

N E T A F I M U S A



COTTON PRODUCTION MANUAL

USING SUBSURFACE DRIP IRRIGATION



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DRIP IRRIGATED COTTON

Cotton is a crop grown all over the southern quarter of the United States from California to Florida. This places this crop in areas of extreme rainfall in certain times to little or none in others. It is a perennial crop we choose to grow as an annual. Like most perennials it is a luxury consumer taking in all it can when times are good and then shedding parts (most significantly bolls) when times get tough.

Irrigated cotton responds well to careful management, resulting in consistently high yields. As the efficiency of the irrigation system increases so does the plants opportunity for yield. Cotton has shown outstanding response to Subsurface Drip Irrigation (SDI). SDI has given the grower ultimate control of inputs resulting in higher returns. Yields have doubled in some areas when compared to other forms of irrigation and have set record yields on farms with high management levels.

SDI is a management tool that allows precise control over the root zone environment of your cotton crop. This control often results in consistently high yields. In addition, better water and fertilizer management can help reduce fertilizer inputs, water needs and runoff. As with any management tool there are tradeoffs. Many growers find the well supplying their pivot circle (125 acres) supplies enough water to do a quarter square (155 acres) with a drip system. In this case they have saved no water and need to use a little more fertilizer but they are cultivating 20% more area. Other growers decide to reduce water consumption, runoff and fertilizer, but do not experience as significant a yield increase.

Drip irrigation may also contribute to an earlier harvest by keeping the soil dry and improving heat units. Because fertilizer and crop protection chemicals can be delivered via the drip system tractor passes can be lowered saving diesel and labor. Drip irrigation also allows growers to better manage salinity in the water and soil.

Some “watch-outs” regarding drip irrigation include high initial cost, the need for regular maintenance and pest management. Your crop rotation program should be considered during system design. Finally, you will need access to specific fertilizers or acids of the quality necessary to be injected into the drip system.

Drip irrigated cotton responds differently than cotton irrigated using flood or pivot. This document is written to assist in management decisions when it comes to growing cotton with SDI. It is not meant as a complete treatise on cotton production but as a guide to getting the most out of your drip system.

Seven main topics pertaining to the production of cotton under drip irrigation will be covered in various chapters of this manual:

1. Suitable varieties
2. Planting date and populations
3. Insect control
4. Weed control
5. Growth hormone program
6. Irrigation
7. Fertilization

The first five topics are covered in the Agronomic section while Irrigation and Fertilization each have their own sections.

DRIP SYSTEM COMPONENTS

OVERVIEW

This section of the manual reviews the layout and function of the components required for a typical Subsurface Drip Irrigation (SDI) system. In SDI the dripperline is permanently buried about 12 inches deep supplying water to, and feeding the roots directly. One advantage of the subsurface delivery of water and nutrients is that the soil surface stays dry, significantly reducing weed pressure and the need for herbicides. Netafim has experience with subsurface drip systems in continuous operation for over 20 years. The longevity of your system will depend on factors such as initial water quality, proper operation, regular maintenance and control of rodent populations.

WATER

Water sources currently used for flood or mechanized irrigation are generally suitable for drip irrigation of cotton. However, there are some special considerations that are required to ensure the longevity of your drip irrigation system. When utilizing a new water source or if you have known conditions such as high salts, iron or manganese it is a good idea to have the source water analyzed before system design begins. Water quality issues can be addressed through proper system design and water treatment but it is most cost effective to do this before the system is installed. Maintenance procedures may also need to be adjusted for specific water conditions. Specific water quality issues are discussed in more details in the operations and maintenance section of this manual.

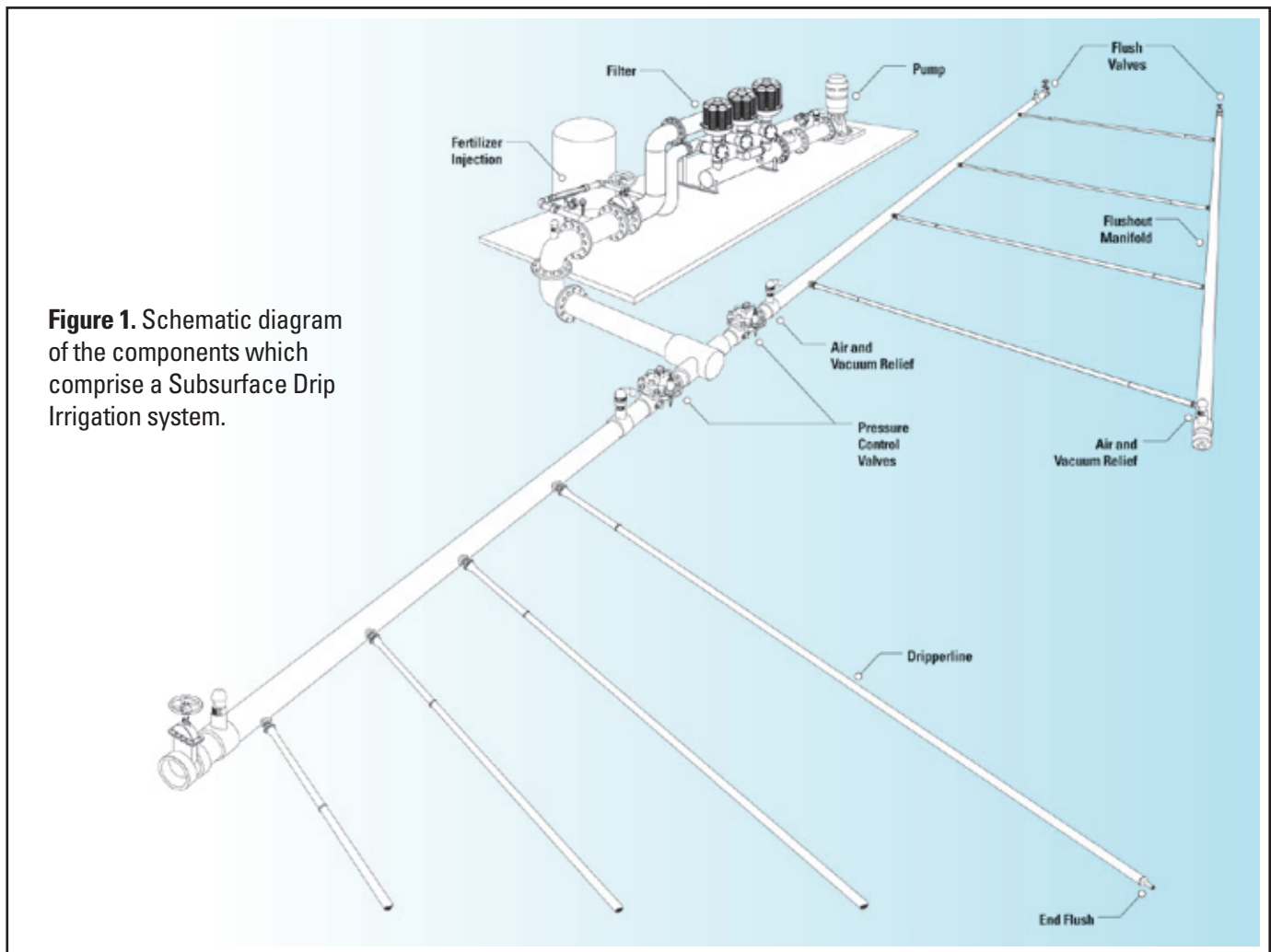


Figure 1. Schematic diagram of the components which comprise a Subsurface Drip Irrigation system.

BASIC SYSTEM LAYOUT

Figure 1 is a schematic layout of the components which make up an SDI system. The heart of the system is the dripperline. For cotton production this may employ pressure compensating or non-pressure compensating emitters depending upon row length and field topography. As the name suggests pressure compensating emitters produce the same flow rate over a wide range of pressures while with non-compensating emitters the flow rate is a function of the inlet pressure. Pressure compensating emitters are generally more complex and hence more expensive than non-compensating emitters. On sloping terrain pressure compensating emitters allow uniform water distribution even though the slope will result in large pressure gradients. This can result in significant water savings and improved yield by producing a more uniform crop.

To protect the dripperline you must employ a high quality filtration system. This is typically a disc or media filtration system. To maintain your dripperline over the long term requires a system for injecting chemicals. Some of these chemicals such as acid will keep your system clean. It is also possible to use this injection system to supply fertilizers directly to the crop roots. With a heavy feeder like cotton supplying fertilizer directly to the roots is the most efficient and effective way to fertilize your crop. Pipeline headers, control and air release valve round out the rest of the system. Our intent is not to describe the process of system design in detail. Your Netafim Dealer is trained to design and install quality SDI systems. Still it is important to understand how the system is put together and why certain design elements are specified.

DRIPPERLINE SPECIFICATIONS

The following dripperline recommendations are meant as guidelines. Soil type, topography and water quality will affect the final design. Your Netafim dealer is familiar with the local conditions and will recommend dripperline that is appropriate for your area. Dripperline should be installed with GPS where possible so that their position can be determined as necessary. SDI systems always employ dripperline with integral drippers. Depending upon local conditions this dripperline can employ either pressure compensating, DripNet PC or UniRam drippers or non-compensating Typhoon or Streamline drippers. Factors such as length of run, topography and zone size in addition to water quality all come into play in choosing the right dripper. Regardless of the emitter employed there are several basic guidelines to follow.

1. A typical drip installation on cotton has a single dripperline buried between two crop rows. Since the most common row spacing for cotton is 30 inches, dripperlines are spaced on 60 inch centers, with one dripperline feeding two rows of cotton. The current trend is toward higher plant densities. To accomplish this some growers are moving to 20 inch row spacing and in this case a dripperline spacing of 40 inches between rows would be standard. The 40 inch dripperline row spacing is more easily adaptable to a soy rotation and is also ideal for other crop rotations such as wheat or alfalfa. In fact, an SDI system with 40 inch row spacing can be used to irrigate most common agricultural crops. Crop rotation should be considered when choosing the desired spacing between dripperline rows.
2. Dripperlines are generally buried at a depth of 12 inches but may be found 8 to 18 inches deep. Soil texture, germination and rodent pressure are the main considerations for dripperline depth. Sandy soils generally demand a shallower burial to expose the plant roots to the largest possible wetted zone. A shallower burial is also suggested when you desire to use the system to germinate your crop. At a depth of 14" or deeper it is difficult to move water to the surface to germinate cotton seed. This is mostly an issue in the arid west where there is little stored moisture in the soil prior to planting. In areas with strong rodent pressure a deeper dripperline is less likely to cross paths with rodent's teeth.
3. The distance between drippers is usually 18 to 24 inches. This may be adjusted to achieve the appropriate application rate.
4. Dripper flow rates of 0.16 to 1.0 GPM may be employed depending upon the soil infiltration rate and the application rate desired. Typically 0.18 to 0.4 GPH emitters are used.
5. Dripperline wall thickness of 13 to 35 mil is usually employed, with 13 mil being most common.

PUMP REQUIREMENTS

The volume output of the pumping station dictates the amount of area that can be irrigated. A simple formula has been derived converting the ET in inches of water per day per acre into gallons per minute per acre.

$$\text{ET (inches/day/acre) *18.86 (conversion factor) = GPM/acre}$$

Using this formula for an ET of 0.25 inches per 24 hours per acre would require 4.72 GPM/acre.

This calculation is for a pump running 24 hours. More commonly as a safety factor, systems are sized for 20 hours of operation. To accomplish this use the following formula,

$$\frac{\text{Hours in a day/ number of hours desired for irrigation X GPM/acre}}{24/20 \text{ X } 4.72 = 5.66 \text{ GPM/acre}}$$

On flat land the pressure output required of the pump stations is mainly dictated by the requirements to flush debris out of the filters and pipes. On hilly terrain the pressure required to lift water to the highest point must also be considered. Most automatic filters require a minimum of 30 PSI to self-clean properly. This is generally the minimum operating pressure of the pump to operate a drip system.

FILTRATION

The filter system protects the drip system from sand and other small particles which can plug the drippers. A well conceived filter system allows for maximum operating life of your SDI system to be realized. Three types of filter methods are recommended:

1. Sand media filters
2. Netafim disc filters
3. Netafim screen filters

In general, screen filters are not recommended for long term SDI systems however for very clean water sources they may be acceptable. Sand media (Figure 2) and disc filters (Figure 3) utilize depth filtration which is most effective at removing suspended particles from the water. The filter system should be set up to clean automatically when the pressure differential across the media is too large. A pressure differential switch in combination with a flushing controller is a common approach for automation of filter cleaning.



Figure 2. Example of AGF Sand Media Filter unit.



Figure 3. An example of a Netafim Apollo Disc Filtration unit (left) and Manual Disc Filter (right).



PRESSURE REGULATING VALVES

The recommended dripper line is not compensated and pressure control valves (Figure 4) are recommended to achieve the correct working pressure in the drip system. Pressure regulating valves must be adjustable to accommodate higher pressures during flushing.

