

The TORO logo is a red rounded rectangle with the word "TORO" in white, bold, sans-serif capital letters. A small registered trademark symbol (®) is located to the right of the word.

A PRACTICAL GUIDE TO SUB-SURFACE DRIP IRRIGATION



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INTRODUCTION

With global water scarcity on the rise, it is important to adopt agricultural techniques that optimise water use. Sub-surface irrigation is a precision irrigation system offering an innovative and sustainable solution to this challenge.

Sub-surface irrigation is a method of watering plants indirectly, delivering water from below through underground pipes or containers placed beneath the soil.

The water then rises through the soil, reaching the roots of the plants directly.

Sub-surface irrigation dates far back into antiquity. Indeed, early civilizations used terracotta amphorae to store and distribute water directly to the roots of the plants. However, scientific advancements and the development of new materials such as polyethylene has allowed sub-surface irrigation to evolve significantly. With the rise of micro-irrigation, it has become a precise and reliable agricultural practice that optimises water use, enhances crop productivity and promotes sustainability.

The primary reason for developing sub-surface irrigation techniques is the need to conserve water, particularly in arid climates. This method enables farmers to use various water sources, including wastewater.

Since the mid-19th century, researchers have been experimenting with various types of sub-surface irrigation techniques. The first attempts to create a basic sub-surface irrigation system were carried out in 1860 by German researchers, who pumped irrigation water into existing underground drainage systems. Later, in the 1920s and 1930s, several researchers explored the use of porous irrigation pipes.

The creation of polyethylene in an English laboratory in 1935 marked a decisive stride in materials science. In the early years of its development, only the low-density form of polyethylene (LDPE) was known; it was not until 1948 that high-density polyethylene (HDPE) was developed.

It is evident that subsurface irrigation has always been closely linked to the development of drip irrigation. Modern sub-surface irrigation is described as a pressurised drip system, positioned below ground level, that supplies water and nutrients to crops.



Photo 1 – Buried Amphora



BENEFITS OF MICRO-IRRIGATION

Drip irrigation delivers water to the soil in a precise and gradual manner, respecting the field's water-holding capacity. This crucial agronomic concept refers to the maximum amount of water the soil can retain through capillary forces, once excess water has percolated downwards. This offers a significant advantage over sprinkler systems, which cannot align as precisely with the physical characteristics of the soil.

Furthermore, micro-irrigation allows greater control of the irrigation depth. Ideally, a dripper for supplying water and nutrients to the crop should have a very low flow rate. This ensures that the water penetrates the soil at a rate equal to or slower than the soil's effective absorption capacity. This prevents excessive water percolation into deep layers, where the roots are inactive, or water stagnation that can asphyxiate the soil.

Consequently, the primary benefit of micro-irrigation is its ability to manage irrigation based on the relationship between water, roots and soil. Additional advantages of drip irrigation include:

- lower water consumption: water is distributed only where needed, thus reducing waste.
- improved weed control: water is not distributed across all of the soil, thereby limiting weed growth.
- increased crop production and quality: targeted irrigation promotes plant health.

Finally, drip irrigation pairs perfectly with fertigation, i.e. the administration of nutrients alongside water. The efficiency of micro-irrigation in maximising plant growth makes drip irrigation the ideal system for optimising fertigation.

SHALLOW AND DEEP SUB-SURFACE DRIP IRRIGATION

There are two main types of sub-surface irrigation: shallow and deep.

Shallow sub-surface irrigation involves the use of a heavy or light drip line placed just a few centimetres below the soil surface. This allows farmers to benefit from the advantages of sub-surface irrigation without the need for extensive excavation work. While this technique helps reduce the cost of burying drip lines, it also requires their removal and replacement each season. For this reason, farmers tend to select the thinnest possible drip lines, depending on environmental conditions. The drip line is often installed alongside a plastic mulch film and is commonly used for seasonal crops such as vegetables, strawberries and melons.

Deep sub-surface irrigation (hereafter simply referred to as sub-surface irrigation) involves installing a heavy or light drip line at a depth of at least 10 cm below the soil surface. The main goal is to ensure the longevity and effectiveness of the drip line by protecting it from weather damage or agricultural activities. Indeed, this method allows the irrigation system to remain functional for over 20 years! For this purpose, the drip line, which can vary in thickness from 12 mil to 47 mil, is buried at depths ranging from 10 to 40 cm.

For long rows or sloping terrain, self-compensating (PC) and anti-siphon (AS) drip lines can be used. These systems compensate for pressure differences along the irrigation line, ensuring uniform water distribution despite the complexity of the soil.



BENEFITS OF SUB-SURFACE IRRIGATION

Although sub-surface irrigation requires a higher initial investment, it proves to be an excellent long-term choice, enabling significant savings on water and energy, as well as an increase in crop yields.

By recognising the economic and environmental benefits this technology offers in terms of yield and savings, more and more farmers are adopting this method.

