SUB SURFACE DRIP IRRIGATION (SDI) SYSTEMS HANDBOOK

Advanced Drip Irrigation Technologies

2022
v 1.0

NETAFIM™
GROW MORE WITH LESS

FOREIGN LANGUAGES

In the event that you are reading this manual in a language other than the English language, you acknowledge and agree that the English language version shall prevail in case of inconsistency or contradiction in interpretation or translation.

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INTRODUCTION

Introduction

Quality and dependability from the leaders in drip irrigation

For more than 55 years, growers world-wide have counted on Netafim™ for the most reliable, cost-effective and efficient ways to deliver water, nutrients and chemicals to their crops. This tradition continues with sub surface drip irrigation (SDI), an advanced method for irrigating agricultural crops. With proper management of water and nutrients, a sub surface drip irrigation system can deliver maximum yields and optimal water use efficiencies.

Over the years, Netafim™ has developed various products and methods, tools, and accessories that gradually improved sub surface drip irrigation and turned it into a reliable irrigation method. Despite the many years of continuous research on SDI, it was only in the 1990's that the "doctrine" of sub surface drip irrigation was fully formulated, including the development of specific products especially suited for SDI.

Currently, numerous types of crops are irrigated using SDI, the major ones being sugarcane, cotton, ornamental gardens, fruit orchards and vegetables.

SDI experiments are currently being conducted in agricultural research institutes throughout the world, with many large universities having special departments engaged in extensive research into the doctrine and practices of SDI.

Sub surface drip Irrigation (SDI) often results in increased production and yields as well as increased quality and uniformity. It provides more efficient use of the applied water resulting in substantial water savings. The flexibility of drip irrigation increases a grower's ability to farm marginal land.

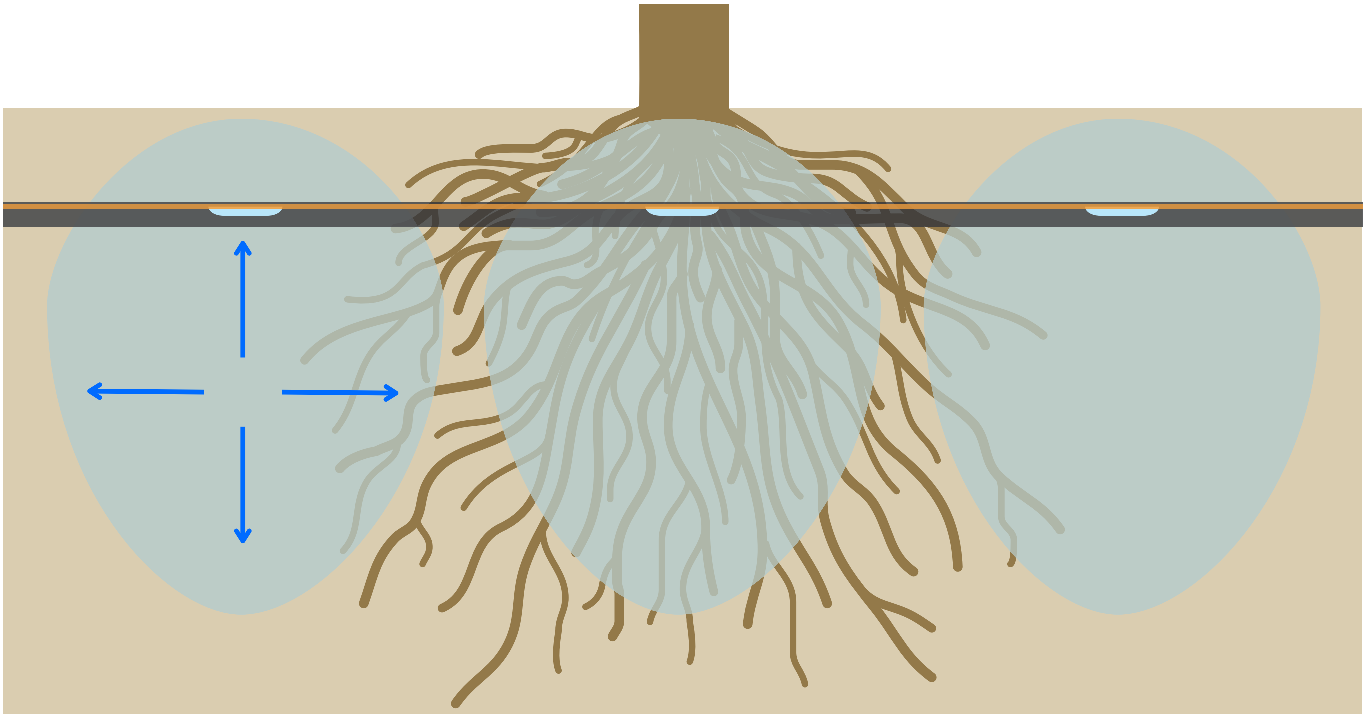
Netafim™ has accumulated extensive experience in sub surface drip irrigation in nearly every country in the world and in a wide variety of crops.

Nowadays, sub surface drip irrigation is an accepted and common practice. SDI is an irrigation management tool that enables precise control over the root zone environment of your crop. This control often results in consistently high yields. In addition, better water, nutrients and fertilizer management help reduce fertilizer inputs, water usage, and runoff.

This guide describes the specifications, design, installation, operation, products, tools and maintenance of a SDI system. It is intended as an aid in the selection of sub surface drip irrigation technology and the management of this technology to obtain the desired results.

What is sub surface drip irrigation (SDI)?

Sub surface drip irrigation is a variation on traditional drip irrigation where the dripline (tubing and drippers) is injected beneath the soil surface, rather than laid on the ground, supplying water directly to the roots. The depth and distance the dripline is placed depends on the soil type and the plant's root structure. SDI is more than an irrigation system; it is a root zone management tool. Fertilizer and/or nutrients can be applied to the root zone in a quantity in which it will be most beneficial - resulting in greater efficiencies and better crop performance, lower evaporation, fewer weeds and multiple other benefits.



Water movement in SDI systems

When applied slowly to the soil at a single point, water moves through the soil in two directions:

1. Downward pulled by gravity forces.
2. Sideways and upward, pulled by capillary forces.

Dripline injection depth

Depth depends on the soil type and the plant's root structure. The depth normally determining dripline insertion ranges between:

- Shallow*: Up to 10 cm (Single season crops)
- Medium: 10-25 cm (Semi permanent crops)
- Deep: 25-40 cm (Permanent crops)

* In many installations when deploying thin wall driplines, the driplines are injected 2 to 5 cm below the soil surface to prevent wind damage of driplines installed on the surface.

Sub surface drip irrigation (SDI) advantages

The key benefit of a sub surface drip irrigation system is to apply low volumes of water and nutrients uniformly to every plant across the entire field. SDI delivers many advantages beyond surface irrigation.

Agricultural advantages

- Keeps surface soil dry
- Reduces weeds population, reduces fumigation use and cost
- Reduces danger of root neck diseases
- Reduces soil compaction, less tillage
- Prevents surface runoff
- Shortens time between crop cycles, increases yield
- Improves fertilization efficiency (particularly phosphorus availability)
- Improves water consumption efficiency

Ecological advantages

- Usage of recycled water for SDI (vegetables - FDA approval), reduces water costs and fertilizers application
- Reduces the need for herbicides
- Reduces nutrients and fertilizers quantities – dripline is located in the middle of the root system
- Reduces CO_2 emissions
- Reduces evaporation

Technical advantages

- Reduces mechanical damage to irrigation system; prevents damage by animals and theft
- Reduces manpower costs (Opex) – no need to lay out or recoil equipment every season
- Facilitates equipment mobilization - no limitations on operating machinery in the field (sowing, harvesting, etc.)
- Extends the irrigation system's work life

Commercial advantages

- Reduces manpower costs (Opex)
- Reduces energy costs (tractors, pumps)
- Less herbicides, nutrients and fertilizers
- Reduces/eliminates cultivation
- Increases profitability
- Extends irrigation system's work life

When should SDI be used?

Before taking a decision about whether to install a sub surface irrigation system the following topics must to be evaluated:

- Long-term land ownership, for long-term investment
- Large-scale growers and projects, less labor costs than on surface drip irrigation
- Areas with high labor costs - SDI requires less labor
- Areas with labor shortages - SDI requires less labor
- Zero or minimum tillage
- Areas with water shortages - SDI saves an additional ~15% of water compared to on surface drip
- Areas with high insurance costs - SDI costs less than other methods

Common crops grown with SDI

Field crops	**Orchards**	**Vegetables**
Cotton	Vineyards	Processing tomatoes
Sugarcane	Almonds	Potatoes
Alfalfa	Olives	
Corn	Coffee/Tea	
Soybean	Fruit trees	
Sunflower	Avocado	

Myths vs facts

- **Irrigation systems aren't needed in areas with good amounts of rainfall**
  A drip system is a delivery system. It enables you not only to apply water when needed (e.g. during dry periods) and to eliminate the risk of crop stress, but also, more importantly, to apply fertilizer. It's been proven that irrigation together with fertigation in rain-fed areas can increase yield.

- **Drip is hard to operate and labor-intensive**
  A drip system is very simple to handle, since it has no moving parts, motors or gears; it's basically a conduction system comprised of pipes and valves. Since drip systems are computer-operated, most operations can be carried out from remote, using mobile phone or desktop computer, and allow you to handle hundreds of hectares on your own.

- **Drip requires extensive maintenance**
  Drip doesn't require any more maintenance than other farm machinery. The farmer needs to flush the driplines a few times a year, and apply acid or chlorine once per season to clean the system.

- **Drip doesn´t fit my field or farm**
  Drip irrigation systems are suitable for all plot shapes and sizes, all slopes, and all soil types.

/ ACHIEVING SUCCESS

Achieving success

Critical aspects that need to be considered in order to achieve success in SDI

- Land preparation is essential for the future performance of the system and should be applied throughout the entire area at the initial stage of the project.
- Additional irrigation. In most crop areas, SDI provides enough moisture to germinate the crop. However, in some very dry areas, sprinklers or flood irrigation may also be needed for crop emergence and stand establishment.
- Regular maintenance. An SDI system requires regular maintenance to ensure that it performs to specification, since this is long-term permanent irrigation system.
- Logging and recording. SDI is more than a watering device, it is a root-zone management tool. To receive the maximum benefit requires careful recording of crop and system activity.
- Long-term planning. Given the potential long life and cost of the SDI system, crop rotation and cultivation practices such as deep cultivation must be considered when formulating an SDI plan.
- Insects and Rodent management. Rodents can damage an SDI system as well as the crop. A rodent management plan must be implemented.

Site evaluation - selecting the best emission device for your application

Site evaluation is the first step in developing a successful SDI system. It requires assessments of the water quality and availability, soil and topography. Listed below are some general guidelines to help in the selection of an emission device for your specific application.

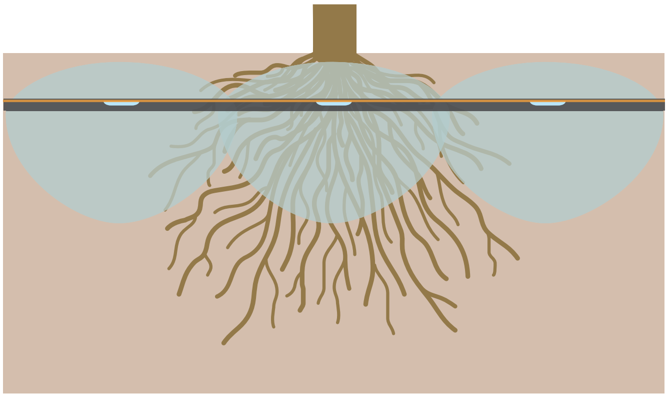
Water quality and availability

Properly addressing water quality issues often solves most problems associated with the successful operation of the SDI system:

- Physical - suspended particles and filtration
- Chemical - pH, iron, bicarbonates, carbonates
- Biological - bacteria and filtration/chemical treatment

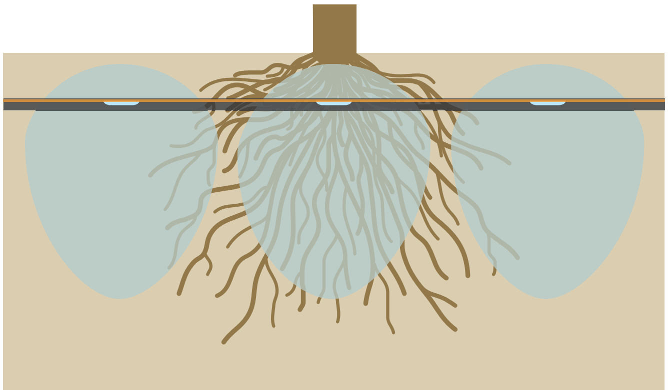
Soil type

Soil type and absorption play an important role in determining dripper application. Maintaining a dry soil surface is essential. When water migrates to the surface, weeds germinate and compete with the crop for water and nutrients. Water moves to the soil's surface easily when the dripline is installed too shallow or if a high flow dripper exceeds the soil's ability to absorb water - resulting in channeling.



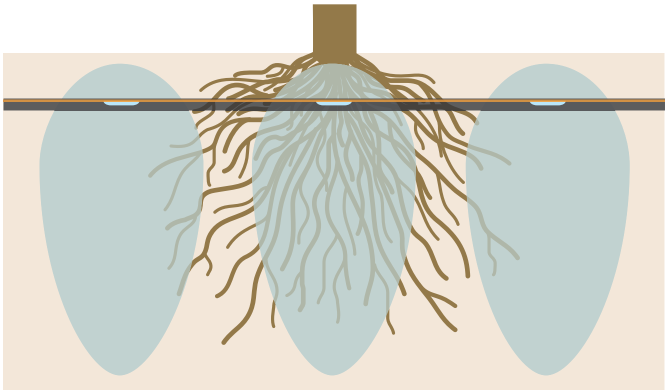
Heavy clay

Low flow drippers are recommended.



Medium textured

Requires closer dripper spacing (compared to clay soil). Lower flow drippers are recommended.



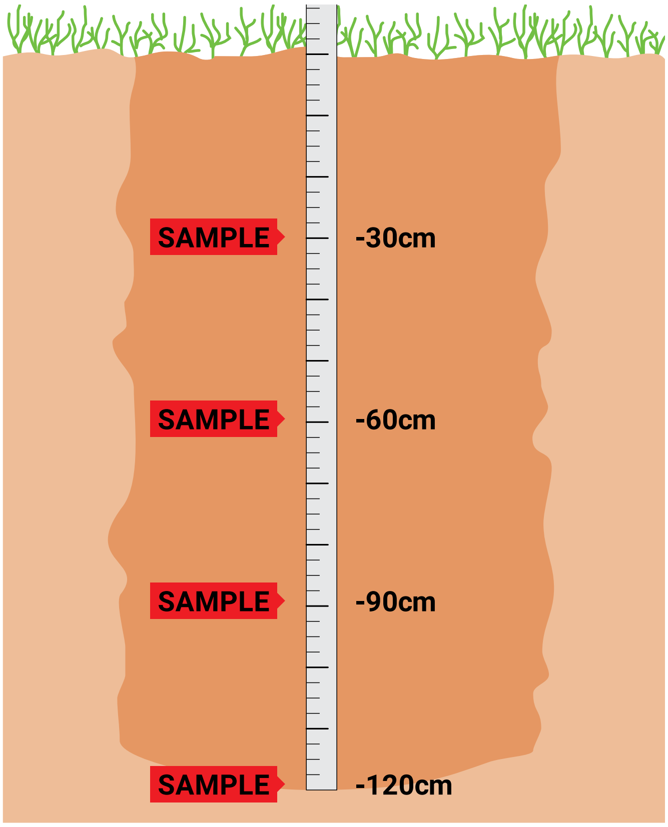
Light textured

Closer dripper spacing is required in order to uniformly wet the soil profile. High frequency irrigation can be used to achieve similar results.

How to carry out a correct study evaluation of the soil

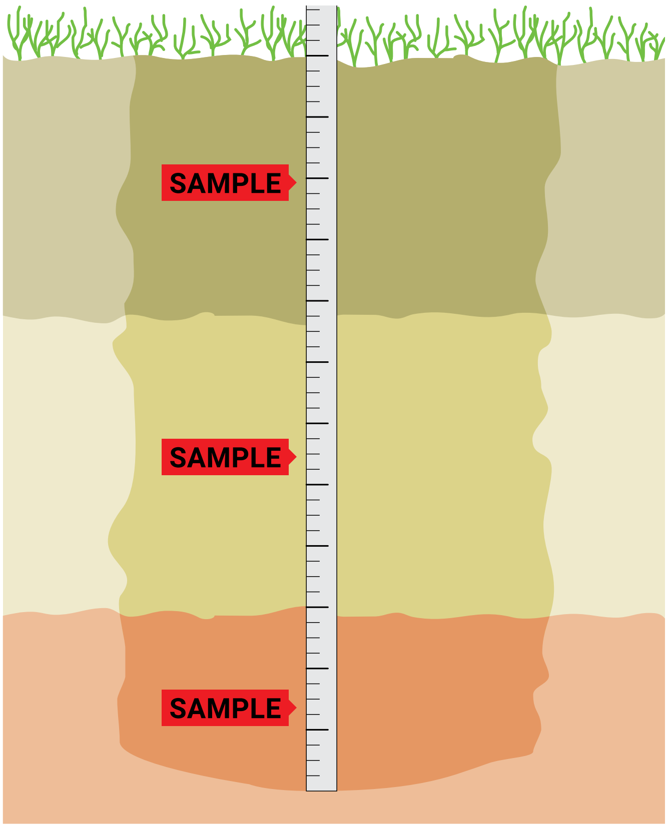
If the soil is uniform, this test should be performed in 1-2 places (depending on the size of the total plot)

If there are no visible layer differences, take a sample of at least 0.5 kg every 30 cm.



If the soil is not uniform, this test should be performed in 1-2 places (depending on the size of the total plot) of each of the sections where the difference in soil texture is seen.

Take a sample of at least 0.5 kg at mid-height of each layer.



Send the soil samples to a lab test for physical evaluation (% clay, % silt, % sand) and chemical property analysis.

Main considerations for determining injection depth in open field crops

- Depth of the crop root zone
- The various crops to be grown in the rotation
- Soil type
- Cultivation practices
- Plowing and tillage

Shallow Injection	Superficial / shallow root system Crops that require the upper layer of the soil to remain wet, potatoes, strawberries	For sandy and superficial soil*
Medium Injection	Medium root zone depth Corn, processing tomatoes, cotton, sugarcane	For heavy and medium soil*
Deep Injection	Field crops that must be cultivated before the start of season Widely used for crops with deep roots where deep plough is needed	For heavy and medium soil*

* Critical to understand that there are multiple other variants to be considered to determine the burying depth, this will be describe later.

When **shallow (2 – 5 cm) SDI** injection is used, the driplines are usually removed from the soil at the end of the season and stored until the next season or sent to recycling when single use applications are used.
However, if **shallow (10 cm) SDI** injection is used for two seasons, it should be treated as a long-term SDI injection, and you should take into consideration factors related to long-term SDI installation, such as the release of air and prevention of vacuums.

One of the reasons for using shallow injection drip irrigation as opposed to surface drip irrigation is to prevent movement of the driplines. This is especially important for diverse crops grown under plastic mulch and in areas **with strong winds**.
Shallow injection is also used with non-covered crops, to prevent movement of the driplines and to protect the equipment during harvest time.
For crops such as watermelons and melons, where the location of the crop and the irrigation equipment changes each season, farmers prefer shallow instead of deep injection, because driplines can be easily removed at the end of each season.
Shallow injection used for germination should be performed at a depth of up to 10 cm. The driplines should be installed alongside the root zone, rather than below it, to prevent roots from coiling around the dripline.

Medium SDI injection is the injection of driplines according to the depth of the central root zones. This depth is easy to work with, but does not enable deep soil cultivation. Medium depth injection is suitable for a large number of crops, especially vegetables, sugarcane, and corn.

Deep SDI injection is widely used for crops with deep roots, for heavy to medium soils, and primarily for field crops that must be cultivated from before the start of the season until the end of the season.
Deep injection of driplines for deep-rooted field crops is usually performed with long-term usage in mind, sometimes even for a series of crop rotations. Injection depth is determined according to the needs of the most problematic crop in the rotation. In any case, driplines must be injected below the depth of the deepest cultivation penetration projected.

Main considerations for determining injection depth in orchards crops

In vineyards and tree orchards, the number of driplines and the distance between them vary per crop and soil types. The current worldwide trend is to inject at least two driplines per row, one on each side of the tree row, when the distance between rows exceeds 4 m. In densely populated orchards with a planting distance of 2.5 – 3.5 m between rows, only one dripline is injected.
The distance between the two driplines is usually 1.2 m to achieve a continuously wet strip in the tree root zone. In light soils, the distances between driplines are reduced.
In mature orchards, it is preferable to inject the lines as close as possible to the tree rows (wherever possible) with a distance of approximately 1.5 m between driplines.

When selecting dripline wall thickness for orchards, the following should be considered:
Thinner dripline walls are usually selected because of their relatively low cost. However, a minimum dripline wall thickness of 0.63 mm (25 mil) is normally specified.
For coarser soils, consider thicker dripline walls, because sub surface injection of thin driplines through the coarse soil might damage the dripline.

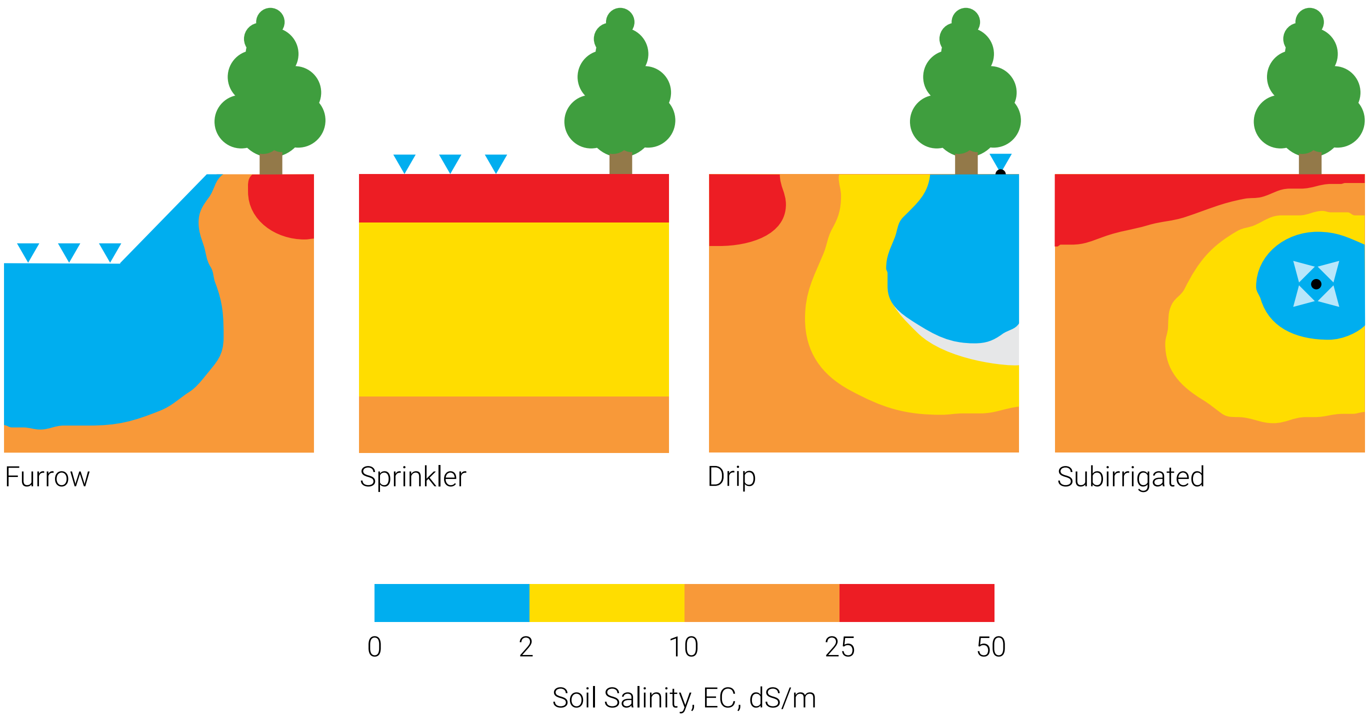
SDI systems currently installed in vineyards and orchards vary greatly in the dripline depth, from 5 cm (shallow) to 50 cm (deep) below the soil surface. When determining how deep to inject the driplines in an orchard, keep in mind the following:

- Driplines need to be installed deep enough to avoid damage from tillage equipment.

Saline soils

How to ensure high yields using sub surface drip in saline/sodic soil:

- Drip does not flush the soil; it keeps a bulb with optimal conditions (high hydraulic potential)
- Irrigation must be applied daily to keep the high hydraulic potential
- In case of rain, up to 15 mm irrigation should be applied to avoid backwashing of salts from surface into the root zone
- In case of less rainfall the flushing system should be applied when salinity increases



Furrow Sprinkler Drip Subirrigated

Topography

Field slope will determine whether a designer selects a pressure compensating or non-pressure compensating dripper. Netafim™ offers heavy, medium and thin wall driplines with both pressure compensating and non-pressure compensating drippers. Heavy wall driplines are recommended for permanent crop sub surface applications.

Flat terrain

Typhoon™ Plus or Aries™ thick, medium or thin wall driplines: economical non- compensating driplines for all flat terrain:

- Ideal for long runs and multi-season use
- Wall thickness options: 0.38 up to 1.20 mm
- Flow rate options: 1.0 up to 4.0 l/h

Streamline™ X can be considered in single season applications that requires shallow burying to protect the dripline.

Steep terrain

UniRam™ thick wall or DripNet PC™ thick or medium wall driplines: pressure compensating driplines for steep terrain:

- Ideal for long runs and applications demanding high uniformity
- Wall thickness options: 0.63 up to 1.20 mm
- Flow rate options: 0.4 up to 3.8 l/h

Or Thin wall Orion PC™ for single season applications that requires shallow injection.

Getting the best return on your investment

The goal is to get the best return on your investment. A well-designed system quickly pays for itself and adds to your bottom line. SDI systems allow growers to cut labor expenses and to manage water and nutrients more efficiently and to reduce chemicals uses..

Product selection, make the right decision

Driplines are available in many different configurations to meet your unique crop and soil conditions. The options you choose will determine the overall cost of the system:

- Wall thickness - consider planned number of seassons to irrigate
- Tubing size and dripper spacing
- Dripper type - pressure compensating or non-pressure compensating
- Dripper performance - consider product history, physical characteristics of the flow path and hydraulic parameters

As described previously, Netafim™ offers several heavy, medium and thin wall driplines manufactured to fit your specific crop and soil requirements.

Contamination from external particles

In rainy periods, due to rain and the fact that sub surface driplines are empty, water may flow in the opposite direction, from the soil to the drippers´ outlet, bringing soil particles with it. Under these circumstances, the driplines act as draining tubes.
Sand particles might penetrate the drippers when the soil is oversaturated due to rainfall. If these conditions are foreseen, Netafim™ recommends using anti-siphon (AS) drippers.

If AS drippers are not used, when the sub surface driplines are empty and the soil becomes oversaturated due to rainfall, water could flow in the opposite direction, from the soil to the dripper outlet, bringing sand particles with it. The small particles of sand that are carried towards the dripline may eventually clog the drippers.

Irrigating during the rain event will help. During irrigation, the pressure in the driplines exceeds the pressure exerted by the water present in the surrounding soil, preventing the sand particles from penetrating the drippers.

In the case of a very intense and long rainy period, it is recommended to flush the system prior to the beginning of the next irrigation sequence.

The Anti-Siphon mechanism blocks contaminants from being drawn into the dripper from outside, making it a critical addition to driplines installed in a sub surface drip irrigation system (SDI).

Netafim™ offers AS (anti-siphon) drippers (UniRam™AS, DripNet PC™ AS) to prevent these phenomena.

* "Flap", in thin wall driplines, as physical barrier, helps also in preventing contaminants entering the dripper, so in case of using TWD it is recommended to install driplines with “flap” outlet.

Root intrusion prevention

Plant roots can penetrate the drippers, causing a reduction in the flow rate and possibly an obstruction. This is known as root intrusion and may occur when the plant suffers water stress and the roots are searching for moisture. One of the main causes of root intrusion is insufficient irrigation. This occurs when the plant's water consumption exceeds irrigation. Under these conditions, the roots tend to develop near the dripper and eventually penetrate it. Gradually, the roots may grow into the dripper, blocking the water passage in the dripper. Maintaining proper humidity in the surroundings by means of adequate irrigation planning allows the roots to spread and use the entire available moistened soil volume, instead of concentrating around the dripper. Continuous soil humidity monitoring allows better control over the moistening pattern, thus maintaining optimal soil humidity within the dripper's surroundings.

Root intrusions to driplines are rare.
In order to prevent these phenomena, one can perform:

- Technical irrigation in order to maintain proper moisture in the surroundings to allow the roots to spread and use all the available moistened soil.
- Injection of herbicides (chemicals) - useful for the prevention of root intrusion. Detailed explanation on the types of herbicides dosage and way of applying it can be found in Netafim™ maintenance manual.
- UniRam™ drippers have a physical barrier that improves their resistance to root penetration.
  The water outlet hole on the lateral pipe is relatively far from the outlet hole of this water from the dripper, between them there is a «pool». Thanks to it, if some root could penetrate through the outlet hole of the dripline, it would take a long time to find the other hole through which, if it did penetrate, it could plug the water outlet.
  In addition, within this «pool» there are two plastic obstacles, which tend to attract the growth of possible rootlets near them. Roots do not grow in a vacuum, they will always approach a surface and therefore they will grow first of all near and around these obstacles.
  This entire physical barrier offers the farmer reaction time, both to realize that an action of penetration of rootlets may be beginning and to react and use some type of herbicide (according to the crop and its phenological state) that helps to solve the problem.

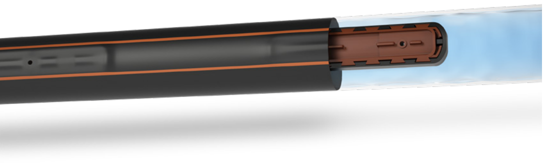
Technical irrigation:

If there is a period during which the plant does not receive the minimum amount of water necessary and a hydric stress occurs or in the case that stress times must be programmed to obtain some type of reaction from the plant, it could be the case that the roots of the plant will seek to approach where there is moisture.
The last place that will remain wet will be inside the dripline and therefore these roots will try to penetrate inside it, thus being able to obstruct the water passages.
One way to prevent root penetration in SDI is by treating the water or the drippers themselves with an herbicide, for example, with trifluralin or pendimethalin .
The addition of the herbicide may necessitate an injection pump that releases the herbicide at a prescribed dosage and rate, or alternatively emitters may contain the herbicide. This provides a continuous slow release process of the herbicide as water passes through it. This also carry with it risks that we need to consider.
In addition to the other means that Netafim™ offers / recommends (use of drippers with XR and XRS characteristics, use of drippers with physical barriers., all them mentioned in this chapter of the handbook), the use of technical irrigation can reduce the remote possibility that these rootlets penetrate into the dripline.
Technical irrigation, is watering the soil not for irrigating the plant, but more for creating wet environment near the dripper outlet that do not stimulate the rootlets entering into the dripper looking for the water , hence clogging.
Technical irrigation is a short irrigation of 5 to 10 minutes per day, this very small amount of water will not influence the aforementioned processes but it will be enough to maintain a minimum humidity level in the area near the buried driplines and thus the rootlets will be able to find what they are looking for (moisture) without having to penetrate inside the dripline.

Netafim's exclusive root intrusion barrier: XR drippers

In addition to the above possibilities, Netafim™ offer exclusive products:

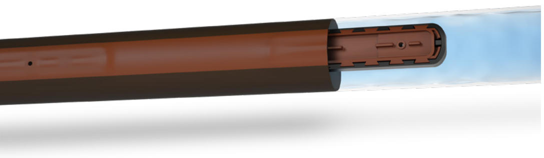
Netafim™ AS XR drippers



Netafim™ pressure compensated drippers (UniRam™, DripNet PC™) with Anti-Siphon mechanism and extra resistance to root intrusion.

- Anti-Siphon with extra Root resistance and root barrier
- Reduces significantly the risk of roots penetrating and clogging the drippers by incorporating copper oxide that inhibits root growth within the dripper
- Long lasting effect throughout dripline life
- Netafim™ XR drippers dramatically reduce the amount of chemicals needed to fight root intrusion
  50% less chemicals needed, compared with Netafim™ AS drippers
  75% less chemicals needed, compared with competitors
- This propriety innovative root inhibitor, embedded in the dripper, does not migrate with the water to the soil
- Copper oxide has been proved as antimicrobial, and endows the dripper with antimicrobial properties. This offers an advantage when using gray water.

Netafim™ AS XRS driplines



The innovative XRS product includes, in addition to the use of the drippers with the XR characteristics, an outer strip produced with the same root growth inhibitor, added during the production of the driplines and with the same characteristics.
The use of this product, in addition to protecting the dripper, prevents roots from growing near the pipe and thus increases the resistance of this pipe to the constriction of the pipe by the roots (root strangulation prevention).

Use of driplines with 'flap' outlet

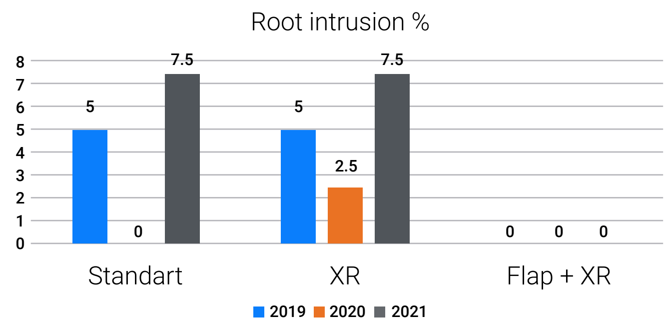
When thin or medium wall driplines are chosen, it is highly recommended the use of «flap» outlets that will help prevent sand penetration during injection and improve root intrusion resistance.
A combination of «flap» and XR drippers give the ideal prevention to root intrusion.

Advantages of the flap outlet
During installation of a sub surface irrigation system (shallow or deep), the flap prevents the penetration of sand/soil into the dripper's bath area and minimizes the possibility of clogging.

When used in a sub surface irrigation system, due to the relatively small water passage of the flap outlet, it acts as a physical barrier and substantially reduces:
- Penetration of roots into the dripper
- Penetration of sand/soil into the dripper.

* Netafim™ driplines with flaps are not anti-siphon and not intended to inhibit root penetration as compared to the Netafim™ anti-siphon XR dedicated line of products.

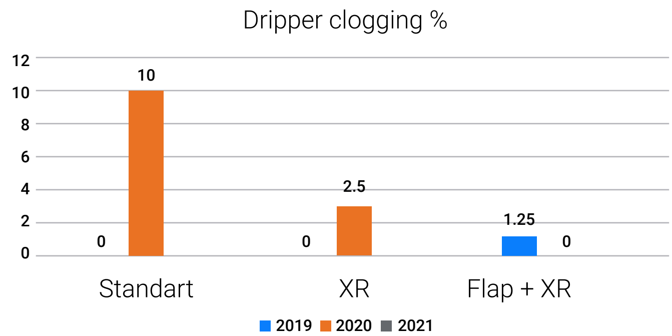
With flap outlet:
- More resistance to root intrusion
- More resistance to ants and insects' damages
- No sand penetration, in sub surface installation
- Can be combine with the XR and the AS solution



Insect damage prevention

Though not common insect that exist in the soil might create damage for the injected driplines or drippers (membrane), in order to prevent this from happening, follow Netafim™ guidelines described in this booklet.

Trial in real field conditions – showing a significant advantage for the use of flap reducing dripper roots intrusion and clogging



DATA COLLECTION AND DESIGN PARAMETERS

Data collection and design parameters

The SDI design process begins with the collection of the information needed for a successful design. This information is referred to as design criteria. These criteria include information about climate, crops, soils, energy considerations and water quality, as well as system management and operational considerations.

The first step is to define the lot on a topographical map. The map scale should not exceed a ratio of 1:5.000, and contour lines should not exceed 1 meter vertical intervals.

Planning for the long term

An essential step in the design of an SDI system is to consider how the use of the area will change over time. It is not enough to plan only for next year's crop. A well-designed and maintained system should be in operation for 20 years, so you must plan for the long term.

Consider crop rotation, tillage systems, and your management capabilities in the design process.

When considering crop rotation, also take into account the traffic patterns of each crop, i.e., what type of agricultural machines are used for this crop, and how frequently they pass across the fields. Row crops and field crops are often rotated because of their similar traffic patterns. For example, corn and cotton may both be grown in rows that are 90 / 96 cm apart and they have similar production systems. However, the traffic patterns for winter wheat and soybeans most probably differ from the traffic patterns of row crops.

Water requirements

The SDI system must deliver the required amount of water to the crop at the required time. This is called the "crop water requirement".

You must ensure that your SDI system can supply the "peak" water requirement, which is the amount of water that a crop uses during its highest water use period. While you may consider rain to reduce the irrigation requirement throughout a season, do not take rain into account when calculating a peak use rate. Even in humid regions, the probability of receiving appreciable rain at a critical period is low. Plan your system so that it can provide water during a drought. Keep in mind that the climate also affects the peak water requirement because the evapo-transpiration values are different for humid vs. arid regions. In addition, moisture stored in the soil is normally not considered when designing for peak demand.

Crop type also influences the water requirements. Different crops and different planting dates result in different water requirements.