AIR VALVES

The sucking in of soil just after shutting down the system can give problems if vacuum valves are not used. For every 50 laterals there should be one anti-vacuum valve (Figure 4) on the highest elevation. It is further recommended that an anti-vacuum valve be mounted on the flushing manifold's highest elevation. A double purpose automatic air valve must be installed at the pump.

FERTILIZER INJECTION SYSTEM

The system must be designed to supply fertilizer to all irrigation blocks. This can be a completely automated system or a simple injection pump. Please consult your Netafim Dealer to determine which fertilizers may be safely applied through the drip system. Figure 5.

FLOW METER

It is essential to monitor flow in order to monitor the operation of your system and crop water use. Your SDI system is designed to produce a specific flow rate at a given pressure. Changes in the flow rate may indicate leaks in the system, improperly set pressure regulating valves or even changes in the well and pumping plant. Figure 6.

Use pressure gauges to ensure that the drip system, filter system and pump operate at the correct pressure. Pressure gauges are also critical to assess potential problems with the system.



The above is an example of a saddle meter installed on a mainline.



Figure 4. Top photo and photo above are examples of field installation of pressure regulating air and release valves.



Figure 6. A Netafim fertilizer injection and irrigation control system. Flow meters are located on the right a pressure gauge is visible on the left.

FLUSH MANIFOLDS

Most permanent SDI systems employ flush manifolds so that entire zones can be flushed at a single time. A manifold at the end of the field also improves system uniformity. The use of flush manifolds is highly recommended to reduce the labor required to properly maintain the system. Access to a pressure gauge port is helpful on the flush manifolds in order to read pressure at the end of the fields.



SDI LAYOUT AND DESIGN FOR COTTON OVERVIEW

Spacing between rows of dripperline, depth of placement, dripper spacing and dripper flow rate are the four variables which define your SDI system. These must be matched with soil type, water availability, pump capacity and crop water use to complete your system design. With your input, your local Netafim Dealer provides a customized drip system design and layout. Trained designers familiar with local conditions will ensure that you receive a system that will last for years. GPS guided installation allows for precision farming of your cotton crop. Consideration of the cropping system, crop rotation and soil conditions is an important part of the design process. This section is not meant as a treatise on the hydraulic design of the drip system but more of description of the SDI system parameters as they apply to cotton production.

TYPICAL SYSTEM LAYOUT

For cotton planted in 40 inch rows a typical SDI system will have the dripperline spaced at 80 inches placed in the furrow such that one dripperline feeds two rows of cotton. More recently, to accommodate a wider range of rotation crops a row dripperline is placed in each cotton row which means the dripperline is spaced 40 inches apart. The dripperline is usually buried at depths ranging from 8 to 16 inches.

At a given row spacing, the flow out of each dripper and the spacing between drippers will determine the application rate. The application rate desired is dependent on the water requirements, water availability and cultural practices. A common system may use 0.16 GPH Typhoon emitters spaced at 24 inches. This will give an application rate of 0.038 inches/hour or 0.91 inches in a 24 hour period. To take advantage of existing pumps and to maximize the efficiency of your water supply your SDI system

is typically divided into zones or blocks. In the above example the system could be divided into 4 blocks each operating for 6 hours. This results in an application rate of .23 inches per block which is close to the ET for many regions of the country. Your Netafim Dealer will design systems that supply the appropriate amount of water for your region taking into account weather, soil type, cropping system and crop rotation.

Research done by Hansen et al (2008) demonstrates the extent of lateral water movement for subsurface drip irrigation. This work was done on tomatoes but applies to cotton fields as well. Figure 7 shows the wetting pattern for a clay loam for dripperlines placed at varied depths. At a dripperline depth of 6 inches some moisture reaches the soil surface with horizontal wetting occurring out to about 12 inches. At depths of 12 and 18 inches the soil surface remained dry and maximum horizontal wetting of 25 to 30 inches was obtained. This suggests that for this soil type 80 inch spacing between dripperlines is acceptable.

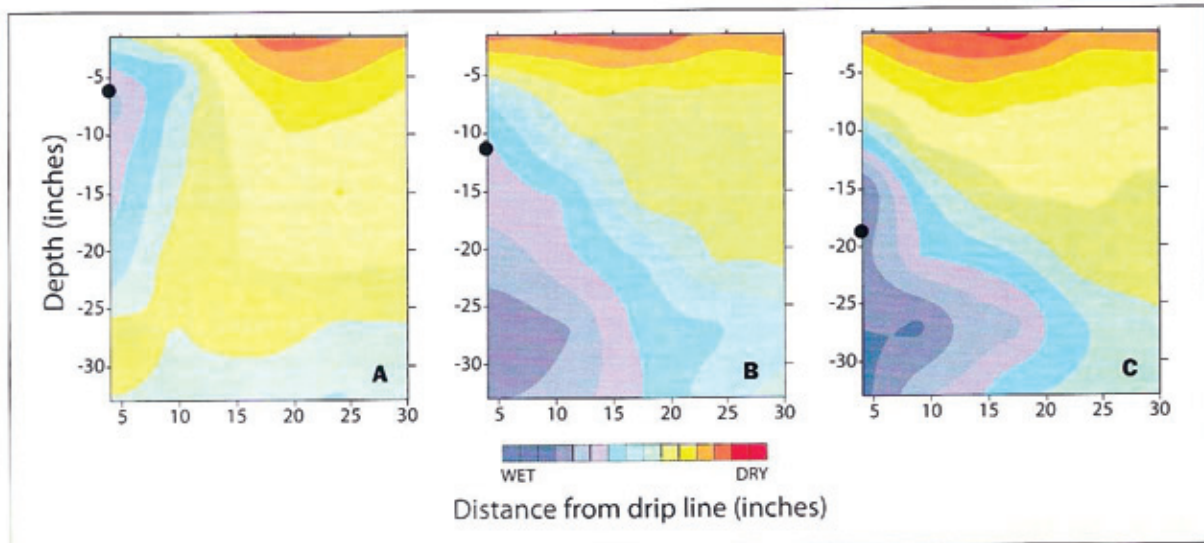


Figure 7. Wetting patterns for subsurface drip irrigation for different dripperline depths. (A) 6 inches deep, (B) 12 inches deep and (C) 18 inches deep. Soil Type was clay loam. The black dots are the locations of the dripperlines.

A second factor that will determine dripperline spacing is crop rotation. A subsurface drip system can last up to 20 years so it is important to have a rotation plan in mind prior to installation. In addition to row spacing, dripperline depth and the potential need for sprinkler or flood irrigation to germinate rotation crops must also be considered in your rotation plan. Experience has shown that an SDI system with dripperline placed every 40 inches will water the entire soil volume. Thus, it is suitable for most crops with a moderately deep root system. For instance, several growers have successfully cultivated wheat and safflower over SDI systems designed for cotton crops. Row crops such as soybeans, tomatoes or corn can be easily accommodated with a drip system designed for field cotton.

DRIPPERLINE DEPTH

It is possible to place the dripperline in a cotton field at any depth but there is little reason to place it shallower than 8 inches. Dripperline placed at 12 inches or deeper results in little moisture reaching the soil surface potentially reducing weed pressure on your crop (see Hansen et al above). The advantage of a dry soil surface may be a disadvantage when it comes to germinating your crop particularly in very arid regions. In much of the western cotton belt soil moisture from winter snows provides enough moisture for crop germination in the spring regardless of the depth of placement of the dripperline. In dryer regions in the far west sprinklers may be required for germination of your cotton crop. Dripperline placed at a depth of 8 inches allows for consistent germination of your cotton crop under any conditions. However a shallower dripperline will result in a wet surface which may encourage weed growth. In areas with severe rodent pressure dripperline placement at a depth of 15 to 18 inches or may help reduce rodent damage. This is below the depth of the majority of gopher activity.

Recent feedback concerning subsurface drip irrigation shows that it leads to less soil compaction. Cotton has a strong root system, which lessens soil compaction or the necessity of follow-up deep cultivations. It is not foreseen that follow-up soil preparation for rotation crops need to be done to deeper than 10 inches. Still if the system is installed using GPS rotation crops can be easily planted relative to the dripperline and deep cultivations can be accomplished between the dripper lines.

NO-TILL AND MINIMUM-TILL SYSTEMS

Subsurface Drip Irrigation (SDI) is well adapted to “No-Till” and “Minimum-Till” systems for several reasons.

1. A properly operated SDI system does not wet the soil surface reducing weed pressure and reducing herbicide application. This saves money in reduced tractor passes and lower crop protection costs.
2. Water movement from the buried dripperline moves primarily through capillary action not via mass flow in the soil. This gentle movement helps maintain and even improve soil structure in No-Till and Minimum-Till cropping situations.
3. The application of water and fertilizer directly to the root zone via SDI is much more effective in No-Till and Minimum-Till situations compared to surface application of water.

DRIPPER SPACING AND FLOW RATE

Dripper spacing and flow rate along with row spacing determine the water application rate. These are designed to supply adequate water to satisfy the peak water use for your crop (Etc) usually expressed as inches/day. In the U.S. peak ETc usually occurs in July and ranges from 0.25 inches/day to over 0.5 inches per day in much of the irrigated western U.S. The precise peak water use depends upon the climate in your specific area and can be obtained from your local extension service. If you have poor quality water or soil, a leaching factor needs to be added to the system so that the additional water is available as needed. The section on irrigation and scheduling include more information on ET.

FIELD PREPARATION

Your drip system is expected to last 20 years or more. As a result ground preparation is critical. Your SDI system is not just a watering tool but allows for fertilization over the course of the crop. This is critical to maintaining economic yields over an extended period of time. Still the soil should be properly amended at the time of initial land preparation. Soil samples should be taken and analysed before establishment to determine what chemical ameliorations are required.

Cotton performs best when the soil is in a pH range from 6.3 to 7.5. Soils with a pH of 6.0 or lower must be limed. Soils with a pH above 8.2 indicate excess sodium and must be reclaimed. Excess salts in your soil or water can significantly reduce yield. . In high salinity areas it is necessary to design the drip system so it can provide adequate leaching. Consult your local extension service for more information on problematic soils in your area. When dealing with problematic soils it is necessary to allow sufficient time for the reclamation process to take effect before planting. Your local Netafim Dealer can give you guidance as to the proper field preparation prior to installation which will make installation go smoothly.

SOIL FERTILITY

Fertile soil is fundamental to crop establishment. Even though SDI allows for the application of fertilizers directly to the root zone while the crop is growing it is important to start out with the right fertility in the seedbed. Have a soil sample analyzed prior to planting. Follow the recommendations of your local laboratory or extension service to prepare your field for planting. Of particular concern is phosphorous. This nutrient is quite immobile in the soil and an effective pre-plant will start your crop out right. This fertilizer can be broadcast and disked or harrowed. Banding phosphorous with or below the seed has worked well. This method places the phosphorous where it is readily available to the cotton and not the weeds. See the section on fertilization for more information on the fertilizer needs of cotton.

SDI SYSTEM STARTUP OVERVIEW

This section offers guidelines for the successful startup and operational testing of your SDI system. Many times your Netafim dealer will conduct initial start-up and testing of your system. However, during the course of operation there may come times when the system needs to be started after a shutdown such as the off-season or following repairs. These procedures should be followed after any extended shutdown of your system. All drip system owners should make themselves familiar with the process of start-up and testing of their drip system.

SYSTEM STARTUP

Your SDI system should be operated as soon as possible after installation. Installation planning should include well operation and hook-up to the header system so dripperlines can be charged as soon as possible after installation. Filling the system with water inhibits insects as the inflated diameter of the dripperline is too big for their mandibles. The wet soils created by operating the system are a slight deterrent to rodents looking for a chew.

Whether you have just installed a new system or are starting your system up after sitting through the off season, a few simple steps taken before you begin irrigating will help to ensure optimum system performance

1. **Flush the well before operation through the filter.** New wells, may discharge sand on startup. This “plug” of sand can overwhelm the filtration system. Under these conditions the filtration system will backflush repeatedly without cleaning the system. This occurs because the clean water flow used to flush the filters is so reduced it does not sufficiently clean the dirty filter. In this case the unit must be disassembled and cleaned by hand. If the well discharges sand on a regular basis it may be necessary to install a sand separator before your regular filtration system. A sand separator continuously removes sand from your system as it is operating. Consult your Netafim Dealer for more information on sand separators.
2. **Thorough flushing of the laterals and mains before system operation.** In new systems, chances are good that during installation some dirt and PVC pieces accumulated in the system. These need to be flushed out properly. A properly designed drip system should have valves installed for flushing mains, submains and dripperlines. Your Netafim dealer will review their operation prior to turning on the system. Your drip system needs to be flushed on a regular basis. Filters do not exclude 100% of particles in your water, often letting through fine silt. This will settle in lines and can clog your system. Debris also can get into the lines after a break has occurred and your system should be flushed after any repairs. Depending upon the condition of your water this flushing may need to be done as often as once a month or as little as once a year.
3. **Check for leaks in dripperline laterals.** Laterals are occasionally damaged during installation. System start-up is the right time to check for leaks, before the crop canopy expands making repairs difficult. Leaks in the dripperlines usually appear as isolated wet spots on the surface of the field.