The main benefits of sub-surface irrigation are:

- **Increased protection from atmospheric agents:** burying the irrigation system shields it from ultraviolet rays and temperature fluctuations, thereby extending its lifespan.
- **Reduced drip line maintenance:** the lack of direct contact with the air prevents the drip lines from drying out completely, thus avoiding the formation of white deposits that could clog the drippers over time.
- **Increased irrigation water efficiency:** supplying water close to the root systems optimises the use of water resources, reducing waste and improving crop absorption.
- **Increased water saving:** sub-surface irrigation eliminates surface water evaporation, which can reach up to 45% in traditional sprinkler irrigation systems.



Photo 4 – Water saving



Photo 2 – Shallow sub-surface irrigation



Photo 3 – Deep sub-surface irrigation

Deeper burying of the drip line is suitable for a variety of crops, including sugarcane, corn, cotton, vineyards, tomatoes, fruit trees and alfalfa. This method also provides an effective solution for crop rotation, allowing the same irrigation system to be used for different crops without the need to remove and reinstall the drip line each time.

In general, **deep burying** of the drip line, commonly referred to simply as sub-surface irrigation, is a drip irrigation method that offers

numerous benefits, such as multi-seasonal use of the system, uniform water distribution, the ability to irrigate sloping terrain, and compatibility with various crops.

In summary, through a deeper understanding of agronomic processes and technological advancements in micro-irrigation, deep sub-surface irrigation has become increasingly widespread and is now applicable to an increasing number of crops.

Graph 1 – Rhizosphere irrigation

Burying drip lines allows for water to be distributed directly in the rhizosphere

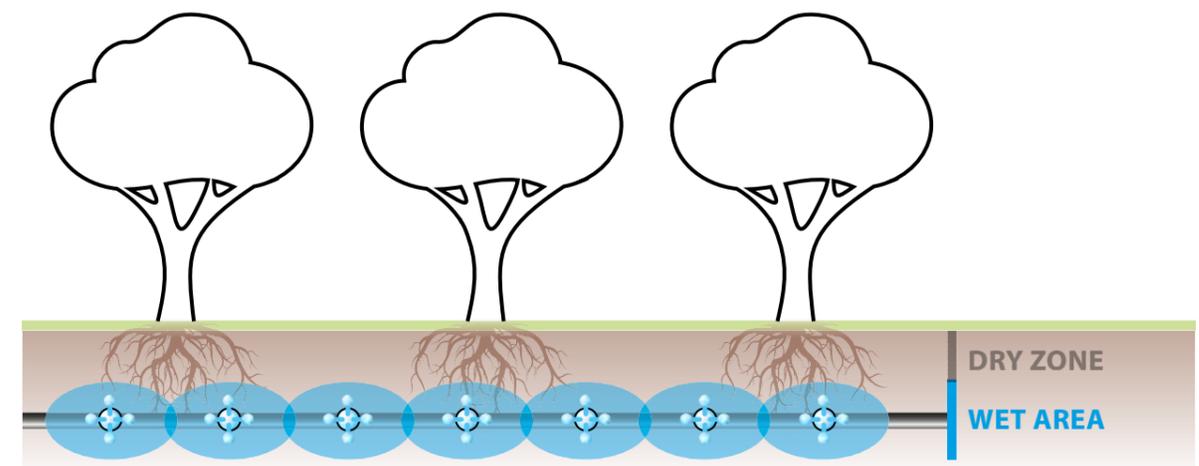




Photo 5 – Weed control

- **Stronger root structure:** when a lateral drip line is buried at 30 cm, roots follow the water's path, encouraging deep rather than surface root growth. This deeper growth improves plant anchorage and enhances nutrient and water absorption.



Photo 6 – Stronger root structure

- **Timely distribution of nutrients:** burying the irrigation system allows the timely distribution of nutrients in the event of nutritional imbalances.
- **Improved root oxygenation:** burying the drip system improves air injection, enhancing root oxygenation and helping to prevent issues like iron chlorosis in heavy soils.



Photo 7 – Root system oxygenation

- **Use of natural fertilisers:** sub-surface irrigation supports the use of natural fertilisers, even those with lower concentrations, enhancing the root environment and promoting efficient nutrient absorption.
- **Targeted chemigation:** This method enables the direct application of fertilisers, herbicides, insecticides, and fungicides to the root zone, achieving up to 97% efficiency—significantly higher than with other sprinkler-based chemigation methods.
- **Reduction of plant diseases:** sub-surface irrigation keeps the topsoil relatively dry, lowering the risk of fungal infections and other moisture-related plant diseases. Additionally, it also makes it possible to irrigate right up until harvest, supporting more efficient water management.



Photo 8 – Reduction of plant diseases

- **Drift elimination:** sub-surface irrigation prevents water drift caused by wind. Dispersion of the mixture beyond the treated field may result in: a) contamination of waterways or other sensitive areas, such as natural parks and wetlands; b) contamination of areas frequented by people, including public facilities such as schools, hospitals, sports fields and playgrounds; residential properties, vegetable gardens and private gardens; roads, tracks and public pathways; c) contamination of crops adjacent to the treated field. The consequence in this case may be the presence of residues of active substances not permitted on the affected crop.
- **Improved plot access:** sub-surface irrigation allows normal access to plots and the use of lawns.
- **Enhanced mechanisation:** the absence of overhead pipes allows full mechanisation of cultivation operations, including installation, pruning and harvesting. Furthermore, field access is simplified, with reduced risk of getting stuck.
- **Irrigation in irregularly shaped fields:** sub-surface irrigation can be used in irregularly shaped plots, maximising production per hectare and enabling efficient use of space.