If you rotate crops, design your SDI system to meet the needs of the crop with the highest water demand. A good "rule of thumb" is to use pumps and main lines that can provide a peak crop water use rate of 7 - 10 mm per day. This is calculated assuming optimal utilization of your system, which is 18 to 22 hours a day at peak consumption. You will need to supply a higher flow rate if you intend to operate the irrigation system for fewer hours a day, and a lower flow rate if you can operate the irrigation system for more hours a day.

Water analysis

If the water source is expected to have varying quality (e.g. a river that flows throughout the year at different intensities may have different levels of contaminants at different times of the year), try to take samples that reflect the water quality throughout the year.

Taking water samples

1. Flush a clean 1 liter bottle, using water from the source to be sampled. Fill the bottle so that no air at all remains inside the bottle (if possible, squeeze the bottle to expel any remaining air).
2. Close the cap firmly, and store the sample in a clean place in the shade.
3. Send the sample to a local authorized laboratory as soon as possible after taking the sample.
4. Write the following data on the sample bottle:
- Grower's name
- Location
- Water source
- Date sample was taken

5. Request an analysis of the following parameters:

- → **EC** (electrical conductivity)
- → **pH** (level of acidity or alkalinity)
- → **Ca** (calcium - water hardness)
- → **Mg** (magnesium)
- → **Na** (sodium)
- → **K** (potassium)
- → **HCO_3** (bicarbonate)
- → **CO_3** (carbonate)
- → **Alk** (alkalinity)
- → **Cl** (chloride)
- → **SO_4** (sulfate)
- → **PO_4** (phosphate)
- → **$N\text{-}NH_4$** (nitrogen-ammonium)
- → **$N\text{-}NO_3$** (nitrogen-nitrate)
- → **B** (boron)
- → **Fe** (iron)
- → **Mn** (manganese)
- → **TSS** (total suspended solids)
- → **TDS** (total dissolved solids)
- → **Turbidity Algae** and **Chlorophyll Zooplankton**
- → **BOD** (biochemical oxygen demand*)
- → **COD** (chemical oxygen demand*)
- → **VSS** (volatile suspended solids)

*when waste, industrial effluent and/or recycled water is present

All the above parameters are essential for a full and accurate analysis.
In some cases, additional parameters such as dissolved oxygen and redox will be required in order to conduct an accurate water quality analysis.
If in doubt, consult the Netafim™ laboratory regarding water quality.

NOTE
Water samples should be taken as close as possible to the planned suction point.

For agriculture, water quality is defined according to the following criteria:
- Agronomic water quality - the extent to which it is compatible with soil type and crop
- Water quality for irrigation - the extent to which it induces irrigation system clogging

Quick guide to the recommended water quality for drip irrigation

Clogging Factors	Clogging Hazard			Treatment
	Minor	Moderate	Severe	
Physical				
Suspended solids (mg/L)	20	20 – 60	> 60	Pumping & Sedimentation & Filtration
Sand (mg/L)	1	1 – 5	> 5	
Silt & Clay (mg/L)	20	20 – 60	> 60	
Chemical				
pH	5.5 - 7.0	7.0 – 8.0	> 8.0	pH modification
$CaCO_3$ (mg/L)	50	50 – 300	> 300	Softening & pH modification
Manganese (mg/L)	0.05	0.05 – 0.2	> 0.2	Oxidation & Mn removal
Iron (mg/L)	0.1	0.1 – 0.3	> 0.3	Oxidation & Iron removal
Sulphide (mg/L)	0.05	0.05 – 0.2	> 0.2	Oxidation & purification
Phosphorus (mg/L)	1.0	1.0 – 10.0	> 10.0	Treatment at water source

The parameters in the table above represent the most common and critical clogging hazards based on stand-alone parameters. Combinations of different parameters might result in higher or lower risks.
For example: High hardness values combined with high pH are riskier than high hardness with low pH.

Water quality

Water quality directly influences filtration requirements, nutrients/chemical injection requirements, and the amount of maintenance needed to prevent drippers from becoming clogged. Drippers may clog due to chemical factors (precipitates or scale), physical factors (grit or particles like sand and sediment), and biological factors (such as algae or bacteria).

Groundwater is generally of a higher quality than surface water and less likely to clog drippers. You must check the iron and manganese levels in the water, as high levels may lead to dripper clogging, and water may need to be treated prior to pumping.

However, most water supply sources for SDI systems are derived from surface water, and this trend is expected to grow.

You should always test the water quality. The test results might make it necessary to build a settling pond for water polishing.

Existence of iron or manganese above a threshold value requires active removal before pumping the water into the system. If you are considering using reclaimed wastewater as a source, remember that the quality and clogging potential vary depending upon the extent of treatment, if any.

The Netafim™ agriculture department provides knowledge and experience accumulated from around the world in order to improve the quality of the water available for all irrigation projects. We highly recommend contacting this department through your local technical representative to receive the appropriate and recommended solution based on the water data supplied.

Complementary products

Filtration requirements

Filtration is critical in any drip system. It is even more important in an SDI system because filter failure is costly and it is very difficult to determine the location of clogged sub surface drippers. Designing a filtration system for an SDI system consists of selecting a filter type and filter size (capacity). The size and type of the required filter depend on the water source and the kinds of nutrients and chemical stock solutions to be injected. The filtration system type is mainly determined by the pH and amounts of particulate matter, algae, sand, silt, manganese, or iron in the water supply.

The filters used in SDI systems are mostly sand media (silica sand or crushed granite) filters, but also disc filters and screen filters are possible depends on the case.

- Sand media filters or disc filters are commonly used for any surface water source or reclaimed wastewater. However, note that deep well water sources, or any well water with high content of sand, might require a Hydrocyclone sand separator to remove sand before it enters the system.
- Disc filters can also be used as primary or secondary filters for surface water sources and as primary filters for well or municipal water sources. These filters contain a series of grooved plastic discs. Disc filters come in sizes that are equivalent to filtration sizes of 200 to 130 micron (80 to 120 mesh), with 130 micron (120 mesh) being the most common. According to Netafim™ data, only a few dripper types can work with 80 mesh filtration. Disc filters have more surface area than screen filters and are therefore better suited for higher flow rates. Disc filters are also easier to clean than screen filters.
- Screen filters are mostly used as secondary filters for surface water sources, or as primary filters for well or municipal water sources. You can use either a manual screen filter or an automatic back-flush screen filter. Screen filters vary also in shape and size. Filtration sizes for SDI systems range from 200 to 130 micron. This is equivalent to 80 to 120 mesh, where the mesh size is the number of openings in the filter per square inch.

For any filtration system, the required level of filtration (the effective micron or mesh size) is dictated by the water quality and potential clogging factors, the drippers' flow-rate, and the passageway size.

When designing a filtration system, take into account filter flushing. Filtration systems are designed for manual, semi-automatic, or fully automatic flushing. Flush cycles for manual and semi-automatic flush systems are manually activated. Flush cycles for fully automatic systems are activated either when a pre-set pressure differential across the filters is exceeded, or by a pre-set operational time interval. When deciding the extent of filter automation, take into account both cost and labor considerations.

All filters, sand media, disc and screen filters, require a minimum pressure downstream of the filters during the back flush cycle. For sand media filters, the required pressure is normally 2.0 bar, while for disc and screen filters it is typically 2.5 bar for standard systems and 1.5 bar for low pressure systems. In certain cases, it may be necessary to install a pressure-sustaining valve downstream of the filters that actuates during the flush cycle in order to maintain the back pressure necessary for proper flushing.

Pumps and power sources

As in most irrigation applications, SDI uses centrifugal (end suction or turbine) pumps. Centrifugal horizontal pumps are more frequently used to pump water from surface supplies, such as ponds. Turbine pumps (a special type of vertical centrifugal pump) are used to pump water from wells, and they may be either vertical shaft or submersible.

An electricity grid is the common power source, as it requires minimal labor and cost, but it may not be available where you need it. Three-phase power is usually required to operate irrigation pumps greater than 10 horsepower. If electricity is not available or desirable, diesel, gasoline, or propane may be used. The most common alternate power source is usually gasoline-driven engines for small pumps, and diesel engines for larger pumps.

The pump's working set point is defined based on the flow-rate and pressure head requirements per shift. Remember to consider filtration back-flush and dripline flushing requirements.

If you plan on pumping from reservoirs, be sure to select a floating suction device to ensure water suction from the upper layers although not from the topmost upper layer. The topmost upper layer may be contaminated by algae due to an excess of light and oxygen. Avoid suctioning from the bottom because the turbulence might cause a large volume of sediment and silt to enter the suction pipe.

Recently, solar driven pumps have become more and more common in areas where electric power is not available, Netafim™ offers these pumps in its portfolio. The use of these pumps requires knowledge in defining and selection. For this, you can contact the Netafim™ representative in your area.

Chemical injection

Chemical injection includes both Nutrigation™ which is the injection of liquid or soluble nutrients into the water system, and the injection of chemicals such as chlorine, acid or others, into the system. Injection of liquid chlorine and acid helps to prevent clogging of drippers. Other benefits of Nutrigation™ and injection of chemicals include uniform and timely application of nutrients, reduced soil compaction due to reduced traffic in fields, reduced labor requirements, reduced exposure to chemicals, and reduced risk of environmental contamination.

Keep in mind the following guidelines:

- Injection rates for nutrients are usually much higher than injection rates for chemicals. Therefore, if the injection system will be used for Nutrigation™, choose a type of system that will meet the Nutrigation™ needs.
- The injection systems most commonly used in drip irrigation systems are the Venturi injector and the metering pump.
- If a Venturi type is selected, make sure to adjust the size and number of Venturi units to the volume of the solution you need to inject per time unit.
- Metering pumps may be positive displacement piston-type pumps, or diaphragm-type pumps. If a diaphragm injection pump is selected, make sure that the rated pressure is at least as much as the pressure you will have at the pump, otherwise the injection pump will not deliver its rated flow. Make sure that the injection system has an adjustable injection rate.
- Any components that will be in contact with nutrients, chlorine, or acid should be corrosion-resistant.
- Any chemical injection system should be placed so that chemicals are injected upstream of the filtration system.
- Always follow state laws and chemical labeling requirements.

Valves

As with any drip irrigation system, proper selection and placement of valves is critical. Water flow rate and pressure throughout the SDI system should be precisely controlled to ensure efficient and timely water application. Valves play a key role in controlling pressure, flow, and distribution under different conditions. In this way, valves optimize performance, facilitate management, and reduce maintenance.

The valves used in a complete SDI system include butterfly valves, check valves, shut-off valves, pressure relief valves, remote-control valves, pressure regulators, air and/or vacuum relief valves, and vacuum breakers.

Valve sizes, maximum working pressure, and valve materials should meet your system's demands. Oversized valves may not open or close properly, and undersized valves may restrict flow and cause excessive pressure loss. In the case of an undulating topography, you will need to exercise extra care in properly locating air and/or vacuum relief valves at high points in the system.

Vacuum breakers

Vacuum breakers must be included in any sub surface drip system. The function of a vacuum breaker is to introduce air into the system during drainage in order to prevent dirt from the surrounding soil from being suctioned back into the drippers. The size of the vacuum breakers (commonly, ,1" - 2") depends on pipe diameter, irrigation zone size, and the specific installation location in the system.

Instrumentation and controls

Automation can pay for itself by reducing labor requirements and by enabling more precise irrigation. A relatively permanent SDI system lends itself to automation. Automation of irrigation that also uses feedback sensors can prevent leaching of chemicals and reduce pumping costs by irrigating only when the crop needs it. It is recommended to base automation and control on a radio wireless connection, which is both cost effective and overcomes topographical and land obstacles; another option would be using single wire communication cables.

Automation commonly includes the following instruments:

Monitoring system. Monitors the multiple variants in the fields and helps growers in their irrigation decision-making. This is done via various sensors in the field such as: soil moisture, water capacity in the soil, etc.

Water meters (mandatory). Basic instrumentation starts with water meters that help monitor system performance and help diagnose potential problems. Install a water meter at the central system control head, and preferably in some additional strategic locations along the system. Install water meters in a few representative zones, and even at the head of selected driplines. Water meters provide feedback for irrigation control.

Pressure gauges (mandatory). Pressure gauges are also vital in an SDI system to monitor pressure and help diagnose problems. Low pressure and/ or increased flow rates during normal operation can help you locate a leak, or receive an early warning about potentially clogged drippers. On the system layout map, specify the expected pressure levels at strategic points.

Irrigation controllers. Irrigation controllers vary in the number of valves that can be controlled, the number of valves that can be simultaneously kept open, the number of irrigation programs available, the number of start times available for each program, and the ability to control and monitor injection of nutrients. The controllers may be connected to various feedback sensors, using either a digital signal or an analog signal. Feedback sensors are commonly located on water meters, nutrient injectors, pressure sensors, "no water" relays, wind speed and direction sensors, rain gauges, temperature gauges, and soil moisture gauges.

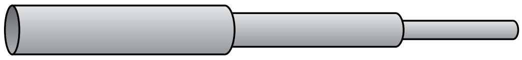
Main and Sub-main design

Proper design guidelines for main line and sub-main piping generally follow normally accepted design practices for surface drip and/or sprinkler irrigation systems.

> **NOTE**
> In this guide, the term 'sub-main' refers to the supply manifolds for the driplines.

Keep sub-mains and flushing manifolds below the dripline level so that solids will tend to collect in the sub-mains and flushing manifolds, rather than in the driplines.
Carefully size sub-mains where field shape varies. Each dripline may have a different length and a different total flow rate. Base the design of the sub-mains on the actual flow rates of the driplines, and not on an "average" flow rate.

Pipe telescoping considerations



In normal irrigation design, pipe size is based on economic, friction loss, and water hammer considerations. As pipe size increases, friction loss decreases (reducing pumping cost) but initial cost increases. Main and sub-mains pipes are normally "telescoped" (reduced in size) as water is discharged, reducing pipe cost.

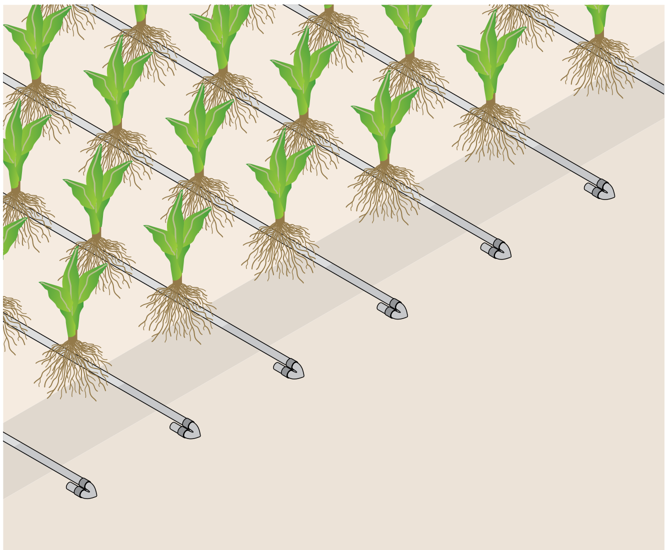
In an SDI system, you must also consider flushing when designing the diameter of the pipes in the system. The major difference between the design of non-SDI irrigation systems and SDI systems is the increased importance of proper flushing, including the flushing of main lines, sub-mains, and driplines. The flow rate necessary for flushing is higher than the flow rate needed for regular irrigation. The piping system must be designed not only to enable the flow rate necessary for normal irrigation but also to enable flow rates that ensure proper flushing velocities in the system.

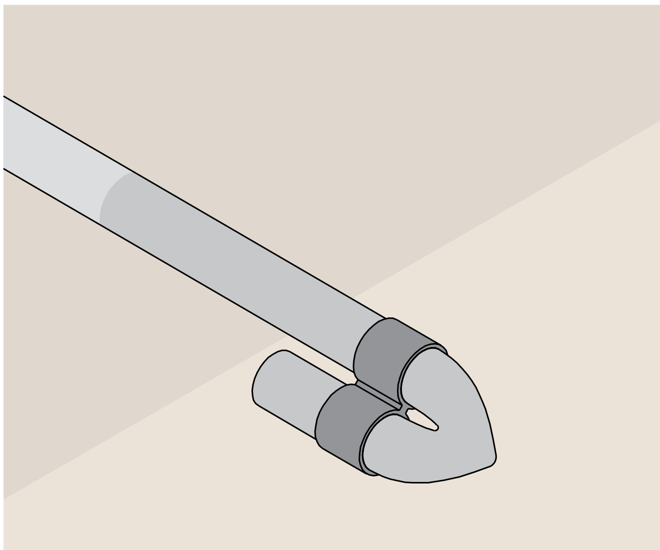
While telescoping the sub-main is done to ensure adequate flushing velocities in the sub-main, too much telescoping may ultimately result in excessive friction loss in the flushing mode. This may result in pressure at the driplines inlet that is inadequate to maintain proper flushing flows and velocities in the driplines. As a general "rule of thumb", it is not recommended to telescope (reduce the diameter of) a sub-main pipe more than 3 times along its length. The design of main-lines may be a telescopic design.

Flushing considerations

Different types of flushing

- Manual open dripline ends
- Auto flush valve at the end of each dripline
- Flushing manifolds
- Controlled flush (Neta-flush)





Manual open driplines ends

Flushing of driplines can be carried out manually, using workers who must open and close the end of each of the driplines (few of them at time) in order to verify good washing.

Benefits:
Only a small number of driplines will be flushed at the same time and therefore not affect the working pressures in the system (making a secondary pump unnecessary) and at the same time ensure that the end of the line remains open for the necessary time needed to expel all dirt - as will be explained here.

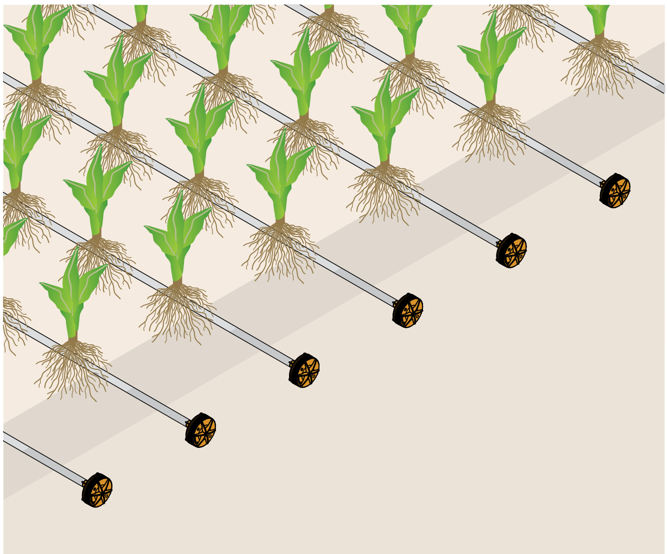
Disadvantages:
Takes many hours of work and you must have enough confidence in the workers to know that the work is being done correctly.

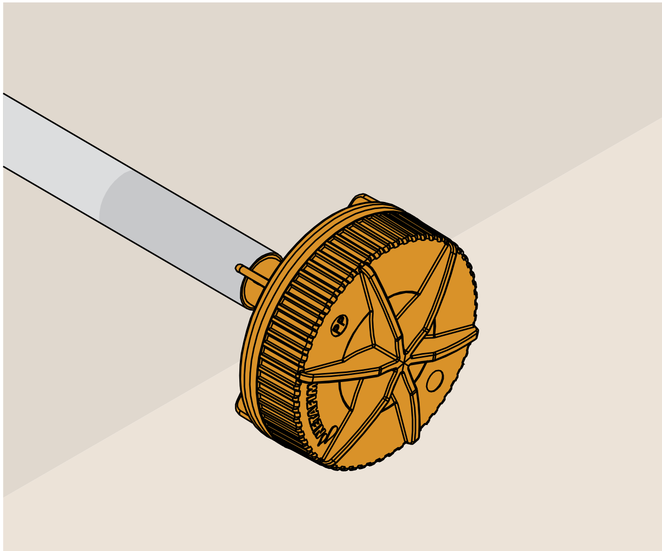
Manual washing can be done by:
a) Unfolding / opening the end of the pipes
b) Using manual end-of-line valves

In both cases, the ends of these driplines should be on the ground. Raising the end of each of the driplines to the surface or following the same depth of the burial of these driplines, make these ends leave a trench inside that has been opened in the field for this purpose and where all the washing water will drain.

Auto flush valve at the end of each dripline

Netafim™ offers an auto-flush valve that opens automatically at the beginning of each irrigation cycle and closes itself after +/- 10 seconds. This possibility ensures that every time an irrigation cycle begins, the driplines are flushed for a few seconds, thus preventing the accumulation of dirt at their ends.





Benefits:
Every time we activate the irrigation, cleaning is carried out. It is not necessary to invest hours of workers' time to perform this activity. No need to worry if the work is done correctly, or not.

Disadvantages:
All the driplines, of each irrigation section, will open at the same time and this will lead to a change in flow rates and pressures that must be taken into account when designing the system. In certain cases it will be necessary to install a supplementary pump that will be activated to cover these differences.

NOTE

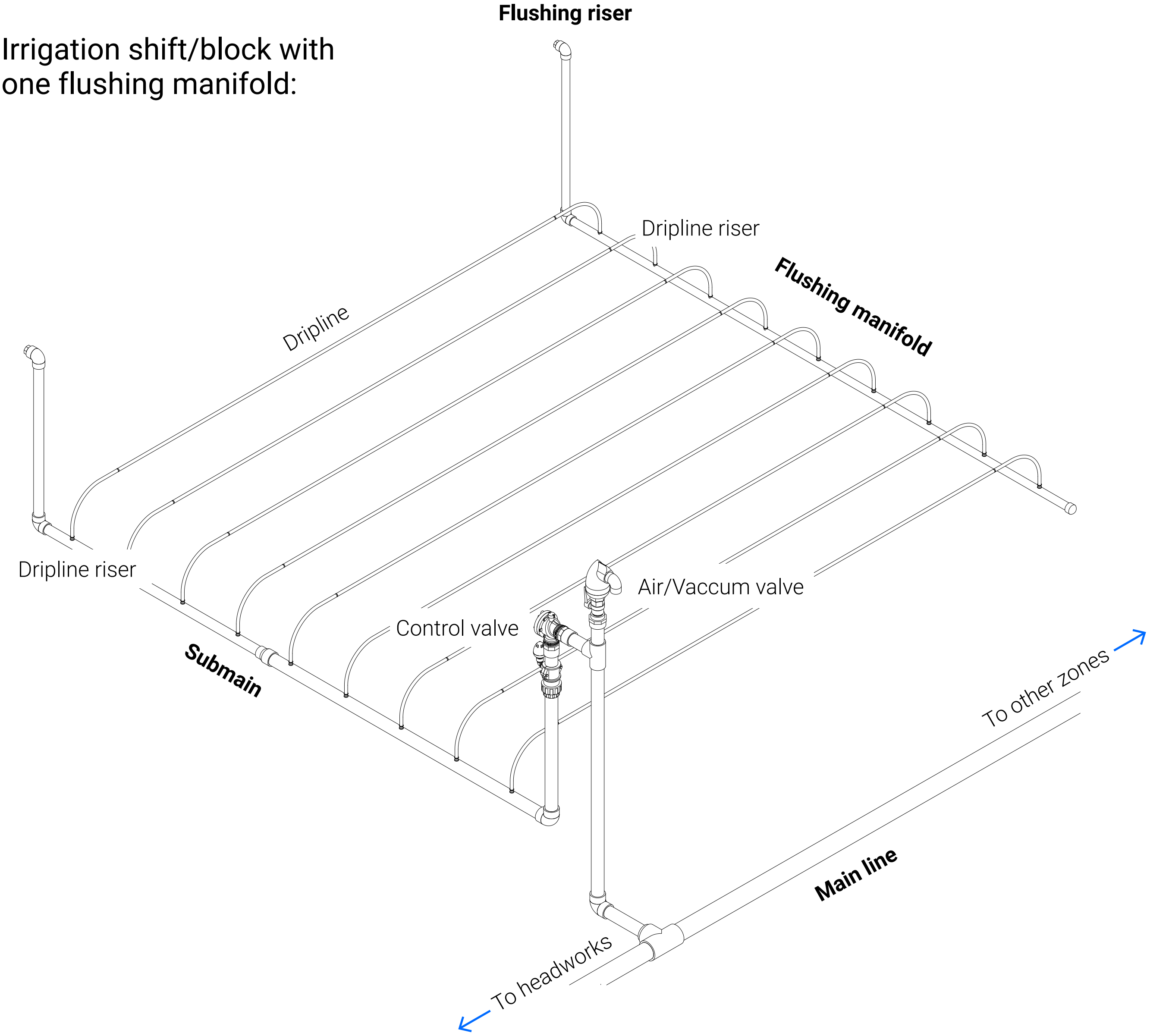
An appropriate strategy to avoid a difference in flows and pressures at the beginning of each irrigation section is to divide this section into several subsections activated with a difference of 15 seconds between them, thus preventing the influence of many end of lines open at the same time; this will greatly improve the flushing efficiency.

The ends of these driplines should be on the ground, raising the end of each of the driplines to the surface or following the same depth of the burial of these driplines, make these auto-flush valves leave inside a trench that has been opened in the field for this purpose and where all the washing water will drain.

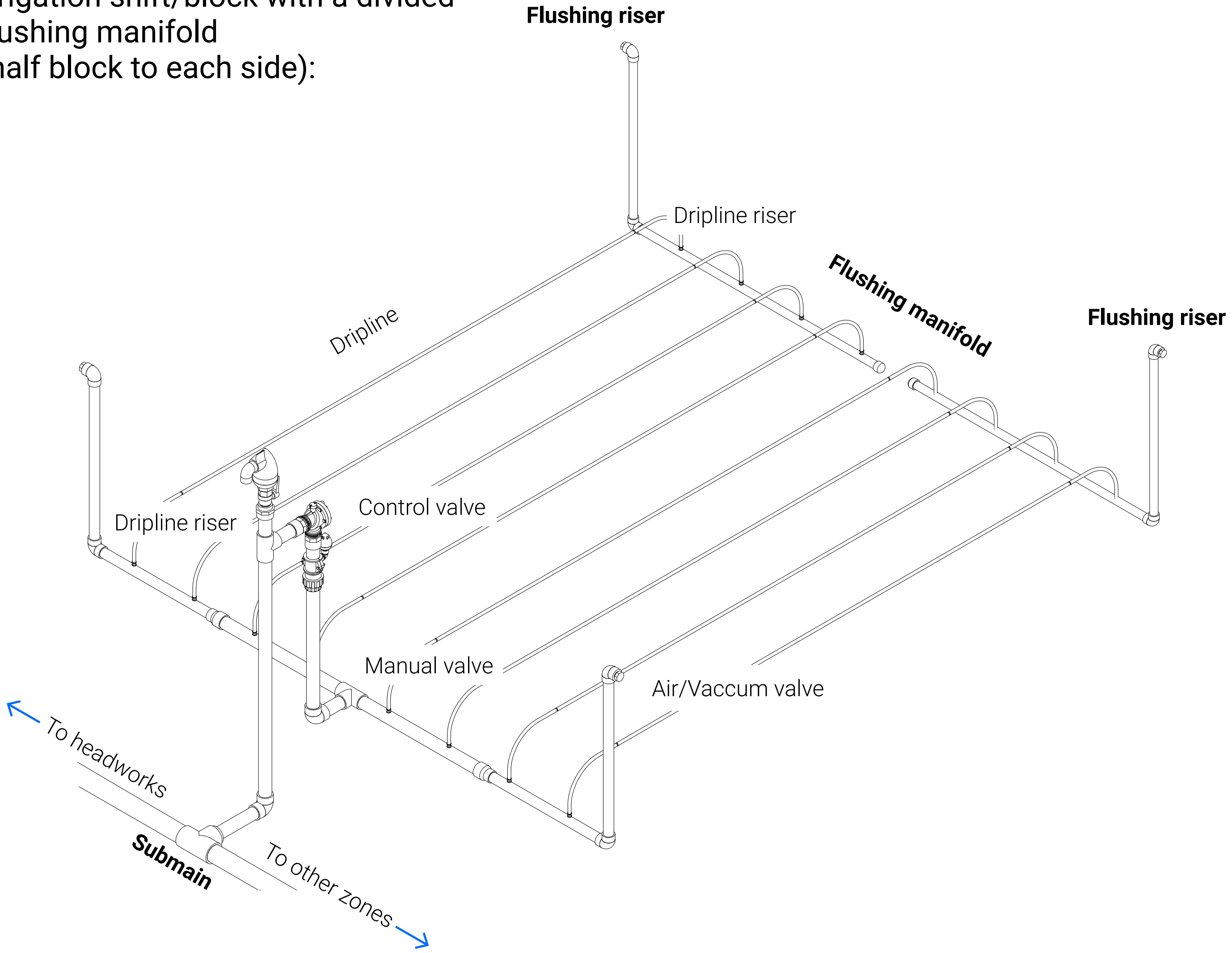
Flushing manifolds

In an SDI system, you cannot alter the number of driplines flushed within a zone. When designing a sub-main for irrigation only, the last section or two of pipe, where operating flows are low, may have insufficient flushing velocities. Size the piping system to allow flushing of the entire main or sub-main to allow a more thorough cleaning if the need should arise. When designing the system specifically for flushing, the design should aim for velocities of at least 2.5 m/s in the largest section of the main or sub-main when in flushing mode.
The figure below shows some typical SDI zone layouts. The lower layout shows an irrigation zone split into two sections, with manual valves on either half of the sub-main that enable flushing half the zone at one time. This provides flexibility and enables.

Irrigation shift/block with one flushing manifold:



Irrigation shift/block with a divided flushing manifold (half block to each side):



Performance of the SDI system must be checked in two states:

- During normal operation (irrigation only)
- During flushing.

When checking during irrigation only, achieve the required flushing flow and velocities in main lines by adjusting the number of zones flushed at one time. When checking during flushing, place valves at the distal end and size in conjunction with the pipe to allow flushing flows and velocities in the larger diameter sections.

Designing the dripline's flushing manifold

The flushing manifold at the end of the driplines is fitted with a flushing riser and a manual valve to enable flushing of the driplines. When the flushing valve is open, flow rates and velocities through the driplines are greater than during normal operational mode. The higher flow velocities remove settled solids and precipitants from the system to help prevent dripper clogging.

Flow regimes may be quite complicated in irregularly-shaped fields having different dripline lengths within the same irrigation zone.

However, because SDI zones are closed-loop systems, pressure tends to equilibrate and zones with differing dripline lengths can be designed using an average dripline length.

A careful balance between flushing velocities in the manifolds and in the driplines is critical when designing SDI zones. To determine the pipe size in the flushing manifold, consider the flow through the end of the driplines during flushing. Select a flushing manifold pipe size that will provide a flow velocity of 0.4 m/s (not less than 0.3

m/s) at the dripline ends to ensure removal of sediment from the driplines.

The diameter of the pipe in the flushing manifold may remain constant, or may increase in the direction of the flushing riser. It is recommended to limit telescoping of the flushing manifold pipe to two equal-length sections, with the smallest pipe diameter limited to about two-thirds of the largest pipe diameter.

As a “Rule of Thumb”, the system will be designed with two flushing manifolds per block (half block to each side), the diameter of the pipe in the flushing manifold should be one grade below the diameter of the pipes in the supply manifold.

Flushing temporarily increases the flow requirements of the system, which in turn decreases the water pressure in the system. Thus, when specifying the pump’s working set point, you must also consider proper discharge and pressure for flushing. In some cases, you may not be able to reach the desired flushing velocity. For example, some irregular field shapes may require large amounts of piping to connect the ends of all the driplines in a particular section or zone. However, when zones are relatively large, the pumping system may not be able to supply the flushing flow rates required to achieve the desired velocity at the ends of the driplines. In these cases, separate the irrigation zone into two to four separate flushing manifolds (as illustrated at the bottom of the above figure). This separation will enable you to maintain a proper flushing pressure.

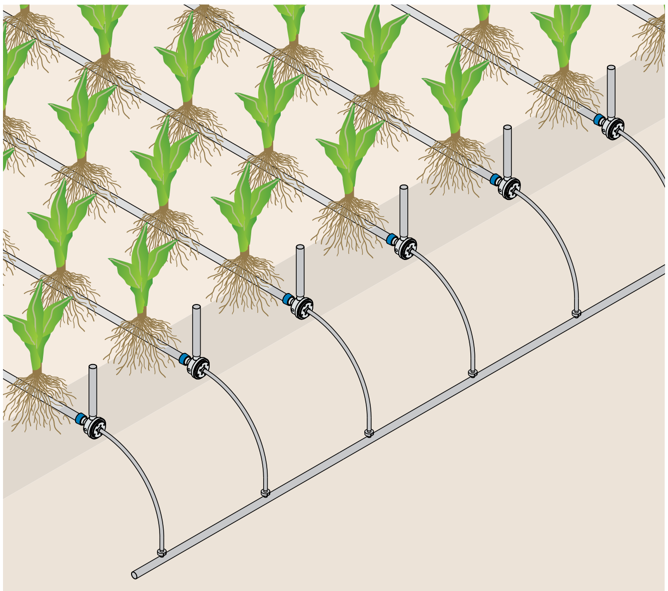
Alternatively, you can perform single dripline flushing by installing a flush valve at the end of each dripline. The design must provide sufficient pressure to ensure that the valve will close after short flushing.

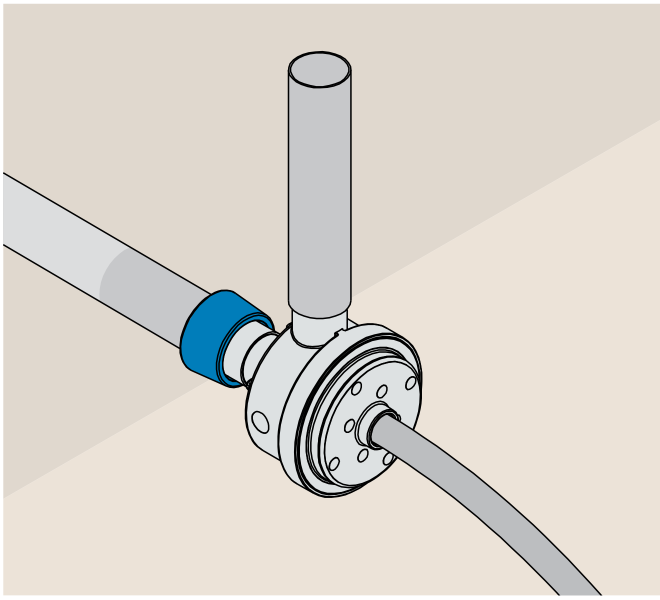
NOTE

Details on how to operate this flushing procedure are explained in the maintenance section of this booklet.

Controlled flush valves (NetaFlush)

This innovative system, developed and produced by Netafim™, allows correct flushing, at relatively high pressures (not at the beginning of the irrigation of the section), and for the necessary time of previously considered groups of irrigation driplines.





Benefits:
Flushing is carried out when the flow rates and pressures of the system have already stabilized. The time in which the end of lines will remain open can be defined at the moment of the flushing action (this time can vary according to the quality of the water during the irrigation season).

Disadvantages:
A water conduction system is required (16 mm diameter hydraulic pipe) that carries the order of activation and completion of the flushing between the valves. A manual or automatic system is required to activate the process.

The ends of these driplines need to follow the same depth of the burial of these driplines, make these auto-flush valves leave inside a trench that has been opened in the field for this purpose and where a tube will be installed for this purpose .

Drippers products

Dripline design

In any irrigation system, the design process starts at the plant and proceeds to dripline design. The following sections describe what to take into consideration during dripline design: dripline selection, wall thickness, dripper discharge, spacing between drippers, spacing between driplines, and specification of dripline depth.

Dripper considerations

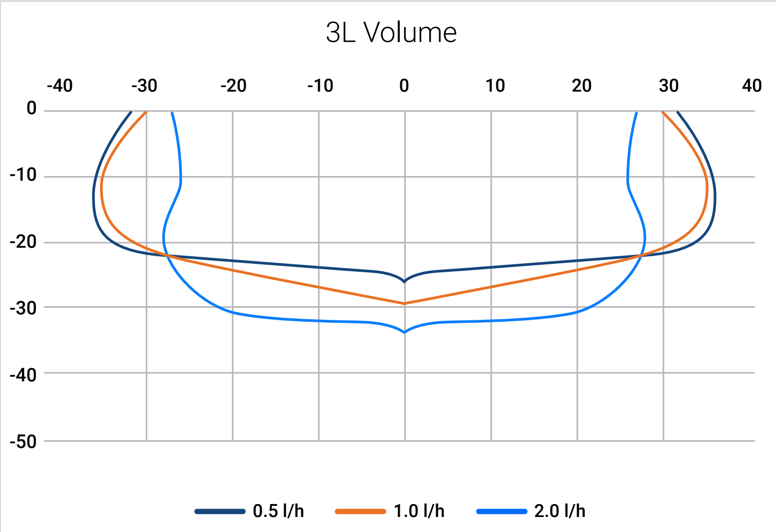
- Choose between Pressure Compensated (PC) or non-PC drippers. The PC drippers are characterized by a shorter labyrinth and wider cross-section at lower flow-rates.
- The standard flow rate for PC drippers is 0.4 l/h (0.6 l/h in AS model) up to 3.8 l/h. The smaller the dripper spacing, the lower the selected flow rate.
- The standard flow rate for non-PC drippers is 0.5 up to 4.0 l/h.
- Lower dripper discharge rates may be required in heavy-textured soils, such as clay, so that the discharge rate does not exceed the hydraulic conductivity of the soil. If the discharge rate is too high, “surfacing” may occur as water takes the path of least resistance to the surface via void spaces.
- It is recommended to design sub surface driplines associate with the Anti-Siphon (AS) dripper mechanism, which avoids the suction of dirt back into the dripper.
- In open field crops, where thin wall driplines are selected, it is recommended to use driplines with “flap” outlets.