STARTUP PROCEDURE

1. If possible, run your pump station for a few minutes with the discharge to waste, not through irrigation system, to flush out any sand.
2. Open mainline flush valves with any sub-main valves closed and operate your system until discharge water runs clear for 5 minutes. Pay attention to the flow rate and whether and how often the filter system back-flushed during this operation.

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3. Open submain valves with dripperlines still disconnected to clear the submains of debris. Make sure that you are not pushing muddy water into the laterals during this operation.
 4. For each submain, open the control valve until discharge water at the end of the lateral runs clear. If the capacity of your water supply is insufficient to flush all laterals simultaneously, it may be necessary to terminate some laterals flushing only a few at a time. Close the submain valve.
 5. Operate the system until it is fully pressurized and all air is discharged.
 6. Check system for leaks and repair.
 7. Re-flush the lines after leaks are repaired.
 8. Check pressure gauges and adjust all pressure regulators, or regulating valves as necessary.
 9. Check for proper operation of all system components; pumps, controllers, valves, air vents, pressure regulators, gauges, flow meters, filter system and chemical injectors.
 10. Record readings from all pressure gauges and flow meters and check on the frequency of backflush cycle of your filters. If backflushing is frequent (several times an hour) consult your Netafim Dealer.

SYSTEM PRESSURE AND FLOW TESTS

Upon initial startup it is best to evaluate the uniformity of your drip system. This is accomplished by:

1. Measuring the pressure in the system at various points and comparing this to the design pressure.
2. Reading from your water meter or calculating the system flow and comparing the result to the design flow rate.

These evaluations should be conducted as part of system startup and as an ongoing part of system maintenance. Consult the maintenance section of this manual for a complete program for system care.

SYSTEM PRESSURE EVALUATION

Drip systems are typically designed to operate between 10 and 25 psi. Measuring the pressure at several points in your drip system is the simplest way to evaluate the performance. A good evaluation will include pressure measurements at a minimum of 3 points along the header end of the field and 3 points at the far end of the field. Because of the relationship of flow rate to pressure of Netafim drippers this variation in pressure will usually give distribution uniformities of 95% (see design section). Pressure measurements at more points in the field including along the length of the laterals will give a more complete picture of system uniformity but are usually not necessary if the end pressures are within several psi of the header pressure. Please note that if your system employs pressure compensating drippers the pressure drop across your system could be 10 or more psi and still be highly uniform. Check with your Netafim dealer to determine what pressure measurements are reasonable.

SYSTEM FLOW RATE

A flow meter is an important component of every drip system. It gives a quick indication of the operational performance their system and is used to determine proper water application rates. Every new system should be designed with a flow meter. Older systems without flow meters should be retrofitted with one. The system design should include an estimated system flow rate and the measured flow rate should be within +/- 5% of the designed rate. To calculate the flow rate expected for each zone use the following formula.

$$\text{Flow rate (GPM)} = (0.2) \times \text{length of dripperline (ft)} \times \text{drripper flow rate (GPH)} / \text{drripper spacing (in)}$$

CONVERTING SYSTEM FLOW RATE TO INCHES OF APPLIED WATER:

Irrigation schedules are usually based on evapotranspiration (ET) rates which are expressed in inches of water evaporated over a given time period, usually a day or week. It is simple to convert a flow rate in GPM, either one read from a meter or calculated as outlined above, to inches of water applied per hour by using the following formula.

$$\text{Inches of water applied per hour} = (0.00221) \times (\text{flow rate, in GPM}) / (\# \text{ acres})$$

For example, a typical SDI system on cotton will have 60" spacing between dripperline rows with 0.16 GPH drippers spaced at 24 inches. One acre of the above system has 42 rows each 208 feet long for a total of 8736 ft. This gives a flow rate 11.65 GPM.

$$(0.00221) \times 11.65 / 1 = .025 \text{ inches per hour which equals } 0.3 \text{ inches in 12 hours}$$

Another way of figuring your application rate is:

$$231.1 \times \text{GPH/dripper} \text{ divided by row spacing} \times \text{drripper spacing}$$

$$231.1 \times .16 \text{ GPH} / 24 \times 60 = .025 \text{ incher per hour}$$

MONITORING YOUR DRIP SYSTEM

To achieve the high yields and water savings possible with drip irrigation, it is necessary to monitor your system and make adjustments. In addition, regular system monitoring may give advance warning of potential problems.

MONITORING SYSTEM PRESSURE AND FLOW RATES

As presented earlier measurements of system flow and pressure give a good picture of your system's performance. Because of the large number of variables at play in an irrigation system the measured water application rate can not be expected to exactly match the predicted rate. Still, large differences in calculated versus measured values, may indicate a problem with your calculations or a physical system problem such as a broken or clogged line. Over the growing season changes in the flow rate or pressure in your system can be used to diagnose problems with the system. Table 1, details some of the problems that can be diagnosed by monitoring system pressure and flow rate. This is by no means a comprehensive list but is a good place to start.

INDICATION	POSSIBLE PROBLEM
Gradual decrease in flow rate	Dripper plugging Possible pump wear (check pressure)
Sudden decrease in flow rate	Stuck control valve Water supply failure
Gradual increase in flow rate	Incremental damage to dripperline by pests
Sudden increase in flow rate	Broken lateral, submain, main line Pressure regulator failure
Large pressure drop across filters	Debris buildup in filters Inadequate flushing of filters
Gradual pressure decrease at filter inlet	Pump wear or water supply problems
Sudden pressure decrease at filter outlet	Broken lateral, submain, main line Pressure regulator or water supply failure
Gradual pressure increase at filter outlet	Dripper plugging
Sudden pressure increase at filter outlet	Stuck control valve Other flow restrictions
Sudden pressure decrease at submain	Damaged or broken lateral

Table 1. Problems diagnosed from system flow rates and pressures.

With proper care your drip system will last many years. K-State in Colby KS has had a drip system with older technology continuously operating for 20 years. There is no reason to believe that another 10 to 20 years is possible. As with all of your farm equipment it all starts with good maintenance.

SUITABLE VARIETIES

Different cotton varieties respond differently to drip than to other types of irrigation. Therefore it would be beneficial to have variety trials consisting of the more common varieties grown in your area as well as others that might be on the horizon. Keep in mind that planting cotton to be irrigated with drip, to get maximum yields will require planting varieties with maximum potential. Do not plant short season low yield potential cotton and expect high yield results. It is always suggested to plant as early as possible with long season high yielding varieties. This allows for maximum yields and also gives you time and genetics to make up for any problems that might occur early season such as flea hopper damage or adverse weather. What you miss early you can put on later with a long season cotton. Choose a variety with good early vigor. The first 40 days of a cottons plant life is the most critical. This includes stand establishment. Select transgenic varieties that are the most suitable for your growing area – things to take into consideration:

- Long staple length
- Premium micronaire
- High strength
- Plant confirmation for most efficient harvest
- Plant maturity types
- Disease tolerance



The photo above is an example of different varietal responses to SDI.

PLANTING DATE AND POPULATIONS

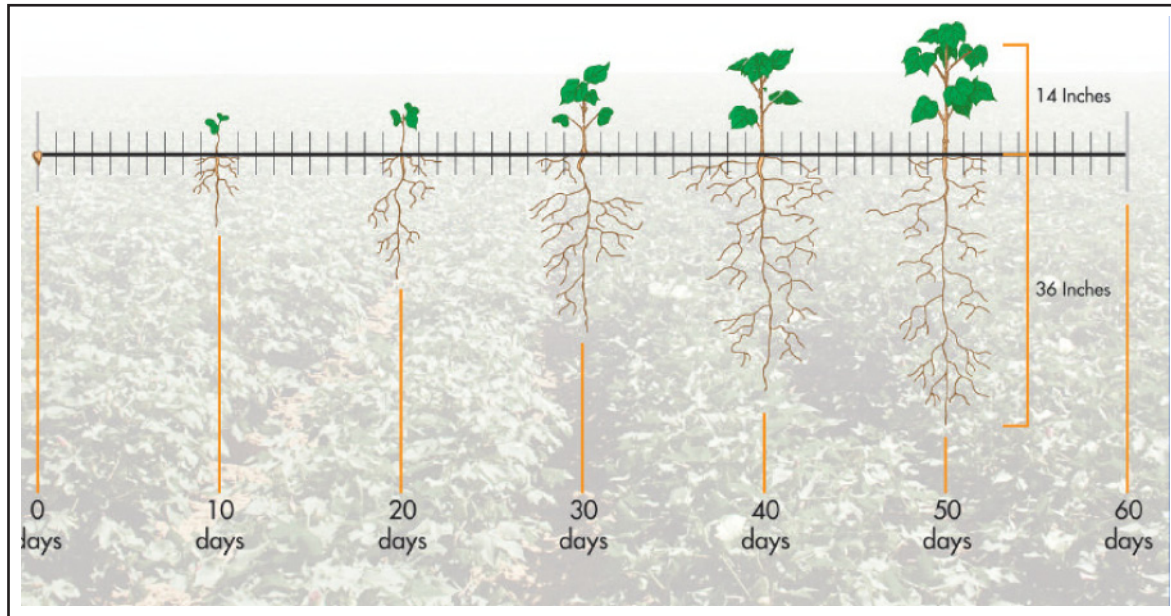
Seedbed preparation plays a vital role in emergence and plant population. Studies show that at planting one half of the variable costs, as well as all of the annual fixed costs are spent prior or during the first 40 days of the crop. Seeds placed in a good seed to soil contact, with warm soil temperatures of at least 65 degree Fahrenheit, and adequate soil moisture and fertility, will get the crop off to a good start. This will also get weeds off to a good start so early prevention and management of weed seed and host plants are necessary as well. Herbicide resistant varieties are not meant to compete in their early life with weeds for moisture and fertilizer.

Planting dates will vary by regional locations. Soil temperature affects germination. Cold soils delay germination. Each day germination is delayed after the process begins has proven to cause reductions in yield and seedling vigor. Environmental stresses such as insects, mites, nematodes, weeds, fertility and soil moisture will also play a critical role with early development.



AFFECTS OF PLANTING DATES

- Earliness
- Lower levels of insect pressures
- Maturity during high temperature
- Reduced risk of weather



The chart above shows optimum development from 0 to 60 days.

Plant populations should be managed according to variety, plant characteristics, row spacing, environmental conditions, and length of growing season. A long season, more vegetative plant will require fewer plants per acre than a more compact plant. Allowing plants to crowd will cause the canopy to shade out the lower branches which might lead to boll rot in high humidity areas and lack of sunlight use efficiency. Plant height should match or be very close to your row spacing, within 10%. If you are planting on 30 inch beds the cotton needs to be held to 30 inches. This allows for maximum sunlight on leaf surface and proper air circulation in the canopy. This can be accomplished by maintaining your internodes length to a maximum of 1.5 to 2 inches. Plant spacing of 3 to 4 inches can help accomplish this. SDI gives the grower the capability of more control with inputs like water and fertilizer to manage the crop on a daily basis. Managing the fifth internodes from the terminal of the plant will aid in decision making of when to water or fertilize along with plant growth regulators.



Here is an example of excess internodes length due to not limiting consumption. Plant on left is flood and the middle and right are drip.

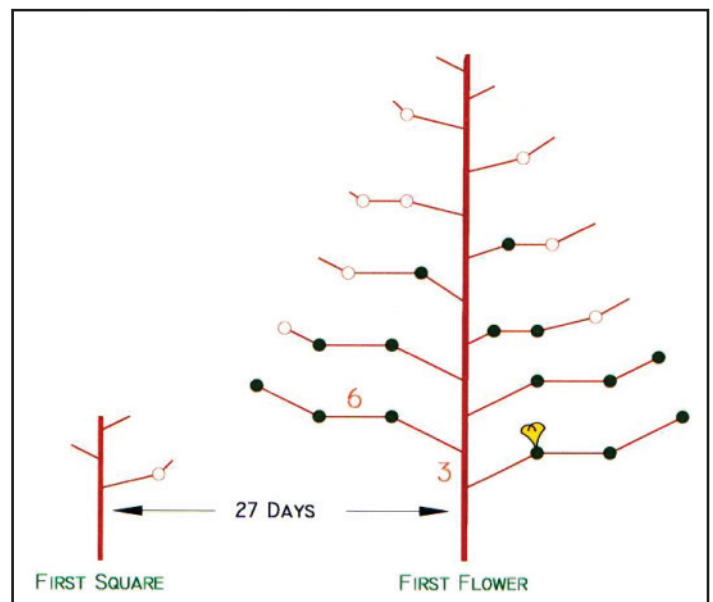
A plant's height is measured from its cotyledons (seedling leaves) to the terminal. Height to node ratio should range from 1.3 to 2.0. To calculate this measurement divide the height of the plant by the number of nodes. A plant 20 inches tall with 15 nodes would have an HNR of 1.33. This ratio will change as the season progresses.