Photo 9 – Mechanised operations

- **High-frequency irrigation:** sub-surface irrigation employs high-frequency irrigation, delivering multiple small doses of water to prevent water stagnation in the soil, while maintaining crop oxygenation and promoting root development.
- **Improved aesthetics:** burying the pipes enhances the visual appeal of fields and reduces the risk of vandalism, particularly in parks and gardens.



Photo 10 – High-frequency irrigation

TORO SUCCESS STORIES

Sub-surface drip irrigation for rotational crops

Argenta (Ferrara)

The first system Toro installed in Italy in 2001, in Argenta (Ferrara), is still in perfect working order today, delivering water and nutrients precisely and efficiently.

It serves approximately 7 hectares of land, divided into 6 irrigation sectors. The Aqua-Traxx® PBX tape was installed at a depth of approximately 45-50 cm. The distance between the tape lines is 150 cm, with a length varying between 200 and 270 metres.

The exceptional versatility of the sub-surface irrigation system underpins the company's ability to remain competitive in the market. This innovative decision, made back in 2001, has led to a rapid reduction in system costs, with immediate benefits to the company.

Over the years, it has been possible to produce and irrigate a variety of crops profitably, including corn, beets, sunflower seeds, industrial tomatoes, soft wheat and soybeans.

The high efficiency of the sub-surface irrigation system, combined with first-rate agronomic and managerial expertise, has led to extraordinary results not only in terms of yield but also of production quality.

Furthermore, the system's versatility has allowed for the rotation of numerous crops:

- Corn (short cycle) has reached productions of 135 q/ha (dried value - humidity 14%) against an area average of less than 100;
- Industrial tomato: 1175 q/ha with Brix 5.0;
- Beet: 168 q/ha with a sucrose content between 16-19° (the highest value was achieved where air injection was active).

Year	Crop	Year	Crop
2001	Corn	2010	-
2002	Beetroot	2011	Corn
2003	Sunflower Seed	2012	Soy
2004	Industrial Tomato	2013	-
2005	Beetroot	2014	Corn
2006	Wheat	2015	Soy
2007	Sunflower Seed	2016	-
2008	Soft wheat	2017	Soy
2009	Beetroot		

Sub-surface drip irrigation for corn

Cox Valley View Farms, Long Island, Kansas

More than 20 years ago, Steven Cox installed the first sub-surface drip irrigation system on his 1,500-hectare farm. The conversion allowed him to exploit limited water resources to the full, while increasing yields and grain quality.

"Before implementing sub-surface drip irrigation, we were trying to flood irrigate 25 ha with a 55 m³/h well, achieving yields on just 25% of the field; now we achieve maximum yields on 100% of the field, due to the uniformity and efficiency of drip irrigation."

Cox has seen the many benefits of using sub-surface drip irrigation. To begin with, it requires little labour and energy. Then, fertilisers can be delivered exactly where they are needed, eliminating the need for more invasive work. Finally, no water is wasted, and uniformity

is typically above 90%. "That means that for every 1 litre of water, the driest plant will get 0.90 and the wettest 1.10. This allows me to get the most out of every litre of water from the aquifer".

"We place the drip line 150 cm away and bury it at a depth of 30-45cm. Recent excavation works revealed roots at a depth of up to 150 cm and more, as well as an impressive root density in the top 30 cm below both the tape line and the corn row."

Like any technology change, Steve Cox's successful conversion to sub-surface irrigation required significant upfront effort, but he didn't do it alone! Holdrege's Central Valley Irrigation provided local support for the project design, installation and start-up phases, using quality products supplied by Toro. The heart of the system is the Toro 7/8" diameter, 15-mil thick Aqua-Traxx® FlowControl™ drip line. The drippers are spaced 60 cm apart and provide a delivery rate of 0.78 l/h. The tape is supported by pipes, filters, valves, vents and monitoring devices to ensure proper operation, including a flush manifold to maintain the system's longevity.



Photo 11 – Sub-surface drip irrigation for corn

Sub-surface drip irrigation for alfalfa

Bob Thomas Farms, Seeley, CA

Bob Thomas is a newcomer to the farming world, but he is no stranger to success. With the proceeds from the sale of his construction company in 2005, he purchased ranches in Utah, Colorado and California's Imperial Valley.

On the Lyons Road Ranch near Seeley, in California, Bob and his son Rob have installed a sub-surface drip system on 150 hectares of their 250-hectare ranch. "15 years ago, I learned that some of the leading growers at the time were using sub-surface irrigation not only to save water but also to significantly increase yields. It was exactly what I was looking for: to grow more crops and make the farm efficient."