Spacing between drippers

- The spacing between drippers, in conjunction with dripper flow rate and spacing between driplines, defines the hourly application rate.
- In deep injection of SDI, the dripper spacing design should meet crop requirements. This usually means reducing the spacing between the drippers compared to the spacing in on surface drip irrigation systems.
- In field crops and alfalfa (when considering irrigation of the total soil coverage), the standard spacing between drippers is 0.3 - 0.5 m. depending on the soil type and structure.
- In orchards, the standard spacing between drippers is 0.40 - 0.75 m. (according to the type of crop and soil and the distance between the trees).
- In vegetables, intensive crops or turf that uses shallow SDI, the spacing is 0.2 - 0.4 m between drippers, depending on the specific crop and soil type.

The aim of selecting dripper flow and spacing is to create a uniform wetted strip:

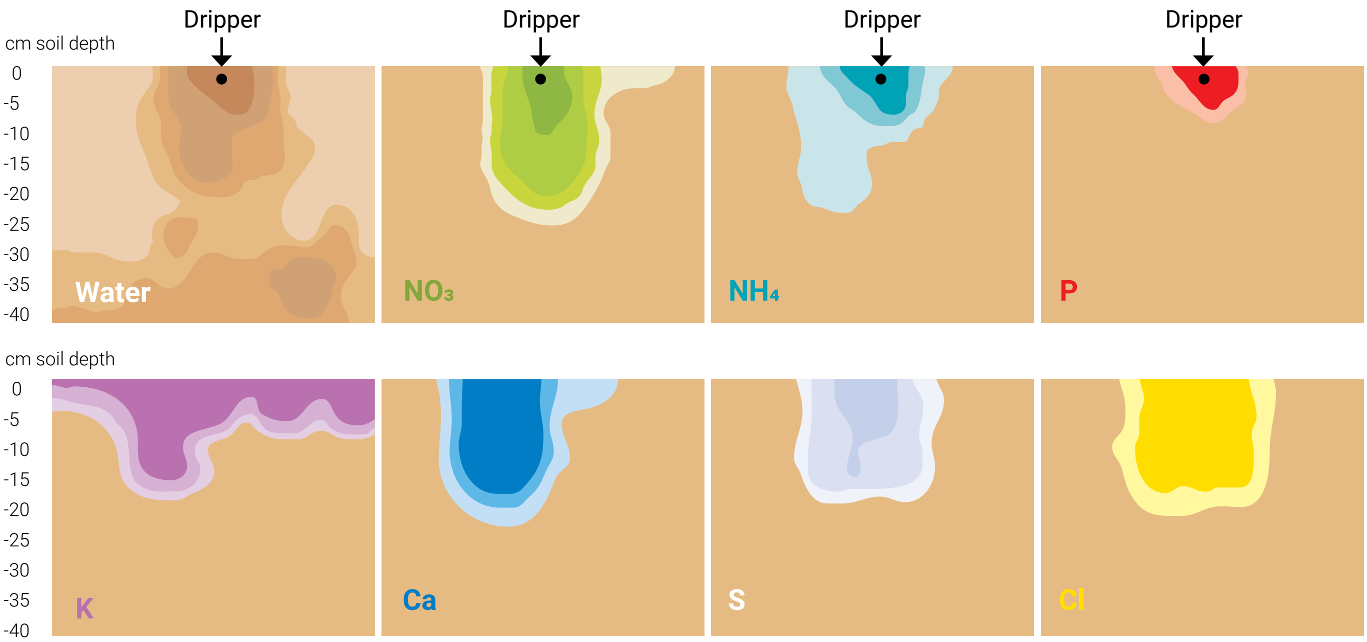
- Low flow do always give better water distribution, it can give advantage for better design (more efficient and economic)



The common dripper spacing for SDI are:
Sandy soil: 0.30 - 0.50 meter
Medium soil: 0.40 - 0.60 meter
Heavy soil: 0.50 - 0.70 meter

* Trail results in citrus - Netafim™ SA showing the low flow have better water distribution mainly at the beginning of the irrigation

- Take into consideration: nutrient movement in the soil does not follow the water movement in the same rate especially to the laterals



* Demonstration of different nutrients movement using fertigation with the same amount of water applied. Source: YARA

Spacing between driplines

There are two SDI alternatives for setting the distance between driplines in field crops:

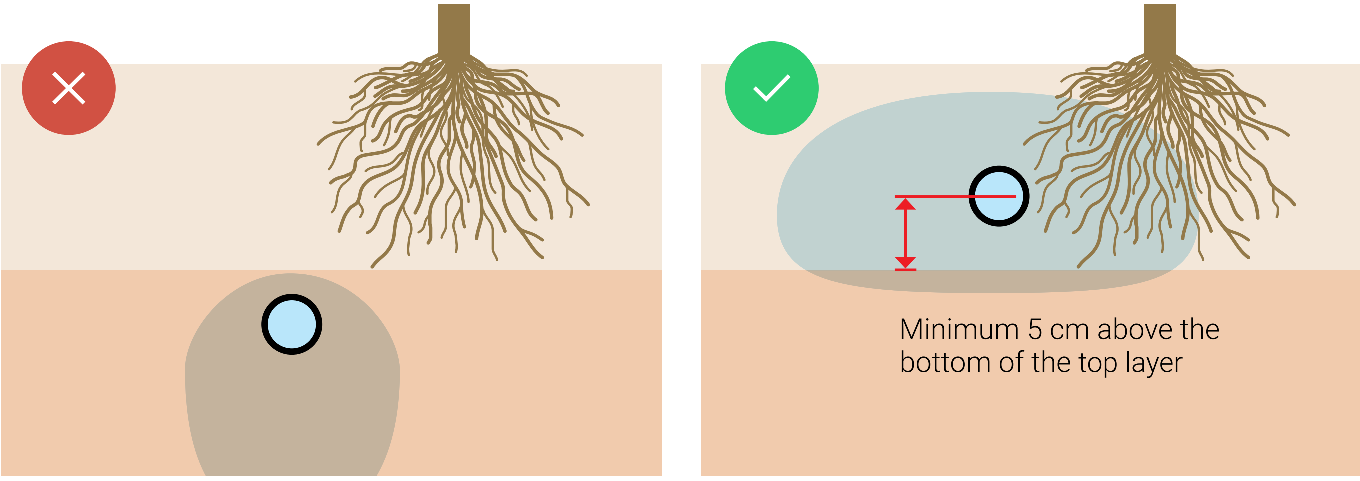
- **Distance between driplines is designed for full overlap of soil wetting.** Based on this approach, cotton growers, for example, install SDI with driplines injected 1.0 (+/-) meters apart. The drawback of this method is its high investment cost, however, this allows crop rotation.
- **Distance between driplines does not provide full overlap of soil wetting.** The location of driplines is designed to only meet the requirements of a specific crop and its root system. Based on this approach, cotton growers, for example, install SDI with driplines +/- 2.0 meters apart, centered between two rows and depending on the use of agro-machinery equipment.

Dripline position and planting pattern

Dripline position in different soil layers

Always position the dripline in the top soil layer.

From 5 cm below the dripline location and upward toward the surface, the texture must be consistent. If it isn't, consider elevating the dripline position.

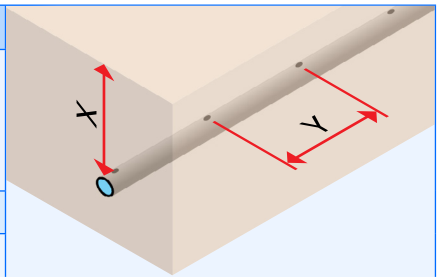


NOTE

Sandy soils have superior water conductivity when saturated, conductivity in dry soil is inferior, and therefore, water does not move laterally for long distances from the dripper.

Optimal dripline insertion depth and dripper spacing for different soil textures (excluding germination)

<table>
<tr><th></th><th></th><th>X</th><th>Y</th></tr>
<tr><th>Group</th><th>Soil texture and profile</th><th>Maximum dripperline insertion depth (cm)</th><th>Recommended dripper spacing (cm)</th></tr>
<tr><td>A</td><td>Sand; Loamy sand</td><td>30</td><td>30 - 40</td></tr>
<tr><td>B</td><td>Sandy loam</td><td rowspan="4">40</td><td rowspan="4">50 - 60</td></tr>
<tr><td>C</td><td>Silt loam; Loam;
Sandy clay loam</td></tr>
<tr><td>D</td><td>Silty clay loam;
Clay loam; Sandy clay</td></tr>
<tr><td>E</td><td>Silty clay; Clay</td></tr>
</table>



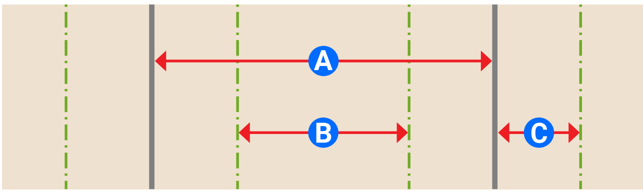
Optimal field planting pattern and dripline distance from crop row (excluding germination)

Group	Soil texture and profile	Maximum allowed horizontal distance between dripline and crop row (cm)
A	Sand; Loamy sand	40
B	Sandy loam	50
C	Silt loam; Loam; Sandy clay loam	
D	Silty clay loam; Clay loam; Sandy clay	
E	Silty clay; Clay	

Precise RTK lateral installation and planting with 150 cm lateral spacing

Suitable for wide-row corn, corn on corn, and rotation with cotton or others.

- 33% dripline savings compared to full-coverage concept.
- Offers the best coverage with minimum water usage.



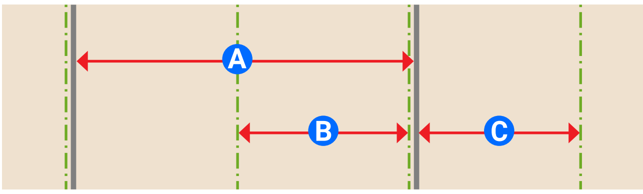
A Horizontal distance between driplines: 150 cm

B Horizontal distance between crop rows: 75 cm

C Maximum horizontal distance between crop row and dripperline: 40 cm

Non-precise planting with 150 cm lateral spacing

Recommended since the maximum horizontal distance between crop row and dripline is too great (ufficient for rain-fed areas where drip comes into use only toward the end of the season).



A Horizontal distance between driplines: 150 cm

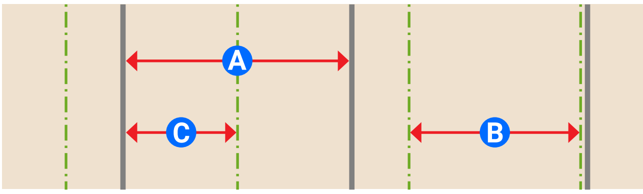
B Horizontal distance between crop rows: 75 cm

C Maximum horizontal distance between crop row and dripline: 75 cm

Full-coverage concept - 100 cm lateral spacing non-precise planting

Suitable for narrow-row corn and rotation with soybean, alfalfa, wheat and sorghum (milo).

- Requires 33% more dripline than with precise RTK planting.



A Horizontal distance between dripperlines: 100 cm

B Horizontal distance between crop rows: 75 cm

C Maximum horizontal distance between crop row and dripline: 50 cm

ATTENTION

Stony soil: Soils with extremely stony content – over 25% – are problematic for SDI due to possible damage to the dripline and unexpected water movement patterns within the soil, causing deep percolation. In such cases, we recommend the following:

- Thick-walled dripline (25 mil or more)
- Shallower insertion (not exceeding 20 cm)
- Stronger installation plow (bar and shank sizes)
- Narrower dripper and lateral spacing

You must also consider whether to install a dripline per single row or per double row:

- Installing a single sub surface dripline per single row has advantages for germination and water savings, but the system costs are high, depending on the type of equipment used.
- Installing a single sub surface dripline per double row offers a cost advantage, but you can use it only if you use a 'permanent path' cultivation technique. In this case, germination must be done using sprinkler or flood irrigation in case there is not enough rain to germinate.
- For vegetable crops, the accepted method is a single dripline per pair of rows. Certain crops, however, require special design practices.
- Dual row allows also changing the growing pattern that allows multiple benefits from agronomical aspects like light and aeration

Dripline wall thickness

- For single use applications:
  Shallow burying, driplines wall thickness: 5 up to 12.5 mil, *mainly for vegetables.
- For semi-permanent uses:
  Shallow and medium depth burying, dripline wall thickness: 13.5 up to 25 mil, mainly for forage crops.
- For permanent uses:
  Depth burying, dripline wall thickness: 0.8 up to 1.2 mm (30 to 47 mil), mainly for orchards.

NOTE
The use of driplines with "flap" outlet is highly recommended

Wetted bulb test

The design of a drip irrigation system begins by determining the flow and distance between the emitters necessary to wet a given volume of soil.

This data is obtained from a good estimate of the shape and dimensions of the wetted bulb formed by the dripper, which depends above all on the soil properties and characteristics of the physical profile, volume, water flow applied by the emitter, and the topography of the terrain.

Any scientifically reasonable method can be used to estimate the shape and dimensions of the wetted bulb. Several software applications, based on tables or field test results, can be used for this function.

Field testing is undoubtedly the most reliable and safest method for irrigation design purposes.

We face the challenge of selecting dripper flow, spacing between drippers, depth of burying for drip irrigation projects. In some cases, we must also determine the most effective distance between drippers in order to provide a uniform distribution of water over the entire length of the wetted strip.

It is important to point out that knowing the shape and dimensions of the wetted bulb obtained from an emitter will help in determining the number of emitters necessary to wet a given volume of soil, as well as the depth of burying, which will significantly influence the irrigation efficiency and installation cost.

An easy methodology is proposed for determining this, so that, together with the interpretation of these data, there is a technical and agronomic basis to decide on the flow rate of the drippers, and the necessary distance between them, given the soil type and condition, and depth of burying.

Infiltration Test

This consists of analyzing the distribution of water in the wetted bulb in a given type of soil, using different dripper flows, and applying the same volume of water.

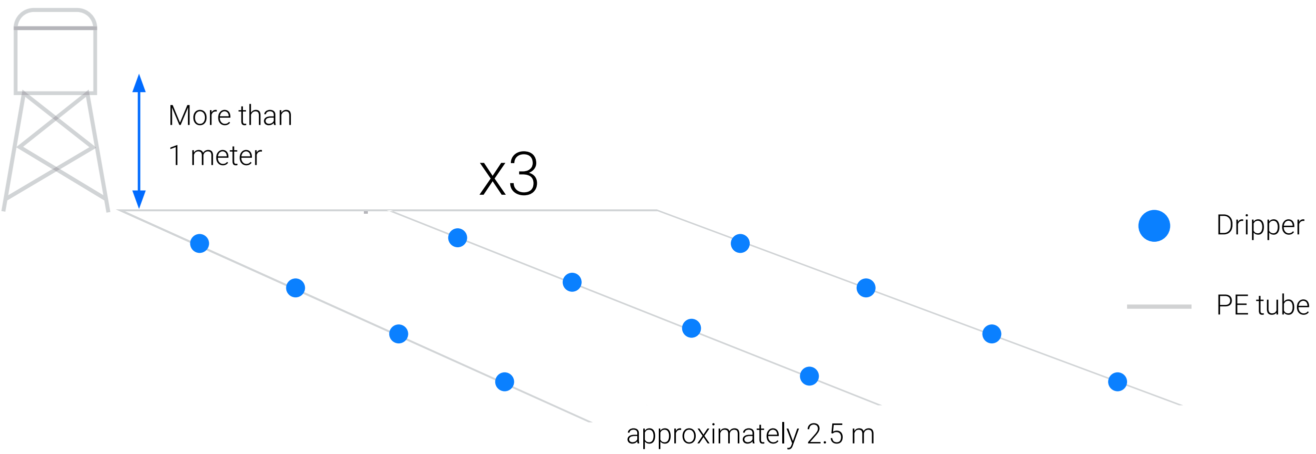
Location Features

The test site should fully represent the characteristics of the entire area where the project will be installed in the future.

- On-site water availability (running or stored water).
- Good logistics with easy access for people and machines.
- Speedy access to the site.

Procedure

- A small drip irrigation system is built, consisting of pumping and energy equipment that ensures a minimum pressure of 1.0 meter on the irrigation laterals, a water tank of at least 200-liter capacity, blank hose of 16 mm, and the drippers we wish to evaluate.
- This irrigation system must be installed in the soil where the project will be carried out; it must be pre-defined whether the field test of humidity bulbs will be carried out in moist soil (previously watered) or dry soil (recommended).
- The distance between the irrigation distribution pipes will be sufficiently spaced to make them independent from each other (approximately 2.5 m), and through this the irrigation will be applied according to the volume and times estimated by the calculation.



- After the application process, following each irrigation time, need to evaluate, by sampling or opening a test pit.
- Need to measure the diameter and depth of the wetted bulb, as well as a photograph for each repetition made.
- It is recommended to perform at least 3 repetitions of the infiltration test in order to minimize local interference.

Dripper flow rate calculation

The flow rate of a dripper can be obtained from the following formula:

$$Q = K * P^x$$

Where:

Q = dripper flow rate, liters per hour
K = fixed coefficient of each type of dripper
P = water pressure in meters
x = dripper exponent

If will be using technical data for Netafim™ Button non-compensated drippers, will obtain the following flow rates depending on pumping working pressure or the height at which install the base of our small reservoir.

Dripper Model	Flow rate (l/h) at working pressure (m)										
	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
2.0	0.66	0.80	0.92	1.12	1.29	1.43	1.56	1.68	1.80	1.90	2.00
3.0	0.99	1.21	1.38	1.68	1.93	2.15	2.35	2.53	2.69	2.85	3.00
4.0	1.33	1.61	1.85	2.25	2.58	2.87	3.13	3.37	3.60	3.80	4.00
8.0	2.65	3.22	3.69	4.49	5.15	5.74	6.26	6.74	7.19	7.61	8.00

Once the necessary equipment for the test is installed, on the same level where the project will be installed, the water is opened to “start irrigation”.

Netafim™ offer a complete Wetted bulb test kit, catalog number: 42000-027230

Irrigation Time

Generally, in drip irrigation projects, we find two soil moisture conditions:
a) Completely dry soil, which is watered with the aim of forming a wet volume, known as “wetted bulb”.
b) Soil already moistened by the action of previous rains or irrigation.

It is better to carry out the test in dry soil as there is more security regarding the distribution of moisture in it. The irrigation time is mainly related to the soil texture, since this is the characteristic that, together with the dripper flow, most influences the pattern of water distribution in the irrigated soil. The working time will be equal to the number of hours of irrigation necessary for the size of the wetted bulb to reach its maximum dimension, without the wetted depth exceeding the desired depth. This time can be between 12 to 20 hours in light soils and 30 to 40 hours in medium and heavy soils, beginning with irrigation of dry soil.

To determine the irrigation time, it is necessary to start the irrigation and determine the evolution of the size of the bulb in relation to the elapsed time. These measurements are made by measuring the distance between the emitter (dripper) and the edge of the wetted bulb in formation, and should be carried out at regular intervals, remembering that the increase in the size of the bulb is more pronounced in the first two or three hours of irrigation. For this purpose, the method of trenches or pits can be used perpendicular to the irrigating line in intervals of 2, 6, 12 and 24 hours, as an example.

Once the size of the bulb no longer increases, or only shows a small change in relation to time, this is the maximum size of the wetted volume, under these conditions (flow, working time and type of soil).

You must know the root depth of your crop. Any water or any wetted profile below root depth is wasted water. It is important to know the lateral dimensions of your wetted profile at the desired root depth. In shallow rooted crops, this depth will determine how close you need to pull in your dripper spacing. In deeper rooted crops, you will be able to expand your dripper spacing. Avoid spacing your drippers such that when the wetted profiles meet up laterally you have gone beyond your root zone in depth.

Take care when opening trenches:

- Close the record according to the planned schedule.
- Wait for about 1 hour and start opening the trenches.
- Start the opening of the trench parallel to the drip tube (about 50 cm) with the hoe and move closer (use a trowel or cutting shovel) carefully until it reaches the dripper, avoiding the collapse of the soil.
- Carefully delimit the ends of the wetted bulb formed.
- Mark the opening radius of the wetted bulb every 10 cm.

Output

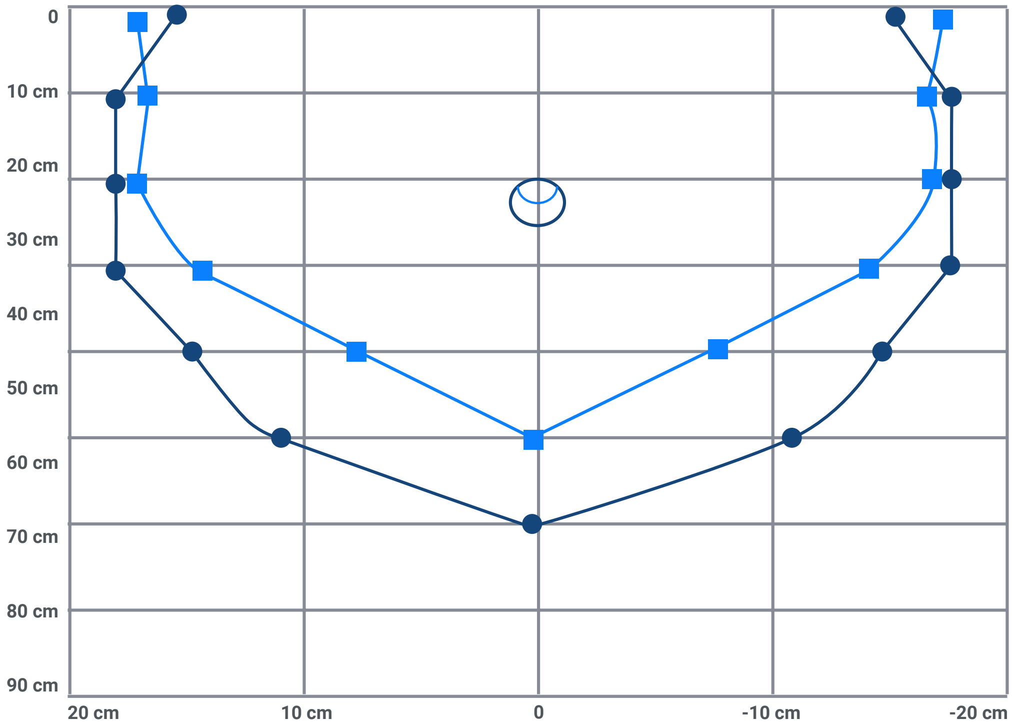
- Average wetted bulb diameter.
- Average wetted bulb depth.
- Control charts according to emitter flow, volume or applied irrigation time.

Based on the test results it is possible to draw the following conclusions:

- Which emitter flow rate is most suitable for the tested soil.
- What the recommended minimum spacing should be between the drippers for the wet bulb to be formed.
- Assistance in the management of irrigation and Nutrigation™, as it will be possible to estimate the behavior of the bulb according to the different irrigation times applied.

The goal of this trial is to evaluate the wetted bulb which helps us determine the depth of burying.
This also depends on the crop i.e. whether we are looking for a complete wetting front, or otherwise:

- Set the desired drip laterals at the desired depth. It is recommended to install at least three laterals for each treatment, at lengths of 10 m.
- It is also necessary to pre-clean the area and bury the drip tube according to the depth pre-established in the project, dismantling the soil as little as possible.
- Irrigate the plot for the desired irrigation cycle.
- Dig the soil at the center of the wet circle and measure the wet front.
- Pick one place on each treatment, and measure the depth and the diameter of the wetted bulb.
- Fill the spreadsheet with the dimensions of the bulbs formed.


0
10 cm
20 cm
30 cm
40 cm
50 cm
60 cm
70 cm
80 cm
90 cm
20 cm
10 cm
0
-10 cm
-20 cm

MAINTENANCE

Maintenance

The implementation of a simple yet strict maintenance program for drip irrigation systems will achieve the following:

- Keep the system operating at peak performance.
- Increase the system's working life expectancy.

For optimal performance, drip irrigation systems require routine system maintenance. Even though recent innovations in dripper design have made clog-resistant driplines readily available, the nature of agricultural water sources, nutrient injection practices, natural limitations of filtration equipment and the general agricultural growing environment make maintenance a priority.

Correct preventative maintenance ensures long-term use of a durable and efficient SDI system.

General

The following guidelines concentrate mainly on issues which are related specifically to SDI systems, such as: driplines monitoring, sub surface driplines flushing, prevention of root intrusion, and prevention of rodent damage.

The rest of the maintenance procedures and activities are identical to those performed in any above-surface drip system and are therefore not discussed in detail here.

For a complete description of maintenance activities, see Netafim's Operation and Maintenance Manual.

Keep in mind that in an SDI system, it is practically impossible to physically access drippers or visually check them after installation; therefore, maintenance operations have a bigger impact on system performance, and must be performed professionally and consistently.

Maintenance consists of two categories:

Preventive maintenance, aimed at preventing clogging of the drippers, can be divided into three categories:

- Flushing the system
- Chemical injection
- Irrigation scheduling*(technical irrigation)

> **NOTE**
> Irrigation scheduling (technical irrigation) is not a distinct maintenance practice, and therefore it is not discussed in this book. However, the application of an orderly irrigation plan is of utmost importance to the prevention of clogging of the drippers.

Corrective maintenance consists mainly of removal of obstructions already present in the drippers:

- Flushing the system

  And one or more of the following practices according to the nature of the obstruction:
- Organic formation - treated with hydrogen peroxide.
- Mineral sedimentation - treated with acids (or a combination of acid and hydrogen peroxide).
- Organic formation and mineral sedimentation - treated with a combination of acid and hydrogen peroxide.

Maintenance timetable

When operating a new system for the first time

- Flush the piping - main line, sub-mains and distribution pipes.
- Flush the driplines.
- Check actual flow rate and working pressure for each irrigation shift (when the system is active for at least half an hour).
- Compare the data collected to the data supplied with the system (planned). The tolerance should not be greater than ± 5%.
- Write down the newly acquired data and keep it as a benchmark for future reference.
- If the flow rate and/or the working pressure at any point in the system differ by more than 5% from the data supplied with the system, have the installer check the system for faults.

Once a week

- Check actual flow rate and working pressure for each irrigation shift under regular operating conditions (i.e., when the system is active for at least half an hour and stabilized).
  Compare the data collected to the benchmark data.
- Check that the water reaches the ends of all the driplines.
- Check the pressure differential across the filters. A well-planned filtration system should lose 0.2 - 0.3 bar (when the filtration system is clean).
- If the pressure differential exceeds 0.8 bar, check the filter/s and their controller for faults.

Once a month

- Check the pump's flow rate and pressure at its outlet.
- Flush the driplines. (A higher or lower frequency may be required, depending on the type and quality of the water.)
- If the filtration system is automatic, initiate manually flushing of the filter/s and check that all components work as planned.
- If pressure-regulating valves are installed, check the pressure at the outlet of each one of them and compare these figures with the benchmark data.

Once a growing season

In some cases, the following need to be performed twice or three times in a growing season, depending on the type and quality of the water used.

- Check all the valves in the system.
- Check the level of dirt in the system (carbonates, algae and salt sedimentation).
- Check for occurrence of dripper clogging.
- Flush the piping - main line, sub-mains and distribution pipes.
- If necessary, inject hydrogen peroxide and/or acids as required.

At the end of the growing season

- Inject chemicals for the maintenance and flushing of the main line, the sub-main lines, the distribution pipes and the driplines.
- Flush the driplines.
- Prepare the system for the inactive period between the growing seasons.
- Perform winterization of the system in regions where the temperature might drop below 0ºC.

System maintenance

Regular baseline readings and monitoring of flow, pressure and condition of flush water will guide your maintenance scheduling.

In addition to flow, pressure and condition of flush water, the overall condition of the pump station and distribution system, including control equipment engines, motors, reservoirs, injectors, pipelines, valves, fittings, flow meters and pressure gauges, should be routinely inspected and/or calibrated.
Broken or dysfunctional equipment should be immediately repaired or replaced with the same or similar equipment that will perform the same function according to system design criteria.

Inspection of the pump

Once a month

- Visually inspect the pump for integrity and for leaks from its impeller chamber (if applicable), inlet, outlet pipes and accessories.
- Make sure the pump and its immediate environment are clean and free of any unrelated objects that might obstruct proper aeration of the pump's motor or block accessibility for maintenance.
- Check the screen at the pump's inlet for clogging.
- Check for rust on the pump and its accessories.
- Make sure the electrical supply to the pump is properly isolated and protected from moisture.
- Make sure the pump starts smoothly. (In the long term, startup vibrations might damage the pump).
- Check that the pump sounds as usual, free of hiss or irregularity that might suggest stress or a mechanical problem within the pump.
- Check the flow rate and the pressure at the pump's outlet and compare the results to the benchmark data.

Inspection of the filter

Pressure differential across a filter

Every filter must cause a loss of pressure in the system while filtering. This loss of pressure is demonstrated by the pressure differential across the filter (between the inlet and the outlet of the filter / filtration array). Check the filter documentation for the allowable pressure differential across the filters.

Most filters are subject to an increasingly higher pressure differential between inlet and outlet due to friction as the filter becomes clogged. Monitor the filter pressure differential frequently, especially as water conditions change in the course of the season.

The pressure differential in a filter might be higher than the allowed maximum due to the development of biofilm, scale or mineral sedimentation in the filter.

The pressure differential in a filter might be lower than the allowed minimum due to poor operation and maintenance practices or improper calibration of the automatic flushing control.

Filter	Higher than the maximum	Lower than the minimum
Gravel/sand	Partial or total clogging of medium	Tunnels in the medium or breakage and loss of medium
Screen	Screen clogging	Screen ripping or bursts through the screen (meat grinder)
Disc	Clogging of filtration grooves	Leakage through discs due to solids trapped between the discs (preventing the discs from being pressed close together and causing gaps in the disc array)

A pressure differential that is higher or lower than the recommended range for the specific filter may lead to debris passing through the filters and/or poor irrigation system performance.

Visual inspection

Visually inspect the filtration unit or medium and all other filter components and accessories for mechanical integrity.

Automatic flushing

Check the frequency of automatic flushing.

Flushing frequency is too high	Flushing frequency is too low	Automatic flushing is not triggered
The filtration unit or medium remains clogged after flushing. The pressure range is incorrectly set in the controller. Faults in automation or sensor.	The filtration unit or medium is breached or leaking. Faults in automation or sensor. Mechanical failure.	Faults in automation or sensor. Mechanical failure.

Frequent automatic flushing occurs when the filter is not properly cleaned and the pressure differential across the filter remains high immediately after flushing.

Gravel/sand filter

Periodic inspection of the medium in gravel/sand filters is an essential maintenance task that is frequently neglected. Gravel/sand should not be caking* and/or cracking** and should be adequately cleaned during the automatic back-flush cycles.

** Caking:*

The gravel in the filter sticks together, forming a clod and making water passage through the filter difficult. Check it by inserting a fist (or an object of similar size) into the medium. A good condition medium should be penetrable. If the medium is hard to penetrate, it might be caking.

*** Cracking:*

Cracks and fissures appear on the medium's surface. Check it visually.

The filter might lose some gravel/sand during the back-flush cycles, so even if the filter is in proper working order, it may require additional gravel/sand from time to time.

During inspection, examine the gravel/sand by touch. The gravel/sand grains should be sharp-edged, not rounded and smooth like beach sand. The sharp edges promote better filtration. The gravel/sand will wear smooth over time. If this has occurred, replace the gravel/sand.

Once a month

If the filtration system is automatic, initiate flushing of the filter/s and check that all the components work as planned.

Inspection of the valves

Once a growing season

- Visually inspect each valve for integrity and for leaks.
- Activate each valve - manual, hydraulic or electrical - and make sure it opens and closes according to its specific function and purpose.
- Visually inspect air relief valves for dripping that might suggest faulty sealing of the valve mechanism.
- If pressure-regulating valves are installed, check the pressure at the outlet of each one of them and compare it to the benchmark data.
- Make sure the flushing valves installed at the dripline flushing manifold open when dripline flushing is initiated.

Inspection of main, sub-main, distribution and flushing manifolds pipes

Visually inspect the main, sub-main and distribution pipes and the dripline flushing manifolds for integrity, for leaks and for damage from agricultural machinery or from rodents and pests.

Inspection of driplines (laterals)

Once a week

- At the start of the irrigation sequence, when the flow and pressure are stabilized, visually inspect the driplines for integrity and for leaks; check for puddles that might suggest the existence of leaks.
- Check the pressure at the end of the furthest dripline when the flow and pressure are stabilized.
- At the end of the irrigation sequence, visually inspect the wetting pattern on the soil. Dry areas or an uneven pattern might suggest clogging in the dripline.

Visual inspection of water quality

System maintenance should be performed as soon as water quality begins to degrade, as shown by color, grit, organic or any solid materials in the flush water. The ends of the driplines should be opened regularly (in extreme cases this might be required as often as each irrigation) and the contents emptied into the hand or a jar for visual inspection of water quality.

Flushing the main, sub-main and distribution lines

Flushing the main, sub-main and distribution lines is an important operation that often doesn't get the attention it requires.

Even with a primary filter at the head control station, small particles can get by and should be physically removed from the piping system.

Flushing the main, sub-main and distribution lines will considerably reduce the accumulation of organic and mineral materials in the system. This will prevent those materials from reaching the drippers and eventually clogging them, thus minimizing the quantity of chemical products required to maintain the system.

Regular flushing of the main, sub-main and distribution lines will result in a significant saving of labor time and chemicals.

The main, sub-main and distribution lines in the system should be flushed in sequence.

Each one of them should be flushed for at least two minutes or until the flushed water runs clear.

The pipes must be flushed at regular intervals. The frequency depends mainly on the water quality and the maintenance program (minimum: once a growing season).

Flushing is effective only when the flow rate within the main, sub-main or distribution line is sufficient to allow for proper flushing velocities in the system.

Manual flushing of main, sub-main and distribution lines

Manual flushing of main, sub-main and distribution lines should be carried out as follows:
- Flush the pipes in this order: main line, sub-main lines, distribution lines.
- Open the flushing valves of each one of them in turn while under pressure.

The process of flushing the main, sub-main and distribution lines consists of two waves for each:
- The first wave removes contaminants collected at the end of the pipe.
- The second wave removes contaminants from the pipe.
  In the second wave, the color of the water is not as dark as in the first wave, but the process takes more time. Flushing must be continued until the water is visually clean.

Obtain the velocity of the water flowing in the pipes
The velocity of the water in a pipe depends on the flow rate and the internal diameter of the pipe.
Identify the diameter of each pipe section to be flushed separately using the table below, which presents the most common diameters of pipes used for main, sub-main and distribution lines:

<table>
<tr><td rowspan="2">Nominal pipe diameter</td><td>inches</td><td>3</td><td>4</td><td>6</td><td>8</td><td>10</td></tr>
<tr><td>millimeter</td><td>75</td><td>110</td><td>160</td><td>225</td><td>250</td></tr>
<tr><td colspan="2">Actual internal pipe diameter millimeter</td><td>67.8</td><td>101.6</td><td>147.6</td><td>207.8</td><td>230.8</td></tr>
</table>

The table represents the inside diameters (ID) in pipes of one specific standard among many.

Check the flow rate in each pipe section to be flushed separately at the closest water meter installed upstream from it.
The velocity for each pipe section to be flushed can be calculated by knowing the diameter of the pipe and the flow rate. The recommended flushing velocity is 1.5 m/sec . The allowed velocity range for flushing is 1.0-2.0 m/sec.

Calculating the area of the pipe's cross-section (A)

$A = \pi * r^2$

π = 3.1416
ID = Inside diameter (m)
r = ID / 2 (m)

The pipe's inside diameter (ID) varies according to the pipe's material, standard and model.
See the actual inside diameter of a particular pipe in its product documentation.

Calculating flow velocity in a pipe (V)

Velocity (speed) is the distance water passes in one unit of time in a pipe (meters per second).

$V = (Q / A) / 3600$

V = Velocity (m/sec)
Q = Flow rate (m^3/h)
A = Area of the pipe inside cross-section (m^2)
3600 = Constant for conversion of the result from m/h to m/sec

Monitoring driplines

The flows and pressures of each irrigation zone (controlled by a single valve) must be thoroughly and accurately inspected and recorded once installation and commissioning is completed. Update the design documents with the actual flows and pressures.
This recorded data, in the form of a table, is the most important tool for monitoring system performance. It will serve as a baseline of the actual nominal values of the installed system to be compared with future checks.

- Conduct weekly flow rate and pressure tests before and throughout the entire season. Compare it with the table of baseline values to ensure optimal operation.
- Whenever water quality becomes poorer (as seen visually in the water source, or when automatic filters flushing becomes more frequent), test the system performance more often.
- It is most important to check driplines ends. A uniform flow of water should be seen when opening end-lines. If low or no flow is evident, there is clogging, a leak, or a disconnection along the dripline and it should be repaired.

Flushing the driplines (laterals)

During the irrigation season, driplines must be flushed so that dirt and sediments can be expelled from the driplines. Several times per season (sometimes only twice per season), as determined by the operator, the sub-main should be flushed before flushing the driplines.

Driplines require periodic flushing to purge them of settled debris, organic or mineral, and of any residues of chemicals injected into the system.

In SDI systems, **dripline flushing must be given high priority** since frequent dripline replacement is impractical and driplines are expected to last up to 20 years or even longer. Even for short-term dripline use, flushing is important to maintain irrigation uniformity.

Flushing should be performed as often as needed to keep the driplines clean; this depends on seasonal water quality and the effectiveness of the system filter.

All the driplines in a plot should be flushed in sequence in a single flushing event.

Driplines should be flushed until the flushed water runs clear.