After bloom the space between the nodes will shorten as developing bolls demand more of the plant's carbohydrates and other nutrients. If the HNR increases above 2.0 after flowering starts, inspect the field for insect damage. If insects are not the cause check nutrient levels from petiole reports and adjust inputs or apply plant growth regulators.

INSECT CONTROL

Everything discussed above will not matter if there is no insect control. This needs to be followed from preplant insecticides to timely application for flea hoppers and other piercing, sucking insects. If flea hoppers are missed early season the crop will mature later, make less lint, grow taller and be less efficient.

When it comes to insects always be proactive instead of reactive. There are labeled insecticides for drip irrigation that are more effective than topically applied. Always consult your crop protection agent and follow labels.



It is very critical to protect these first bole positions.

CRITERIA FOR SUCCESS IN CONTROLLING INSECTS

- Proper crop monitoring
- Preserving populations of beneficial insects
- Avoiding unnecessary applications of all insecticides
- Using recommended label rates
- Timing applications of insecticides based on thresholds
- Optimizing coverage
- Managing insect resistance

WEED MANAGEMENT

Drip irrigation delivers the proper amount of water and nutrients to the targeted plants. If there are weeds in the field they benefit as well. This competition will only take away from your crop's potential yield as well as host unwanted disease carrying insects.



Suggestions:

- Plan weed control program for entire farm prior to planting
- Start the season clean and weed free
- Rotate chemistries and engage multiple modes of action
- Use proper rates
- Keep a field record
- Manage the seed bank
- Sanitize equipment
- Spray by weed size not by crop stage
- Manage weed flushes

PLANT GROWTH REGULATORS

These products are used to control the height and fruit set of a cotton plant. If the plant has been properly managed, has a good fruit load, and has adequate moisture less PGRs will be used. Remember that stressing cotton to control plant size is not the best management practice. It often leads to fruit drop and poor lint quality. PGRs respond best if used throughout the season in small amounts if necessary. They need to be kept at a specific ppm in the biomass to properly control growth. Certain varieties respond differently to different rates. The PGR control is usually about two weeks so keep a sharp eye on the fifth internode from the terminal of the plant to know when to add additional product or skip the application. If the internode is longer than 2 inches you might need to apply the PGR. Again these applications will need to be discussed with your crop protection agent for maximum benefits.

PGR Use Suggestions:

- Can use PGRs as early as pin head square at low rates to control plant
- Applications should be made ahead of the growth curve
- Use the 5th internode from the terminal as your measurement
- Avoid high rates prior to blooming
- Varietal differences can affect rates and timing
- Applications during flowering stage may require higher rates



IRRIGATION SCHEDULING INTRODUCTION

Subsurface drip irrigation (SDI) will keep the soil closer to the optimum water content, can be applied immediately following cutting and requires less labor than sprinkler or flood irrigation. All of these factors attribute to the higher economic yield possible from using SDI to irrigate cotton. Irrigation management has probably the greatest impact on cotton yields than any other input. In addition proper irrigation practices will maximize the benefits of other crop inputs such as fertilizer and pest control. No irrigation system gives as much control over water and fertilizer management as SDI.

Cotton, being a perennial plant that is grown as an annual has a complex relationship with applied irrigation. It is a luxury consumer and will exhibit strong vegetative growth at the expense of yield in response to excess water.

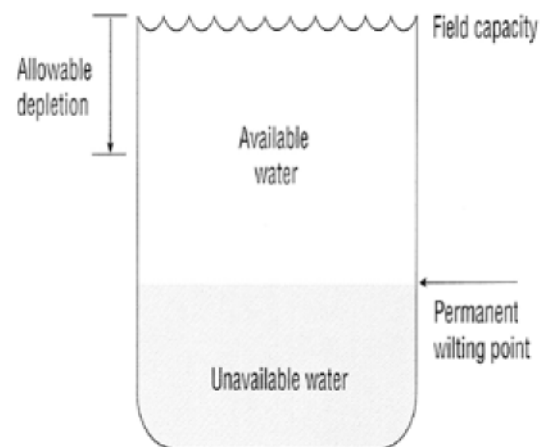


Figure 8. The soil-water reservoir can be thought of as a storage tank with easily available water and water that is bound to the soil and is unavailable for plants to use.

SOIL FACTORS AND IRRIGATION SCHEDULING

Soil is the storage from which plants extract water (Figure 8) If too much water is applied the storage reservoir will overflow and water will runoff or percolate below the active root zone of the crop. If the storage reservoir gets too low, the plants will be stressed and yield reduced. The science of irrigation management is to keep the storage reservoir at the correct level so stress and runoff is avoided. Your SDI system is the tool to manage water application.

Soil type determines the capacity of the soil reservoir. Soil is composed of particles of varied size, organic matter and pore spaces. Water occupies the smaller pore spaces and is held as a film around the soil particles. Sandy soils with large particle have few large pore spaces and have relatively low water holding capacity. Fine textured soils have many smaller pore spaces and a relatively large water holding capacity.

Plant roots also need air (oxygen) to uptake water and nutrients. The root requirement for oxygen for water uptake is a common observation when plants are over-watered. Flooded plants often wilt even though there is plenty of water around. That is because the roots are starved for air. The amount of air held in the soil is inversely proportional to amount of water held. Thus sandy soils hold relatively more air than water compared to fine soils. The real key to irrigation management is to maintain the balance of water to air.

The water status of the soil can be described in the following manner.

Saturation – The soil is essentially flooded. All pores in the soil contain water. This situation takes place when the rate of water applied exceeds the rate of gravity influenced movement in the soil. This usually occurs immediately after heavy rain or when irrigating using flood and sprinkler systems. The water flow in saturated soil is through the large pores under the influence of gravity.

Field capacity – Gravity has pulled all the water from the largest pores. The smallest pores hold the water against gravity, while the larger pores are filled with air. This is the optimal condition for crop development; the water is held at a force that is easily overcome by the uptake power of the roots, whereas at the same time the soil is sufficiently ventilated to enable the roots to breathe.

Wilting point – Not all the water in the soil is available to the plants. The water held in the film around soil particle or in very small pores is held too tight for the plants to remove it. Plants can be observed to wilt even if the soil feels damp. The wilting point is where the water absorption power of the crop cannot overcome the holding power of the soil. Unlike saturation and field capacity which are primarily influenced by the soil, the wilting point is crop dependent as some crops wilt much more easily than others.

Available Water – The amount of available water is the difference between field capacity, and the wilting point. In a theoretical sense all of this water is available. However, the available water and allowable depletion are gross large scale descriptions of soil water holding capacity. Soils are not uniform and more importantly crop water extraction will not occur uniformly across the field. Thus, it is not good practice to schedule irrigations to the wilting point. To provide a safety factor, crop irrigation scheduling is designed around “easily available water” which, as a rule of thumb, is assumed to be about 50% of the total available water. This is referred to as the limit of allowable depletion before an irrigation event must be triggered. Soil properties determine the limits of when to irrigate and how much to apply. Cotton must be irrigated when no more than 50% of the available water has been depleted. The amount of water to apply is the amount required to fill the soil reservoir to field capacity. Table 2 summarizes typical quantities of available water and allowable depletion for various soil types and for a rooting depth of 4 feet.

SOIL TYPE	AVAILABLE WATER (IN./FT)	ALLOWABLE DEPLETION (IN./FT)	AVAILABLE WATER IN 4FT ROOT ZONE (IN.)	ALLOWABLE DEPLETION IN 4FT ROOT ZONE (IN.)
COARSE SAND	0.5	0.25	2.0	1.0
LOAMY SAND	1.0	0.50	4.0	2.0
SAND LOAM	1.5	0.75	6.0	3.0
FINE SANDY LOAM	2.0	1.00	8.0	4.0
CLAY LOAM	2.2	1.10	8.8	4.4
CLAY	2.3	1.15	9.2	4.6
ORGANIC CLAY LOAMS	4.0	2.00	16.0	8.0

Table 2. Estimates of available water content and allowable depletion for various soil types.

An allowable depletion of 50% is the maximum limit before an irrigation event must be triggered or there may be loss of yield. Subsurface drip irrigation will allow you to irrigate more precisely so that the soil is kept in a narrow, more productive zone of water content.

IRRIGATION MANAGEMENT

Irrigation management is the scheduling and adjustment of an irrigation program based on the influences of climate and the crop. Irrigation scheduling requires knowledge of the water holding capacity of the soil, as discussed above, in combination with the water needs of your crop as determined by the crop and its environment. Irrigation and fertigation management is a major factor in maximizing crop productivity and economic returns.

IRRIGATION SCHEDULING

The goal of irrigation scheduling is to determine an irrigation duration and frequency that keeps the root zone below field capacity and above the allowable depletion. At this point the crops roots are exposed to an ample supply of easily available water with sufficient oxygen to promote healthy root growth.

Because drip systems apply water directly to the roots with thousands of water sources throughout the field they are forgiving of poor irrigation scheduling, however, a little time taken to develop and apply an appropriate irrigation schedule will allow your drip system to operate at maximum efficiency.

Two principle methods are used to schedule irrigations in cotton fields. One method is called water budgeting and it involves estimating crop water needs based on the evaporative demand of the environment; the other technique relies on soil-based measurements. Both methods have their limitations. The water budgeting method looks at gross water demand and does not specifically look at your crop or soil. Factors are used to adjust for your specific growing conditions. The measurement of soil moisture is limited to the specific areas where measurement devices are placed. If the location of the device is not representative of the entire field the information can be misleading. The best approach is use a combination of both techniques. Most commonly irrigations are scheduled using water budgeting and verified by measuring soil moisture at select points in the field.

WATER BUDGETING

Water budgeting involves tracking additions and losses and balancing them. The losses are due to crop water use, any leach requirements and inefficiencies in the irrigation system. The additions are due to irrigation and rainfall. The objective of the water budget method is to maintain soil moisture near the optimum level by keeping track of crop water use and then irrigating to replace the water used. Knowledge of crop water use is essential to using the water budget approach.

Crop water use is also called the evapotranspiration rate (ET). The term evapotranspiration refers to the combined loss of water through evaporation from the soil and from water taken up and evaporated from the plants (transpiration). The rate at which plants use water is determined by the growth stage of the plant, in the case of cotton cutting, and the weather. Small plants use less water than large plants and plants generally use more water the hotter or dryer the conditions are. Wind and clouds also affect the evaporation rate.

The reference evapotranspiration rate (ET_o) can be calculated from weather data or measured as evaporation from a calibrated pan of water. Both methods give a close approximation of the environmentally induced evaporation rate from a given area of soil. Real pan evaporators are still used in many parts of the country and it is simple to construct your own pan evaporator (see the end of this section). However, more frequently the ET_o is estimated from weather data which includes, temperature, relative humidity, wind velocity and solar radiation using a modified version of the Penman equation which relates these variables to evaporation rate. A discussion of the Penman equation is beyond the scope of this manual. Suffice it to say that the ET_o for your area is commonly available from a variety of local sources.

Actual crop water usage is usually not exactly the same as the reference evaporation rate (ET_o). First, plants regulate how much water they require by closing or opening stomata (small pores in their leaves used to maintain appropriate water levels in the plant). The difference between the actual peak crop water use and the pan evaporation rate is referred to as the crop factor (K_c). The ET of your crop expressed as E_{tc} can be calculated from the ET_o using the following formula.

The following is an example of the calculation of the required irrigation time according to reference evaporation:

$$ETc = ETo \times Kc$$

The crop coefficient (Kc) for fully leafed out cotton is 1.0 . If the ETo either measured from a pan or calculated is 0.3 inches/day then your cotton crop will be using:

$$ETc = 0.3 \times 1.0 = 0.3 \text{ inches/day (2.1 inches/week) for a fully leafed out crop}$$

The water budget system for irrigation is relatively straightforward, but must be adjusted for crop growth stage and environmental conditions such as rain.