MORE CROP PER DROP

After months of research, in late August 2009, they installed the Toro 7/8" Aqua-Traxx® PBX tape with a 10-mil wall thickness and a spacing of 30 cm between drippers. The tape lines were installed 30 cm deep, with 1-metre spacing between lines to accommodate both alfalfa and future vegetable crops. Since they were using conventional irrigation for the rest of the ranch acreage, they could easily compare both methods. "Harvesting the sub-surface irrigated field was much easier," says Bob. "With sub-surface drip irrigation, the field is cultivated flat, with no waste, so harvesting is really easy."

The system was built to ensure longevity and efficiency. Buried PVC pipes supply the lateral lines at the top of the field and collect water

from the ends of the lines, allowing it to flow through gate valves approximately every 2 weeks.

Custom-designed valves regulate the pressure on each block, ensuring air is released and preventing a vacuum when the system is started and shut down. Filters remove organic and inorganic contaminants (including weed seeds) from the water channel, while a chemigation unit injects fertiliser and acid to control pH.

Scheduling is probably one of the most challenging tasks. Drip systems do not require field preparation or too much labour, so growers can decide when to irrigate and for how long, allowing them to set up a precise schedule.

Additionally, complexity is further increased by varying soil structures, cropping schedules, weather conditions and water availability in the district.

"Most of the ranch has sandy soil, but there are areas that need to be watered more often. With the drip system, we can run irrigation blocks a little more frequently so as to meet the needs of the crop more accurately," says Rob Thomas.

Furthermore, with sub-surface drip irrigation, the dry period before and after harvesting can be minimised, further reducing unnecessary stress on the crops during the harvest.

Finally, the Thomas family would also like to implement automation. This would allow for remote monitoring and operation of the system, without ever replacing the need for field personnel. "Someone still has to grow the crop! Automation would simply eliminate more redundant tasks and increase our ability to monitor system operations".

Bob Thomas and the Imperial Irrigation District serve over 180,000 ha of cropland, 25% of which is planted with gravity-irrigated alfalfa.



Photo 12 – Sub-surface drip irrigation for alfalfa



SUB-SURFACE DRIP IRRIGATION FOR CROPS

Sub-surface irrigation is an ideal solution for multiple crops and application contexts. Below is a summary of the most common applications for different crops:

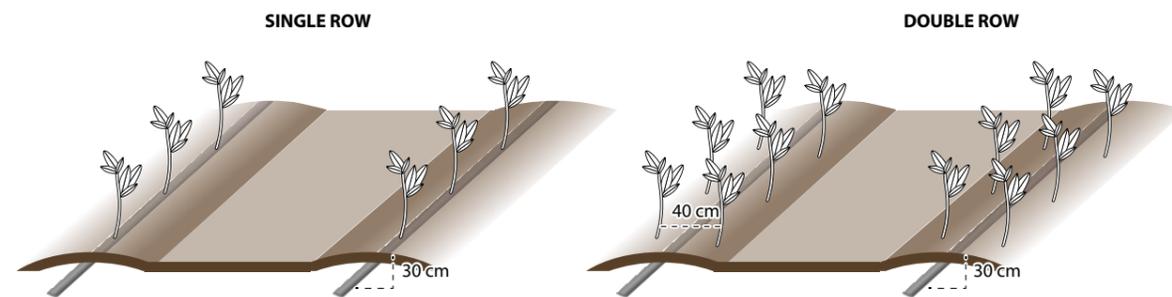
Row crops such as corn, sunflowers and beets

Benefits: Opting for low-pressure drip irrigation allows for higher yields and lower costs, leading to significantly greater long-term profits.

Product: Aqua-Traxx® PBX or Aqua-Traxx® FlowControl™, depending on the topography of the land and the length of the lines, with a wall thickness of 15 mil, a flow rate of 1.14 l/h, and 30 cm spacing.

Design: install at a depth of 30 centimetres beneath the surface. Each drip line can accommodate either a single or a double row of crops. In the case of a single row, the drip line will be positioned directly beneath the plant. In the double row configuration, the plants will be spaced 20 cm from each side of the drip line, creating a 40 cm inter-row distance.

Lifespan: over 15 years.



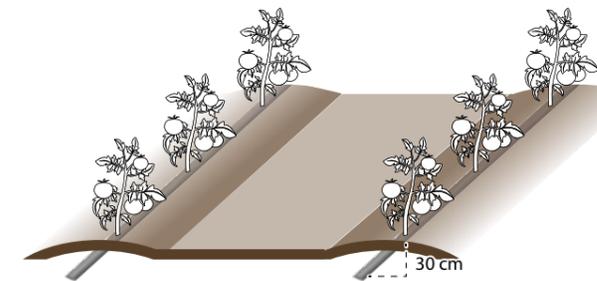
Tomatoes

Benefits: Maintaining the surface dry is crucial to minimise the formation of mould and fungi. Using sub-surface irrigation brings significant improvements in tomato quality, enabling more precise control of sugar levels. Moreover, the plant's roots develop around the water release point, simplifying nutrient distribution management and allowing for easy adjustments to the nutritional supply, based on the plant's needs.