Flushed water should be disposed of properly to avoid deteriorating the system's inlet water quality and/or the quality of the environment surrounding the site.

- Flushing will temporarily increase the flow requirements of the system, which in turn will decrease the system pressure. In some cases, in order to supply the flow rate required for flushing, an additional pump at the head of the system is used. The additional pump will be activated only during flushing to add the missing flow rate.
- Do not flush more than ten (10) driplines at the same time

The length of driplines affects the required flushing duration. Longer driplines need longer flushing durations.

Dripline flushing with flushing manifolds

Some drip irrigation systems are equipped with flushing manifolds to simplify the dripline flushing process. This method is common mainly in SDI systems.
Its purpose is to facilitate the task of dripline flushing and save labor hours.
The flushing manifold at the end of the driplines is fitted with a flushing riser and valve to allow flushing of the driplines.

When the flushing valve is opened, flow rate and velocity through the driplines are greater than those in normal operational mode. The higher flow velocity allows efficient removal of settled solids and precipitants from the driplines, preventing them from clogging the drippers.
The flushing manifold is sized for a flow velocity of at least 0.5 m/sec at the end of the driplines to ensure sediment removal.
Flushing will temporarily increase the flow requirements of the system, which in turn will decrease the system pressure.

In some cases, in order to supply the flow rate required for flushing, an additional pump at the head of the system is used. The additional pump will be activated only during flushing to add the missing flow rate.
During dripline flushing, carefully monitor the water flowing out of the flushing valve. Do not close the flushing valve before the water is satisfactorily clean.

Verification of the flow velocity in the dripline during flushing

Place the open end of the dripline over a 1.5-liter bottle, using a funnel. Verify that all the water enters the bottle. Measure the time (in seconds) it takes to fill the bottle, and use the following table in order to make sure that the velocity is at least 0.5 m/sec.

Dripline ID (mm)	11.8	14.2	16.2	17.5	20.8	22.2	25.0	35.0
Quantity of water per 1 meter of dripline length (liters)	0.109	0.158	0.206	0.241	0.340	0.387	0.491	0.962
Maximum time for filling a bottle (seconds) for a velocity of at least 0.5 m/sec	27.4	18.9	14.6	12.5	8.8	7.8	6.1	3.1

The dripline flushing process consists of two waves:

- The first wave removes contaminants collected at the end of the dripline.
- The second wave removes contaminants from the dripline.
- In the second wave, the color of the water is not as dark as in the first wave, but the process takes more time. Flushing must be continued until the water is visually clean.

Flushing is more effective when the flow rate within the driplines is increased and allows the flushing of contaminants from the driplines' internal walls. In some cases, the downstream pressure must be increased in order to enable these flow rates in the driplines. The pressure should not exceed the maximum flushing pressure value indicated in the Netafim™ technical pages tables, according to the dripline's wall thickness.

Filtration and Chemical Treatments

- Inspect the filtration and Nutrigation™ systems at least three times per season. Check the secondary filters (also called control filters) for damage or for permanent sediments every 120 irrigation hours.
- Very poor water quality may require continuous or intermittent chemical treatments as specifically instructed by a Netafim™ expert. The recommended treatment is usually chlorination or hydrogen peroxide or acid treatments.
- When flushing the sub-main and the driplines (via flushing manifolds if they exist) at the end of the season, the procedure may include injection of chemicals if recommended by a Netafim™ expert.

Hydrogen Peroxide (H_2O_2) as an oxidizing agent

For more than a decade, the use of hydrogen peroxide for disinfecting and oxidizing irrigation water has become increasingly widespread.

Prior to this, chlorine was used but it was found that after the oxidation and disinfection process, organic chlorides, which produce carcinogenic compounds, such as Trichloromethane, started to appear, and the process also contaminates the environment.
In fact, many countries have passed laws against chlorinating water and this is a growing trend.
Nowadays, hydrogen peroxide is used for cleaning screen, disc and gravel filters. It is also used as an oxidizing agent for fruits and vegetables prior to storage, and for disinfecting public premises.
Hydrogen peroxide is a strong oxidizing agent. It releases oxygen atoms that react quickly, oxidizing organic matter.

The advantages of hydrogen peroxide

- Quick reaction speed
- Environmentally safe
- Does not generate dangerous by-products.

Hydrogen peroxide is environmentally friendly, does not contaminate the soil, does not harm the aquifer, and indirectly makes more oxygen available for the soil and the plants.
The oxidation reaction is quick, so the hydrogen peroxide is consumed immediately upon contact with the irrigation water, and it is biodegradable. Its speed enables the use of the hydrogen peroxide for quick oxidation and disinfection of the water source and also in close proximity to the filters.
Hydrogen peroxide is also suitable for oxidizing iron and manganese.
Hydrogen peroxide is commonly used in greenhouses, net houses and tunnels, or on substrates, where the irrigation systems traverse only short distances. Chlorination could cause significant damage to the roots in substrates.

The required concentration of hydrogen peroxide at the system inlet depends on the water quality (oxidation potential and the reduction and concentration of organic matter in the water). In general, between 1 and 10 cc (ml) of hydrogen peroxide (active agent) are required for each cubic meter of water (1 to 10 PPM).

Uses of hydrogen peroxide

Hydrogen peroxide is a powerful oxidizing agent and is effective for the following:

- To prevent the accumulation of bacterial slime in the sub-main pipes and driplines.
- To clean irrigation systems of accumulated organic deposits and bacterial slime.
- To oxidize micro-elements (such as iron and sulfur) and trace elements (such as manganese), and prevent bacterial propagation.
- To improve the main and secondary filtration under high organic-load conditions.
- To disinfect and treat waste water, sewage, irrigation water, drinking water and swimming pools.
- To prevent and eliminate water odors and interference with biological activity.
- To reduce BOD/COD values by oxidizing organic and inorganic polluting materials.

Hydrogen peroxide is one of the most powerful known oxidizers. It always decomposes in an exothermic reaction into water and gaseous oxygen:

$$2\,H_2O_2 \Rightarrow 2\,H_2O + O_2$$

NOTE

Do not use hydrogen peroxide if the pipes and/or storage tanks are made of steel or asbestos cement or if they are covered with cement.
Hydrogen peroxide is not effective for preventing or dissolving scale sediments, sand, etc.

Preventing root intrusion into SDI driplines

Plant roots can penetrate the drippers, causing a reduction in the flow rate and possibly an obstruction. This is known as root intrusion. The intrusion of roots may occur when the plant suffers water stress and the roots are searching for moisture.
One of the main causes of root intrusion is insufficient irrigation. This occurs when the plant's water consumption exceeds irrigation. Under these conditions, the roots tend to develop near the dripper and eventually penetrate it. Gradually, the roots may grow into the dripper, blocking the water passage in the dripper. Maintaining proper humidity in the surroundings by means of adequate irrigation planning allows the roots to spread and use the entire available moistened soil volume, instead of concentrating around the dripper. Continuous soil humidity monitoring allows better control over the moistening pattern, thus maintaining optimal soil humidity within the dripper's surroundings.

Water stress may be:

- Planned at the farmer's discretion.
- Caused by a lack of water or a faulty water supply.
- Due to an unforeseen increase in water consumption by the crop (For example, a few consecutive days of unexpected exceptionally high temperatures, without proper irrigation to compensate for the higher water consumption during those days).

If a crop requires a stress period:

- A precise dosage of herbicide should be injected to prevent rootlet ends from growing near the dripper, without damaging the plant itself.
- Chemical treatment should be executed prior to the start of the stress period.

Determining the quantity and frequency of treatments

The number of treatments per season with one of the above-mentioned herbicides should be 1 or 2, depending on the type of soil, unplanned or induced irrigation interruptions, and duration of the irrigation and the Nutrigation™ seasons.

In perennial fruit trees, the recommendation is for up to two treatments per season, starting from the second year of age. The first treatment should be implemented in the first third of the irrigation season. The second treatment should be implemented when beginning reduction of water applications to the crop towards the end of the irrigation season.

Young trees are vulnerable to these chemicals. In the case of new plantations and plantations of up to one year of age, consult Netafim's Agronomy Division.

In open field crops (seasonal or perennial), it is highly recommended to implement the treatment once a year. The time for this mandatory treatment is when beginning reduction of water applications to the crop towards the end of the irrigation season.

Certain crops will require one additional treatment during the irrigation season, because previous interruptions or reductions of water volume that were carried out increase the potential for root penetration into drippers.

In the case of sandy soils (more than 70% sand and less than 8% clay), regardless of the type of crop, it is recommended to execute the herbicide treatment, dividing the application into two injections, each of which should be half of the dose calculated for a single application. The interval between these two injections should be two weeks.

For any query, please contact the Agronomy Division at Netafim™.

When not to use herbicides to prevent root intrusion

The treatment is contraindicated under the following conditions:

- When the soil is saturated (due to rain or irrigation).
- Near the time of crop planting or sowing and/or when the volume of the roots is very small.
- In soilless substrates.
- When the relevant authorities prohibit the specific treatment.
- When driplines are not evenly inserted in the soil.
- When driplines are covered by a plastic sheet.

Before treatment

Perform the following tests a few days before the scheduled treatment:

- Turn the water on for 20 minutes. If puddles appear, the soil is too wet and not suitable for treatment.
- Check the driplines for leaks and bursts. Repair all defects before the treatment.
- In grass, verify that the driplines are properly inserted and are not located between the surface of the soil and the grass carpet.
- Verify that the pump and the central controller are in proper working condition.

> **NOTE**
>
> The soil must not be too wet during treatment. If the soil is too wet, it is recommended to partially dry the soil by postponing an irrigation cycle intended to be performed before the treatment.

Treatment procedure

- Turn the water on and let it flow until pressure stabilizes.
- Fill a clean tank with a volume of water equal to the volume required for an injection lasting 20 minutes.
- Immediately add the herbicide to the water in the tank.
- Inject the mixture from the tank into the system. If the solution was calculated correctly, the injection will end in 20 minutes.
- Before turning off the system, allow the water to continue flowing through it during the required period of time

> **NOTE**
>
> - Observe the irrigation and injection advancement time (you can check it with Netafim's Technical Department).
> - Do not delay or advance the system's shut down.
> - After treatment, wait at least 24 hours before the next irrigation cycle.

TIP

Use or choice of XR drippers will help prevent root development, and at the same time, reduce usage of chemicals by about 50 - 75 %.

Rodent control

Unmanaged populations of rodents in agricultural fields can cause significant damage and loss of productivity in a wide range of crops. A wide variety of rodents may inhabit agricultural lands, including:

- → Voles
- → Mice
- → Rats
- → Ground squirrels
- → Gophers

Small rodents such as mice and voles damage young and older trees alike in nurseries and orchards by girdling the tender saplings and branches. Studies in New York have shown up to a 66% reduction in apple yields as a result of girdling by an overpopulation of voles.

In field crops, these small mammals love to unearth and devour newly planted seeds and snack on the young seedlings that survive.

Larger rodents such as pocket gophers damage field crops by eating the root system out from under the plant.

Rodents can also cause damage to farm equipment and infrastructure. They may gnaw on small-diameter cables and irrigation pipes.

The mounds created by larger rodents can damage or disrupt harvesting equipment, while the tunnels can cause leaks in irrigation channels and even small earthen dams.

In general, rodents responsible for the majority of damage to agricultural crops and systems live underground for at least part of their lives. A physiological feature of rodents is that their teeth grow continuously. As a result, these animals must chew to wear down their teeth so that they fit in their mouth; otherwise the animal will starve. Both the feeding and the need to gnaw cause damage to crops and equipment.

There is no single, simple method for managing rodent overpopulation on agricultural lands. Control of these potential pests requires a well-designed plan that is executed on a consistent basis.

The formation of a systematic plan for managing rodents in sub surface drip irrigated fields requires research into the predominant species in the region and formulation of rules regulating how these populations may be managed. The aim of this chapter is to outline the components of a well-designed rodent control plan, and to help growers formulate such a plan.

Rodent management plan

Management of rodent populations on agricultural land generally falls into the following categories:

- Habitat modification and exclusion to reduce population pressure.
- Trapping and removal.
- Use of repellants to deter invasion.
- Use of repellants to deter gnawing.
- Extermination.

Each category is discussed with respect to protecting crops and equipment.

Habitat modification to reduce rodent pressures
Existing rodent pressures either from surrounding fields or within a newly planted field are the first source of conflict between rodents, crop, and equipment.

A cultivated zone surrounded by unkempt ground or by open fields infested with rodents represents a continuous battle. Thus, the first step in an integrated rodent management program is to reduce the pressure of high rodent populations in the entire area.

First take a visual count of rodent presence in the surrounding fields. Large rodents such as pocket gophers will leave tell-tale mounds. Smaller animals such as mice and voles will not be as obvious. The presence of "runways" in grassy areas is one sign of small rodent activity.

Assessing the rodent population in the general area will provide an indication of the intensity of the management required to protect the crop and the irrigation system.

After assessing the situation, establish a buffer zone around the field. Elimination of weeds, ground cover and litter around the field will reduce habitat suitability. Cultivating this area is a good deterrent for small rodents as it destroys runways and may eliminate them outright.

Larger animals such as pocket gophers can burrow under this area, but the lack of food may slow them down.

If cultivation is not an option, weed control is still imperative especially for pocket gopher management. Weeds often have large tap roots which are the preferred food for gophers, while fibrous rooted grasses are less appealing. The opposite is true for smaller rodents, which enjoy the cover that grasses provide. Thus, in fields of corn, which has a fibrous root structure, the main rodent pressure may be mice and other small rodents.

Trapping and removal
Trapping can be an effective method to reduce the population of large rodents such as pocket gophers in small to medium-sized fields (< 50 acres).

Trapping is also effective to clean up remaining animals after a poison control program. In the case of smaller rodents such as mice, trapping is not usually cost effective because these animals have such rapid reproduction rates.

Body-gripping traps work exceptionally well for capturing pocket gophers.

Traps can be set in the main tunnel or in a dripline, preferably near the freshest mound. Consult a specific pocket gopher control guide for details on how and where to set these traps.

Gophers usually visit traps within a few hours of setting, so newly placed traps should be checked twice daily. If a trap has not been visited within 48 hours, move it to a new location.

Trapping is usually most effective in the spring and fall, when the gophers are actively building mounds.

Repellants
Rodent repellants can be divided into two large categories, those that affect the population at large and those that repel the rodent from gnawing on cables or small-diameter tubing such as a dripline.

Two repellants that have proven effective in reducing rodent populations over a large area are owl boxes and wet soil.

Owl boxes are being employed in greater numbers as part of rodent management programs. The principle is simple: the higher the owl population, the fewer the rodents. The application of owl boxes to deter rodents is becoming more prevalent. This technique works especially well for small-bodied rodents such as mice but also affects larger rodents because owls prey on the young. Consult the local extermination service for the design and placement of owl boxes appropriate for the area.

Wet soil, but not flooded, can be an effective deterrent for rodents that spend much of their time in tunnels. The repellant effect of wet soil seems to be the result of poor oxygen transfer through it. Rodents that live in tunnels depend upon the air traveling through the soil for oxygen. In wet soils, the rate of oxygen diffusion is greatly reduced and produces an environment that is inhospitable to the rodents.

Flooding the soil to drown the rodents is not as effective. The rodents are mobile enough to avoid drowning, and most have tunnels designed to avoid the wettest areas in the field in the case of heavy rains.

The soil need not be saturated to affect the population. In practice, the use of soil wetness to repel rodents is limited because many crops require soil drying before harvest and because the irrigation system is turned off for a period of time.

Other general repellants are less effective in rodent management over a large area.

Sound or ultrasound generators have not been proven effective in driving out rodents.

Taste repellants such as capsicum may affect some rodents such as voles, but have less effect on pocket gophers.

Targeted repellants applied on or around the object to be protected, such as a sapling, cable or dripline, may be effective when combined with a plan to reduce overall populations.

Proper dripline installation practices can reduce rodent damage, particularly by mice. When inserting thin-walled driplines in deep installations, the insertion shank can leave cracks in the soil and a path down to the dripline that mice love to follow, chewing as they go. Best installation practices dictate that these installation cracks in the soil be sealed by running a tractor tire over cracks created by the plow. This will close the opening in the soil and cut off easy access by mice or voles to the loose soil around the dripline.

Preventive installation procedures

The following installation procedures can significantly reduce potential rodent damage to sub surface driplines. It is highly recommended that all these procedures be followed:

- Prepare a buffer zone around the field and apply rodenticides according to a plan drawn up with the local extension agent if rodent pressures are high.
- Have the field as free of crop residue as possible. Field mice are especially fond of plant residues.
- Insert driplines as deep as practical for the crop being grown. Driplines inserted at depths greater than 30 cm exhibit less rodent damage.
- Apply a repellant or toxicant when inserting the dripline.
- Seal the slit made by the shank by using front tractor tires to reduce ready-made paths for small rodents. The front tires should be narrow, single-ribbed, cultivating tires and the front of the tractor must be weighted. This operation must be completed on the same day as the dripline insertion.
- Operate the irrigation system for 12 hours per zone within two weeks of completing the installation. Do not reach a situation where the driplines are inserted in the fall and the first irrigation is performed in the spring.

Rodents, especially pocket gophers, are often most active in the fall and early spring. It is often at these times, when the irrigation system is not being used, that the most damage occurs. Experience has shown that rodent damage when the system is shut down can be reduced by properly applying an acid treatment. As acidification of the dripline is standard practice for end-of-season cleaning, a slight modification of this process may also help to protect driplines from rodent damage.

Follow these guidelines:

- → Flush each zone at the recommended pressure.
- → If the field is dry, pre-irrigate each zone for 6 hours.
- → Inject N-pHuric* at 200 ppm for 1 hour before shutting down each zone.
  Shut down zones leaving N-pHuric in the lines.

> **NOTE**
> N-pHURIC combines the benefits of both urea and sulfuric acid while virtually eliminating the undesirable characteristics of using sulfuric acid alone.

Chemigating with a properly labeled pesticide that has a strong odor or fumigation effect will cause many rodents to keep away from sub surface driplines.
This may be an effective technique for early season deterrence.
Make sure the pesticide is properly labeled for use in the area.

Extermination

Several rodenticides, including toxicants and anticoagulants, are in current use for managing rodent populations.

> **CAUTION**
> Consult the local authority for approved rodenticides - toxicants and anticoagulants - in the country/area and always follow the application directions.

In general, placing approved baits around the perimeter of the field prior to irrigation system installation will reduce rodent pressures on a new field.
For pocket gophers, a mechanical "burrow builder" that releases bait is effective in perimeter applications.
Hand baiting tunnels is time consuming but effective if done by a trained applicator.
The usual treatment for gophers is bait plowed in every other furrow and around the perimeter of the field.
Fumigants applied in the tunnels are usually not as effective as toxicants and trapping because they tend to diffuse, giving the gopher enough time to escape.

Rodent management action plan

An integrated approach must be taken to reduce rodent damage to crops and equipment. This plan must involve reducing acceptable habitats for rodents close to the field and may involve trapping or poisoning to control active populations. In addition, the dripline itself can be protected by using the repellant effect of some pesticides and slightly acidifying the soil around the driplines.
Fall and spring are the seasons when rodents are most active and may cause the most damage. Therefore, any management program must focus on these seasons. Do not underestimate the wealth of reference materials and the help of local extension agents and pest control specialists. Many growers have implemented successful plans for rodent management on their fields, protecting the investment in their irrigation system and improving yields.
To be effective, any rodent control plan must be diligent and consistent in a timeframe determined by the extent of the rodent pressure in the surrounding area.

Insect control

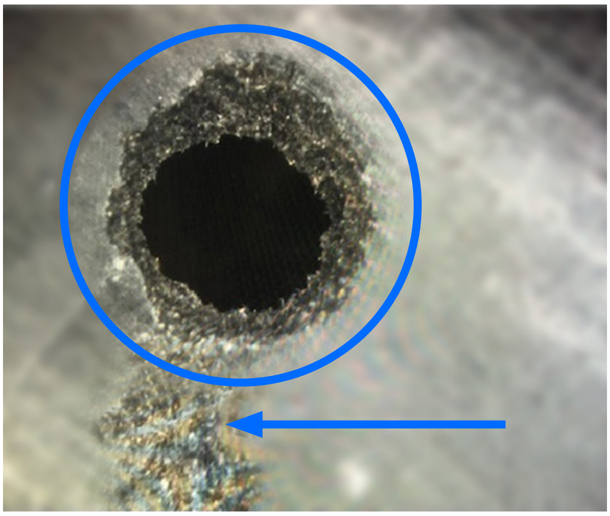
Understanding the phenomenon

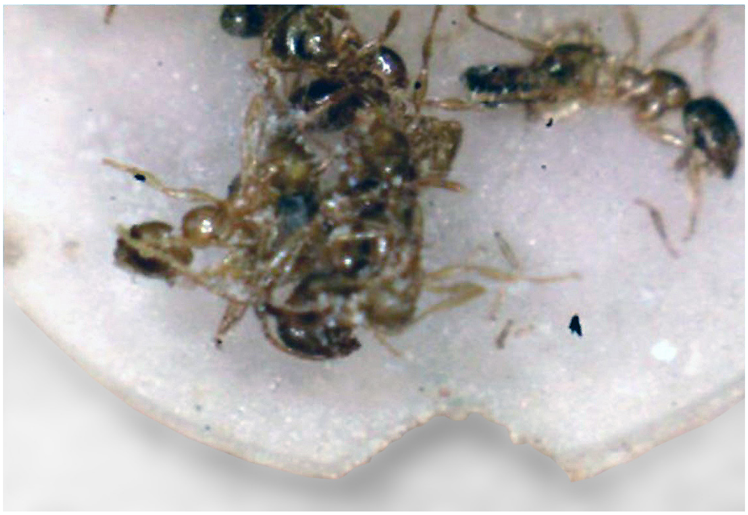
Insects can be found any place in the field – in the air, on the plants, in the water, and in the soil.
There is an almost infinite number of insects in the soil, from hundreds of species – ants, beetles, worm, caterpillars, crickets, and many more.
Most of them are essential to the health and functionality of the agricultural soil, some of them can hurt the plants, and as we shall learn, there are some insects that are harmful and some that are extremely harmful to the drip irrigation equipment.

Damage to drippers and driplines

Damage to irrigation equipment is most commonly seen in SDI applications, but not only. There are also cases in which thin-wall on surface driplines were damaged by insects.

Large insects, such as mole crickets, can bite the pipes.





Small insects can nibble the pipe until there is a hole.

Some small insects can enter the pipe through the dripper hole and nibble the dripper – sometimes the polyethylene part, and sometimes the dripper's membranes.

Insect management methods

There are 4 main common methods to deal with the insect problem (in the soil):
1. Broadcast spraying.
2. Adding insecticides to the plastics.
3. Chemigation through the drip system.
4. Localized spraying over the dripline during installation.

1. Broadcast spraying
Advantages: Can prevent insect damage; no need to identify the specific insect.
Disadvantages: High insecticide amount; mostly effective for plant insects but not for underground insects.

2. Adding insecticides to the plastics
There are now several irrigation companies in the market that offer this type of solution. Using chemicals in any plastic article requires a strict regulatory process, and one should check to see if companies have used the chemical insecticides properly.

Advantages: Theoretically offers constant protection.

Disadvantages: Most of the relevant materials (repellants and poisons) are volatile and have short lifetime in the polyethylene matrix.
The lifetime includes the time before installation, starting from the day of dripline production.
Since the time from production to installation is not necessarily determined, the chemical materials may have already migrated from the pipe prior to its installation in the soil.
Since these materials can migrate to the pipe surface, these added insecticides can affect people in the production, storage and installation processes.

It is super critical to follow the local regulatory guidelines in each country that allow the usage of these treated products.
Some of the treated products uses materials that are non-environmental friendly.

Until a proper solution is found to warrant safe exposure to people and the environment, that conforms to regulations, we can't offer or recommend such a solution, especially due to the lack of effectiveness of such a solution.

3. Chemigation through the drip system
Advantages: Effective use in insecticides reduces the total amount of materials, direct contact with soil.

Disadvantages: Needs specific labeling, the insecticide requires minimum solubility in water.

4. Spraying during installation
Advantages: Limited and safety use in herbicides, should be effective only for one season, should be cost effective.

Disadvantages: A type of broadcast treatment.

Summary

There are multiple methods of insect treatments to protect your driplines. We recommend injecting the chemicals using the drip system, or broadcast spraying with chemicals, that conforms to local regulations concerning crops and insecticides in your area. These are the most effective and safe methods for growers.

Netafim™ has a detailed manual for treating insects and rodents. Netafim™ has also developed the machines and the tools to apply chemicals either by drip or spraying during SDI installation.

Winterization

Winterizing the system is necessary in climates where water may freeze and expand, possibly damaging plastic and metal system components.
Water from filters, valves, chemigation equipment, pressure regulators and sub surface pipes and driplines should be emptied, especially at lower ends of the field where water typically accumulates.
Polyethylene driplines are not subject to damage from freezing since drippers provide drainage points and polyethylene is somewhat flexible.

Prior to a winter shut-down period:

- Perform chemical injection, flushing of all pipes and driplines, and cleaning of the filters.
- Empty filters, valves, chemigation equipment, pressure regulators and sub surface pipelines.

Water tanks and soil reservoirs coated with PE or PP liners

The same recommendations apply for the freezing period in winter, with the addition of the following instructions:

- The liner becomes very sensitive to movements, strikes and vibrations when the temperature drops below 0°C (32 °F). Therefore, it is important to keep it still, with minimum movements caused by the wind.
- The wind tends to penetrate the gap between the liner and the metal walls, and blow the liner off. The best way to avoid this is by keeping the tank full with water.
- According to manufacturers' experience, the ice will not damage the metal walls or the liner, unless water is pumped/ drained from the bottom of the tank when a layer of ice exists on the top water surface. In such a case - a hole should be drilled in the ice layer and a pipe of a diameter suitable for the filling flow rate should be inserted into it. Water should be added through the pipe to avoid an air cavity between the ice and the water.
- If the intake and the supply line to the pumps are steel pipes - no special preparations are required to protect them. If they are PVC lines - they should be drained and then sealed to prevent water penetration during the winter.
- To avoid penetration of water into the supply line, a manual valve should be installed at the water tank outlet and kept closed during the freezing period.

Pumps

Proper preparation of the pumping system for extended periods of non-use in freezing as well as non-freezing climates is important in order to preserve the system's performance and duty-life expectations. Investing a short amount of time and following the procedures below will preserve the pumping system's performance and longevity.

General preparation:

- Disconnect the power to the pumping system before beginning any work.
- Ensure that the winterized pump cannot be accidentally activated and insulate any exposed leaks.
- Remove exterior dirt and grime and any substance that may trap moisture. Exposed metal is subject to oxidation; prime and repaint as necessary. Ensure motor vent screens are clear of debris.

- Flush suction and discharge lines. Check for leaks and replace any worn gaskets.
- Drain the pump by opening the air bleed valve or port plug on top of the pump impeller chamber and remove the port plug closest to the bottom of the chamber (if applicable).
- Flush the pump and clean rust and debris that may have accumulated in the impeller chamber (if applicable).
- Precaution must be taken to ensure that the exposed tank(s) (if applicable) and piping are also drained.
- A low pressure (3.5 meters, 5 PSI), high-volume blower may be used to purge the system with air.

- If the pump is to be stored wet, do not use anti-freeze solutions other than propylene glycol. Propylene glycol is non-toxic and will not damage components in the pump and/or pumping system. Use a 40% propylene glycol / 60% water solution to protect the pump at temperatures down to -45 ºC (-50 ºF).
- Lubricate bearings (refer to the Pump Owner's Manual).
- Keep the pump clean and dry during the storage period to guard against corrosion.
- Shelter the pump from elements when possible.
- To avoid condensation and corrosion problems, do not wrap or seal the pump with plastic.
- Air must be permitted to circulate around the pump.
- Rotate the pump's axle periodically to prevent freeze up of internal components and keep bearings coated with lubricant to prevent oxidation and corrosion.
- Grease the pump according to the instructions in the pump manual. (If the pump is equipped with grease nozzles, it may be serviced with a grease gun.)

Removal of pump from installation site (if applicable)

- Place fittings (bolts, nuts, shims (spacers), wire nuts, pipe fittings, etc.) in a heavy gauge plastic bag and attach it to the pump.
- Remove the pressure gauge from the system (and others gauges if necessary) and store them with the pump.
- Seal all open ports to keep out foreign objects, insects, rodents, dust and dirt.
- Replace gaskets as necessary.
- Disconnect all suction piping from water reservoir (if applicable) to prevent freeze damage, or alternatively drain all suction piping.

Head control

- The head control and particularly the filters should be examined for dirt and sediment and treated accordingly (chlorine or acid treatment).
- For gravel filters, the final result of the treatment should be clean, loose gravel, with no caking or cracking.
- After the treatment, the filters, the fertilizer injection unit and all the components of the head control should be flushed with clean water.
- Then, the head control should be emptied of water, so that all the components are dry: filters, manifolds, water meters and valves.
- The fertilization system should be protected from the elements.
- The openings in the system (as a result of removing the accessories) need to be well covered to prevent dirt and animals from getting inside; however, air should be permitted inside to avoid condensation.

Main line

- All main lines, sub-mains and driplines should be flushed.
- Then, the flushing valves should be opened at the low points to enable the water in the pipes to flow out.
- In freezing areas, if water still accumulates at the end of the lines, and the lines do not drain completely, it is necessary to expel the remaining water from the pipe. A low pressure (3.5 meters, 5 PSI), high-volume blower may be used to purge the system.
- All openings in the main line (due to valve removal) should be covered by a plastic bag to avoid penetration of animals and dirt.

Risers and valves

- It is necessary to ensure that no water remains in the valves and their risers.

WARNING
At low temperatures, PVC risers can break, even if touched lightly.

- The location of PVC risers should be marked by 4 colored (red and white) high posts around the risers.
- It is important to let the water out of the command chamber of the valves and from the command tubes.

Sub-mains

- It is necessary to drain the sub-main pipes of water towards the lower points, and if water remains at the line ends, it should be pumped out.
- The line ends of the sub-mains should be marked by 4 colored (red and white) high posts.

Driplines

- There is no special winter preparation for driplines, besides the standard chlorine/acid treatments and flushing, as the driplines drain through the drippers, and even if some water remains, it will not damage the driplines.

GENERAL GUIDELINES FOR SDI INSTALLATION

General guidelines for SDI installation

The following guidelines focus mainly on issues related specifically to SDI installation, such as land preparation, sub surface injection of the driplines, and the order and timing of the various installation stages.

In SDI systems, the proper injection of driplines into the soil is vital and has a major effect on system performance. In addition, unlike on surface installation of driplines, defective injection is, in most cases, irreversible. **Therefore, careful attention must be paid to installation issues, and installation must be executed professionally, with maximum attention and concentration.**

Do not start the injection process until the following important issues are concluded together with the agricultural expert and project designer:
- Injection method, which tools or machinery to employ.
- Injection depth.
- Location of the driplines in relation to the crop rows.
- Whether to employ a 'permanent paths' cultivation method, and if so, which method.
- The location of various risers on the flushing manifold and sub-main ines (flushing valves, vacuum valves, etc.).

Overview of main SDI installation stages

Bush clearing. Clear bushes, trees, and root remnants if any, and dispose of them or burn them. This step is mainly relevant to virgin soil (mandatory).

Acquaintance with project. Study in detail the design map, the various drawings, and all technical documentation.

Corroboration of design. Compare the design with the actual conditions and dimensions on-site. Request changes or updates if required.

Surveying and demarcation survey and mark on site all roads, main line, sub-main and flushing manifolds routes, irrigation zones layout, and infield head-works locations.

Logistics and infrastructure. Make sure to have the following ready on-site:
- A sufficient quantity of the irrigation equipment to be installed.
- All required machinery and tools.
- A sufficient number of workers and supervisors.
- Required infrastructure such as: water availability, power supply, access road, on-site logistics and storage center.
- Roads and drain canals construction: construct all primary and secondary roads and drain canals within the area to allow for efficient access and working conditions on-site.

Soil preparation considerations:
Good soil preparation is critical for the project success, it is come to importance in several stages: the quality if the drip insertion, the furrowing, covering and mainly the germination process.
For optimal soil preparation, three main factors should be taken into consideration in this operation: the size of the soil clods, presence of plant residue and the depth of soil preparation.
The soil preparation process must aim for the following:
- Soil clods size should not be greater than 4 cm in diameter from soil surface to 15 cm depth
- Plants residue, no longer than 20 cm
- Soil preparation depth should be at least 40 cm for good root development, high quality furrowing and drip burying

Steps in land preparation involve the following

In order to achieve the above, it is crucial to do land preparations with the right soil moisture content, If the soil is too wet - machinery will get stuck and destruction of soil structure will occur. If soil is too dry - penetration of tines will not be deep enough causing more mechanical breakdowns. The sub-soil will just break into massive solid clots which will have a detrimental effect on water movement in the soil.

Drip Insertion in rocky conditions

The soils characteristics

Several factors must be taken into considerations:

1 Percentage of stones in the soil

1. Up to 20% - relatively easy to install

2. From 20% to 50% - difficult do install

3. Above 50% - not recommended

2 Average size of the stones

1. Up to average diameter of 10 cm - easy, the stones are pushed a side during the installation.

2. Above average diameters of 10 (most of the stones at size resemble a size of a football) - difficult, the stones are too big to be pushed aside, and the drip line not inserted properly

3 Type of stones

1. Cobbles (rounded and smooth) - less risk for damage to dripline, can also be used thin wall dripline (12.5 - 15.0 mil)

2. Rocks (sharp edges) – risk of damage to the dripline recommended use 25.0 mil wall thickness and above

Less then 20% stones and small stones
(less then 10 cm diameter)

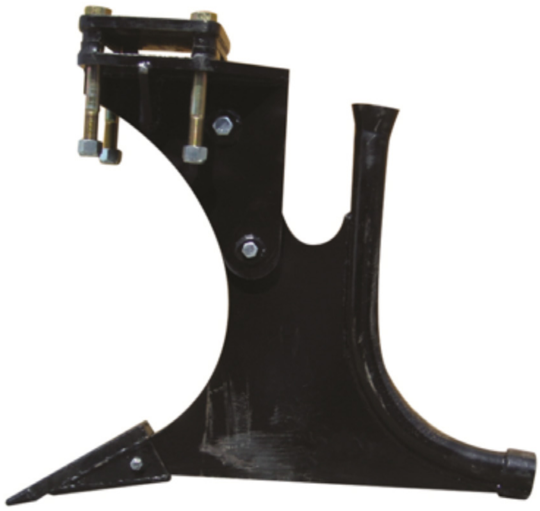
Above 50% stones and large stones
(bigger then 10 cm diameter)

Rocks (sharp edges)

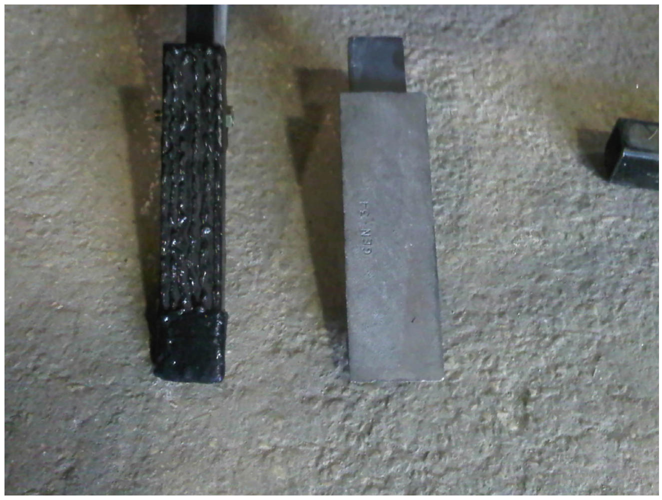
Cobbles - Rounded and smooth

Recommended components to be use in rocky soil

1. Frame - recommended to use reenforced frame 150 x 150 mm
2. Insertion shank - use original Netafim™ burring shank with Manganese (chrome) coverage over the shank shoe
3. Spare parts - make sure the are sufficient spare parts especially “share bolts”
4. Dripline - from 25.0 mil Wall Thickness and up. Dripper spacing: 40 cm



Netafim™ original burring shank



Standard shank (left) and Manganese covering for the shank shoe (right)

Land (soil) preparation

This is essential for the future performance of the system and should be applied throughout the entire area at the initial stage of the project.
In some projects, this may not be possible at the initial stage because of climate conditions or because planting dates for some parcels are a long time after project initialization. For these projects, land preparation at the initial stage should be performed only for the strips of main line, sub-mains and flushing manifolds routes (4 m strip). Full land preparation of the entire area will be performed later, just before dripline injection and planting.

Clear the surface from clods or ricks - to maintain uniform burying depth (using a depth wheel) → Tillage for full cultivation - accepted order of tillage.In-depth cultivation lengthwise and widthwise using a power plow → Plow to a depth of 25-30 cm

→ Disk to break up soil clods → Leveler → Bed opening → Level for compacting the soil

→ Burying the equipment = preferably before the rainy season for compaction → Mark the location of the laterals - physically or with GPS for continuous tracking

Marking the location of planting rows and driplines.

In SDI systems, you must perform this marking prior to injecting driplines into the soil in order to ensure permanent and uniform spacing of rows and driplines. There are two options for the order in which to install the sub-main and the driplines. The decision of which option to use depends on system design, soil and climate conditions, machinery used for trenching, development plans of the farm, etc. The options are:

- → **Option 1**: The sub-main is installed in the field before the driplines.
  This is the option most commonly used. In this case, marking is also required to ensure that the holes drilled along the sub-main (for inserting the risers) will align with the future driplines and planting rows.