SPECIFIC IRRIGATION RECOMMENDATIONS FOR COTTON

It is always best to start the growing season with a full soil profile. This can be from rainfall or pre-irrigation. This makes it easier for the grower to maintain optimum growing moisture with less stress of either over irrigating or under irrigating. It's always best to establish the plants water needs by stages of growth and or water sensing devices such as tensiometers or other similar equipment. You can also get access to Pan Evaporation and Potential Evapotranspiration (PET) from local universities or county web sites. The cotton's water requirements will increase as it accumulates biomass, (taller plants demand more water). Avoiding water stress at the beginning of first square is critical in establishing adequate plant structure to facilitate yield goals. The growth rate is represented by the internodes length. From first square to peak bloom the internodes length needs to be 1.5- 2 inches. If it is over 2 inches the plant is getting excess water or fertilizer. If the internodes are less than 1 inch the plant is under stress. The irrigation needs to be based on a weekly program:

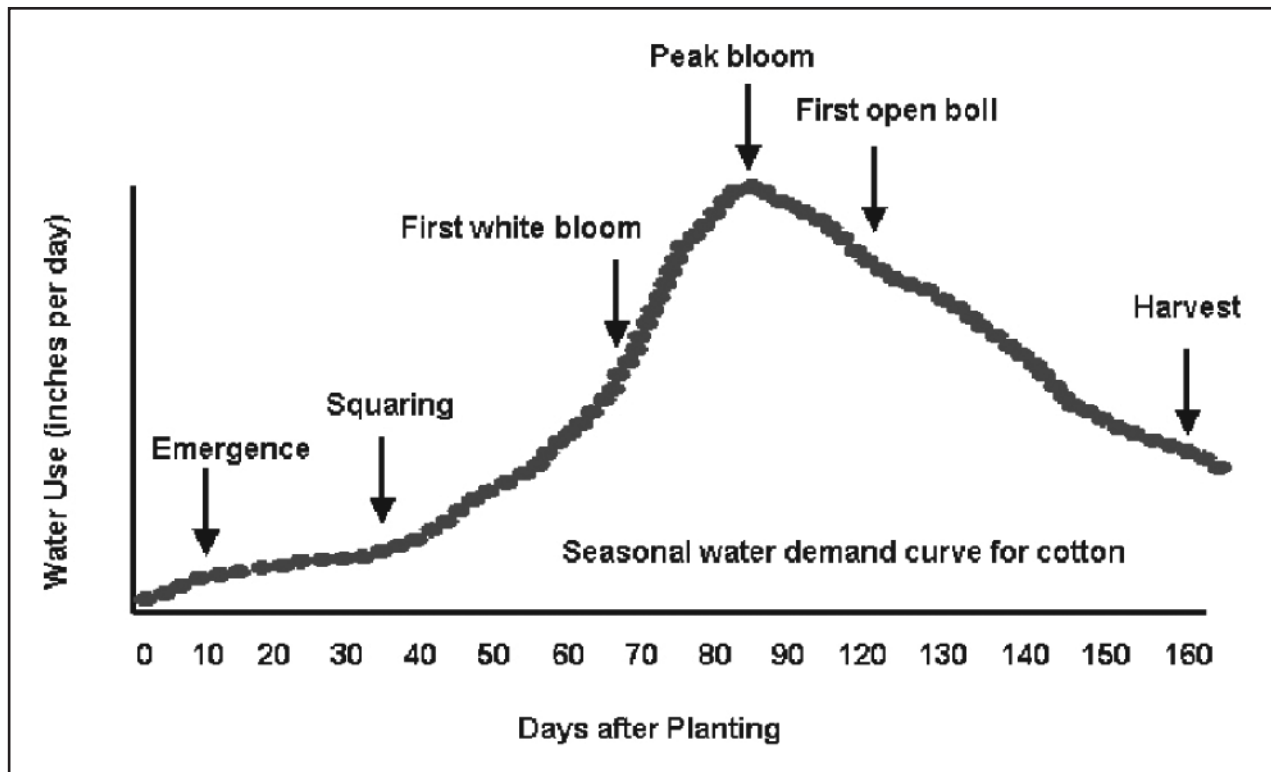
Germination to first square: Irrigate only to maintain growth and or as a carrier of nutrients.

1st Square – replace 30-35% of PET. Keep internodes length to 1.5-2inches, add 5% per week for 4 weeks. This may vary upon regional climates. An area of higher relative humidity might reduce this amount some according to internodes length. Be timely with your irrigations. Once this stage begins do not let the plants stress.

1st Flower – 50-55% PET. Add 10% per week for 4 weeks. Again, watch petiole reports, internodes lengths, fruit set, and cloudy weather and adjust if necessary. Manage weed populations in order to maximize water and fertilizer.

Peak Bloom – 90-95 % PET. This might be adjusted downward if the cotton has closed furrows and is holding moisture in the canopy. Also look for moisture surfacing in the furrow. If this occurs cut back on the time of irrigation and increase frequencies.

Irrigation needs to continue until cotton is at 25-50% open bole. If you cut off your irrigation too soon the top crop will not mature properly or just abort. If you have kept your moisture levels at optimum you can cut back 10% per week for three weeks to finish the cotton. This will allow for proper ripening and better defoliation.



The graph above shows the seasonal water demand curve.

INFLUENCE OF RAINFALL ON IRRIGATION

In many regions there is rainfall during the irrigation season. It is necessary to consider the quantity of water provided by the rainfall based on the soil condition and crop. The agronomical term “Effective Rainfall” refers to that part of rainfall that is considered as available water.

If the rainfall provides less than ¼ inch and is the first rain, there is no need to consider this amount as a water contribution to the soil. Stronger rainfall providing 1 inch or more must be taken in account according to the specific circumstances.

It is difficult to predict which part of rainfall is the effective rain. However, in the case of strong rainfall providing up to 2 inches, the effective rain may be no more than 60% of the total quantity. If a rainfall provides 2 inches or more, only 1 1/2 inch will be considered as effective rain and the rest will be runoff.

It is obvious that these calculations require a certain amount of interpretation. Hence, it is highly recommended to check the status of the water in the soil in the active root zone using the hands, soil drill or tensiometers before resuming irrigation. The use of tensiometer may provide valuable information, since the readings will indicate the presence of water in the root zone.

MONITORING SOIL MOISTURE

Measuring the soil moisture content is a good way to check and make adjustments to your irrigation schedule. In areas that receive significant rainfall soil moisture measurements are critical in assessing the amount of useful water received in a rain event.

There are several practical ways to assess soil moisture content. Experience irrigation specialists can use the “look and feel” method where the moisture level is determined by handling a soil sample. This is an excellent way to confirm the measurements given by more sophisticated equipment.

Tensiometers measure the strength which the soil is holding onto the water (soil matric potential). Tension is a measure of the work a plant must do to remove water from the soil. The higher the tension the harder the plant must work to remove water from the soil. Tension is usually expressed in bar or centibar (1bar = 100 centibar). The drier the soil, the more tightly the soil holds onto the water and the higher the tension measurement. The main drawback to tensiometers is that they require a certain skill to set-up and get to operate properly.

There are numerous sensors that measure the moisture content of the soil. The most common are moisture blocks but new sensors such as capacitance and resistance sensors are being developed all the time. Moisture content is a measurement of the water contained in the soil as a percentage of the volume of the entire soil solution. In general, sensors do not measure the moisture content directly but use an electronic calculation to infer the water content of the soil. Measurements expressed as moisture content can directly indicate how much water you need to apply to bring the soil to field capacity. The main drawback to these sensors is that they are sensitive to salts in the soil and water. Newer models do a good job of correcting for salt concentration but they may need to be calibrated more often than you think.

To get a complete picture of the water status of your soil it is best to take soil moisture measurements at several depths. Portable sensors can simply be inserted at different depths while inexpensive sensors can be buried permanently at the desired depth. Select a minimum of 2 sites to verify conditions across the field. Table 3 illustrates the information obtained by sensors at varied depths.

DEPTH BELOW SURFACE*	RESULT
6 inches	Reflects moisture content in the root zone in young or shallow rooted crops
12 inches	Monitors the root zone as plants mature and their root systems enlarge. This is the most active root zone.
24 inches	Monitors the degree of leaching below the root zone. The moisture level here should change little during drip irrigation.

Table 3. Sensor Depth.

MONITORING SOIL SALINITY

Even with low salinity water, salt can accumulate in the soil unless some leaching occurs. In addition to the salts that are in the soil and are a part of almost all irrigation water, fertilizers can add to the salt content. It is best practice to send irrigation water and soil samples to a lab for analysis. In problem areas consider purchasing an EC sensor which will give instantaneous readouts of water and soil salt conditions. If salt levels are found to be increasing over time it is necessary to include a leach factor to your irrigation system.

COTTON FERTILITY

Soil information is critical. Residual nutrients, nematode counts, root rot pressure, soil type, depth of soil, pH, and crop yield data all need to be evaluated. Netafim recommends soil samples pulled in 12 inch increments from one to three feet. This is especially recommended when cotton is following heavily fertilized vegetable crops. This lets the grower make fertility decisions from preplant to first injected fertigation. Excess nitrogen on drip cotton early season will only cause non productive vegetative growth or costly early season growth hormone applications.

Knowing your soil pH and residual nutrient level allows the farmer to plan his fertility program. Studies have shown that a cotton plant removes 50-65lbs of N and K and 20 lbs of P for every bale produced. Studies have also shown that most of that N&K are taken up from peak bloom to first open boll so heavy amounts of N are not needed early as typically applied to conventionally grown cotton. SDI allows the grower to apply the nutrients when needed and directly into the root area. This allows for the quickest response and most economical application.

Benefits of Fertigation

- Apply nutrients when needed
- Friendlier to environment
- Lower finance cost of fertilizer
- Less equipment across the field
- More uniform delivery
- Less exposure to elements
- More control of plant growth and response
- No mechanical root pruning
- Manage pH and EC
- Apply systemic chemicals for early pest control

On the opposite side, not fertilizing your crop enough could be just as detrimental. Cutting your crop short of phosphate coming into peak bloom could cause poor flower sets and fewer bales. Nutrients should be managed from preplant to 25% open bole. This will need to be done with both soil samples as well as timely leaf petiole samples throughout the season. Petioles should be taken every two to three weeks. In high pH soils always keep a close eye on the micro nutrient levels such as iron and zinc which are critical to bole set. Not all fertility needs to be injected through the drip system. As much as 50% of your P&K can be applied preplant with dry or liquid fertilizers. Proper placements of these fertilizers affect their availability. Banding preplant phosphate has proven to keep it available longer than broadcasting on top of soil and cultivating in. The remainder of your fertility can be injected into the system according to plant growth stage and petiole reports. Remember it normally takes 50-65 units of N to produce 1 bale of cotton. Keep this in mind when selecting varieties and yield potential. Here are our recommended rates:

Preplant

- 30-40 lbs of Nitrogen, take into account what shows on your soil samples
- 30-50 units of Phosphorous- some Nitrogen will come with this application
- 30-50 units of Potassium

1st square – 1st flower

- 40 lbs of Nitrogen per acre at 10 lbs per week
- Apply P&K as needed according to petiole recommendations

1st flower to peak bloom – balance of total N required. Total N required is based on potential yield at 50-65lbs of N /acre/bale. This yield is estimated on plant population, plant mapping, available water, and insect pressure.

Example – If your yield assessment is 3.6 bales/acre. $3.6 \times 60 \text{ units N} = 216\# \text{N}$

$216\# (40 \text{ PP} + 40 \text{ 1st flower}) = 136\#$ applied in the next 4-6 weeks depending upon the length of the growing season. Spread this out evenly over the 4-6 week period. Keep close watch on your K levels in your petiole tests. You will need to apply K with the N later in the season for lint and seed quality.

FERTILITY SUGGESTIONS

- Broadcast dry or liquid fertilizers are not recommended for use with SDI due to depth of placement in relation to the wetted drip area.
- P should be knifed in preplant, injected through drip system, or a combination of both.
- K can be injected at later stages according to petiole tests
- Composts can be applied seasonally to benefit soil microbial activity
- N should be managed throughout the entire growing season and applied through the drip system.

- Availability of most nutrients depends on soil pH
- Always consider the impact of the previous crop's residue on N application
- N and K are taken up by the plant with healthy roots so manage nematodes and seedling diseases.
- Foliar applied nutrients rarely correct deficiencies and are much less cost effective

Subsurface drip irrigation applies fertilizer directly to the root zone (Nutrigration). This is the most efficient method to deliver fertilizer, water, and chemicals to irrigated crops such as cotton. This ability to use the SDI system for delivering these inputs means more effective timing and utilization of fertilizers without the additional cost of traditional application practices thereby reducing both labor and energy. As a result it is possible to maintain a near optimum level of nutrients in the soil solution, available to the plants, helping promote plant health, production, and return per unit applied.

This guide is not meant as a complete treatise on cotton nutrition. It is meant as a guide to properly feed your crop using your SDI system. A more thorough approach to nutrient management in the Midwest is found in an appendix.

ESSENTIAL PLANT NUTRIENTS

Fourteen mineral elements are needed in varying amounts for plant growth (Table 4). The nutrients most often required by cotton are nitrogen, phosphorous, potassium, calcium, and magnesium and zinc. The remaining elements are also important but vary in amounts and frequencies which may vary by region.

