation water. Therefore chlorine must be injected before the filters, and time must be provided for the precipitates to fall out of solution. The filter system must be able to adequately screen these precipitates. Where the risk of precipitate formation is high, it may be necessary to reroute the chlorinated water to delay passage through the filter. Chlorination rates must be adjusted to compensate for the effect of dissolved solids on the free chloride concentration. For heavy algal infestations, first flush the system with the lateral lines open, then close them to clear the emitters. Chlorine is corrosive to irrigation system components and should be flushed from the system after treatment. Some fruit species ,such as black currants, are very sensitive to chlorine and supplemental flushing with untreated water is recommended to avoid toxicity problems. Other biocides are available but many are extremely toxic and should be avoided. Acids and hypochlorites need to be stored carefully so that they don't contact each other. Accidental mixing of these chemicals results in the release of large amounts of chlorine gas and heat, which may result in a fire.

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