- → **Option 2**: The sub-main is installed in the field after the driplines have been injected.
  In this case, it is not necessary to ensure the alignment of driplines with the sub-main, but trenching and back-filling of trenches is problematic and requires careful work.

Point to consider	The sub-main is installed in the field before the driplines	The sub-main is installed in the field after the driplines have been injected
Time from furrow-ing to planting	Less time, less risk for furrow being erosion	More time risk of furrow erosion
Connecting the dripline to the sub-main	If the sub-main trench was covered the riser is not connected in a direct line	Proper connection
	Furrowing can not be done properly at the age of the field unless the trench was covered	Furrowing done completely
	Less damage	Damage to dripline while opening trench
	Labor to expose the raiser and adjust the furrow	Less labor
Matching between the dripline and the raisers	The furrowing is guidance by the sub-main	GPS must be used or marking connecting raisers based on the dripline position

Pump station and system control head installation and trenching.

You can install the pump station and system control head, and perform trenching for main line and sub-mains at the same time that you are preparing the land.

Main line installation.

During the trenching, install main lines and back-fill the trenches. While performing main line installation, install all infield head-works (valves and secondary filters).

Valve's location

Several options for valves location and design. Each option has advantages and disadvantages as described in the following table:

Option	Description	Advantage	Disadvantage
On surface	Valves + accessories are raised on surface and exposed	Reduce cost and easy maintenance	Risk of damage or thefts
Buried	The valve is fully buried only accessories are raised on the surface	Reduce cost, highly protected for damage or thefts	Difficult maintenance for the valve, accessories are exposed to risk
Buried or on surface protected	The valves and the accessories are protected by a strong structure (usually concrete)	Highly protected with easy access for maintenance	High cost and drainage difficulties
Cluster	All valves	Protected for damage or thefts Easy to control and maintenance Reduce the need for automation	High cost due the need extra irrigation main lines

On Surface

Buried

Protected

Cluster

Sub-main and flushing manifolds installation.

After marking is completed, install the sub-mains (and flushing manifolds, if designed), mount all risers for the driplines, and temporarily close the end-lines. Back-fill the sub-main and flushing manifold trenches only partially, this will protect the pipes and enable future tractor crossing during land preparation (if applicable) and driplines injection. Make sure to leave the area around the risers uncovered to enable easy connection of the risers to the driplines after the sub surface injection.

Main line and sub-mains flushing.

Flush main lines and sub-mains, run pressure tests, and fix any problems found.

Completion of land preparation.

To be done if necessary. Make sure beds/furrows/rows are clearly marked. If not, renew the marking for accurate driplines injection.

Preparation of planting furrows.

This operation is required only for certain crops/projects (such as sugarcane). Cultivating sugarcane using SDI necessitates planting dual/single rows inside planting furrows. Follow the markings prepared for planting rows, to prepare furrows using a tractor drawn implement. The implement used for preparing furrows consists of a pair of tines several centimeters apart, spaced at a certain distance from another pair of tines.

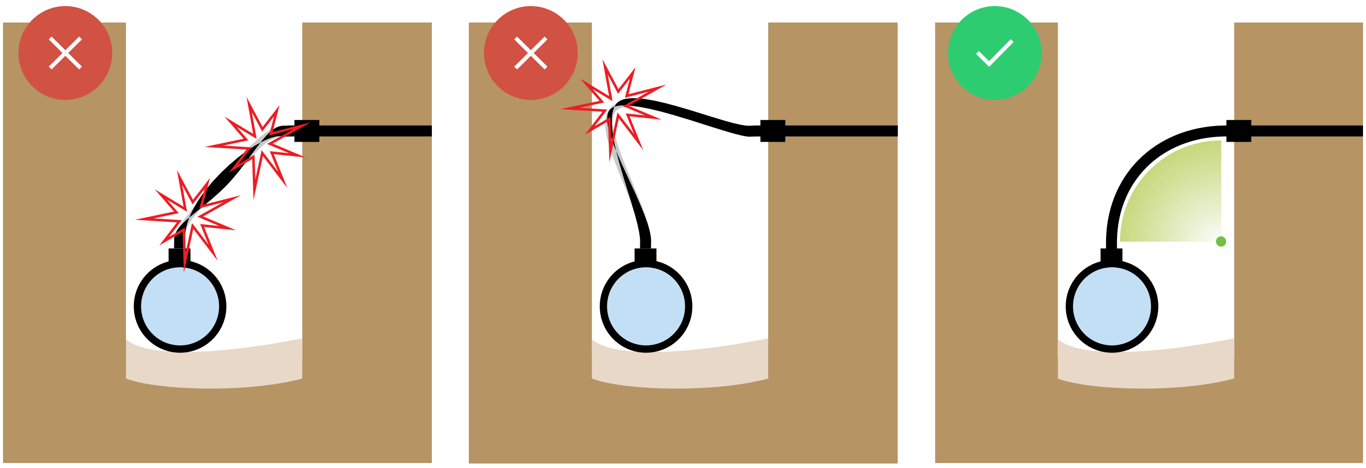
In some projects/crops, furrowing is done together with another agronomic operation (such as: driplines injection, planting, or covering) in the same operation/pass. This is possible due to the availability of new machines and especially new planting machines, which enable performing several agronomic operations at once. For these cases, a specific solution can be tailored.

There are many sowing/planting techniques that vary from one crop to another, thus, the actual correlation between sowing/planting and furrowing/dripline injection/ overing, is detailed in the relevant crop appendices.

Driplines injection.

Inject driplines according to the instructions detailed in Netafim™ Overview of Driplines Sub surface Injection. Connecting driplines to sub-mains. Manually dig into the wall of the sub-main trench and flushing manifolds trench underneath each dripline so that the dripline will meet the riser via a round mild curve and not at a sharp angle.

Different methods of installation and their possible problems.

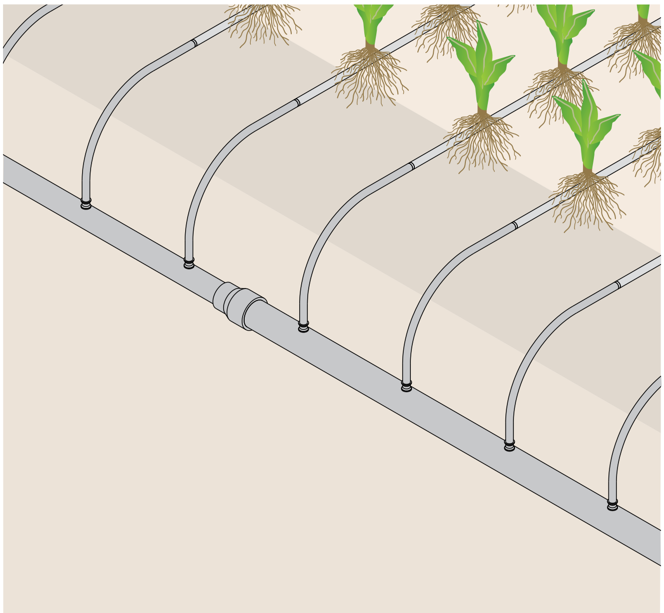


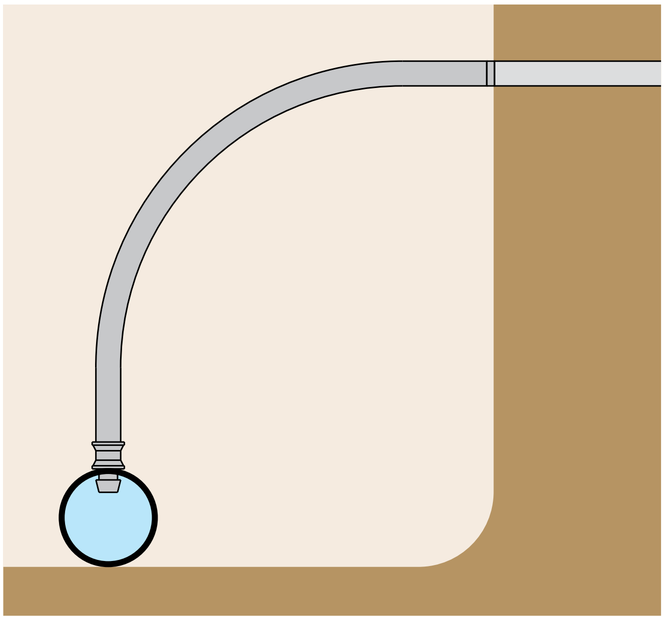
Cut the risers and the sub surface driplines accurately so they can connect without any excess pipe length. Excess pipe length can create a kink in the riser or the dripline.
Different types of risers:

→ PE risers
→ IPS hose (PVC)
→ Q-Flex™

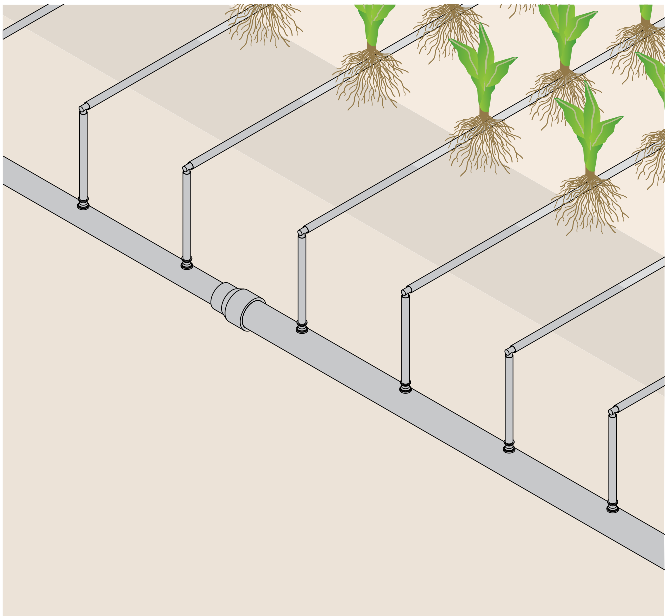
Examples with different type of risers:

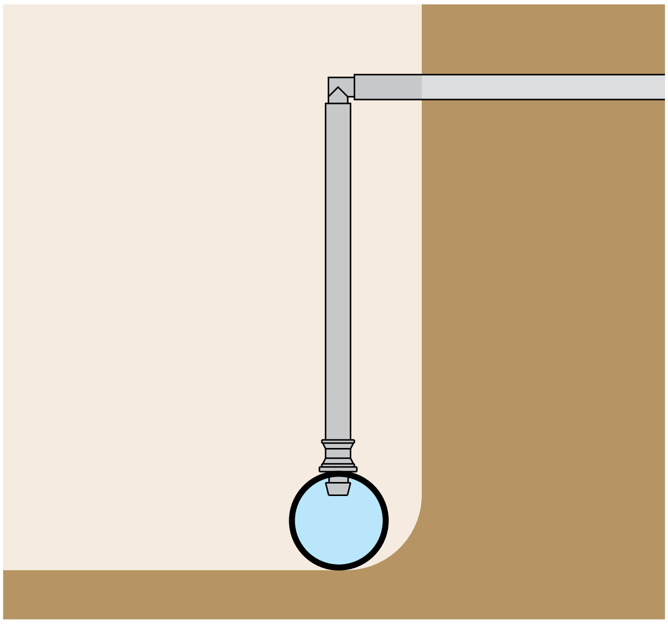
PE risers





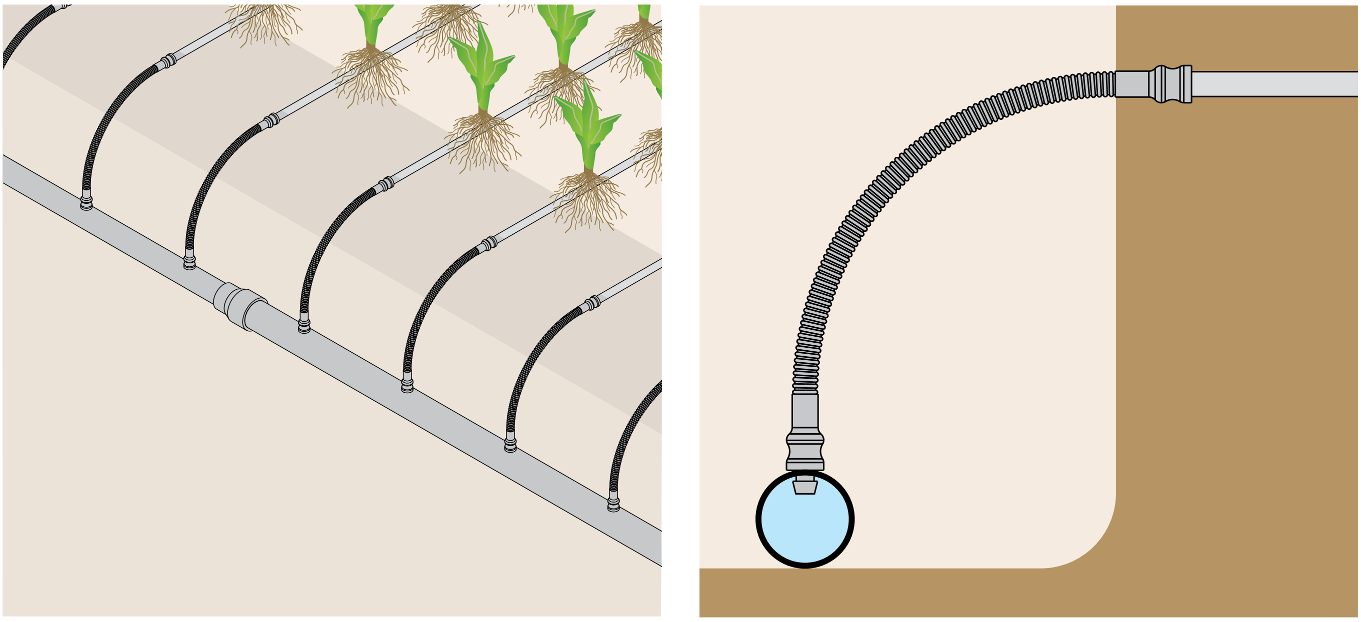
IPS hose or PE pipe





In this type of installation it is very important to keep the riser close to the trench edge in order to protect it from kinking while coverage the trench.

Q-Flex™



Q-Flex™ - The innovative and flexible solution to connect driplines to sub mains.

Before backfilling the trench, make sure the risers will be well protected with soil around them or insert a pipe sleeve (that later, at the end of the work, will be removed) to protect them from kinking during backfilling.

Dripline pressurization and flushing.

Let water flow through the system as quickly as possible. This minimizes the risk of insect damage to driplines, and of driplines not being able to swell when pressurized. Flush all driplines, section by section.

Inspect the ground to ensure water is emitting from the drippers of each dripline. If water does not appear, the dripline or the riser is probably kinked, or bent or torn somewhere. In that case, locate the problem and fix it.

Connecting driplines to flushing manifolds.

Connect all driplines to the flushing manifolds (if these exist), or close all driplines using end-lines (after the driplines were flushed).

System commissioning and start up.

Follow the commissioning procedures for the entire system.

DRIPLINE EXTRACTION

Dripline extraction

Objective - to extract the dripline after the crop is removed. In sugarcane as in other many crops its is expected to be after several years buried in the soil at a depth of 20 to 40 cm or more.

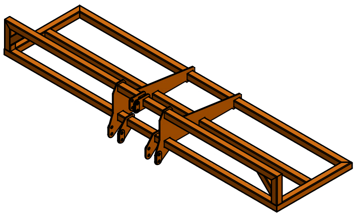
Prior to start the extraction, the field must be harvested and the crop eliminated.

In case the soil is very dry, it is also recommended to irrigate using the drip system to full water distribution and then wait for the soil moisture to drop to 50% of TAM (total available moisture / field capacity).

The recommneded machine to do the extraction consists of a 3-bar frame, 5 parts for the extraction operation, and depth control wheels.

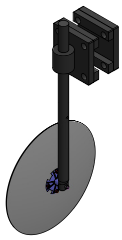
The machine can be designed for 1 line, 2 lines and 3 lines. It can also be used for single- or dual-row planting.

The frame - use a 100 x 100 mm profile and 10 mm thickness.

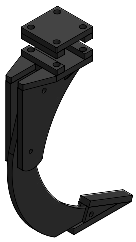


The extraction machine components:

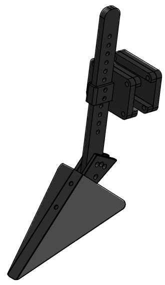
1 Vertical cutting disk - for a single row, use one disk at the center. For dual rows, use 2 vertical disks. The disk must be placed above the crop row: its objective is to cut the stools so that each subsoiler can break through the compacted soil without accumulating plant residues that might block the soil flow between the 2 subsoilers.



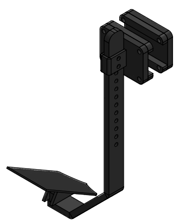
2 Subsoiler - the objective is to loosen compacted soil around the area of the dripline (up, below and on the sides)



3 Furrower - set at 5 cm above the dripline by setting the depth control wheels. The purpose of the furrower is to clear as much soil as possible above the dripline.



4 Lifting furrower - after the 3 operations mentioned above, the lifter is to be set around 5 cm below the dripline depth and its objective is to loosen and lift out the dripline.

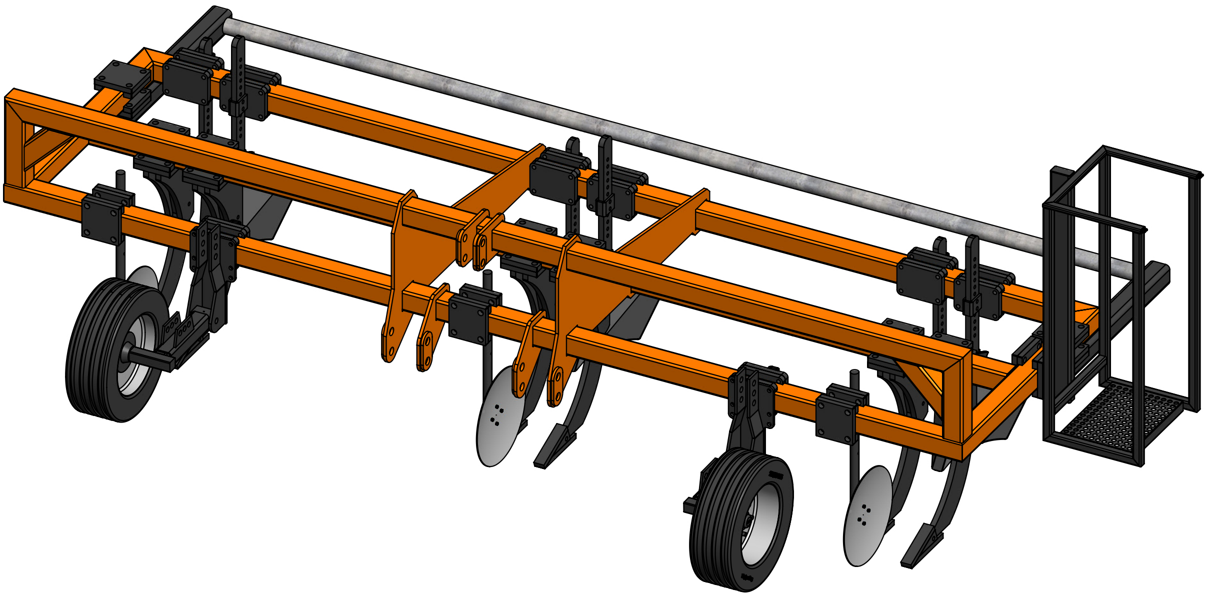


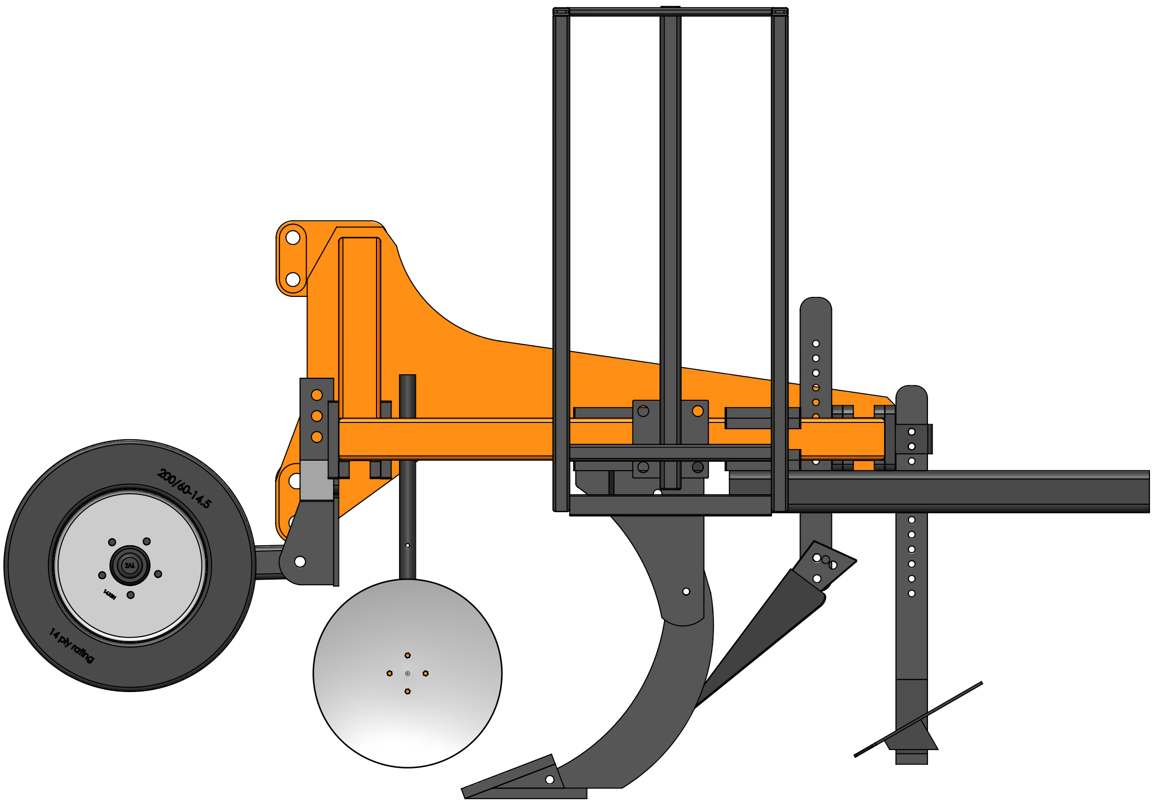
5 Rolling tube - its objective is to roll over the extracted dripline and place it on the soil surface

Recommended depths and relations between the parts:

Assuming dripline is at 25 cm depth:

- Cutting disk - set to be on the plant row
  - Single row - 20 cm depth
  - Dual row - 25 cm depth
- Subsoiler - on both sides of the dripline, 20 cm aside from the dripline, and 35 cm depth
- Furrower - 20 cm, it is important not to damage the dripline while it clears the soil above the dripline
- Lifter - 30 - 35 cm deep, working below the dripline





INSTALLATION RECOMMENDATIONS

Installation recommendations

Laying driplines facing up

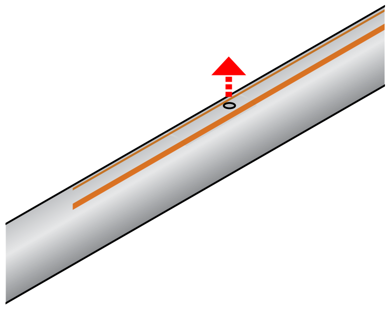
It is important to lay the driplines so that the drippers are facing upwards. This minimizes settling or suction of suspended solids due to vacuums when irrigation is stopped. However, for thick-walled driplines, it should be noted that it is impossible to ensure that the drippers will uniformly face upwards.

→ Install the reel holders in the direction of travel

CAUTION

It is higly recommended that the dripline are inserted with the drippers facing up*

To achieve this the reel holders should be installed in the direction of travel. It is also possible (not recommended) to install the reel holder perpendicular to the direction of travel only in case the field condition and the associated machinery dictate it as it will cause the dripline to be twisted and the drippers to face other directions.

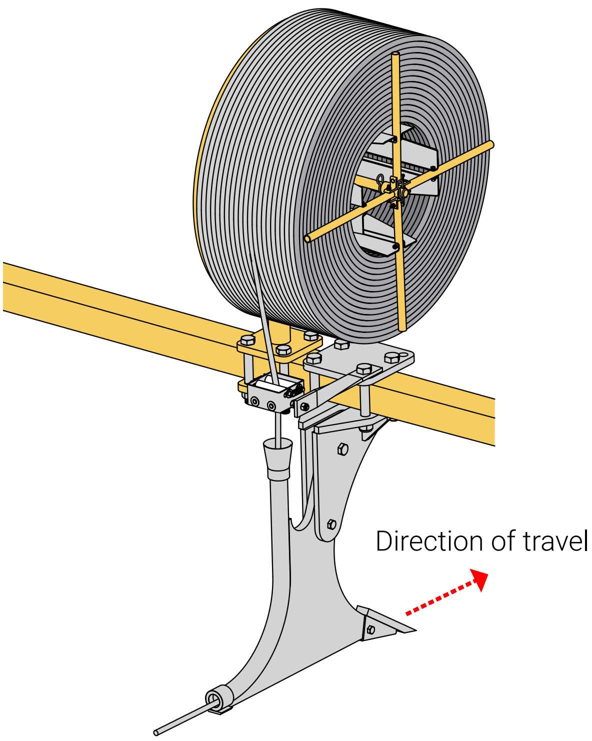


NOTE

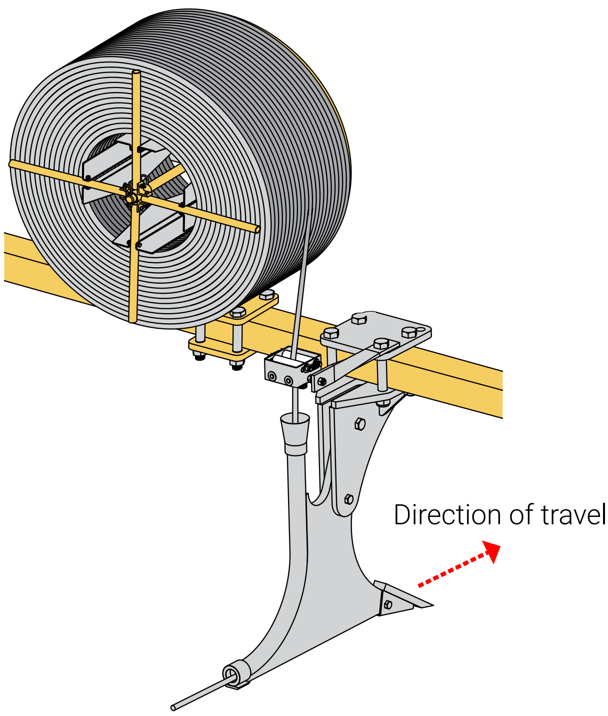
Netafim™ driplines are characterized by two orange stripes along the dripline.
These stripes can assist the installer to identify that the dripline is positioned with the drippers facing up.

** In orchards where we have a deep root system the direction of the drippers is not critical as it is in field crops. Although it is still recommended to insert the dripline with the drippers facing up, but due to the complexity of maintaining the direction of the drippers facing up along the entire reel, it is also acceptable to have drippers facing other directions due to pipe twists.*

Reel holder installed in the direction of travel



Reel holder installed perpendicular to the direction of travel



Injection site conditions

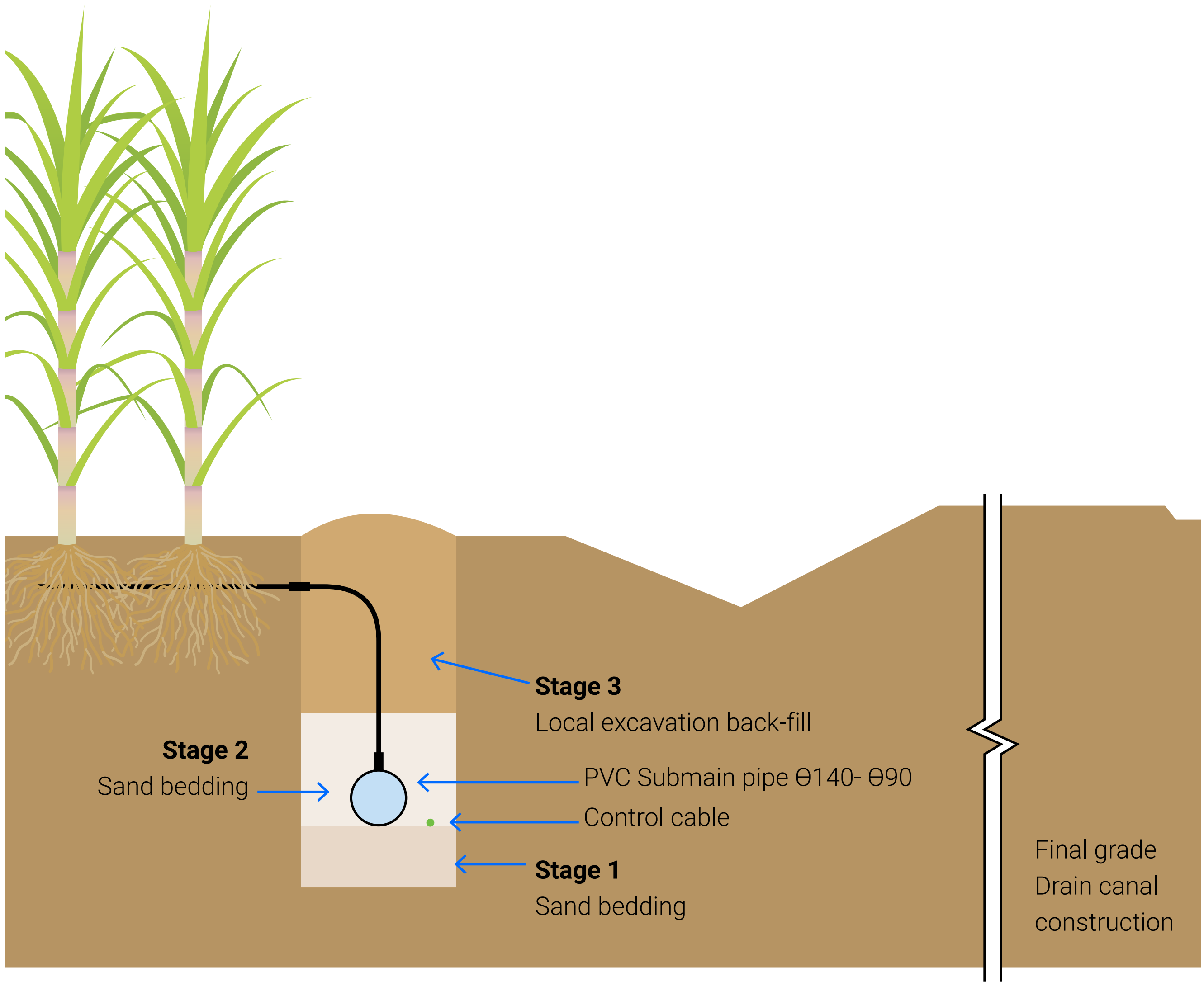
- Favorable timing and conditions for dripline injection is before the rainy season when the soil is moist and easy to cultivate. Injection before the rainy season enables the coming rains to compact the soil above the grooves in which the driplines are laid, thus preventing the 'chimney' effect and allowing capillary movement of water upwards during first irrigations. Excess wetness during injection is harmful to the soil and may cause irreversible damage.
- Prior to injection, the potential site should be checked for existing old drainage systems which may disrupt the installation and hence the irrigation. Installing SDI in a site having drainage canals is complex yet possible, provided their exact location and depth are known in advance. Generally, try to avoid injection of driplines in areas with existing drainage canals.
- A rodent repellent applicator should be installed next to the conic pipe inlet (funnel) to allow application of the granular repellent into the soil (when a rodent hazard is expected). This should be done concurrently with dripline injection. The repellent is applied at a depth of 10 cm above the dripline.
- The size of the tractor accommodating the injection machine will vary depending on the depth of injection, soil condition, and the number of driplines injected at a time.

General work guidelines

- Inject the driplines at least 5 cm below the maximum expected cultivation depth of the specific field.
- To prevent possible failures, injection speed should not exceed 6 km/h.
- Stopping a tractor during the injection process should be generally avoided. It should be allowed solely for coil replacement when needed.
- During injection, verify that driplines are not damaged due to overstretching.
- Additional reserve coils (reels) should be carried on the machine. As well a box with the proper driplines connectors.
- Clearly mark the track that the injection machine should follow in order to ensure consistent, aligned progress. This will ensure uniform spacing between driplines.
- When injecting Netafim™ driplines, you must ensure that the injection machine follows the Netafim™ injection machine guidelines. That is, the dripline is fed via a set of leading rollers (roller box) and through a conic inlet into the feeder pipe.
- You can use either of the following methods to inject thick-walled driplines such as UniRam™/DripNet PC™ or Aries™:
  a) Mount the bundle coils on the metal reels of the injecting machine and inject the driplines in the regular way (as it is recommended for thin-medium wall thickness driplines).
  b) Deploy the driplines out in the field before injection, alongside the rows or injection routes. The injection machine will then drive over the driplines which are fed horizontally into the shanks via sets of roller boxes and a curved track. This is done for various reasons and/or when crop germination cannot be performed with sub surface driplines.
- For optimal injection, it is recommended to perform the task with 2-3 workers (a driver and 1-2 assistants). This ensures that the driver can concentrate on driving along the marked route, while the assistant(s) can oversee the dripline injection operation which is occurring behind the machine.
- Once the system is operating and pipes and driplines are filled with water, make sure trenches are fully backfilled.
- After flushing, ensure that the design flow rates and pressures match the actual flow rates and pressures recorded in the field.

Location of trench for sub-main and flushing manifolds

- The general location of trenches is specified in the design layout. However, the exact location of the trenches in relation to roads and drain canals is very important. Locate trenches to enable easy operation and maintenance of the system and the site (such as reconstruction of drain canals).
- It is recommended to avoid installing any piping (both sub-main and flushing manifolds) under drain canals in order to minimize future damage to the driplines' risers.
- It is recommended to leave sufficient clearance between the road and any driplines, sub-mains, and flushing manifolds to ensure that the tractors and machines will be able to turn around without damaging the driplines or the dripline risers.
- It is best to avoid installing sub-main lines in the center of the field. Whenever possible, use instead long driplines that extend across the entire field. Keep in mind that this may have an economic cost, since dripline length and the existing topography will naturally affect the dripline diameter and dripper flow rate selected.
- Avoid installing the flushing manifold in the center of the field. It is recommended to design and install the flushing manifold next to the field road to facilitate driplines flushing.

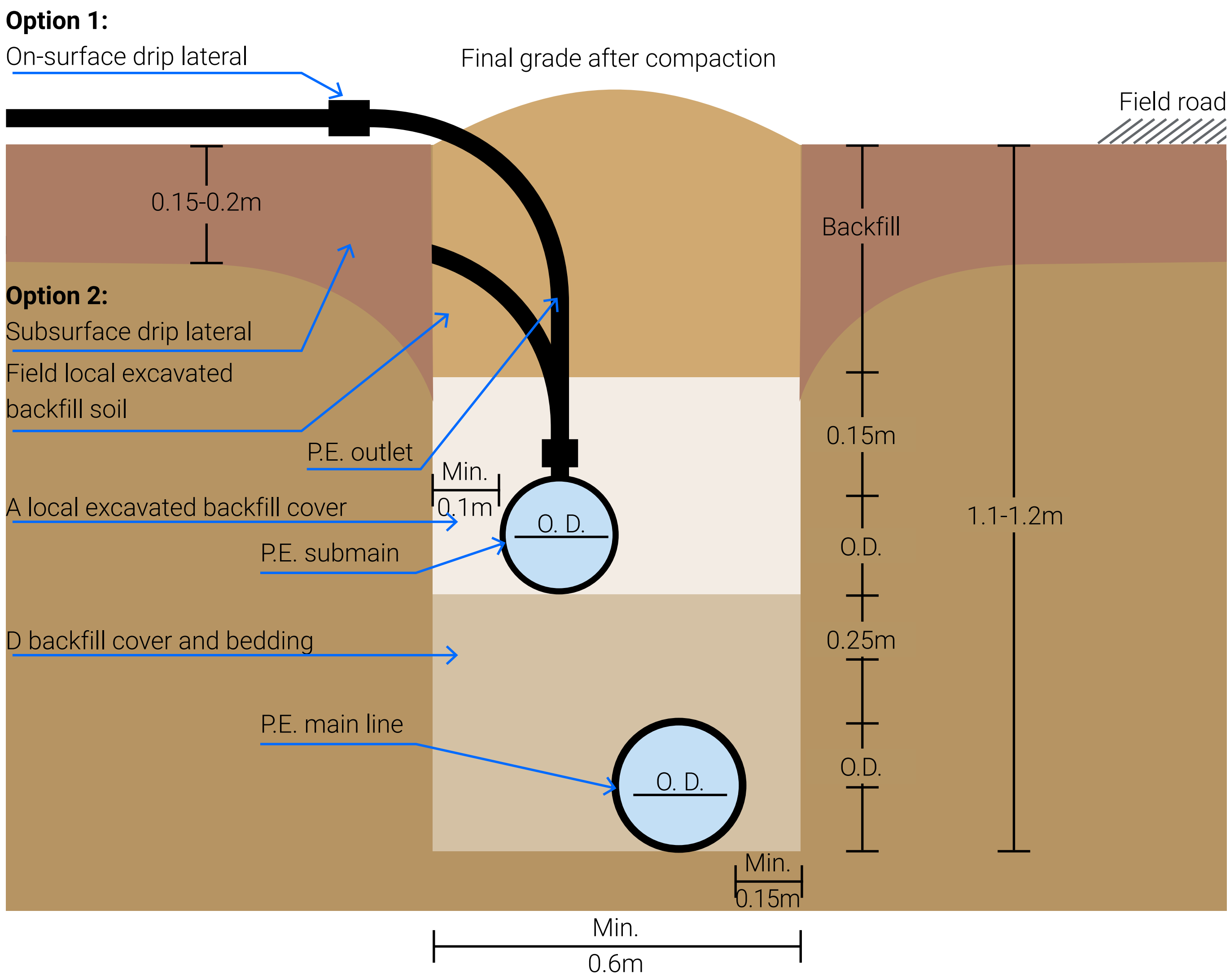


Specifications of trench for sub-main and flushing manifolds

- You can position the sub-mains/flushing manifolds either above the surface or below it, depending on the required depth of the driplines.
- Sub-main/flushing manifolds above surface. This option does not require any trenching and is relevant for shallow injection of driplines. Shallow SDI injection, in which sub-main lines are installed for temporary use, uses primarily PE pipes, as well as the more popular flexible pipe FlatNet™, which is less expensive and easier to maneuver. In addition, agricultural vehicles can ride over the FlatNet™ lines when they are not under pressure.
- Sub-main/flushing manifolds below the surface. This option requires trenching and is relevant for all medium and deep injection of driplines.
- There are few trenching options for sub-mains or flushing manifolds. Choosing an option is related to many factors such as: availability of machinery, soil type, trench dimensions, cost of labor and machinery, etc. The options are:
  a) By backhoe or excavator. This produces a wide trench with a minimum width of 40 - 60 cm which enables easy installation and easy connection of risers inside the trench.
  b) By trencher. This produces a very narrow trench having a maximum width of 25 - 30 cm. This option is feasible only if you install the piping and risers outside the trench and then lower them into the trench. The advantage of this method is that it minimizes backfill and cleanup work, and that backfill material is well crumbled.