Evaluating the nutrient status of your crop and soil is a key aspect of designing a fertility program for your cotton crop. This evaluation can be done by visual observation of previous crops, soil analysis and plant tissue testing. Using all three provides the best results. Always examine your crop looking for nutrient deficiencies that might exhibit symptoms such as light green streaking in the leaves common with zinc deficiency. Consult you local extension for visual guides for each of the nutrient deficiencies that are common in your region. Unfortunately visual symptoms can often be confused with insect injury, diseases and restricted root growth. In addition, once a deficiency results in a visual symptom there has already been a yield reduction. Therefore it is good to be familiar with deficiency symptoms in the odd case they are manifested during growth but more emphasis should be placed on soil and tissue samples.

Soils tests provide an estimate of nutrient availability for uptake by plants. Soil tests must be taken prior to planting and the soil amended based on the laboratories recommendations for cotton. If possible soil samples should be taken at a depth of 8 inches, 24 inches and sometimes 36 inches. This will give an indication about nutrient movement in the soil and uptake by the plants.

ESSENTIAL ELEMENTS	SYMBOL	APPLICATION
Nitrogen	N	Frequently
Phosphorous	P	Frequently
Potassium	K	Frequently
Calcium	Ca	Less Frequently
Magnesium	Mg	Less Frequently
Sulfur	S	Frequent
Iron	Fe	Less Frequent
Manganese	Mn	Less Frequent
Chlorine	Cl	Seldom
Boron	B	Seldom
Zinc	Zn	Frequent
Copper	Cu	Seldom
Molybdenum	Mo	Seldom
Nickel	Ni	Seldom

Table 4. The nutrients most often required by cotton are sulphur, phosphorous, potassium, boron, and molybdenum. Calcium and magnesium are also often required and are most often added during site preparation. The specific needs in your region may vary.

Therefore it is good to be familiar with deficiency symptoms in the odd case they are manifested during growth but more emphasis should be placed on soil and tissue samples.

Soils tests provide an estimate of nutrient availability for uptake by plants. Soil tests must be taken prior to planting and the soil amended based on the laboratories recommendations for cotton. If possible soil samples should be taken at a depth of 8 inches, 24" and sometimes 36 inches. This will give an indication about nutrient movement in the soil and uptake by the plants.

Taking soil samples from a drip irrigated field is slightly different than sprinkler or flood irrigated fields. The drip system creates a wetted area in the soil profile. Nutrients injected through the drip system are only found in this wetted area. It is important to sample within this wetted area to get a good assessment of the fertility of the soil. The goal is to test near the dripperline but not to hit it. This can be tricky. It is a good idea to develop some type of marker system so you can find an appropriate spot. Some growers rely solely on soil testing to determine their fertilizer regime during the life of the crop. However, it is more common to use tissue tests for this purpose. The objective of soil testing is to get a fertility map of the field. Samples should be taken from areas that are troublesome as well as productive regions often referred to as benchmark areas. The benchmark areas should be chosen so that they can be located year after year.



Plant tissue testing is by far the most precise method of determining the nutrient needs of cotton. Such tests are the best reflection of what nutrients the plant has taken up and are far more accurate than soil tests. Plant tissue tests give rapid feedback on the current fertility status of the plants and the effectiveness of fertilization.

Not all fertilizer formulations are suitable for injecting through your SDI system. The fertilizers must be soluble and have a low propensity for reacting with your water and forming precipitates. Table 5 lists many common fertilizers that are compatible with your drip system. Your local Netafim dealer will steer you in the right direction regarding fertilizers which are incompatible with your drip system.

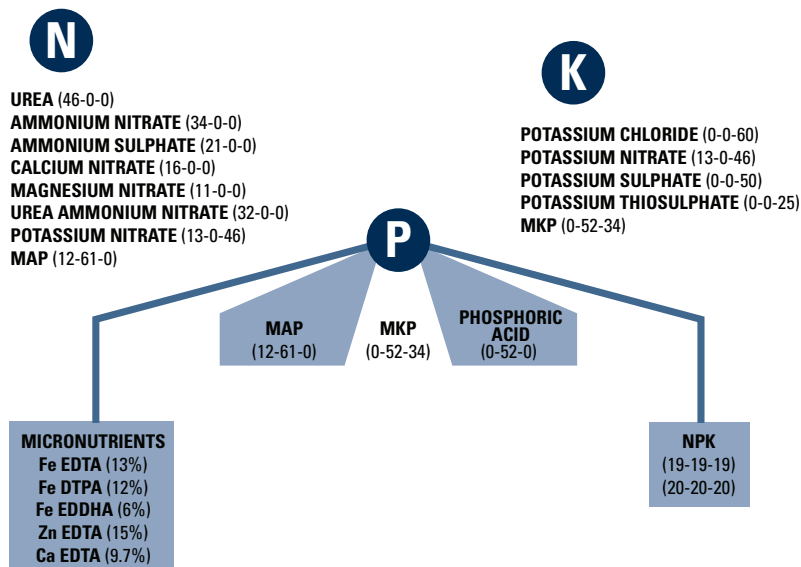


Table 5. Soluable fertilizers suitable for application through a drip system.

In areas where drip irrigation is prevalent fertilizer formulators can be found to produce the desired nutrient mix. In areas where fertilizer dealers are not familiar with fertilizers compatible with drip irrigation consult your local Netafim Dealer or representative.

When choosing the right fertilizer to put through your drip system of particular concern is elements that may react with each other or with your water and form precipitates which may clog your drip system. Polyphosphates (10-34-0 and 11-37-0 are not recommended to inject into SDI systems as they are highly reactive with Calcium and Magnesium in your water. Sulfates can also react with Ca and Mg to form gypsum in your dripperline. In most cases Micronutrients are supplied as chelates which are highly soluble and available to the plant.

NITROGEN

Nitrogen is one of the major plant nutrients required with cotton production. Paying close attention to application rates and timing will greatly affect return on investment. Nitrogen is also one of the most mobile nutrients that can be leached readily with excess water from rain or irrigations. The cotton plant doesn't require significant amounts of N until 3 weeks after germination. SDI eliminates the early preplant applications of large amounts of N that is common in growing furrow or sprinkler irrigated cotton.

PHOSPHOROUS

Phosphorous is also one of the major nutrients required for cotton, Starting off your field at appropriate phosphorous levels is critical to a good stand. Any good quality source of phosphorous can be incorporated in the field as a preplant. Cotton responds very well to liquid P starter fertilizers sprayed into the seed drill. In high pH soils it is not recommended to mix zinc with your P because it tends to tie up quickly in the soils and become unavailable to the plant. Phosphorous sources appropriate for application through the drip system include, Mono Ammonium Phosphate (MAP), Mono Potassium Phosphate (MKP) and phosphoric acid. MKP is expensive but it is highly soluble and is an excellent source of Potassium as well as Phosphorous. Again in high pH water it might be necessary to amend the water with sulphuric acid to lower the pH and keep the P in solution. Dry sources of P may also be used if placed in an area where the early root development will find it.

Phosphoric acid is good if the pH of the soil or water is a little high, but it is also expensive. When using Phosphoric acid be aware of high Ca and Mg levels in the water as they may react.

POTASSIUM

Potassium is the forgotten nutrient. It is often available in adequate amount but your crop will still respond to added potassium. There are several good choices for adding potassium through the drip system. Potassium chloride is generally the cheapest but Potassium sulfate, Ammonium thiosulfate, and Potassium thiosulfate are good choices if you need added sulphur. Mono Potassium Phosphate is an expensive but excellent source of Potassium and Phosphorous. Don't forget that cotton uses one unit of K for every unit of N applied. Keep a close watch on K levels in the tissue tests.

SULPHUR

It is important to have an adequate level of sulphur in the soil prior to planting. However, soil tests are not a reliable method for predicting sulphur deficiency in a growing crop. The best approach is to determine if there is a history of sulphur deficiency in your area. If Sulphur is needed, the most economical practice is to broadcast apply and incorporate elemental sulphur at 200 to 300 pounds per acre. At this rate elemental sulphur can last 4 to 7 years. The elemental sulphur will be gradually converted to the phytoactive sulphate form. To ensure a long slow release the particle size of the sulphur should range from 10 percent 100 mesh to 60 percent 6 mesh. The finer 100 mesh particles will convert to sulphate faster than the larger particles. A good source of S, K, and Mg is KMAG, a mined dry fertilizer Potassium Magnesium Sulfate. For injecting Sulphur through a SDI system KTS is a good source. This should be discussed.

IRON

Iron deficiency must be confirmed with a tissue test. Chelated Iron is the best choice for application through the drip system.

ZINC

Zinc is critical for square retention. Since it is not recommended to mix with preplant fertilizers all of the zinc should be applied through the drip at the 4 true leaf stage and again in two weeks at rates of 30 ounces per application. Make sure the zinc is in a form that is compatible with your water quality.

BORON

Cotton needs this nutrient early from germination to V5 and late in pollination to maturity. Watch tissue levels and apply when necessary. It is only required in very small amounts and is usually one of the minors supplied in common micro element packages added to liquid fertilizers.

CALCIUM AND MAGNESIUM

Calcium and Magnesium are important in the pollination production and pollination of the ear. The levels of these nutrients in the soil should be adjusted prior to planting. Alkaline water or soil can contain a lot of calcium and magnesium in comparison to potassium, which makes it important to apply maintenance potassium even if the soil analyses show adequate potassium levels. Gypsum and magnesium sulphate are good sources for these nutrients.

FERTIGATION

Fertigation is the application of liquid or dissolved water-soluble fertilizer through the irrigation system in a controlled and efficient manner. The best way to maximise the performance of cotton is to install a fertigation unit that will accurately inject fertilizers into the water supply for uptake by the crop.



Figure 9. Netafim fertilizer injection system.

Figure 9 is a more sophisticated irrigation control and fertigation system. This system controls multiple valves and has multiple injection pumps. It also allows you to monitor the EC and pH of your water during fertigation. This is important because with drip irrigation you are applying fertilizer mixed with water directly into the active root zone. Excess fertilizer such as N can cause the EC to increase to a level that could damage tender roots. Remember that most fertilizers are salts and too much is not good. Growers with poor quality water and complex irrigation requirements may be better served with such a system. Your Netafim Dealer can supply a system that is appropriate for your environment.

DRIP SYSTEM MAINTENANCE

The maintenance of your SDI system centers on identification of the factors which can lead to reduction of the performance of your drip system and procedures to mitigate these negative impacts. Factors that can slow or stop flow through the drip system include, suspended material, chemical precipitation, biological growth, root intrusion, soil ingestion and crimping of the dripperline. To ensure maximum system life requires that you reduce or eliminate the impact of the negative factors. This may require water treatment and a systematic program for regular maintenance. In this section we outline the various potential issues that can adversely affect your drip system and offer procedures to mitigate the potential damage.

WATER QUALITY

The type of emitter plugging problems will vary with the source of the irrigation water, either surface or ground water. In general, algal and bacterial growth are usually associated with the use of surface water. Whole algae cells and organic residues of algae are often small enough to pass through the filters of an irrigation system. These algal cells can then form aggregates that plug emitters. Residues of decomposing algae can accumulate in pipes and emitters to support the growth of slime-forming bacteria. Surface water can also contain larger organisms such as moss, fish, snail, seeds, and other organic debris that must be adequately filtered to avoid plugging problems. Groundwater, on the other hand, may contain high levels minerals that can challenge emitter function. Water from shallow wells (less than 100 ft) often will produce plugging problems associated with bacteria. Chemical precipitation is more common with deep wells.

A water quality analysis can give the grower a “heads up” on potential trouble areas for his drip system. This test should be accomplished before the final design of the system to ensure that proper components are installed to address any problem areas. Many laboratories around the United States have Water Quality Analysis services available which are able to conduct a “Drip Irrigation Suitability Test”. The analysis should include testing for pH, dissolved solids, manganese, iron, hydrogen sulfide, carbonate, and bicarbonates. Table 6 lists the more common water quality issues with drip irrigation. Having a water analysis in the moderate or even severe category does not mean drip irrigation cannot be used but only that special precautions must be applied to prevent problems. Consult your local Netafim dealer for more information on water quality and drip irrigation.

TYPE OF FACTOR	MINOR	MODERATE	SEVERE
SUSPENDED SOLIDS (ppm)			
INORGANIC	<10	10 - 100	>100
ORGANIC	<10		>10
CLOGGING			
IRON (ppm)	0.0 - 0.1	0.1 - 0.4	0.4+
MANGANESE (ppm)	0.0 - 0.2	0.2 - 0.4	0.4+
SULFIDES (ppm)	0.0 - 0.1	0.1 - 0.02	0.2+
CALCIUM CARBONATE	0.0 - 50.0	50.0 - 100.0	150.0+
BIOLOGICAL			
BACTERIA POPULATIONS	10,000	10,000 - 50,000	50,000+

Table 6. Water quality factors and their influence on your crop and drip system.