Product: Aqua-Traxx® PBX or Aqua-Traxx® FlowControl™, depending on the topography of the land and the length of the lines, with a wall thickness of 12-15 mil, a flow rate of 0.87 l/h, and 30 cm spacing.

Design: install at a depth of 30 centimetres beneath each row.

Lifespan: 5-7 years.



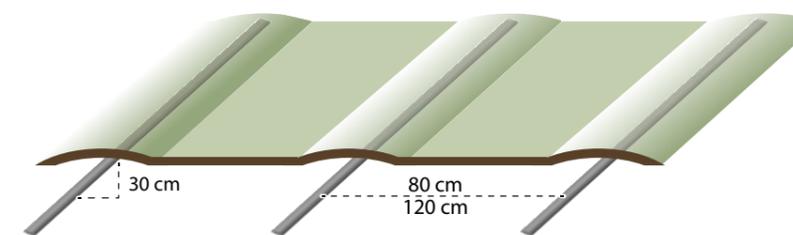
Alfalfa and full-coverage extension crops

Benefits: increased efficiency and the ability to irrigate right up until harvest.

Product: Aqua-Traxx® PBX or Aqua-Traxx® FlowControl™, depending on the topography of the land and the length of the lines, with a wall thickness of 15 mil, a flow rate of 1.14 l/h, and 30 cm spacing.

Design: install at a depth of 30 centimetres and space at 80 - 120 cm, depending on the soil.

Lifespan: over 15 years.



Several trials in both Italy and the United States have confirmed the effectiveness of underground irrigation in the cultivation of alfalfa and of permanent grasslands in general. Compared to pivot sprinkler irrigation, an average increase of 20% in yield was observed. Drip lines are usually positioned at a depth of about 40-60 cm, adapting to the specific hydrological characteristics of the soil. With an hourly flow rate of between 1.6 and 2.1 litres, the drippers can be spaced 30 to 50 cm apart. This highly flexible system facilitates the passage of machinery, preventing the formation of furrows in the soil.

In the case of alfalfa, the main advantage of underground irrigation is its ability to ensure a constant water supply, even when mowing. It is well known that the most critical period for the crop, in terms of water needs, is after mowing, when the grass is left to dry on the ground, preventing the use of sprinkler irrigation. Sub-surface irrigation allows alfalfa to be irrigated immediately after mowing, promoting subsequent regrowth.

Worthy of note among the other benefits of the underground system are water and energy savings, considering that the operating pressure required is only 1.0 Bar. In many cases, the sub-surface system has also been adopted so as to use wastewater for irrigation purposes, thereby contributing to a more sustainable management of water resources.

Vineyards

Benefits: by delivering only a minimal amount of water to the surface, sub-surface irrigation not only protects the crop but also helps limit the spread of weeds and diseases. This targeted approach allows for more efficient control of harmful agents without the need for excessive chemical use, thereby promoting more sustainable and environmentally friendly management.

Product: Neptune PC with a 0.9 mm wall thickness, flow rate 1.6 l/h, 1 m spacing in normal rainfall conditions and 50 - 75 cm when there is limited summer rainfall.

Design: install at a depth of 10 to 30 cm. Place next to the vine at a distance of approximately 20-40 cm or halfway between the rows (maximum 2.0 m from the row for medium-heavy soils and 1.2 - 1.5 m for sandy soils).

Lifespan: over 15 years

DIAGRAM FOR THE UNDERGROUND INSTALLATION OF DRIP LINES POSITIONED CENTRALLY IN A VINEYARD ROW

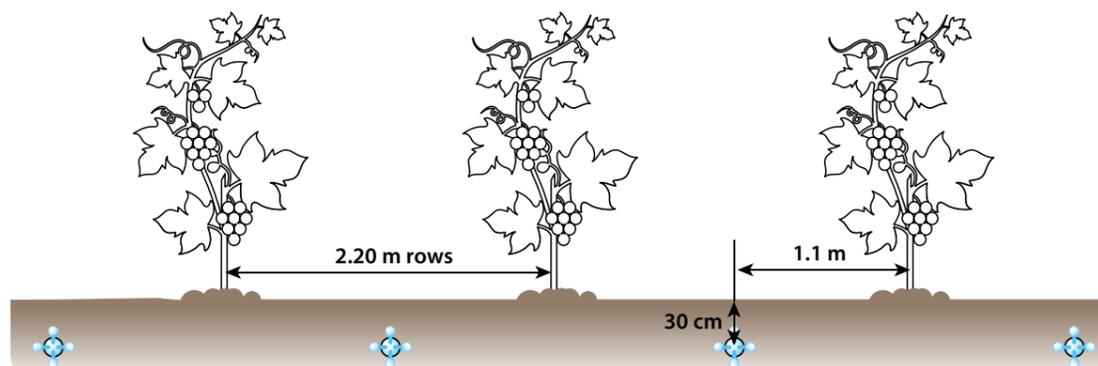
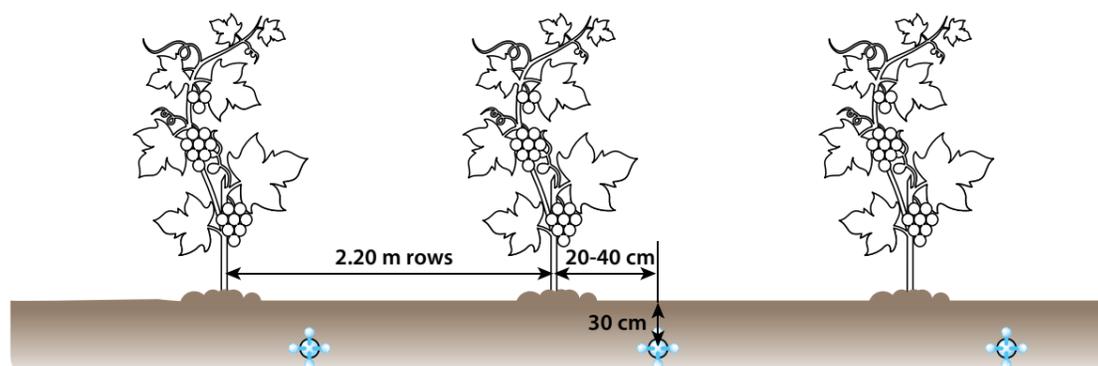