Follow these general guidelines when trenching for sub-main or flushing manifolds:

- For deep sub surface dripline injection, dig a trench at least 40 cm wide to enable pipe installation and convenient dripline connections.
- If you are trenching for sub-mains/flushing manifolds after driplines injection, make sure to manually cut the driplines' end to the required length before trenching. This is necessary in order to avoid the driplines being stretched by the backhoe. Make sure the dripline end is long enough to connect to the sub-main or flushing manifold.
- When using PE piping and shallow or medium depth drip injection, it is easier and much faster to use a trencher. However, if you use a trencher, it is recommended to trench before injecting the driplines in order to avoid damage to the driplines while trenching.
- Perform pipe connections within the trench whenever possible, to avoid possible disconnections or bending.
- Trench depth depends on two factors:
  a) Driplines injection depth.
  b) Agro mechanical techniques used by the farm.
- The depth at which you install the sub-main line is determined by two factors.
  The first is to prevent any damage to the sub-main pipes.
  The second, but no less important, is to prevent penetration of dirt from the sub-main pipe into the driplines. The sub-main pipe should therefore be installed at least 15 - 20 cm deeper than the driplines. A typical sub-main trench depth of 60 cm is very common.
- If the design dictates placing more than one pipe in a trench, make sure the trench is wide enough. Position the pipes in the trench logically – for example, place the sub-main pipe on the side closer to the driplines.



Assembly of sub-main/flushing manifolds

After the trenching and pipe laying, drill holes in the pipes for inserting the risers (blind tubes) into the sub-main pipes and flushing manifold pipes. If the trench is narrow, drill the holes before placing the pipes in the trench. If the trench is wide, you can drill the holes after placing the pipes in the trench.

NOTE

If the soil is rocky or cloddy, apply sand bedding at the bottom of the trench, lay the sub-main, apply more sand on top of it and only then cover with local soil. Bedding and topping with a 15 cm layer is a common practice.

For sub surface installation of sub-mains and flushing manifolds, the two most common types of piping are PVC and PE:

PVC pipes

- PVC PN (class) 5 or 6 are used. Pipes are usually connected inside the trench. Both “cement glue” and “flexible union” (rubber seal) are used to connect the pipes.
- The holes for the start connectors are drilled using a special 16 mm Netafim™ drill for PVC pipes (Netafim™ catalog number: 45000-002755). A sharp pin at the end of the drill centers the drill on a single point.
- When non-Netafim™ drills are used, make sure to use a 16 mm diameter drill.

PE pipes

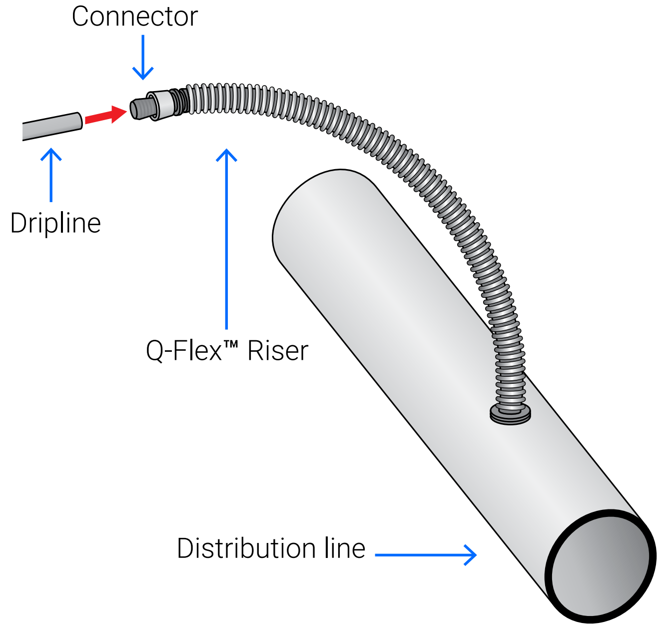
- Two alternative methods are used for connecting driplines to PE pipes, either inside or outside the trench:
  a) Using a PE start connector and an 8 mm drill to punch the holes.
  b) Using a saddle assembly – mounting the saddle first, and then using a special drill to punch holes through the saddle.

The holes for the risers should be drilled so they create the best angle between the dripline and the riser, in order to minimize dripline bending later on. Holes should be drilled at a 45°or 90°angle (from the horizon) according to conditions on-site.
The complete assembly of the risers includes the start connector and a PE blank tube at the required length + 30 cm spare (usually, 0.8 - 1.0 m long). These assemblies are usually prepared at the store in good working conditions and installed into the sub-mains on-site as a complete assembly.
Ensure that the blank tube connecting the start connector to the dripline is made of PE class 4 to prevent bending.
Install the riser assemblies without any sharp angles in the riser tube which could result in kinking and blocking of water flow. After sub-main installation, install related valves and the flushing manifold.
The above was, and still is the common practice when using standard risers such as PE or IPS(PVC) hose. In recent years, Netafim™ has introduced into the market and promoted the Q-Flex™ riser, which has since become the rise recommended by Netafim™.

Assembly of risers

Q-Flex™

The innovative and flexible solution to connect driplines to sub-mains.



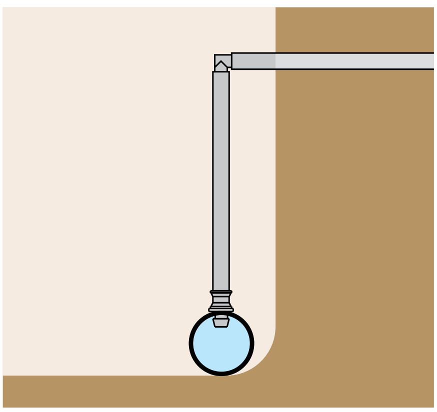
Standard risers' weaknesses

- Regular risers' assembly requires working hands and extra manpower to protect when installed in the field.
- Kinked or leaking risers are known to be the #1 cause for reopening of trenches - wasting time and money.
- Kinked risers can cause under-irrigation and in many cases crop mortality that can lead to compensation claims.

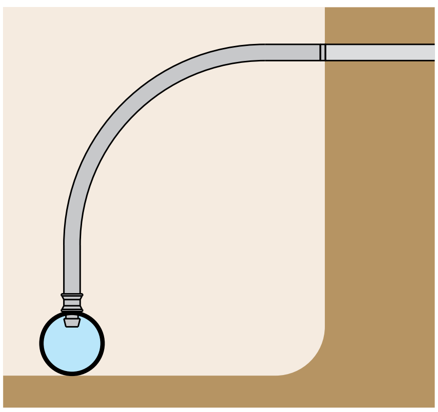
Q-Flex™ benefits

- Kink-resistant corrugated profile.
- Prevents pressure losses or flow restriction with a kink-resistant design and eliminates need for re-digging trenches.
- Saves labor, simplifies and shortens the installation process with a pre-assembled riser.
- Pre-assembled with different lengths and connectors.
- Versatile pre-assembled options for thin, medium and heavy-wall driplines.
- Configurable for diverse connectors options, customizable for connecting driplines to grommet take-offs or threaded connections in sub-mains.
- High-quality polypropylene material provides UV resistance with minimal elongation.

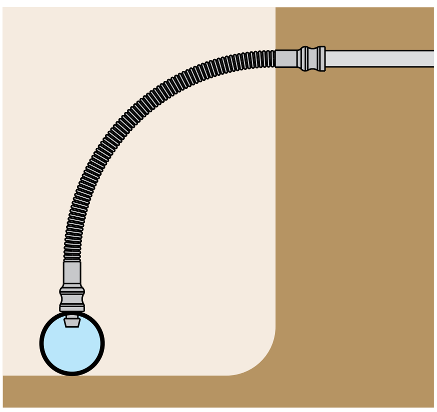
Three different possibilities, PE, PVC and Q-Flex™ risers:



PVC or rigid PE riser



PE riser



Q-Flex™ riser

Backfill the trench
Make sure to temporarily close the risers.

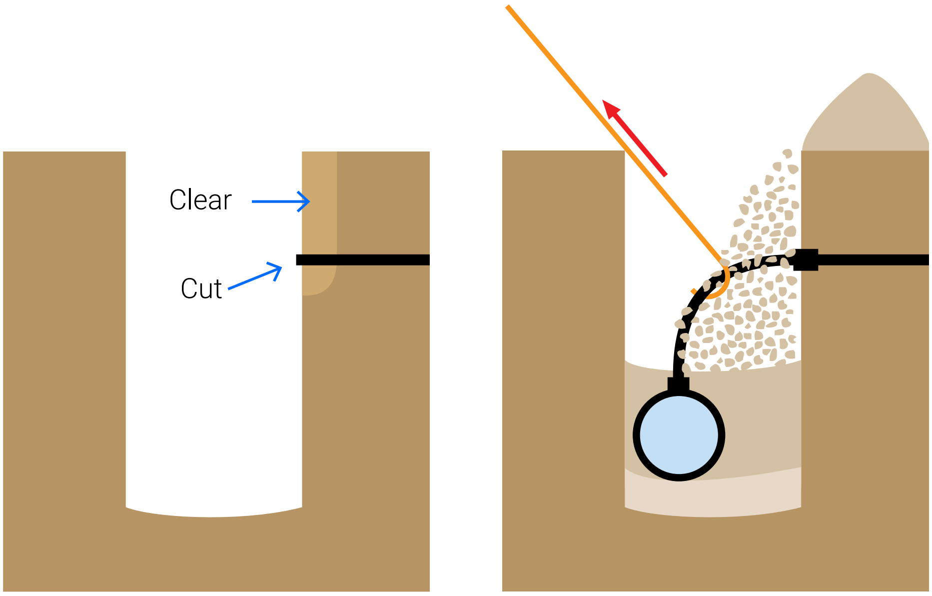
Backfill the trench partially, to protect the sub-main pipes and allow for future tractor crossing during land preparation (if applicable) and driplines injection (if it was not performed yet).

In order to protect the risers and riser connections to the pipes during the backfill, it is recommended to place a 32 - 40 mm protecting sleeve (a pipe) around each riser in turn. Remove the sleeve when backfill is completed for the riser, and use the sleeve for the next riser.

When using Q-Flex™ risers this operation (described in the previous two sentences) is not necessary.
Make sure to leave the area around the upper part of the risers uncovered to enable easy connection of the risers to the driplines after the sub surface injection and sub-mains flushing process.

Connecting risers to driplines

- When connecting the risers to driplines, dig manually into the wall of the sub-main/flushing manifolds trench, underneath each dripline in order to enable it to face the riser via a round mild curve and avoid a sharp angle.



  - Clear the earth around the dripline ends with a shovel,
  - cut the exposed end straight, and make the connection to the take-off.

- Cut the risers and the sub surface driplines accurately so that they will connect together without any excess pipe that might create a kink in the riser or the dripline.
- Backfill the area around the risers manually and carefully after flushing the driplines. Irrigate the area while backfilling, because when the riser is pressurized it is more protected and it is possible to identify any damage and leaks.

Driplines injection

The injection of driplines into the soil is a process that must be executed professionally, and requires maximum attention and concentration. Unlike on surface installation of driplines, defective sub surface injection is in most cases irreversible.

Preliminary actions

Do not start the injection process without strictly following the instructions of the project engineer or designer and/or the agricultural expert regarding:

- Injection method (tools/machinery).
- Injection depth.
- Location of the driplines in relation to the crop rows.
- The permanent paths cultivation method for identifying driplines' location.
- The location of various risers on the flushing manifold and sub-main lines (flushing valves, vacuum valves, etc.)

Required team, machinery, tools, and accessories

- The team should include a team leader, a skilled tractor driver, and 1-2 additional workers.
- The work machinery, tools and equipment should include a tractor (depending on soil type, injection depth and number of driplines to be injected simultaneously), a complete assembly of injector shanks, a suitable wrench for sheering bolts, pruning shears, a rake, and a short measuring tape (3 meters).
- Required accessories include a box with connectors for the driplines, signal flags, several injection shanks (stored in the farm's warehouse in case of shank breakage), and several spare sheering bolts for fixing the shank to the frame.

Required work rate

- The tractor speed should be 5-6 km/h, and the total daily drive should be about 30 km. Hence, injection rate should be about 5-7 hectares/day per shank (for field crops).

Reservations and special cases

- Do not inject driplines in the vicinity of drainage canals.
- Injection should be performed only in relatively dry areas, preferably before the rainy season.
- In mature orchards (citrus, olives, etc.), it is important to inject after pruning.
- In banana plantations, the driplines should be injected before installation of the supporting cables along the rows.

Preparing for dripline injection

- It is highly recommended to perform sub soiling 3 to 4 times along the path of the flushing manifolds and sub-main lines in order to enable easy and swift penetration of the injection shank of the dripline into the soil. This should be executed for medium and deep injections.
- Verify that the dripline reels are suited to the Netafim™ injection machine. Netafim™ has two families of injection machines, one for injecting thin-wall driplines and one for injecting thick-wall driplines.
- Verify there is sufficient dripline length on the tractor for an entire injection operation (a complete length of the dripline, from edge to edge of the field).
- In field crops, it is important that the interval between driplines should match the cultivation tools in order to preserve bed structure and fit the permanent paths.
- The tractor should have stabilizers on both sides of the dripline injector to be stabilized and balanced prior to the start of injection. The SDI injection machine must remain parallel to the ground throughout the injection process.

- It is important to inject the driplines so that the drippers are facing upwards. This minimizes settling or suction of suspended solids due to vacuum when irrigation is stopped.
- For thin-wall driplines, position the reel so that the arrow is pointing in a reverse direction to the tractor's forward movement. This releases the dripline from the top of the reel, allowing it to be injected into the soil with drippers always facing up.
  Remove the nylon covering the dripline coils only after the coils are assembled on the SDI injection machine. This keeps the dripline reel walls stable until they are fixed in position
- For thick-wall driplines, feed the dripline coil into the coil carrier with the drippers facing up.
- Adjust the brakes of the SDI injection machine to enable both the free rotation of the reels and stopping reel rotation when the tractor stops.
- The depth wheels of the SDI injection machine should be calibrated to the required depth, both before and during the injection process.

Injection guidelines

- Start injecting the driplines several meters before the location of the sub-main pipe, and finish injecting several meters after the flushing manifold or the end of the row. This ensures dripline injection to the required depth.
- At the beginning of the injection process (at the edge of the plot or zone) the tractor driver should start driving while the additional worker should stand behind the tractor, holding the end of the dripline in his hand. After about 3-4 meters of driving, the worker should drop the dripline end, jump onto the tractor and sit in the back of the tractor facing backward. The worker should constantly oversee the injection process and handle any problems that may arise (such as replacing the dripline coil on the reel, or replacing the reel).
- The worker should check once in a while that there is no protrusion or foreign body at the end of the feeder pipe that may scratch the entire length of the injected dripline.

Dripline replacement on reel during injection

During injection, when almost all the current dripline has been injected, a new dripline must be attached so that the injection process can proceed smoothly. Follow the procedure outlined below:

- When the worker sitting at the back of the tractor sees that the dripline is about to end, the worker should ask the driver to gradually slow down.
- When the worker sees that the end of the injected dripline passes the rollers box, the worker should tell the driver to stop the tractor.
- The worker should use a connector to tightly connect the injected dripline to the new line, in the space between the roller box and the inlet of the feeder pipe.
- After assembling the connector, the driver should drive very slowly for a few meters until the connector safely exits the feeder pipe. To ensure optimal replacement, the worker should manually assist the entry of the connector into the conic inlet to the feeder pipe.
- After the connector exits the feeder pipe, the driver can return to the regular driving speed.

Solving problems with the shank
Sometimes an obstruction, such as a large stone or a hard lump of soil, can raise the injection shank, or break the shank's sheer bolts. In such cases perform the following:

- Mark the location using a signal flag.
- Arrange for the arrival of a digger and/or worker to find and remove the obstruction.
- If the shank rose, the tractor driver should lower it back down and resume injection operations. The worker who came to remove the stone should also manually lay or fix the dripline at the right elevation and location.
- It is a must to use sheer bolts
- If a sheering bolt is broken, the tractor driver should lift the entire SDI injection machine above the ground, and the worker should replace the broken sheering bolt.
- The injection process can now proceed as usual.

Dripline injection machines

Netafim™ has different injection machines:
Injection machines for injecting thin-wall driplines (up to 0.63 mm / 25 mil wall thickness) with a diameter of 12 - 25 mm.
Some countries use higher diameter up to 35 mm and in some cases even more; in these cases the machine needs to be built accordingly.
In some cases, heavy-wall driplines are coiled on cardboard or plastic spools; in these cases the reel carriers are similar to the thin-wall dripline carriers.

This family includes three types of machines:

→ Regular field crop machines (for cotton, maize, etc.).
→ Special machines with implements such as: furrowers, markers, etc. (for sugarcane).
→ Shallow burying machines with "floating" shanks, specially designed for vegetables and potatoes on beds.

Injection machines for injecting thick-wall driplines with a diameter of 12 – 23 mm. This family includes two types of machines:

→ Field crops machines (for cotton, maize etc., or for mines). These machines include optional additional implements for hosting bundle coils on metal units and for horizontal feeding of driplines into the shanks (via rollers boxes). These are intended for injecting driplines already deployed (rolled out) on-site.
→ Plantations/orchards machines with metal units for hosting bundle coils, and an additional optional implement for under tree injection (with an adjustable bar and shank location).

The two families of machines include many additional sub-types and various applications for various conditions and requirements.

For each family of machines, three injection depths are available:

- Shallow injection – up to 10 cm deep.
- Medium injection – 15 - 25 cm deep.
- Deep injection – 30 - 45 cm deep.

Important components and features of injection machines

- When injecting driplines, roller boxes must be installed on the injection machine to straighten the driplines in order to prevent their bending, while ensuring that drippers always face upwards. Bends in the line interfere with the regular flow of water and in fact block the passage of water down the dripline.
- Whenever possible, it is recommended to use a 1 or 3 shanks machine (rather than a 2 shanks machine) in order to avoid injecting driplines in the compacted route of the tractor wheels.
- The shank (injection pipe) through which the dripline is fed into the ground must have the following features:
  - Diameter of 1.5”.
  - Seamless, schedule 40 steel pipe, without any inner protrusions that might cause damage to the driplines.
  - The inlet to the pipe should be conic to allow smooth feeding of the dripline.
  - As short as possible, but long enough to ensure that the top conic inlet is not at ground level when deep injection is performed.
- Both the shank “nail” and the pipe outlet must be hard and robust. The “nail” must be sharp as well. It is also recommended to coat both parts with manganese to provide a protective layer.
- The shanks should be connected to the SDI injection machine via sheering bolts that will break whenever power exerted on the shank is too high.
- The frame of the injection machine must be parallel to the ground during the injection process. If necessary, use stabilizers to ensure this.
- Brakes must be installed on the axis of the reel deploying the dripline, to ensure that the line is uniformly stretched, and that the reel does not continue to roll freely when the machine stops.
- Adjustable depth wheels are required to ensure uniform injection depth of the driplines.
- For injection in sandy soils, it is recommended to install a special sand-evacuation implement next to the shank’s outlet, in order to prevent sand from penetrating into the shanks.

Later in this booklet there is a chapter devoted to showing how to operate the dripline coils correctly and presenting some ways to properly operate the installation/ injection machines.

Testing SDI system after installation - General guidelines

The water meter installed at the system control head measures flow rate in the various shifts throughout the field. Use the water meter to ensure the regular functioning of the system and to check whether actual performance in the field matches the design values.

Once the system is installed, record the flow rates of each irrigation shift and of each of the irrigation zones. Repeatedly check the flow rate under the same working pressure. A significant rise in flow rate may indicate leakage in the system, whereas a drop in flow rate may indicate clogging.
Consult a Netafim™ technician when a significant change in flow rate values is detected.

If no flushing manifolds are used, visually check each end line of the driplines for flow by opening the end line. If the flow is relatively small (compared to neighboring driplines) or there is no flow at all – the dripline should be checked thoroughly to find the reason.
Pressure gauges are installed, one at the system control head after the filter and the other on one of the flushing manifold’s valves.
A rise in pressure at the system control head may indicate either clogged drippers or filters, whereas a drop in pressure may indicate leakage in the system. A change in pressure could also result from pressure gauge failure.

It is recommended to measure the pressure at different points along the system in order to ensure proper functioning. Any change in the values recorded at these measuring points may indicate clogging processes that do not necessarily affect the total flow rate of the system.
Perform the above-mentioned pressure and flow rate tests in any drip irrigation system.

Commissioning - Detailed Process

Perform the following main steps:

1. Verify that the water level at the pumping sump/reservoir/river/canal/well is adequate for pump/system activation, both for flushing and for irrigation purposes.
2. Clean or flush the pumps suction lines (if applicable) via flushing ports.
3. Verify that pumps are primed (submerging the pump impeller in water) for all “dry installation” conditions according to the following options:
4. Negative suction – Fill the suction line between the pump and the foot-valve with water.
5. Positive suction – Open the suction valve between the pump and the water source.
6. Perform “dry” adjustment of all gauges, meters, timers, flow and pressure regulators, water levels and floats, current and voltage regulators.
7. Verify that the main valve (manual or hydraulic) closest to the pump (within the pump station/system control head) is closed, as well as all on-line valves (such as service valves of the air valves). All air valves should be dismantled or not installed to avoid dirt penetration.
8. Verify that all air/vacuum valves designed to be mounted on the main line system are not installed, and the service valves upstream of the air valves are closed.
9. Verify that all flushing valves mounted at main line end-lines are open. It is recommended to position at each of these flushing points a worker with a radio or a cellular phone.
10. Operate each pump in turn for several seconds to verify that it is working properly and rotating in the correct direction. Change the power connections if needed.
11. Perform initial pressurizing/flushing of the mains system. Perform this procedure at low capacity, low pressure, and a very slow rate.
    - Close the inlet valves to the primary filtration and open all flushing valves/openings, upstream of primary filtration. If there are no flushing valves/openings upstream of primary filtration, take out all filter elements. In the case of gravel/sand filters, fill with media only after initial system filling/flushing and not during installation. You can also open all disc filter/screen filter covers at this time, to allow water flow out of filters for cleaning purposes.
    - Turn on the pump while the pump control valve is completely closed, and monitor the pressure at the pump outlet (“shut off head”).
    - Slowly open the pump control valve (manual or hydraulic) at the pump station.
    - Adjust the pressure relief valves to their designed set point. This is normally ~5m higher than the regular system working pressure.
    - Flush all manifolds upstream of the primary filtration via flushing valves/openings, at a high flow rate.
    - Slowly open the main valve at the inlet to the primary filtration or at the end of the system control head. Make sure that if there are no flushing valves/openings upstream of primary filtration, all filter elements were removed as described above.
    - Keep the main valves mentioned in the previous step throttled so that the upstream pressure head is higher than the normal working pressure, and flow rate in the line is 1/4 of the normal flow, as indicated by the water meter. Continue this process until the system is filled with water and clean water is flowing through the flushing valves mounted at main line end-lines.
    - Drive along the main line routes and monitor the complete system while performing the previous step. Look for un-closed/unplugged openings (except for the flushing ones), major leaks, and burst pipes. Close and fix all problems found.

- Slowly open the main valve until it is fully open. High flow rate is flowing now through the system. Make sure the pump is not cavitating (indicated by a strong sound at pump) due to high flow. If it does – reduce the flow.
- Initial flushing is over when the supervising workers announce that clean water is flowing out of the last flushing valve/opening.

12. Turn off the pump/pumps.
13. Close all flushing valves and openings.
14. Conduct a “pressure test” of the system according to specifications. Fix all minor leaks found, until the results are within the permitted range specified in the project design.
15. Manually backflush all the primary filters as a preparation for system flushing.
16. Flush the system at high velocity flow, section by section. Flush the main lines, sub-mains and the driplines, according to the system flushing procedure described in this booklet.
17. During driplines flushing, check the sub-mains for leaks.
18. Mount all air and vacuum valves, after a short flushing of the risers on which they are supposed to be mounted.
19. Perform initial irrigation of each zone/block, one by one. During this initial irrigation, adjust all pressure regulation and pressure relief valves at the pump station and system control head to their designed preset pressures.
20. Monitor, adjust, and set the pressure on all irrigation pressure regulator valves located at cluster houses or assemblies on-site, shift after shift, until all areas are covered. Perform this procedure according to the data indicated in the design.
21. Monitor and register all pumps and shifts data according to the relevant ‘Pumps test’ protocols.
22. Monitor and register all plots/zones data, including the pressure checks at critical points in plots/zones, according to the relevant protocols.
23. Monitor and register upstream and downstream pressure heads at the project’s “critical valves” (where upstream pressure is close to the required pressure). The list of “critical valves” is provided by the project designer.
24. Test and adjust all pumps and switch gears protections (“No flow” limit switches, high/low pressure “pressostats”, water levels floats switches, etc.) by forced simulation.
25. Test and adjust all protection valves/hydraulic protections.
26. Test and adjust all valves and hydraulic devices manually and then by remote control using forced simulation.
27. Test and adjust the filtration system (backflushing valves, controller, differential pressure device, wiring and tubes) by forced simulation.
28. Program and test the irrigation control system.
29. Test and adjust the Nutrigation™ injection machine.
30. Test, monitor, and adjust the nutrients mixing, supply and storage system (nutrients mixing tanks and pumps, nutrients piping and accessories, nutrients storage tanks, wiring and tubes) by forced simulation.
31. Enter the updated data on flows, pressures, currents, water levels, time delays, etc. into the design maps, diagrams and drawings, and the draft form to be submitted to the project designer for approval and advice.
32. The final result of the commissioning process is a system that performs within the accepted range as indicated originally in the protocols updated by the customer and Netafim™.

System Performance Test

Operate the system according to the irrigation shifts program.

- Open the valves of shift no. 1.
- Operate the pump/s as required.
- Wait until the lines are filled and the pressure has stabilized.
- Check flow rate and pressure using the water meter and pressure gauge, to ensure they correspond with the original design.
- Adjust pressures at the main valves (at the system control head or along the main line) if pressure is not properly adjusted.
- Return to the system control head and recheck the system flow rate and functioning (pumps, filters, pressures, Ampere reading etc.), all according to perform while shift no. 1 is operating, and all the pressures are adjusted according to the plan. Flow rates and pressures of each valve should be recorded in a performance system form if the Netafim™ protocol is used).

> **NOTE**
> If each shift includes several valves, and in order to avoid a situation of low flow rate/high pressure, it is also possible to measure the flow rates of individual zones by closing a single valve (one valve at a time) and subtracting the flow rate measured from the total shift flow rate.

- Open the valves of shift no. 2 and close the valves of shift no. 1.
- Repeat all the tasks in the previous steps for all the specified shifts in the map, making sure to wait each time for pressure and flow to stabilize.
- Once all shifts and zones have been tested, and flow rates and pressures tables are recorded, compare the measurements taken (by valve and by shift) to the design data.
- At this stage, assuming all documentation is updated and based on plans – two outcomes are possible:
  1. Shifts and zones (irrigation valves) flow rates correspond to the plan and no major changes have been recorded (± 5%).
  2. Some shifts or zones flow rates do not correspond to the plan and are outside of the allowed range.
- If the outcome is outside of the allowed range, modifications may have been done to the zones' dimensions and/or the system layout (vs. the plan) without also updating the map. These should now be updated to reflect the real conditions in the field. The most convenient way to do this is to mark changes on the existing design map (such as: indicating the number and length of the driplines deployed in each zone, drawing updated zone boundaries to scale in the map, etc.).
- If there is still an inconsistency between the design / maps and the actual field performance (recorded pressures and flow rates), try to identify the problems according to the Start-up Troubleshooting Procedure below.

> **NOTE**
> This section discusses complete system troubleshooting and not troubleshooting of specific products or assemblies. For troubleshooting of specific products or assemblies, see the Netafim™ maintenance manual.

Start-up Troubleshooting Procedure

When there is a flow/pressure deviation of more than ±5% from the original design once the pipes are filled and pressures stabilized, usually, one of the following three situations has occurred at the pump station/system control head:

Operating flow rate is too high – Usually followed by pressures lower than required in the system. A too-low operating head sometimes occurs only in certain zones and not at the system control head, if the water source is capable of supplying excess flow without pressure dropping under the value required at the system control head.

Operating flow rate is too low – Followed by pressures higher than required or designed for the pump station/ system control head.

Both flow rate and pressure are too low at the pump station.

The following describes typical problems and recommended solutions for each of the three situations.

High flow rate and low pressure at pump station / system control head (after filling the lines and stabilization of pressures) - possible problems and their solutions.

1. More valves than specified in the design are open.
   - Physically check that only the required valves are open.

2. High pressures in some blocks/zones with non-regulated drip irrigation.
   - Adjust the pressures at the pressure regulator valves as required.

3. End of driplines or even ends of sub-main lines are open.
   - Ensure that all driplines and sub-main line ends are closed.

4. Bursts/leaks in the main line or open sub-mains.
   - Verify the serviceability of the main line by testing the water meter or test pressure in a condition where the field valves are closed.
   - Then inspect the sub-main alignment and look for bursts. As necessary, test flow rates at another valve to identify the problem more precisely.

5. Leaks and driplines disconnected from the blocks.
   - Physically inspect the driplines and make repairs where necessary.

6. A block or blocks in the given operation are larger than planned.
   - Verify the dimensions of the blocks or the number of driplines that have been deployed in the various blocks and compare them with the design.
     If there is any discrepancy, contact the project manager or project designer to solve the problem.

7. The water-delivery devices are delivering a higher average flow rate than planned.
   - This is a potential condition due to the shipment of incorrect flow rate equipment, damaged equipment or equipment that has been damaged during installation, flushing or commissioning of the system (such as penetration of sand into the drippers). Contact the project manager or project designer to solve the problem.

8. Incorrect spacing of the water-delivery devices.
   - The spacing between drippers along the driplines is denser or there are more driplines in the field than planned. Consult with the project manager / designer.

9. Improperly calibrated water meter.

- This is an extremely rare malfunction in new equipment. In a large project, the water meter may be replaced with another meter stationed in another parcel for purposes of comparison, to verify that this is indeed the problem.

Low flow rate and high pressure at pump station / system control head (after filling the lines and stabilization of pressures) - possible problems and their solutions.

10. All the operating valves are not open as required.

- Physically inspect and verify that each open/close valve is completely open.
- Physically inspect and verify that each adjustable valve is adjusted as required.

11. Operating pressures are too low in the water-delivery device blocks (all or some of them).

- Inspect and adjust pressure in the different blocks. Verify that the minimum required pressures are obtained at the furthest / highest driplines. (Pressures in the blocks may be increased only if the pressure in the main line is higher than that in the block.)

12. Low pressure in the main lines due to higher head losses than allowable or blockage in the filtration system.

- Thoroughly flush the filters to reach the minimum required head losses. Note that at the start of the first stage of the project there are higher-than-normal quantities of dirt, so it is recommended that frequent flushing be performed based on P Δ (pressure differential), and not on a fixed time between flushing operations.

13. Blockage / throttling of the main line system.

- Inspect the entire main line from the head onward, measure pressures at each possible point to identify the location of the problem (throttled main valve, main valve piloted to a pressure that is too low, contaminants that have been trapped in devices in the grid, etc.).

14. Problems in the outlet area of the driplines from the sub-mains.

- Inspect along the outlets of the driplines from the sub-mains and identify driplines that are not discharging water or in which the pressure is very low. Possible problems: saddles without drilled holes or incomplete holes, PE outlets forcibly kinked, dirt or foreign objects in the outlets.

15. The area irrigated (blocks) is smaller than designed and/or its dimensions are different.

- Verify the size of the blocks and the length of the driplines. If there is any incompatibility between the plan and what is actually occurring in the field, contact the project manager/project designer with a drawing of the field conditions dimensions.

16. Topography in the field is different from that indicated on the map.

- Certain areas in the project are higher than in the plan; these areas have low pressures. Attempt to revise the map topography and forward this revision to the project manager / designer.

17. Average flow rates of the water delivery devices are lower than required.

- Check flow rates in about 10 drippers in the block that have been identified as problematic.
  Possible causes:
  - Blockages within the drippers (usually as a result of inefficient flushing or lack of flushing).
  - Drippers have been sent with a nominal flow rate lower than required. If this is the problem, notify the project manager and forward samples for testing.

18. Drippers spacing larger than planned.

- Verify the spacing. If the spacing is larger than planned, the irrigation rate and the operating flow rate will be reduced as a result. Consult with the project manager / designer.

19. Discrepancy in the main grid installation.

- Piping diameters that are too small were installed erroneously or had to be installed for lack of choice or the main piping is longer than planned. Advise and consult with the project manager / designer.

20. Design error.

- Main, sub-main or dripline diameters are small relative to the required flow rate.
- Topography was not considered as required.
- The pressure required according to the map at the source of water is too low.

  In case of concern about a possible design error, consult with the project designer.

21. Improperly calibrated or partially blocked water meter.

- If the water-meter impeller is clogged by dirt, dismantle the water meter and try to clean it and release it.

Low flow rate and low pressure at pump station / system control head (after filling the lines and stabilization of pressures) - possible problems and their solutions.

22. Pump problem.

- The existing pump is unsuitable or there is a problem in the pump/power-supply system to the pump, or in the pump's water-suction system. Test the pump and check flow rate against pressure at several operating points. Compare actual pump performance with the pump curves and notify the party responsible for the pump (the customer or the project manager / designer).

23. Combination of various problems.

- In this case, it is recommended to notify the system designer / supplier.

Testing the performance of the pump and its accessories

- Test all the pumps according to the order and compare the results with the pump manufacturer's data curve.
- Test at several pressures, flow rates and flow consumption operating points.
- Test the functioning of the back-check valves, open and close them based on flow regimes in the system.
- Test the functioning of the pressure-release valves, opening, closing and maintaining pressure required in the system. Initiate a rise in pressure in the system beyond the planned operating pressure to test the required point of operation of the pressure-release valve (usually 3-5 m above normal operating pressure).

Testing of the functioning of filtration banks

- Filtration system test
  - Test the filtration system by operating several flushing cycles through the controller.
- Test functioning of the differential pressure gauge (P Δ = 5 m).
- In gravel tanks, check the effective flushing time of the gravel and verify that no gravel is escaping during flushing.
- Set the default flushing times:
  - Tank flushing duration: 90 seconds.
  - Dwell time (between flushing one filter and another): 8 seconds minimum.
  - Time between flushing cycles: 90 minutes.
  - Enter a revised flushing program into the controller.
  - Assemble the filter-flushing line at the drainage point agreed with the customer to obtain suitable drainage of the flushed water or recycle it to the tank at a distance from the suction point of the water (if there are no clear guidelines in the drawing – at least 25 m).

Test the functioning of the fertilizing system

- Test and use the fertilizing system by filling the fertilizer tank with water and testing actual injection of each pump.
- Test actual performance of the hourly flow rate of each fertilizer unit in normal operating conditions of the system (according to the operational plan). Record the flow rates and verify compliance with the requirements in the checklist.
- If a computer is available, operate the fertilizing pumps and readout of the fertilizer output by the computer.
- If fertilizing is being performed by a pressure tank, verify the option of reading pressures before and after the main pressure valve. Use of a single pressure gauge on a 3-way valve with a tube to connect to the second testing point is recommended.

General testing of the head control

- Verify the absence of leaks, the functioning of the air release valves, the functioning of the gate valves and the presence of stability supports for the system in accordance with the drawings.
- Arrange for protection and drainage of the pump house and the head control as necessary.
- Repairs of paint and finish:
  - Zip ties in the necessary places.
  - Protective tubes for pipes and cables.

GPS GUIDED SDI INJECTION

GPS guided SDI injection

Introduction

In many countries, marking and injection of the driplines is performed with the aid of a GPS system.
This method is becoming more and more popular and is recommended by Netafim™.
GPS-aided agronomic operations can also improve your planning. Analysis conducted offline using back office applications may create influence zones for irrigation decisions based on non-homogeneity of soil and GIS analysis of resources.