SUSPENDED SOLIDS

Suspended solids in the incoming water are the most common stress impeding upon your drip system and the easiest to control. Each and every Netafim dripper has a large filter built into the unit to keep suspended particle from being trapped in the labyrinth. This filter is located toward the center of the drip pipe so that it can be cleaned by flushing the dripperline. This built in filter plays an important role in the longevity of your SDI system. Thus, most water used for drip irrigation must be filtered to remove suspended solid particles that can lodge in the emitters and reduce or even stop the flow. These particles can be either organic such as algae or inorganic such as sand. Each manufacturer recommends a filtration level based on the technology of the emission device. The Netafim emitters commonly used for cotton production require 120 mesh filtration. This is the lowest filtration requirement of any commercial drip irrigation product. That means that the drippers are more reliable ensuring long service even under harsh conditions.

Surface water generally contains a combination of organic and inorganic suspended particles. These include algae, moss, aquatic animals as well as suspended sand, silt and clay particles. Filtering this mix of material is a challenge that is best accomplished using three-dimensional filtration, such as disc or sand media. Well water generally has lower levels of suspended solids which can be handled using disc filtration or in cases of very low contaminant levels screen filters. If large quantities of sand are being generated by the well the a sand separator may be installed before other filters. Filters for SDI should automatically clean (backflush) during operation when the contaminant levels get high enough (see Drip System Components for more information).

CHEMICAL PRECIPITATION

Chemical plugging usually results from precipitation of one or more of the following minerals: calcium, magnesium, iron, or manganese. The minerals precipitate from solution and form encrustations (scale) that may partially or completely block the flow of water through the emitter. Water containing significant amounts of these minerals and having a pH greater than 7 has the potential to plug emitters. Particularly common is the precipitation of calcium carbonates, which is temperature and pH dependent. An increase in either pH or temperature reduces the solubility of calcium in water, and results in precipitation of the mineral.

When groundwater is pumped to the surface and discharged through a microirrigation system, the temperature, pressure, and pH of the water often changes. This can result in the precipitation of calcium carbonates or other minerals to form scale on the inside surfaces of the irrigation system components. A simple test for identifying calcium scale is to dissolve it with vinegar. Carbonate minerals dissolve and release carbon dioxide gas with a fizzing, hissing effervescence.

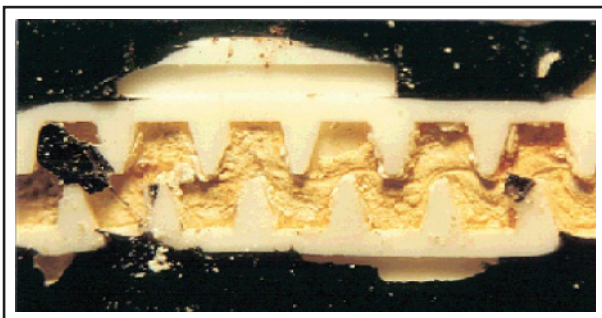


Figure 10. Dripper with calcium precipitate. The black pieces in the picture are pieces of the cut-away plastic dripperline and not contaminates.

Iron is another potential source of mineral deposit that can plug emitters. Iron is encountered in practically all soils in the form of oxides, and it is often dissolved in groundwater as ferrous bicarbonate. When exposed to air, soluble ferrous bicarbonate oxidizes to the insoluble or colloidal ferric hydroxides and precipitates. The result is commonly referred to as 'red water,' which is sometimes encountered in farm irrigation wells. Manganese will sometimes accompany iron, but usually in lower concentrations.

Hydrogen sulfide is present in many wells. Precipitation problems will generally not occur when hard water, which contains large amounts of hydrogen sulfide, is used. Hydrogen sulfide will minimize the precipitation of calcium carbonate (CaCO_3) because of its acidity.

Fertilizers injected into a drip system may contribute to plugging. This may be the result a chemical reaction that occurs when different fertilizers are mixed or because the fertilizer in question is not completely soluble. This type of plugging is completely preventable. To determine the potential for plugging problems from fertilizer injection, the following test can be performed:

1. Add drops of the liquid fertilizer to a sample of the irrigation water so that the concentration is equivalent to the diluted fertilizer that would be flowing in the lateral lines.
2. Cover and place the mixture in a dark environment for 12 hours.
3. Direct a light beam at the bottom of the sample container to determine if precipitates have formed. If no apparent precipitation has occurred, the fertilizer source will normally be safe to use in that specific water source.

BIOLOGICAL GROWTH

A microirrigation system can provide a favorable environment for bacterial growth, resulting in slime buildup. This slime can combine with mineral particles in the water and form aggregates large enough to plug emitters. Certain bacteria can cause enough precipitation of manganese, sulfur, and iron compounds to cause emitter plugging. In addition, algae can be transported into the irrigation system from the water source and create conditions that may promote the formation of aggregates. Emitter plugging problems are common when using water that has high biological activity and high levels of iron and hydrogen sulfide. Soluble ferrous iron is a primary energy source for certain iron-precipitating bacteria. These bacteria can attach to surfaces and oxidize ferrous iron to its insoluble ferric iron form. In this process, the bacteria create a slime that can form aggregates called ochre, which may combine with other materials in the microirrigation tubing and cause emitter plugging. Ochre deposits and associated slimes are usually red, yellow, or tan.

Sulfur slime is a yellow to white stringy deposit formed by the oxidation of hydrogen sulfide. Hydrogen sulfide (H_2S) accumulation in groundwater is a process typically associated with reduced conditions in anaerobic environments. Sulfide production is common in lakes and marine sediments, flooded soils, and ditches; it can be recognized by the rotten egg odor. Sulfur slime is produced by certain filamentous bacteria that can oxidize hydrogen sulfide and produce insoluble elemental sulfur.

The sulfur bacteria problem can be minimized if there is not air-water contact until water is discharged from the system. Defective valves or pipe fittings on the suction side of the irrigation pump are common causes of sulfur bacteria problems. If a pressure tank is used, the air-water contact in the pressure tank can lead to bacterial growth in the tank, clogging the emitter. The use of an air bladder or diaphragm to separate the air from the water should minimize this problem.

ROOT INTRUSION

Plant roots tend to grow toward soil areas with the highest water content. Because of this tendency, roots can clog subsurface drip systems by growing into the emitter openings. Plant roots tend to "hunt" for water when it is in short supply thus, the problem seems to be more acute in when irrigation is not sufficient for the plant needs. This is a particular problem in systems that are left unused for part of the season. Several strategies can be employed to reduce the possibility of root intrusion.



Figure 11. Filamentous sulfur slime completely clogging a small water meter.

1. Short frequent irrigations keep adequate water in the root zone so the roots have no need to look for water.
2. Acid injection that lowers the pH to less than 4 will discourage root growth and can be used to clean roots out of emitters with small amounts of root intrusion. High concentrations of chlorine (100 to 400 ppm), N-pHURIC, phosphoric or metam sodium (Vapam) will also destroy roots in the emitters.
3. In areas where it is allowed, trifluralin is an effective inhibitor of root growth and can be used to prevent root intrusion.
4. Seamed tape encourages roots to grow along the seam and into the emitter. Netafim Products are designed without a seam to discourage this intrusion.

SOIL INGESTION

Soil ingestion is not a problem in properly designed SDI systems. Soil injection occurs when soil is sucked into the drip tape. When a drip system is shut off the water continues to flow to the low end of the field creating a vacuum at the higher end, sucking saturated soil into the line. A properly designed drip system will minimize this potential problem. Supply manifold must be equipped with vacuum relief valves. These valves allow air to flow into the dripperlines when the system is shut off. Use high quality Netafim/ARI valves that will allow sufficient air into the system. Insufficient air will create a vacuum the same as no valve. This is not a good place to skimp.

MAINTENANCE PROCEDURES

Filter Maintenance

Follow the standard instructions for the maintenance of your filter system. Filters are the first line of protection for your drip system and they need regular maintenance to operate at a high level. On a biweekly basis observe the system as it completes a backflush cycle. Make sure all pressures are within the system limits before and after backflushing. Check the operation of backflush valves, pressure differential switches and controller. Make sure you clean the command filter! At the end of the season check the media level in media tanks. Scum can build up on disc filters and the discs may need to be cleaned with acid. In areas that experience a freeze drain all water from the filter, valves and command system!

Dripperline Flushing

To minimize sediment build up, regular flushing of drip irrigation pipelines is recommended. The system design should be such that a minimum flush rate of 1.5 ft/sec can be obtained in the lines. Valves large enough to allow sufficient velocity of flow should be installed at the ends of mains, submains, and manifolds. Also, allowances for flushing should be made at the ends of lateral lines. Begin the flushing procedure with the mains, then proceed to submains, manifolds, and finally to the laterals. Flushing should continue until clean water runs from the flushed line for at least two minutes. A regular maintenance program of inspection and flushing will help significantly in preventing emitter plugging. Flushing is required both at system startup and shutdown. At shutdown it is best to flush all fertilizer from the lateral lines prior to shutting the irrigation system down.

Chemical Treatment

Chemical treatment is often required to prevent emitter plugging due to microbial growth and/or mineral precipitation. The attachment of inorganic particles to microbial slime is a significant source of emitter plugging. Chlorination is an effective measure against microbial activity. Use chlorine and all other chemicals only according to label directions. Acid injection can remove scale deposits, reduce or eliminate mineral precipitation, and create an environment unsuitable for microbial growth.

CHLORINE INJECTION

Overview

Chlorination is the most common method for treating organic contaminants. Active chlorine is a strong oxidizer and as such, is useful in achieving the following:

- A. Prevent clogging and sedimentation of organic substances.
- B. Destroy and decompose sulfur and iron bacteria, as well as accumulated bacterial slime in the system.
- C. Improve performance of filtration systems while reducing back flush water.
- D. Clean systems of organic sediments. (Chlorine has no effect on scale deposits.)

If the microirrigation system water source is not chlorinated, it is a good practice to equip the system to inject chlorine to suppress microbial growth. Since bacteria can grow within filters, chlorine injection should occur prior to filtration.

Liquid sodium hypochlorite (NaOCl)--laundry bleach--is available at several chlorine concentrations. The higher concentrations are often more economical. It is the easiest form of chlorine to handle and is most often used in drip irrigation systems. Powdered calcium hypochlorite (CaCOCl₂), also called High Test Hypochlorite (HTH), is not recommended for injection into micro-irrigation systems since it can produce precipitates that can plug emitters, especially at high pH levels. The following are several possible chlorine injection schemes:

- Inject continuously at a low level to obtain 1 to 2 ppm of free chlorine at the ends of the laterals.

- Inject at intervals (once at the end of each irrigation cycle) at concentrations of 20 ppm and for a duration long enough to reach the last emitter in the system.
- Inject a slug treatment in high concentrations (50 ppm) weekly at the end of an irrigation cycle and for a duration sufficient to distribute the chlorine through the entire piping system.

The method used will depend on the growth potential of microbial organisms, the injection method and equipment, and the scheduling of injection of other chemicals.

When chlorine is injected, a test kit should be used to check to see that the injection rate is sufficient. Color test kits (D.P.D.) that measure ‘free residual’ chlorine, which is the primary bactericidal agent, should be used. The orthotolidine-type test kit, which is often used to measure total chlorine content in swimming pools, is not satisfactory for this purpose. D.P.D. test kits can be purchased from irrigation equipment dealers. Check the water at the outlet farthest from the injection pump. There should be a residual chlorine concentration of 1 to 2 ppm at that point. Irrigation system flow rates should be closely monitored, and action taken (chlorination) if flow rates decline.

Chlorination for bacterial control is relatively ineffective above pH 7.5, so acid additions may be necessary to lower the pH to increase the biocidal action of chlorine for more alkaline waters. Since sodium hypochlorite can react with emulsifiers, fertilizers, herbicides, and insecticides, bulk chemicals should be stored in a secure place according to label directions.

Recipe for Chlorine injection

WARNING!! Active chlorine solutions are dangerous to human beings and animals. So, the manufacturers’ instructions must be followed very carefully. When using chlorine, proper protection for the eyes, hands, and body parts must be worn, i.e. glasses, gloves, shoes, etc. Chlorine contact with the skin can cause serious burns, contact with the eyes can cause blindness, and swallowing may be fatal. Prior to filling any tank with chlorine solution, be sure it is absolutely clean of fertilizer residue. Direct contact between chlorine and fertilizer can create a thermo-reaction, which can be explosive. This is extremely dangerous!! The direct contact of chlorine and fertilizer in the irrigation water after it has been injected into the system is not hazardous.

The contact of free chlorine in water and nitrogenous (ammonium and urea) fertilizer creates the combination of chlor-amine which is called “combined chlorine”. Hence, if possible, avoid any application of ammonium or urea fertilizers together with chlorination. **In the case that chlorination is required, it is recommended to ask your local Farm Extension Service for assistance in the computation and application methods.** Sodium hypochlorite is transported by tanks. It should be stored in a clean tank without any remnants of fertilizers. The tanks should be painted white and placed in a shaded area. In field storage should not exceed 20 days. In case of gas chlorine, transportation, storage and general handling should be carried out in accordance with the manufacturers’ specific instructions under supervision of the relevant authorities.