DIAGRAM FOR THE UNDERGROUND INSTALLATION OF DRIP LINES IN A VINEYARD TO THE SIDE OF THE PLANT (RECOMMENDED FOR VERY SANDY SOILS)



Viticulture is one of the sectors that has most embraced sub-surface irrigation, both in new and mature vineyards dedicated to table grapes and wine production. Most systems involve the use of a drip tape buried at a depth of about 25-40 cm, positioned at the centre of the inter-row, with drippers, spaced 50-100 cm apart, delivering from 1.6 to 4 litres per hour. In highly draining soils, it is possible to reduce the distance between the drip lines and the row, depending on the type of rootstock.

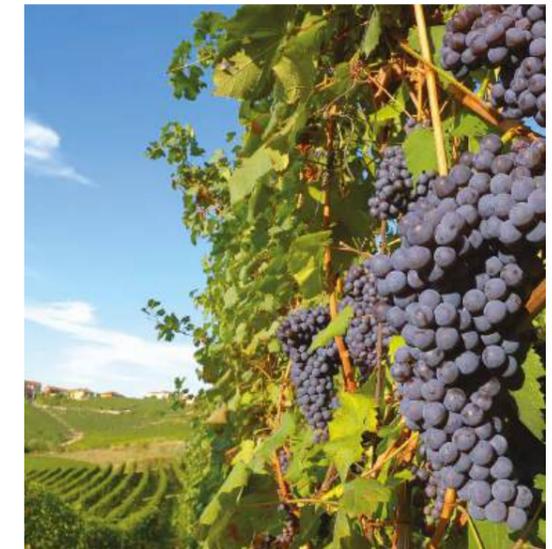
Pergola vineyards have shown promising results, allowing machines to pass during fertigation treatments without the risk of wetting the bunches below the drip points, thereby reducing the risk of fungal disease. Significant water savings, improved weed control with minimal, light interventions during irrigation hours, and greater efficiency in fertigation have all been observed.

In areas with steep slopes, sub-surface irrigation, combined with a slightly higher amount of water, helps maintain grass cover in the inter-rows, reducing erosion during heavy rainfall. This approach has proven particularly effective in eliminating the need for additional support structures for vines grown without poles and steel wires.

Sub-surface irrigation has also proven to be beneficial in mature plantations, eliminating the obstacles posed by pipes and enabling the full mechanisation of agricultural operations, from fertilisation and pruning to harvesting, resulting in significant labour savings.

However, challenges remain regarding the potential damage to drip lines caused by mechanical harvesters and pruning machines. Furthermore, in sloping terrains with surface irrigation, the drip line—typically suspended from the first wire—may interfere with suckering and harvesting, which requires extra care in both operations and in drip line placement.

To conclude, sub-surface irrigation offers numerous benefits in viticulture, including improved water efficiency, better disease management, and the possibility of mechanising agricultural operations.



Rotational crops

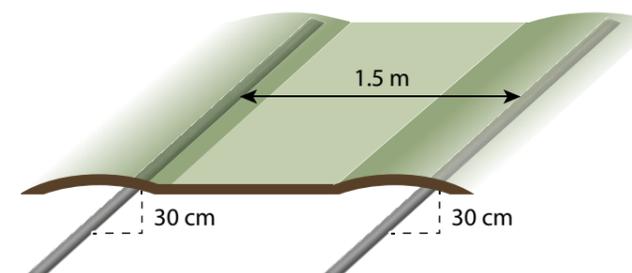
Benefits: crop rotation is crucial, given fluctuations in crop prices and the need for disease management. The adoption of sub-surface irrigation is an effective way to support this strategy.

Product: Aqua-Traxx® PBX or Aqua-Traxx® FlowControl™, depending on the topography of the land and the length of the lines, with a wall thickness of 15 mil, a flow rate of 1.14 l/h, and 30 cm spacing.