Basic terms GPS (Global Positioning System)

The global positioning system, commonly known as GPS, is a space-based global navigation satellite system. The satellites orbiting earth transmit special code sequences which are received by the GPS receiver installed, in our case, on the tractor/agronomic machine. In order to calculate the position of the tractor, signals from at least four satellites must be received. The multiple signals are then processed, and by calculating the distances to the satellites, the receiver determines its exact location, with a probable error of approximately 10 meters.

DGPS

The GPS signals are affected by several factors, mainly by atmospheric interference. As a result, the probable location error can reach 10 meters. In order to reduce the probable error several services can be used. These services are commonly called DGPS – Differential Global Positioning Systems. The basic principle of these services is that a fixed station receives the GPS signals (affected by atmosphere conditions), and by comparing the exact known place to the place given by calculating the GPS signals, it calculates the offset. This offset is then transmitted to the GPS clients that are registered with the DGPS service. As a result, the local GPS receiver eliminates the offset. This gives a probable location error of less than 50 centimeters.

RTK GPS

The most accurate method for compensating the offset (explained above) is called RTK. RTK stands for Real Time Kinematics. The RTK DGPS method differs from the regular GPS method of calculating the position. The RTK GPS uses special hardware that analyzes the satellites' signals and identifies the signal's phase. It can then find the exact location with a probable accuracy of 3 cm, but there is an ambiguity regarding the exact position. The algorithm can find the exact location but in 'jumps' of approximately 20 cm. In order to eliminate this ambiguity, a ground station must be used. This ground station can either be a portable station consisting of a GPS receiver supporting RTK and an RF/cellular transmitter/receiver, or a fixed station having basically the same hardware operated by the GPS equipment manufacturer. The accuracy of the RTK method using a ground station is ~3 cm. Currently it is the best (and only) technology which addresses the demands of SDI application.

Auto steering systems

Auto steering systems are available today for most tractors/agronomic machines. There are several types of auto steering systems and they differ mainly by their connection to the steering system.
There are three main steering technologies: electrical, direct contact (similar to a bicycle dynamo), or connection to the hydraulic steering system. Considerations for choosing the appropriate system should include accuracy needs, installation time, support and periodic calibration, maintenance, flexibility and cost.

Electrical steering: Mounts on the steering wheel shaft, and controls the direction of the tractor/machine direction by using a DC motor to manipulate the steering wheel.

Direct interface steering (bypass): Steers the tractor/machine by bypassing the existing steering mechanism.

Hydraulic steering: A hydraulic block is installed and connected to the existing hydraulic steering system (with the optional addition of a wheel angle sensor). This is possible only in tractors/machines adapted to this kind of integration.

Guidelines for implementing GPS guided SDI

For installing and extracting Netafim™ driplines using GPS, the grower should use any sub-inch tractor positioning system that is based on a GPS-RTK and auto steering system only. The same system is also subsequently used for seeding, spraying, fertilization or combine harvester applications.

- A GPS and auto steering system (Autopilot) for installing Netafim™ driplines must have an accuracy of 3 cm, high reliability, high mechanical quality, and should be as user-friendly as possible to shorten the training time.
- To mark a field, inject driplines in a field, or extract the driplines from the field, apply the usual methods recommended by Netafim™ but use a GPS-RTK and auto steering system.
- Since field patterns and geographical information cannot be easily converted from one GPS vendor to other, it is recommended to use the same GPS vendor throughout the life cycle of the driplines and the drip system components.

NOTE

Each GPS system has its own unique attributes. Consult your GPS distributor for instructions regarding the GPS system you are using.

Before starting the tractor

- Upload the territory files from the PC to the GPS computer.
- Make sure the RTK correction is available and the base station is at its exact fixed location.
- Upload the AB Line from a previously saved terrain file, or, in the case of a new field/terrain, create a new AB Line.
- Set the distance between lines (or beds) in the GPS software.
- Enter the Overlap value in the software. Enter a value of zero for marking the field, injecting driplines, or extracting driplines.

NOTE

Each agronomic mechanical tool may require unique antenna alignment adjustment.

After dripline injection is complete

- Download the data and back it up.
- Perform back office analysis.

Drip Insertion and GPS considerations

The process to insert driplines is designed to be done in the following way:

1. Topographic maps in Autocad format is given to Netafim™ for irrigation design
2. Maps uploaded to Netafim™ irrigation design software – Irricad
3. From Irricad additional conversion to Shape format to fit Trimbale or John Deer GPS system
4. Up-loading the maps into the Tractor

Since the processes include 4 types of conversions and adding the fact that our planet is round (round-flattened) creating un-accuracy problems in field real conditions. Therefore, this method is not so common

What can be done:

Creating an A - B line (as opening the first furrow) creating parallel lines (at a determined spacing)

The disadvantage:

- In the map; the drip location, is kept, but not the sub-main and main lines
- In case where the A - B line was marked with a small diversion from the map and there are significant inclines it can affect the hydraulics

By using the A - B method the dripline buried in the field is very accurate but on the other hand the GPS information is only including dripline location and not the location of the sub-main or the main lines

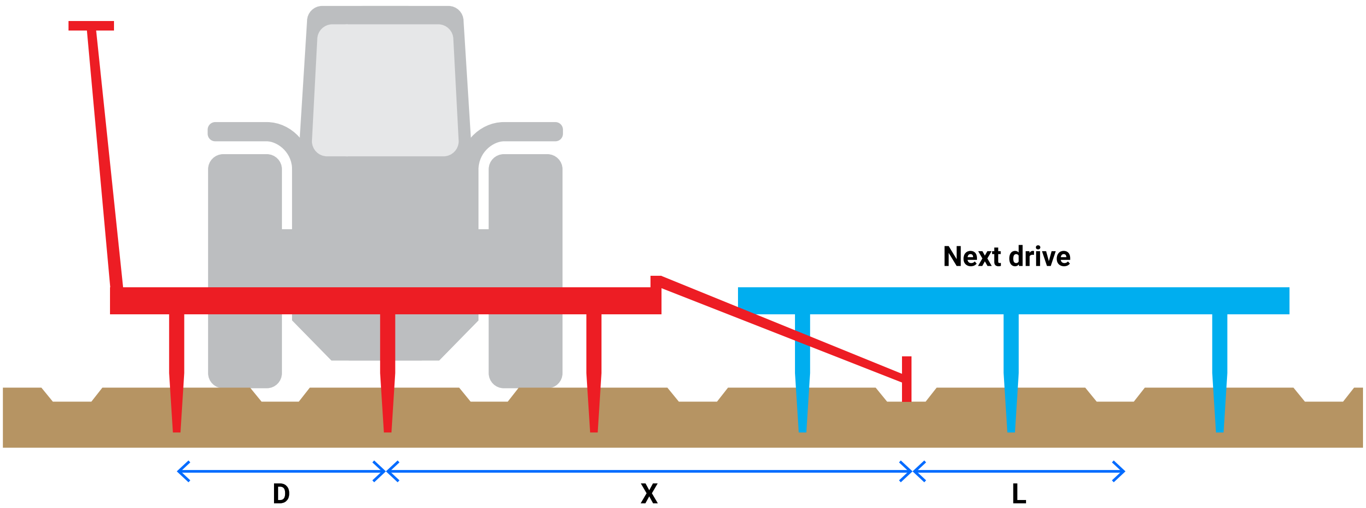
SDI dripline injection guide without GPS

When the tractor doesn't have a GPS system it will be required to install a marker on the injection implement. This marker will mark the next path for the tractor once it has installed the first line. It is possible, and recommended, to have a marker at both sides to allow driving both ways.
For simplicity, it is possible that these markers are hydraulically operated.
The tractor wheel will follow the marks that the marker has left from a previous injection path.

In order to calculate the distance (location) of the marker to the tractor center, please use this formula:

$$X = (N \times D) - L/2$$

Where:
X - The marker distance from the center of the tractor. This is the route of the tractor wheel in the next drive.
N - The number of injection shanks.
D - The distance between shanks.
L - The width between the tractor wheels.



Example:
Number of shanks = 3
Distance between shanks = 100 cm
Width between tractor wheels = 190 cm

X = (N x D) - L/2
X = (3 x 100) - 190/2
X = 205 cm

HANDLING THIN, MEDIUM AND THICK-WALL DRIPLINES

Handling thin and medium-wall driplines

Preparations

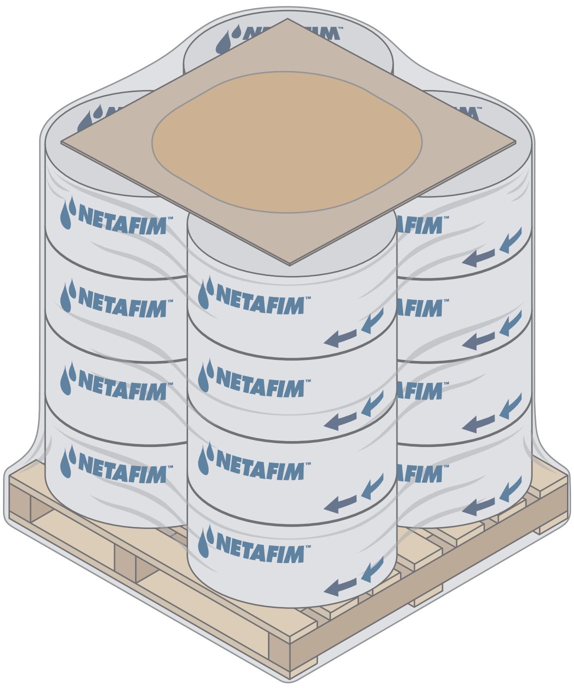
Thin and medium-wall driplines are rolled on a cardboard package (a cardboard roll with a hard core that allows the spool to roll on it in an orderly manner) or on a plastic spool (these drums will reach the farmer wrapped in a plastic protective film).

> **CAUTION**
> When using a cutting tool, take care not to damage the dripline.

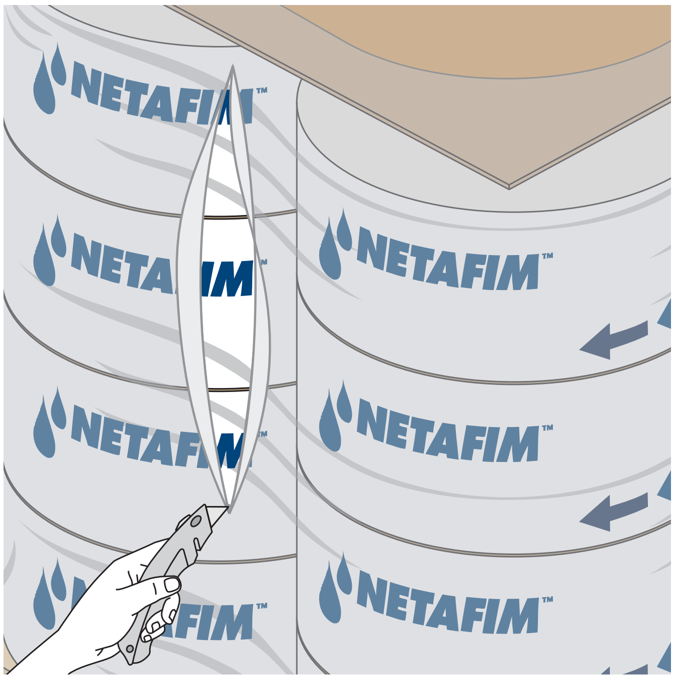
Unloading the pallets

Pallet opening

1. Cut the stretch wrap in the gap between the drums.



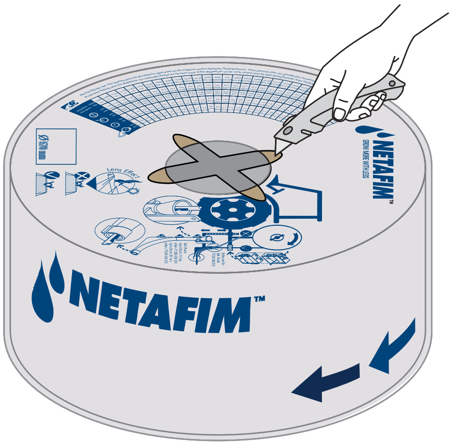
2. Remove the stretch wrap and the top cardboard.



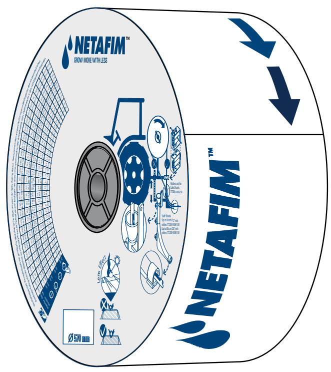
Opening the dripline drum

NOTE
Note the direction of the arrows on the surrounding corrugated cardboard. It indicates the direction in which the drum should be mounted on the coil holder of the device/machine so that the dripline unwinds correctly.

1. Carefully cut out a cross in the center of the drum.



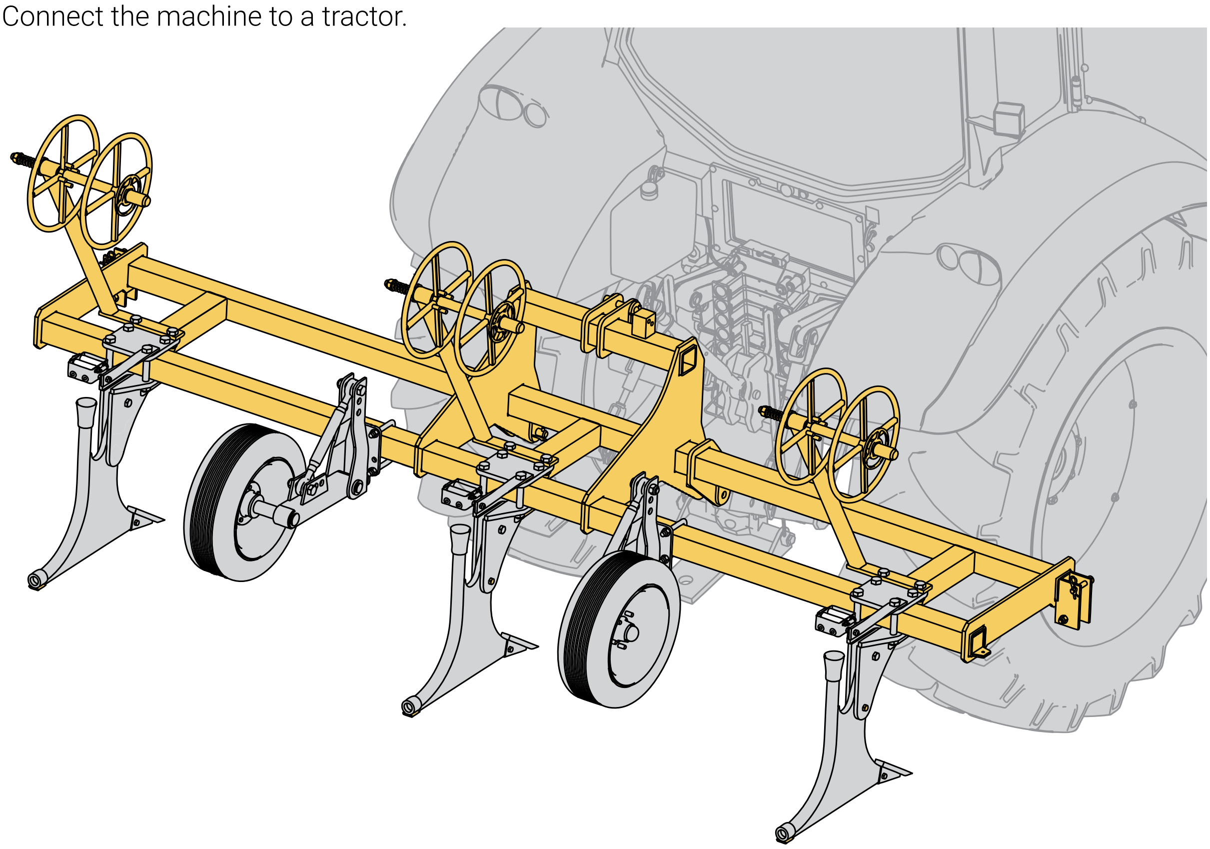
2. Remove the stretch wrap from the drum.



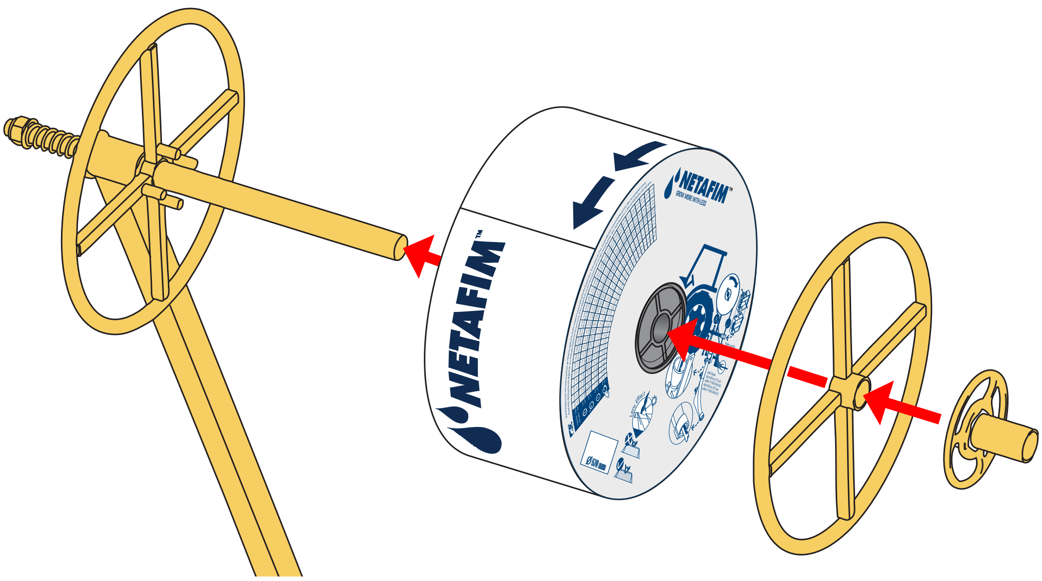
NOTE
Each dripline drum is labeled with a batch number identifying the dripline. Keep the batch numbers for future reference.

Mechanized insertion of driplines

1 Connect the machine to a tractor.



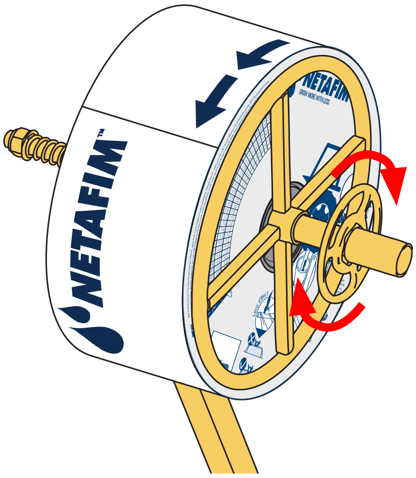
2 Load dripline drums onto the drum holders.



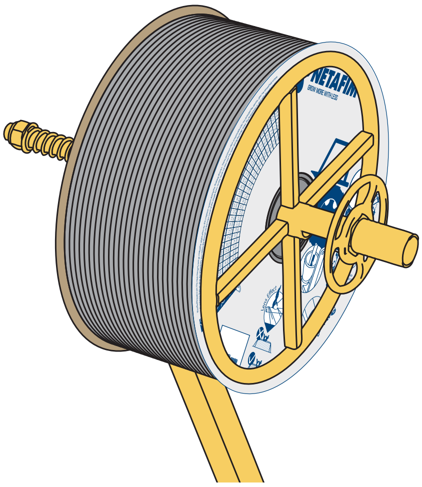
NOTE

Make sure that the direction of the arrows on the surrounding corrugated cardboard matches the laying direction.

3 Fasten the locking nut/s on the drum holder/s.

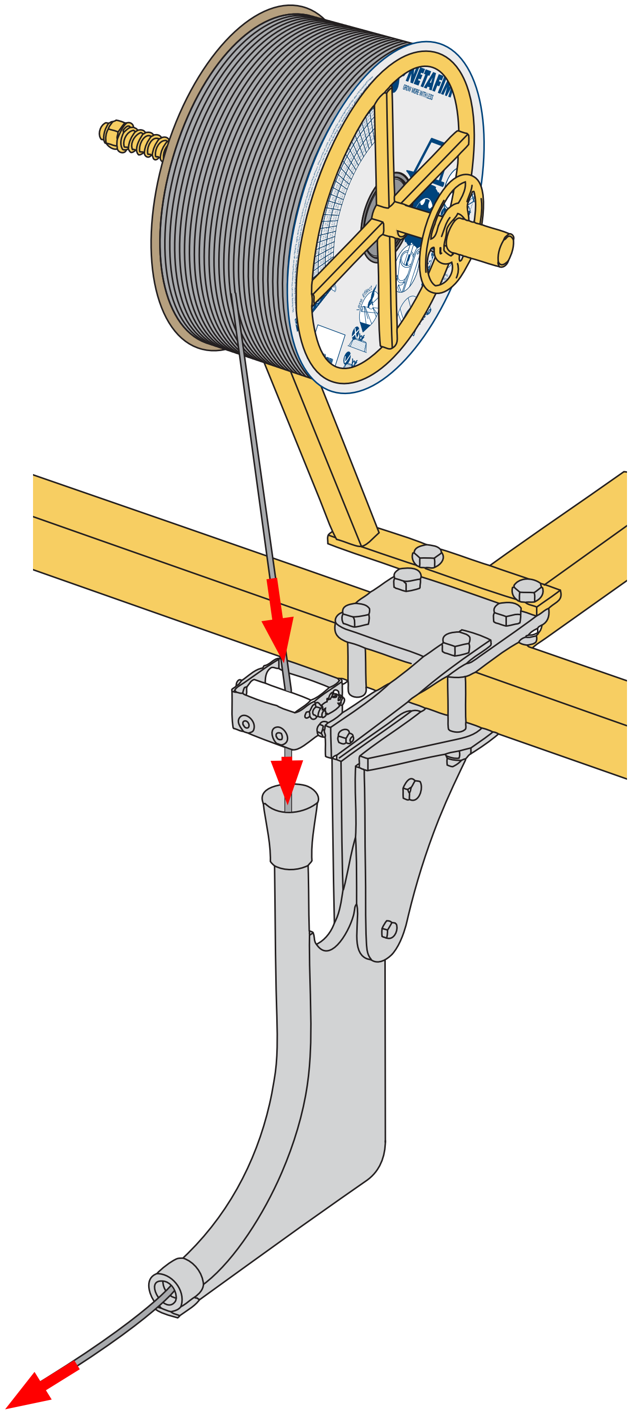


4 Manually remove the surrounding corrugated cardboard from the drum/s.



CAUTION
To avoid damaging the dripline, do not use cutting tools.

5 Thread the dripline through the roller box and the laying tube.

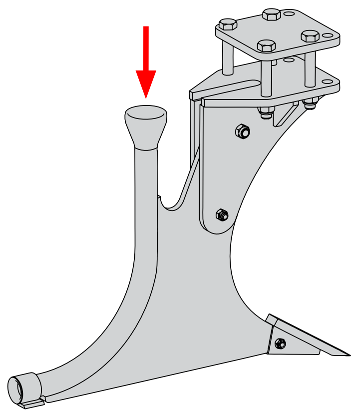


ATTENTION
Make sure the roller box is installed exactly over the top opening of the laying tube.

NOTE
Netafim™ dripline connectors (such as Ring Lock or Twist Lock connectors), are especially designed to pass freely through the Netafim™ insertion tube and roller box without being damaged.

Make sure the inside of the insertion tube is clean

NOTE
- A dirty or partially obstructed insertion tube can damage the dripline during insertion.
- To clean the inside of the insertion tube, flush the tube from the top with water at high pressure.



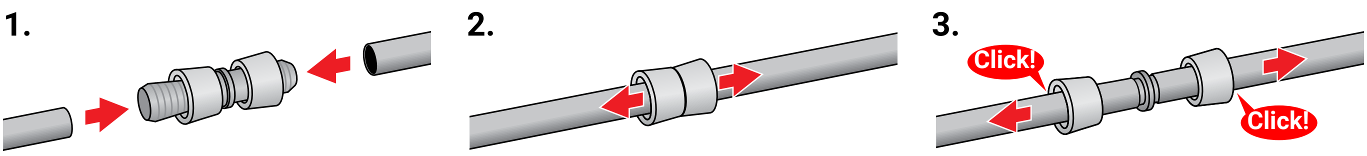
When a dripline drum is empty:

1 Replace the empty drum with a new one.

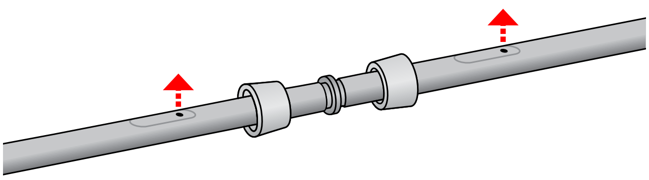
TIP
To save time and avoid multiple stopping of the tractor while laying or inserting driplines with a 3-unit machine, especially when laying pre-recoiled driplines, it is recommended that you stop the tractor when the first of the 3 drums is empty. Cut the leftover dripline on the two other drums and collect the drums with the leftover driplines.
Replace the 3 dripline drums at the same time.
At the end of the day, in your spare time, connect all the leftover driplines with dedicated connectors and recoil them together using a manual recoiling device on a plastic drum for future use.

NOTE
Make sure that the direction of the arrows on the surrounding corrugated cardboard match the laying direction.

2 Connect the next dripline to the previous one using an appropriate pipe connector and continue laying



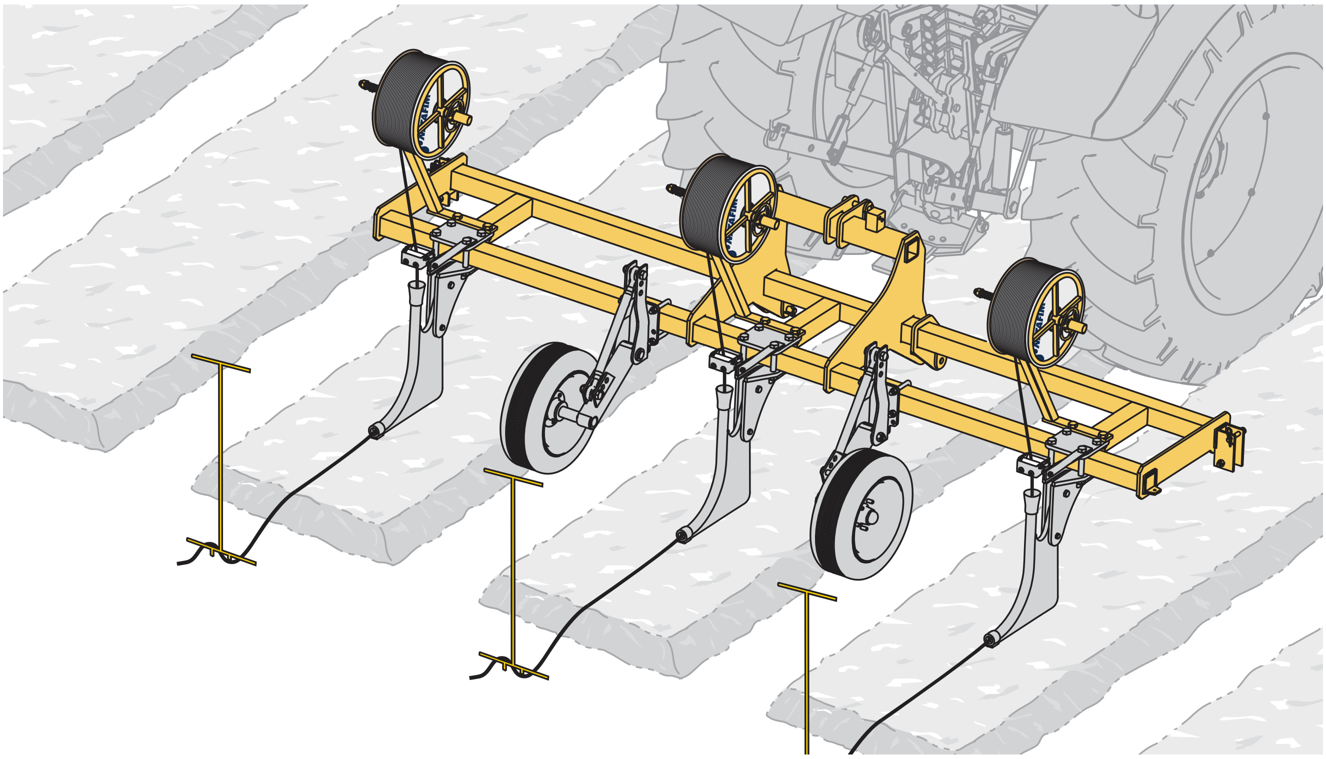
CAUTION
Make sure the drippers of the new dripline are facing the same direction as the drippers of the previous one.



NOTE
The last 3 meters (10 feet) of dripline unwound from a drum might appear to be crumpled, but it only looks that way. Once the dripline is full of water under working pressure, it will appear uncrumpled.

3 Position the tractor at the head end of the field.

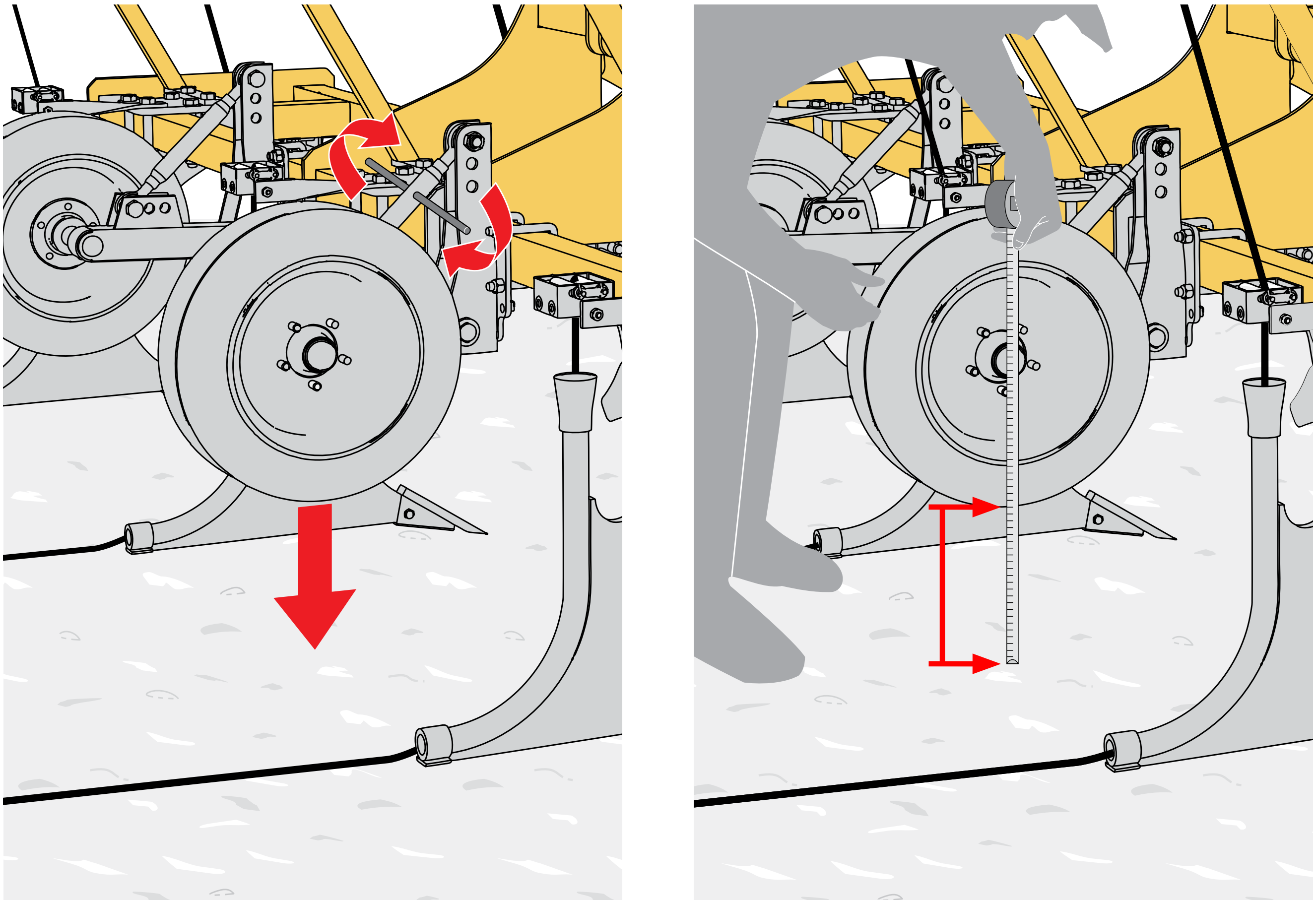
Secure the end of each dripline to be laid at the head of each bed with a dedicated end-of-dripline holding spike (see TIP, page 116).



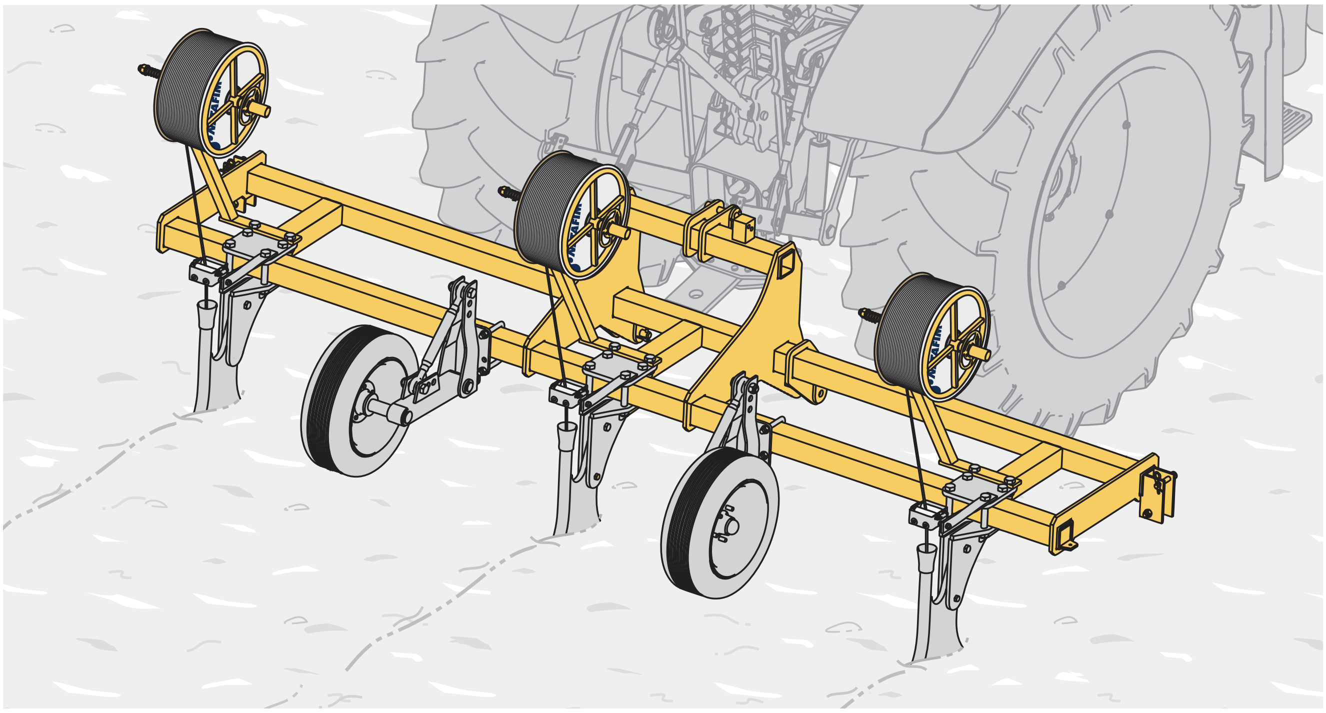
4 Adjust the height of the depth wheels.

Lower the machine until the insertion shank touches the soil.

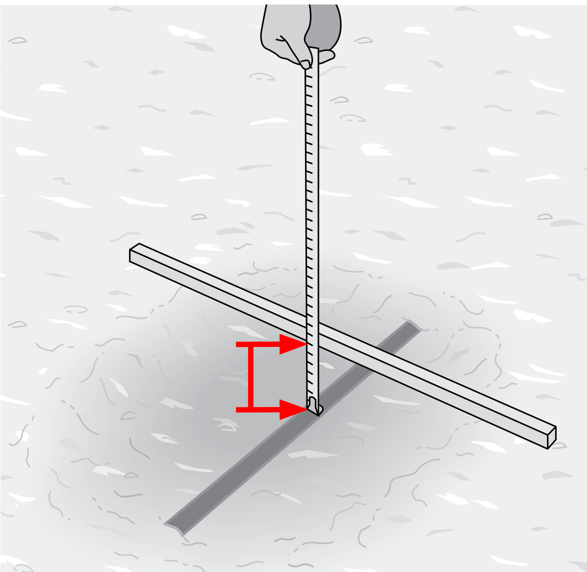
Then lower the depth wheel until its distance from the soil is equal to the required insertion depth.



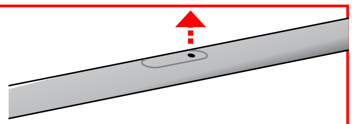
5 Drive for at least 30 - 40 m and stop the tractor.



6 Check for correct insertion depth and proper soil coverage.



CAUTION



Make sure to lay the dripline with the drippers facing up.
Make sure the driplines are laid out with no twists or kinks.