CONCENTRATION AND INJECTION POINT

It is important to remember that chlorine concentration decreases as time and distance from the injection point increases. The lowest concentration will always be found furthest from the injection point. The injection point should be as close as possible to the treated system. The required concentration of active chlorine is a result of the chlorination objective.

CHLORINATION OBJECTIVE	APPLICATION METHOD	REQUIRED CONCENTRATION (PARTS PER MILLION)	
		SYSTEM HEAD	SYSTEM END
PREVENT SEDIMENTATION	CONTINUOUS CHLORINATION	3 - 5	0.5 - 1
	INTERMITTENT CHORINATION	10	1 - 2
SYSTEM CLEANING	CONTINUOUS CHLORINATION	5 - 10	1 - 2
	INTERMITTENT CHORINATION	15 - 50	4 - 5

When the purpose of chlorination is improving filtration performance, the injection point should be close to the filtration plant to assure even distribution throughout the filters. Chlorine concentration downstream of the filter battery should be no less than 1-2 p.p.m. for constant chlorination and three times more for intermittent chlorination.

For continuous chlorination, the injection should start after pressurizing the system. For intermittent chlorination, the procedure should be as follows:

START	By flushing the system.
INJECTION	Inject required amount over time, preferably at the beginning of the cycle.
CONTACT TIME	Preferably one hour, but not less than thirty minutes.
FLUSH	At the end of the process, open the end of the line, flush out and run fresh water for an hour.

CALCULATIONS - Liquid Chlorine

Use the following worksheets to determine the proper injection rate of chlorine in terms of GPH for liquid and lbs./hr for gas.

- Choose the proper chlorine solution factor:
 - 5% Chlorine Solution: The factor is = 2.00
 - 10% Chlorine Solution: The factor is = 1.00
 - 15% Chlorine Solution: The factor is = 0.67
- Multiply the solution factor by the treated flow in terms of GPM.
- Multiply by the desired chlorine concentration in terms of ppm.
- Multiply by the factor of 0.0006.
- The result will be the required injection rate of chlorine in terms of GPH

FOR EXAMPLE: The chlorine solution is 10%. The flow is 100 GPM.
The desired chlorine concentration is 10 ppm.

$$\text{Chlorine Solution Factor} \times \text{Flow GPM} \times \text{Desired Chlorine concentration (ppm)} \times 0.0006 = \text{Chlorine Injection Rate GPH}$$

$$10 \times 100 \times 10 \times 0.0006 = 0.6$$

The injection rate of chlorine solution will be 0.6 GPH

CALCULATIONS - Chlorine Gas

- Determine the flow of the treated zone in terms of GPM.
- Multiply the flow by the desired chlorine concentration in terms of ppm.
- Multiply it by the factor of 0.0005.
- The result will be the injection rate of the gas in terms of lbs. per hour.

FOR EXAMPLE: The flow is 100 GPM. The desired chlorine concentration is 10 ppm.

$$\text{Flow GPM} \times \text{Desired Chlorine Concentration (ppm)} \times 0.0005 = \text{Chlorine Injection Rate (lbs./hr)}$$

$$100 \times 10 \times 0.0005 = 0.5$$

The injection rate of the gas will be 0.5 lbs./hr.

ACID INJECTION OVERVIEW

Acid can be used to lower the pH of irrigation water to reduce the potential for chemical precipitation and to enhance the effectiveness of the chlorine injection. Sulfuric, hydrochloric, and phosphoric acid are all used for this purpose. Acid can be injected in much the same way as fertilizer; however, extreme caution is required. The amount of acid to inject depends on how chemically base (the buffering capacity) the irrigation water is and the concentration of the acid to be injected. One milliequivalent of acid completely neutralizes one milliequivalent of bases.

If acid is injected on a continuous basis to prevent calcium and magnesium precipitates from forming, the injection rate should be adjusted until the pH of the irrigation water is just below 7.0. If the intent of the acid injection is to remove existing scale buildup within the microirrigation system, the pH will have to be lowered more. The release of water into the soil should be minimized during this process since plant root damage is possible. An acid slug should be injected into the irrigation system and allowed to remain in the system for several hours, after which the system should be flushed with irrigation water. Acid is most effective at preventing and dissolving alkaline scale. Avoid concentrations that may be harmful to emitters and other system components.

Phosphoric acid, which is also a fertilizer source, can be used for water treatment. Some microirrigation system operators use phosphoric acid in their fertilizer mixes. Care should be used with the injection of phosphoric acid into hard water since it may cause the precipitation of calcium phosphate.

For safety, dilute the concentrated acid in a non-metal, acid-resistant mixing tank prior to injection into the irrigation system. When diluting acid, always add acid to water, never water to acid. The acid injection point should be beyond any metal connections or filters to avoid corrosion. Flushing the injection system with water after the acid application is a good practice to avoid deterioration of components in direct contact with the acid.

Acids and chlorine compounds should be stored separately, preferably in epoxy-coated plastic or fiberglass storage tanks. Acid can react with hypochlorite to produce chlorine gas and heat; therefore, the injection of acid should be done at some distance (2 feet), prior to the injection of chlorine. This allows proper mixing of the acid with the irrigation water before the acid encounters the chlorine.

Hydrochloric, sulfuric, and phosphoric acids are all highly toxic. Always wear goggles and chemical-resistant clothing whenever handling these acids. Acid must be poured into water; never pour water into acid.

RECIPE FOR THE TREATMENT OF DRIP IRRIGATION SYSTEMS WITH ACID

SAFETY PRECAUTIONS: Contact of the acid with the skin can cause burns. Contact with the eyes could be extremely dangerous. During treatment, and especially when filling containers with acid, wear protective goggles, clothes and boots. Follow the instructions on the Material Safety Data Sheet (M.S.D.S.) attached to the delivered acid.

PROBLEMS OF CORROSION: Polyethylene and PVC tubes are resistant to acid. Aluminum, steel, (with or without inner concrete coating) and asbestos-cement pipes are damaged by corrosion. In every case, resume normal water flow through the system after completion of treatment for at least one hour in order to flush any remaining acid. The importance of flushing cannot be over emphasized when the pipes used are particularly sensitive to corrosion.

METHOD OF OPERATION: Acid can be applied through the drip-irrigation system by a fertilizer pump resistant to acids or by conventional control head with a fertilizer tank.

APPLICATION OF ACID BY FERTILIZER PUMP

The goal of acid treatment is to lower the pH level of the water in the irrigation system to values between two to three for a short time (twelve - fifteen minutes). This is achieved by injection of a suitable quantity of acid into the system.

INSTRUCTIONS:

1. Clean the filters.
2. Flush the system with clean water as follows: flush the main pipes then the distribution pipes and finally the drip laterals. Use the highest pressure possible for flushing. Deactivate the pressure regulators and flush the laterals, a few at a time. Flushing with clean water will prevent blockages during treatment.
3. Ascertain the discharge of the water from the system through which the acid will be injected, and the discharge of the fertilizer pump.
4. Calculate the required amount of acid that should be injected into the system in order to get 0.6% of acid concentration in the irrigation water.
5. Inject the acid into the system within fifteen minutes only after the system has reached maximum operation pressure.

NOTE: Acids suitable to be injected in 0.6% concentrations are:

Nitric acid	60%
Phosphoric acid	75%- 85%
Sulfuric acid	90%- 96%
Hydrochloric acid	30%- 35%

In many cases the most economical acids are sulfuric acid (battery acid) and hydrochloric acid (swimming pool acid).

CALCULATION METHOD:

The injection rate of the acid to the treated zone can be calculated as follows:

Injection rate in GPH = (System flow in GPM) X (0.36/acid % in decimal form)

FOR EXAMPLE: Sulfuric acid 90% and system flow is 100 GPM.

$100 \times (0.36/0.9) = 40 \text{ GPH}$

Because the acid is to be injected only 15 minutes the total acid required is 10 gallons

NOTE: Under certain conditions, i.e., hard water with a very high pH, there might be a need to raise the acid concentrate in the system to 1%. Please consult a Netafim USA Representative prior to such a treatment.

IRON CONTROL SYSTEM FOR DRIP IRRIGATION

INTRODUCTION

Iron deposits create severe clogging problems in drip systems. Iron deposit is described as a filamentous amorphous gelatinous type of brown-reddish slime, that precipitates from water that contains iron. Iron deposits get stuck in drippers and cause complete plugging of the system.

The problem exists in well water areas where the groundwater aquifers are formed mainly of sandy soils or organic muck soils

(very common in Florida) usually with a pH of below 7.0 and in the absence of dissolved oxygen. These waters contain ferrous iron (Fe+2) which is chemically reduced, 100% water soluble and serves as the primary raw material for slime formation.

Iron bacteria, mainly from the filamentous genres like Gallionella Sp. Leptothrix and Sphaerotilus and less from the rod type like Pseudomonas and Enterobacter, when present in the water, react with the ferrous iron (Fe+2) through an oxidation process. This changes the iron form to ferric iron (Fe+3) which is insoluble. The insoluble Ferric iron is surrounded by the filamentous bacteria colonies that create the sticky iron slime gel that is responsible for clogging the dripper.

Concentrations of ferrous iron as low as 0.2 ppm are considered as a potential hazard to drip systems (H.W. Ford 1982). Between 0.2-1.5 ppm emitter clogging hazard is moderate. Concentrations above 1.5 ppm are described as severe (Bucks and Nakayama -1980). Practically any water that contains concentrations higher than 0.5 ppm of iron cannot be used in drip systems unless they are treated chemically or otherwise. Experiments in Florida indicate that chlorination successfully controls iron slime when iron concentrations were less than 3.5 ppm and the pH was below 6.5 (Nakayama and Bucks -1986). It is also stated that long term use of water with a high level of iron, may not be suitable for drip irrigation. The literature mentions that water containing more than 4.0 ppm cannot be efficiently chemically treated and it should undergo a pond sedimentation process before pumping it back to a drip system.

IRON CONTROL METHODS

There are several ways to control iron slime problems. The common denominator of all treatments is prevention of the formation of slime. Basically there are two preventive treatments:

1. STABILIZATION (Precipitation Inhibitors)

Stabilization treatments keep the ferrous iron in solution by chelating it with sequestering agents. Such agents include various poly phosphates and phosphonate.

2. OXIDATION - SEDIMENTATION - FILTRATION

This type of treatment oxidizes the soluble "invisible" ferrous iron into the insoluble "visible" ferric iron, it then will precipitate, so it can be physically separated from the water by means of filtration.

The second procedure is generally the less expensive for the severe iron problems in supply water. The various means to oxidize iron include chlorination, and aeration. There are also other oxidizers but they are generally more expensive. Chlorine injection for iron control is normally handled in the same manner as continuous chlorine injection outlined above, with residual chlorine levels of 1 to 2 ppm. Aeration is most often applied to settling ponds using sprayers or agitators to react the Iron with the air. In this case the pond becomes a pre-filtration component.

SEDIMENTATION - FILTRATION

A sand media filter is the most appropriate filter for settling down the oxidized iron and filtering it from the water. When designing a filtration system for iron removal it is good practice to oversize the filter units. Larger units with slower water velocity will allow oxidized iron to settle and the resultant water will be easier to filter. This is the same principle as exhibited in settling ponds.

Scale Inhibitors

Scale inhibitors, such as chelating and sequestering agents, have long been used by other industries. A number of different chemicals are being marketed for use in microirrigation systems to prevent plugging. Many of these products contain some form of inorganic polyphosphate that can reduce or prevent precipitation of certain scale-forming minerals. These inorganic phosphates do not stop mineral precipitation, but keep it in the sub-microscopic range by inhibiting its growth. Probably the most commonly used of these materials is sodium hexametaphosphate -- as little as 2 ppm can hold as much as 200 ppm calcium bicarbonate in solution.

Sodium hexametaphosphate is not only effective against alkaline scale, but also forms complexes with iron and manganese and can prevent depositions of these materials. Although the amount of phosphate required to prevent iron deposits depends on several factors, a general recommendation is 2 to 4 ppm phosphate for each ppm of iron or manganese.

These phosphates are relatively inexpensive, readily soluble in water, nontoxic, and effective at low injection rates.

Pond Treatment

Algae problems which often occur with surface water sources such as a pond can be effectively treated with copper sulfate (CuSO_4). Dosages of 1 to 2 ppm (1.4 to 2.7 pounds per acre foot) are sufficient and safe to treat algae growth. Copper sulfate should be applied when the pond water temperature is above 60°F. Treatments may be repeated at 2 to 4-week intervals, depending on the nutrient load in the pond. Copper sulfate should be mixed into the pond (i.e., sprinkled into the wake of a boat). The distribution of biocides into surface water must be in compliance with EPA regulations.

Copper sulfate can be harmful to fish if alkalinity, a measure of the water's capacity to neutralize acid, is low. Alkalinity is measured volumetrically by titration with H_2SO_4 and is reported in terms of equivalent CaCO_3 . Repeated use of copper sulfate can result in the buildup to levels toxic for plants.



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