Design: installing at a depth of 30 cm below the surface with 150 cm spacing between rows ensures effective irrigation for a variety of crops.

Lifespan: over 15 years.

SUB-SURFACE IRRIGATION SYSTEM FOR FLEXIBLE ROTATIONAL CROPS



Irrigation for individual plants

In the context of underground irrigation for individual plants, typically used in public parks, a single drip line can be used, arranged in a ring shape around the plant. This approach aims to make the irrigation system invisible, while helping to promote better plant growth.

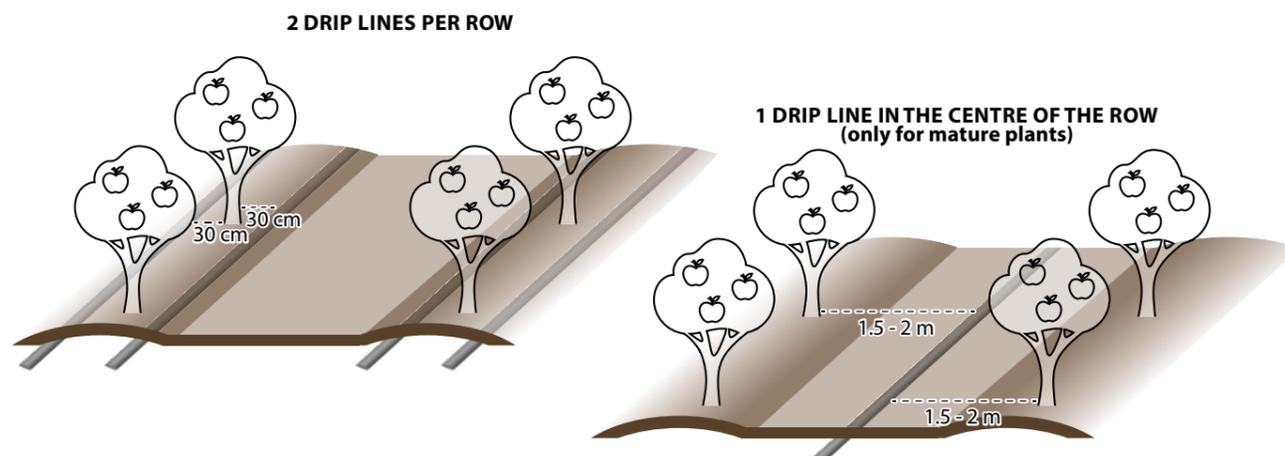
Orchards

Benefits: increased efficiency and ease of harvesting, especially for mechanically harvested dry nuts.

Product: Neptune PC with a 0.9 mm wall thickness, a 1.6 l/h flow rate, and 50 - 75 cm spacing.

Design: install two lateral drip lines at a depth of 30 to 40 cm below the surface, positioned one on each side of the row, 30–50 cm away from the plant. Alternatively, if the plants are mature and the rows are no wider than 4 m, you can opt for a single line in the centre.

Lifespan: over 15 years.



Sub-surface irrigation is a widespread practice in Italy, applied annually to hundreds of hectares of fruit orchards, both for new systems and to replace outdated ones. This technique has been successfully used on various species, including citrus, peach, apple, pear, cherry, hazelnut, prickly pear, etc.

The choice of drip line type depends on the specific needs of the crop, taking into account the soil and climatic characteristics of the location. Normal drip lines, such as the Neptune N and Neptune HW, are widely used. However, in areas with sloping terrain or very long rows, where uniformity of water delivery is essential, we recommend the self-compensating Neptune PC drip line.

The flow rate of the drippers and their distance are assessed individually to meet the needs of the species grown. In loose soil, it is advisable to ensure an hourly precipitation of at least one millimetre, equivalent to 10 cubic metres per hectare. The distance between the drippers depends on the planting distance and the type of soil: in well-draining soils, reduced spacing (40–50 cm) is preferable, while in clayey soils, the drippers can be spaced 90–100 cm apart.

If the planting distance exceeds 3 metres, we recommend using double drip lines per row to promote balanced development of the root system. The position and depth of the drip lines are determined based on the rootstock and soil type, with the aim of creating a moist strip in the area most explored by the roots.

In citrus cultivation, it is possible to bury the drip lines at a greater depth (40–45 cm) and at a distance that prevents strangulation by the anchoring roots. Significant water savings have been recorded (about 25–30% compared to traditional drip irrigation), along with an improvement in fertigation. The distribution of nutrients near the root systems allows for more efficient use of resources, reducing both environmental and economic impact.

Furthermore, the absence of contact with both operators and the edible or above-ground vegetative parts of the plant allows for the use of wastewater for irrigating orchards, particularly in areas where water is a limited resource. In fruit growing, the underground system is also used to improve oxygenation of the root system by injecting air into the irrigation setup.

Olive growing

Numerous trials have been conducted on sub-surface irrigation in olive growing, both on newly established systems and on mature olive groves for the production of table olives and oil. Most systems use two underground drip lines, positioned at a depth of around 35 cm and spaced 120–140 cm apart along the row, with drippers, placed at intervals of approximately one metre, delivering 2 to 4 litres per hour. For younger plantations, in order to prevent water shortages during the first year, we suggest burying the drip lines asymmetrically, preferably on the side closer to the plant, to ensure moisture reaches areas near the roots that are still underdeveloped.