ATTENTION

Accessories for soil coverage and tightening will be added to the machine or operated separately after dripline insertion, depending on the soil structure and the crop needs.

NOTE

During the first run of an insertion project, it is highly recommended that you extract a 10-meter-long section of dripline from the soil, connect it to a water supply, plug the other end, open the water and check for leaks. If any leak is discovered it is a sign that the dripline has been damaged passing through the insertion tube. Check the insertion tube for any internal protrusion and repair it; then repeat the test.

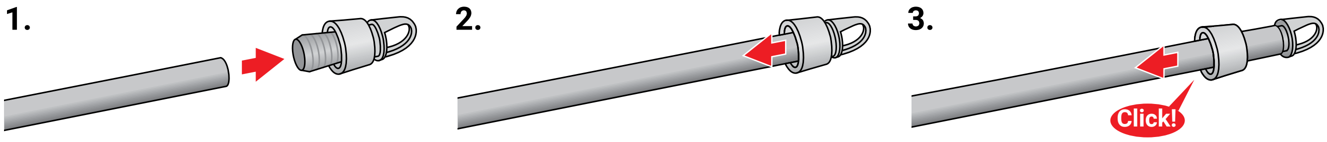
NOTE

Travelling speed should match driver's and workers' skills.The faster the tractor moves, the more severe the effect of abrupt breaking due to an unexpected problem that requires a halt in the laying process.
If the tractor moves too fast, an unwanted length of dripline will be released and will have to be recoiled manually before resuming travel.
Netafim™ recommends not to exceed 5-7 km/h.

Closing the end of a dripline

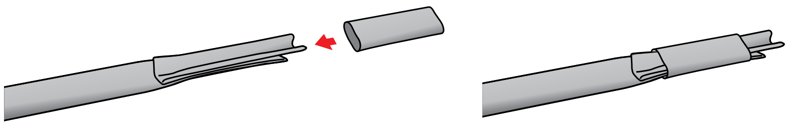
Netafim™ offers various accessories for closing the ends of driplines.
Two basic methods for closing the ends of driplines are shown below:

End-of-dripline closing accessory



Z-folded dripline end

1. Cut a 5 cm (2”) sleeve from the end of the dripline.
2. Fold the end of the dripline in the shape of a “z” and slip the sleeve over the end.

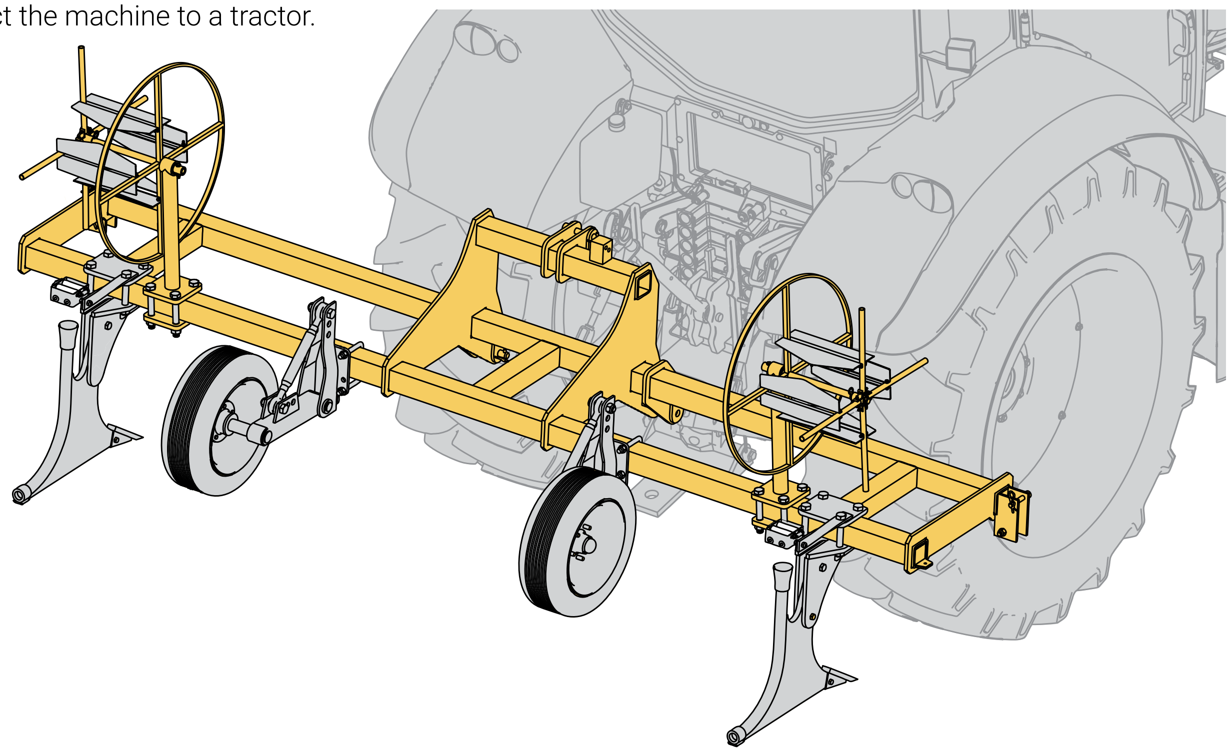


See all the types of pipe connectors and pipe accessories in the Connectors - Product Catalog and further instructions in the Drip Irrigation Handbook

Another option, besides connecting the driplines to the collection pipes that help wash several driplines together (as explained in previous chapters), is to use an automatic flushing valve accessory.
This valve will be activated with each opening of water into the dripline for about 10 seconds and will allow the dirt that has accumulated to wash (if accumulated).
The use of this accessory requires appropriate hydraulic design: flow and pressure suitable for a situation in which the driplines are washed. Or, as another possibility, the driplines will be opened in a graded manner with differences of about 20 seconds (the irrigation block will be divided un few sub-blocks that each of them will have his own valve).
Please consult the Netafim™ technical department.

Mechanized insertion of thick-wall driplines

1. Connect the machine to a tractor.



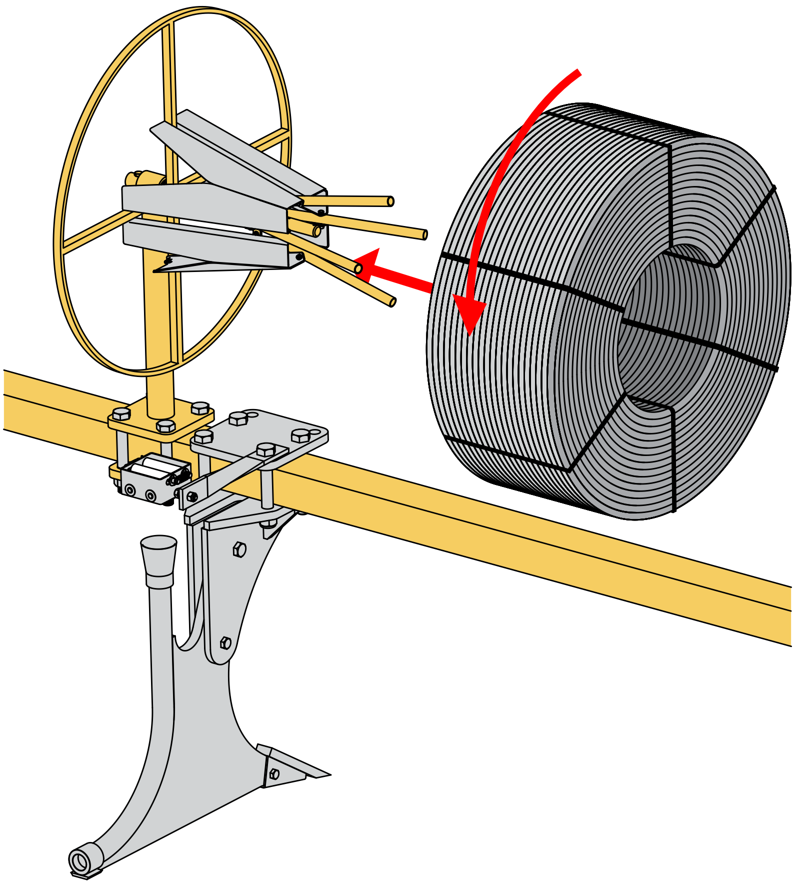
NOTE

If your tractor is powerful enough to withstand a high soil drag you can insert 3 driplines at a time. However the dripline insertion process is presented with 2 insertion units due to the inability of some tractors to withstand high soil drag.

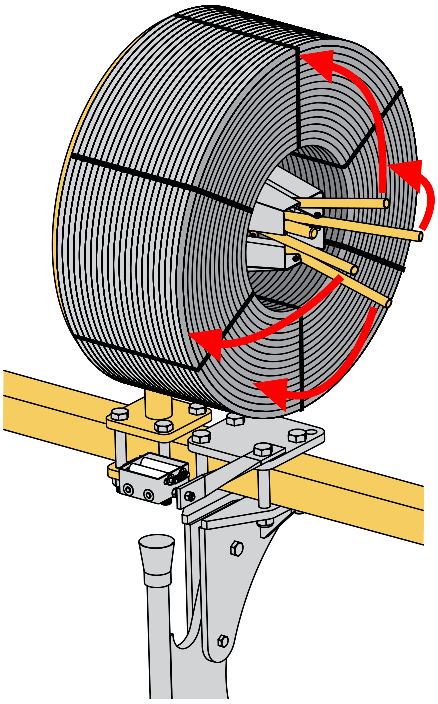
2. Load dripline reels onto the reel holders.

NOTE

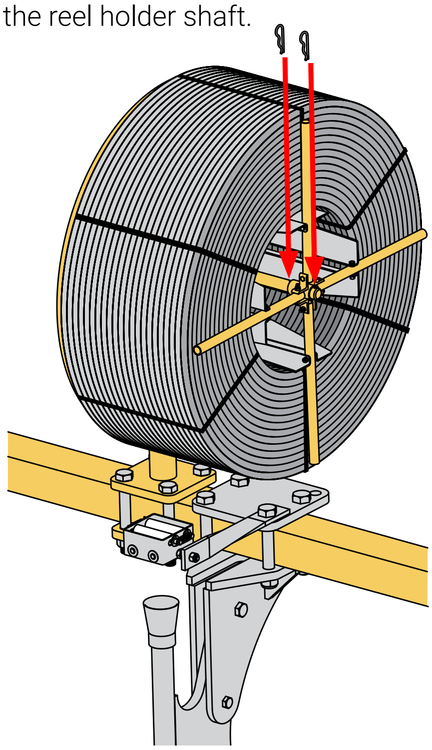
Make sure that the reel is loaded in the correct direction so that the dripline is dispensed above the top of the roller box.



3 Spread the 4 reel fastening rods.

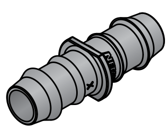


4 Lock the fastening rods in position:
Insert the 2 securing pins onto the 2 holes in the reel holder shaft.

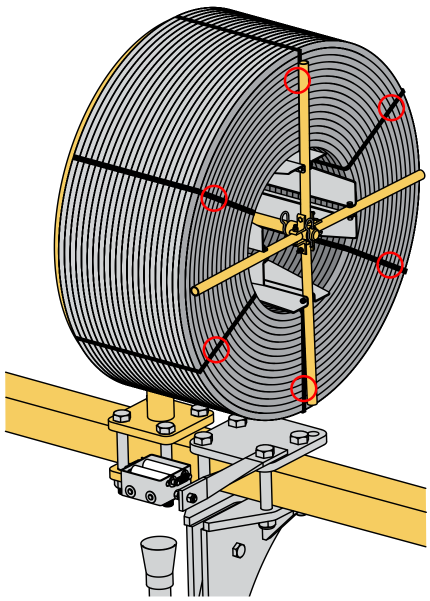


NOTE

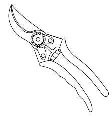
Netafim™ dripline barb connectors are especially designed to pass freely through the Netafim™ laying tube and roller box without being damaged.



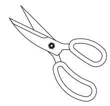
5 Cut and remove the 6 reel ties with



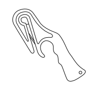
secateurs



scissors



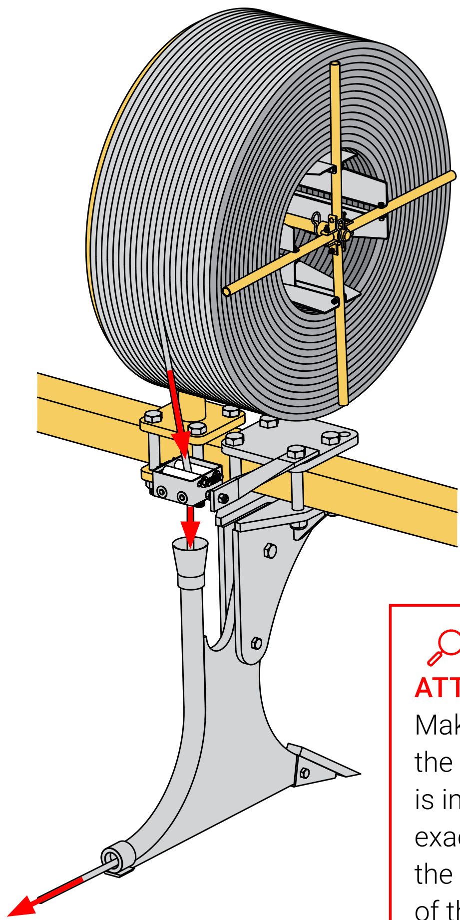
or a dedicated protected cutter



CAUTION

To avoid damaging the dripline, do not use a cutter knife.

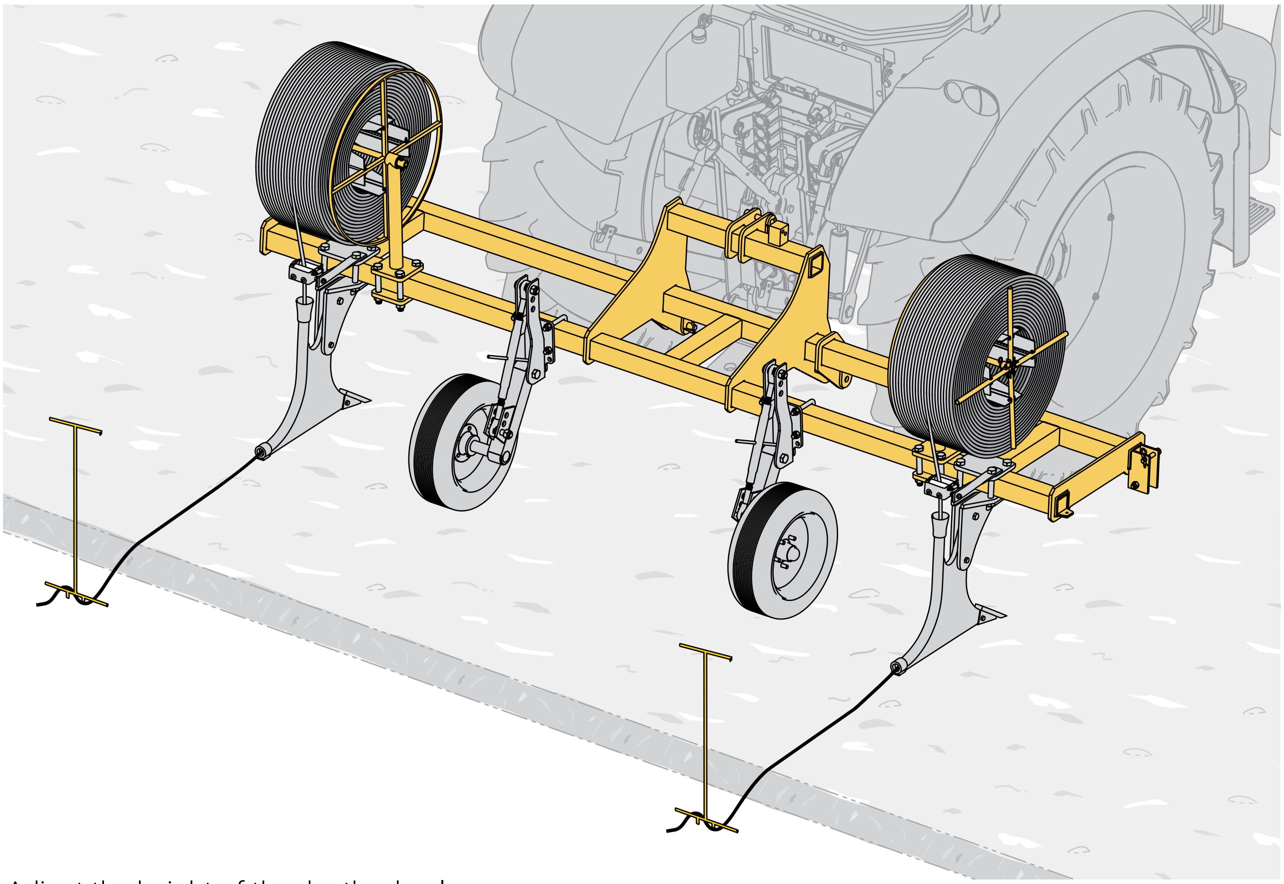
6 Thread the dripline through the roller box and the insertion tube.



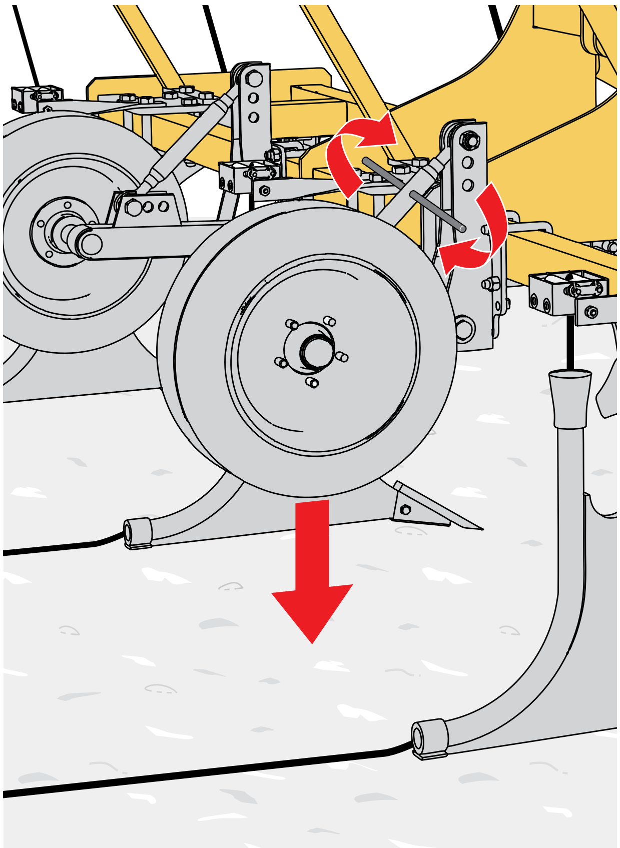
ATTENTION

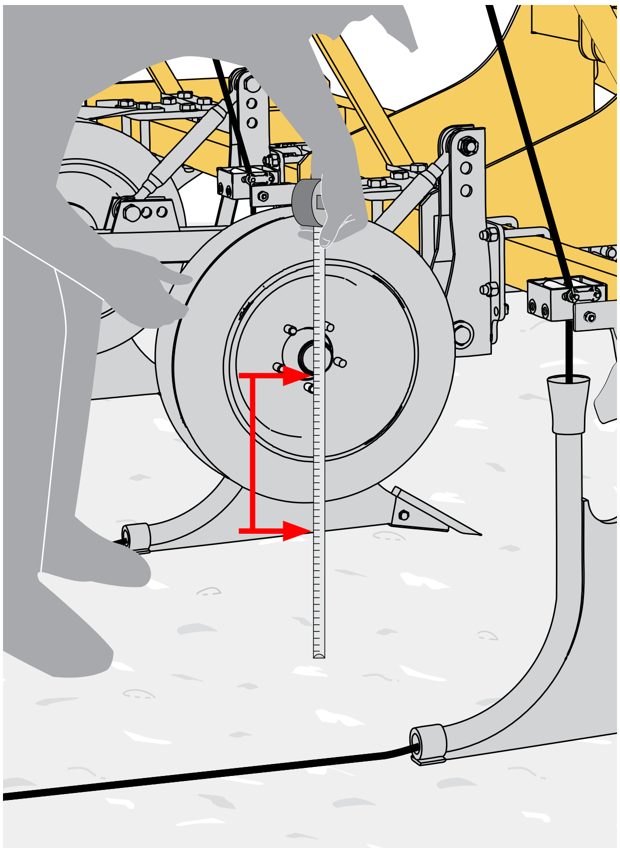
Make sure the roller box is installed exactly above the top opening of the laying tube.

7 Position the tractor at the head end of the field.
Secure the end of each dripline to be laid at the head of the field with a dedicated end-of-dripline holding spike (see TIP, page 116).

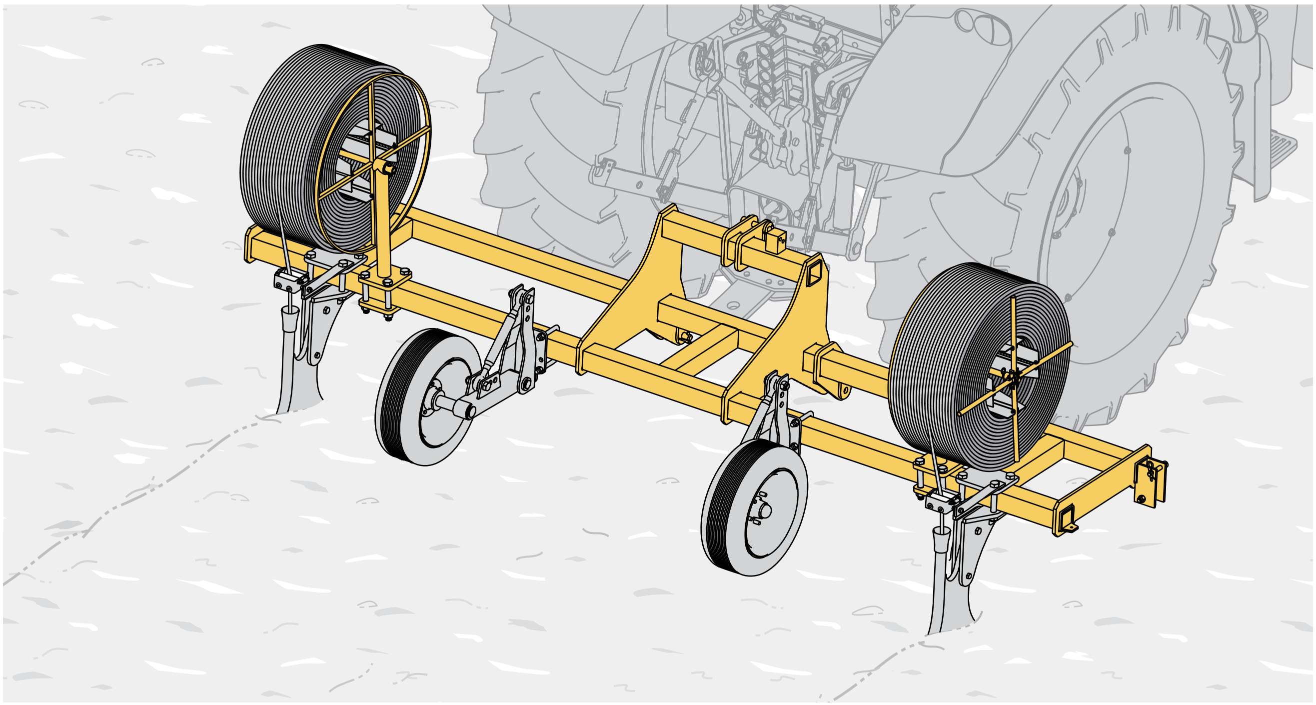


8 Adjust the height of the depth wheels.
Lower the machine until the insertion shank touches the soil.
Then raise the wheel until its distance from the soil is equal to the required insertion depth.

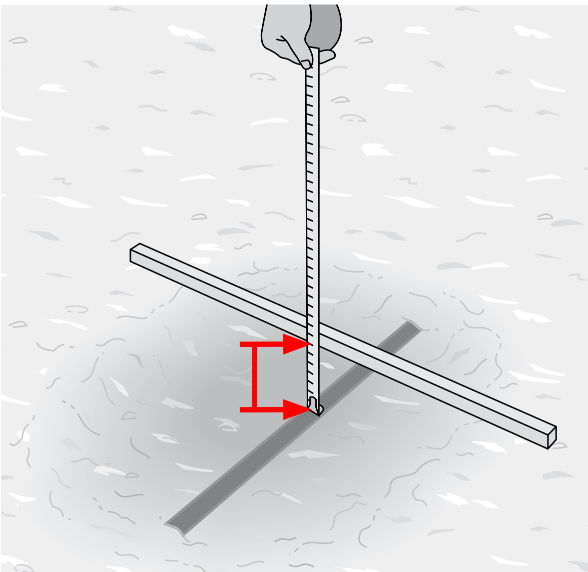




9 Drive for at least 30 - 40 m and stop the tractor.



10 Check for correct insertion depth and proper soil coverage.



CAUTION
Make sure the driplines are inserted with no twists or kinks.

ATTENTION
Accessories for soil coverage and tightening will be added to the machine or operated separately after dripline insertion, depending on the soil structure and the crop needs.

NOTE
During the first run of an insertion project, it is highly recommended that you extract a 10-meter-long section of dripline from the soil, connect it to a water supply, plug the other end, open the water and check for leaks. If any leak is discovered it is a sign that the dripline has been damaged passing through the insertion tube. Check the insertion tube for any internal protrusion and repair it; then repeat the test.

NOTE
Travelling speed should match driver's and workers' skills.The faster the tractor moves, the more severe the effect of abrupt breaking due to an unexpected problem that requires a halt in the insertion process. If the tractor moves too fast, an unwanted length of dripline will be released and will have to be recoiled manually before resuming travel.
Netafim™ recommends not to exceed 5-7 km/h.

When a dripline reel is empty:

1 Replace the empty reel with a new one.

TIP

Replace the dripline reels at the same time.

To save time and avoid multiple stopping of the tractor while laying or inserting driplines with a 2 or 3 unit machine, it is recommended that you stop the tractor when the first of the 2 or 3 reels is empty. Cut the leftover dripline on the other reels.

NOTE

Make sure that the reel is loaded in the correct direction so that the dripline is dispensed above the top of the roller box.

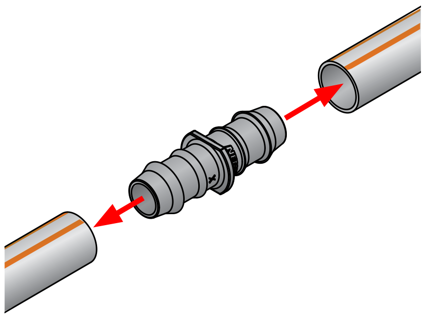
2 Connect the next dripline to the previous one using an appropriate pipe barb connector and continue laying.

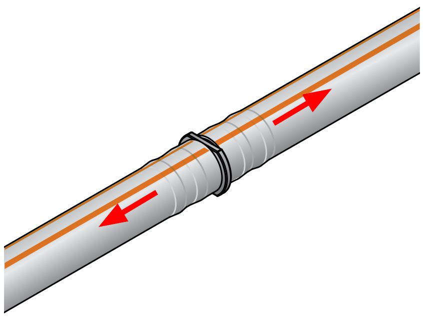
a. Insert the barb connector all the way in.

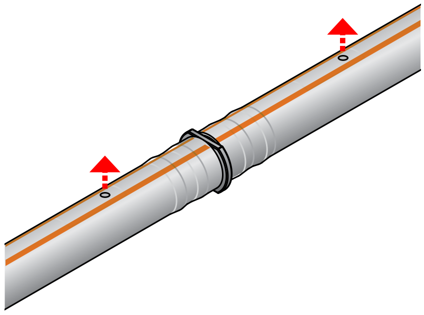
b. Pull the driplines back to make sure they are properly connected.

CAUTION

Make sure the drippers of the new dripline are facing the same direction as the drippers of the previous one.







NOTE

Netafim™ driplines are characterized by two orange stripes along the dripline.

These stripes can assist the installer to identify that the dripline is positioned with the drippers facing up.

Another option, besides connecting the driplines to the collection pipes that help wash several driplines together (as explained in previous chapters), is to use an automatic flushing valve accessory.

This valve will be activated with each opening of water into the dripline for about 10 seconds and will allow the dirt that has accumulated to wash (if accumulated).

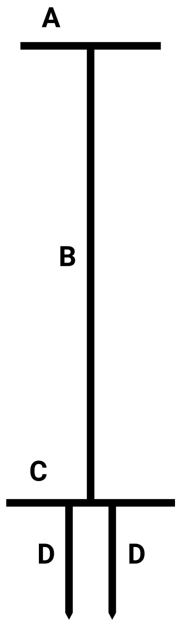
The use of this accessory requires appropriate hydraulic design: flow and pressure suitable for a situation in which the driplines are washed. Or, as another possibility, the driplines will be opened in a graded manner with differences of about 20 seconds (the irrigation block will be divided un few sub-blocks that each of them will have his own valve).

Please consult the Netafim™ technical department.

TIP

Dedicated end-of-dripline holding spike

A dedicated end-of-dripline holding spike can be made easily



1. Use an 8 - 10 mm-diameter iron bar.
2. Cut 5 sections:
   A. 25 cm
   B. 80 - 100 cm
   C. 30 cm
   D. 20 cm (2 pcs.)

> **CAUTION**
> To prevent injury, remove shavings by sanding the ends of each section.

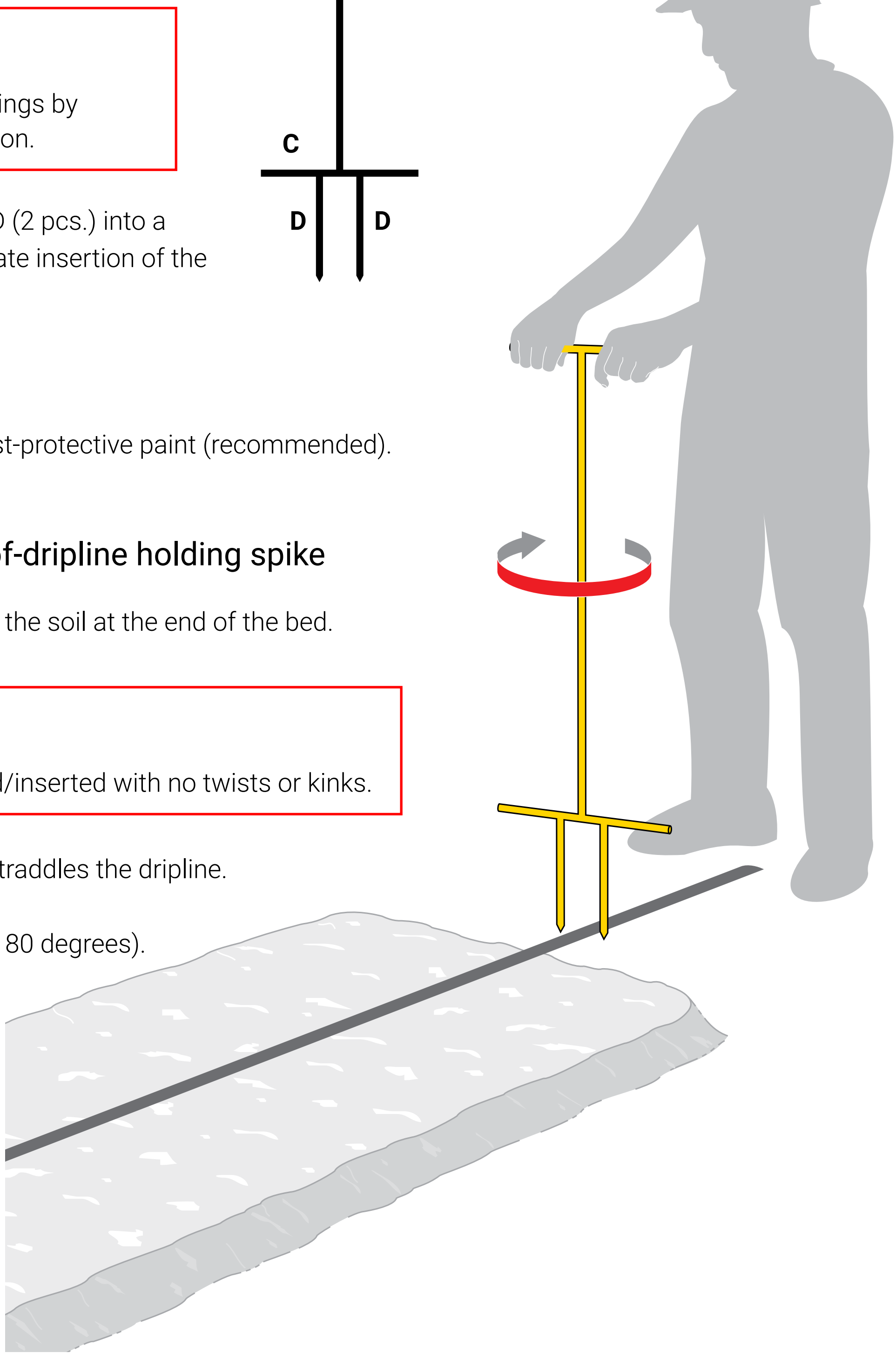
3. Sharpen one end of section D (2 pcs.) into a conic shape. This will facilitate insertion of the spike into the soil.
4. Weld the parts together.
5. Coat the whole spike with rust-protective paint (recommended).

Using the dedicated end-of-dripline holding spike

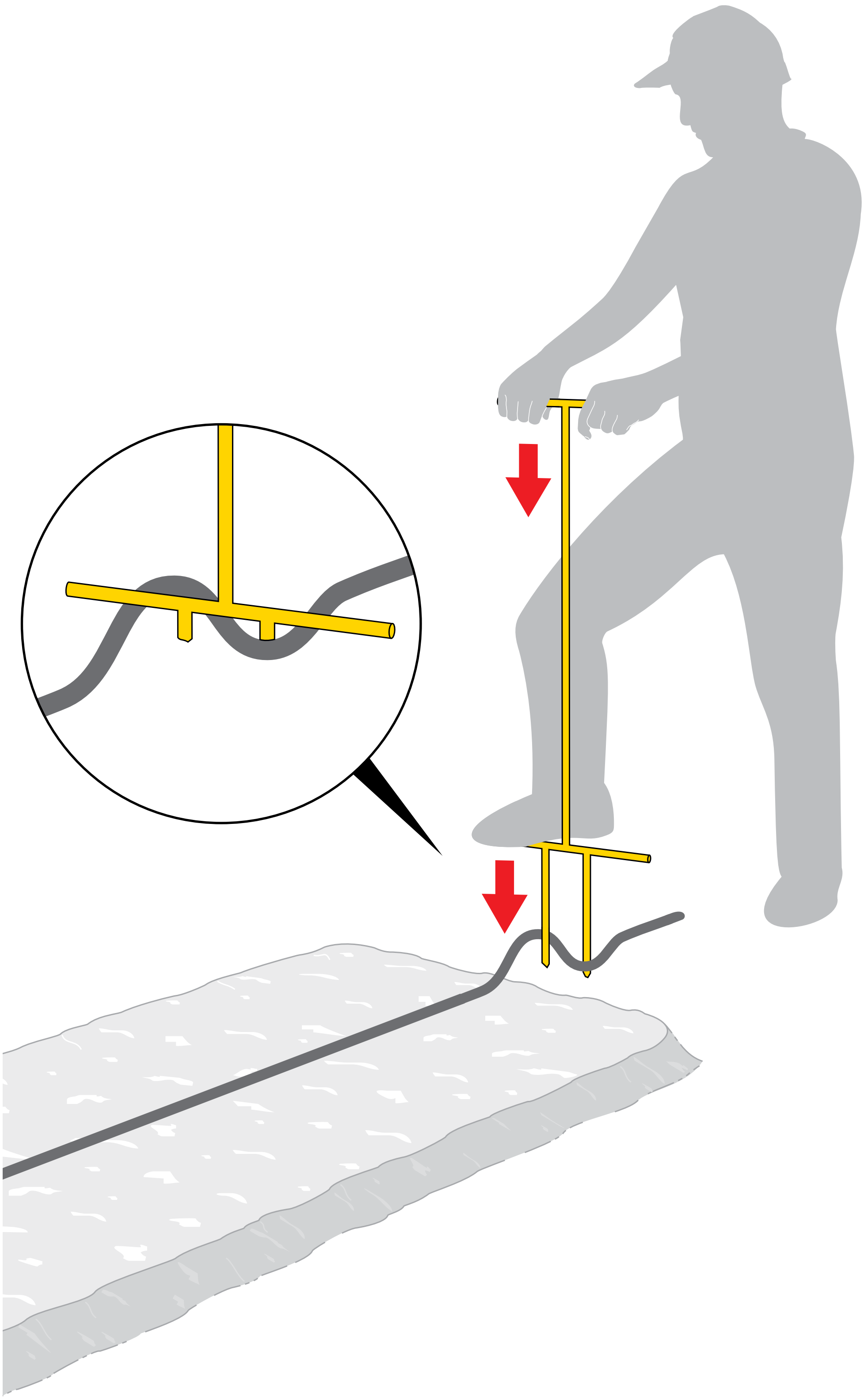
1. Lay the end of the dripline on the soil at the end of the bed.

> **CAUTION**
> Make sure the driplines are laid/inserted with no twists or kinks.

2. Position the spike so that it straddles the dripline.
3. Rotate the spike half a turn (180 degrees).



4 Push the spike down to insert its fork-shaped end into the soil.



5 Check that the dripline is securely held.

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