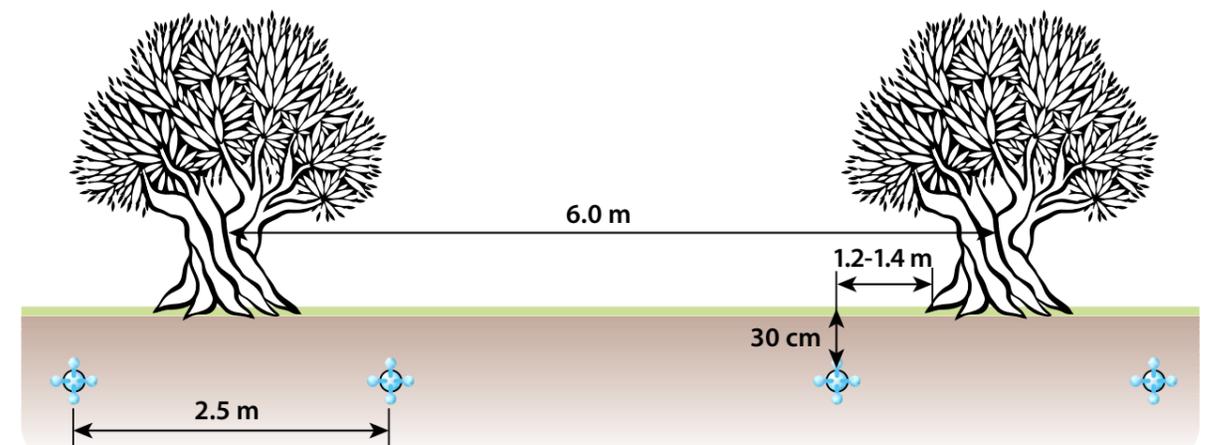
Another common practice consists in using light drip lines arranged on the surface along the rows of plants during the first year, in addition to the underground system. In mature olive groves with large distances between rows and plants of substantial size, a single drip line can be buried in the centre of the inter-rows. This approach is made possible by the roots' widespread development throughout the soil. However, in these cases, it is necessary to reduce the distance between the drippers and to increase their flow rate to ensure adequate water distribution to the crop.

Sub-surface irrigation has also proven effective on soils with large amounts of gravel and rocky areas. In these cases, the drip lines are buried using specialised machinery that can cut through to the desired depth, even in the presence of exposed rocks. Here too, significant water savings have been observed, along with an improvement in fertigation efficiency.

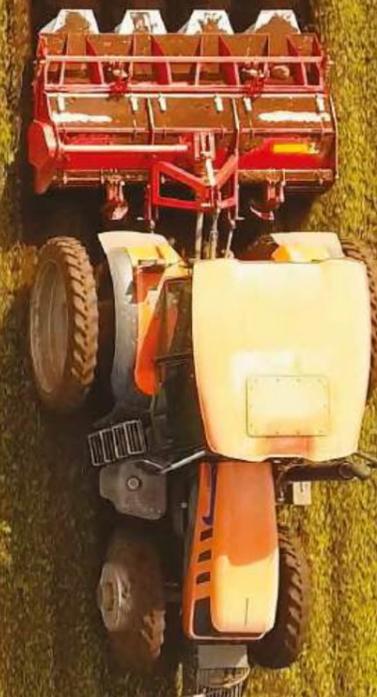


In olive growing, the adoption of sub-surface irrigation has streamlined agricultural operations, removing the obstacles posed by pipes and enabling the full mechanisation of cultivation activities, from fertilisation to pruning and, of course, harvesting. This allows modern olive growers to cut costs and remain competitive on the market with their high-quality oil.

DOUBLE DRIP LINE INSTALLATION IN AN OLIVE GROVE



DESIGNING A SUB-SURFACE IRRIGATION SYSTEM



Designing a system requires a series of detailed considerations to ensure effective and efficient irrigation.

The first phase involves gathering key information, including water availability, water quality, soil type, cultivated species, planting density, plot layout and slope gradient. This data provides an essential foundation for designing the irrigation system.

The second crucial step is to design the irrigation system to meet the specific needs of the crop: considering its water requirements and adapting them to the soil environment is essential for ensuring efficient and sustainable irrigation. This involves carefully considering the pipe size, the dripper flow rate, the spacing, the efficiency of the pump, the pressure losses and the energy costs. This approach helps optimise the use of water resources, reducing waste and improving plant growth.

Water diffusion

Water distribution depends on several variables, starting with the type of soil.

Understanding the difference between sub-surface and above-surface water movement is extremely important.

When designing a system, to ensure plant roots receive adequate water supply, it is essential to consider that water tends to move downwards due to gravity, but can also be absorbed in a capillary fashion by the soil.

This is why soil analysis is an essential and strategic element of any irrigation project. This type of analysis provides detailed information about soil composition and directly impacts the selection and design of the most suitable drip irrigation system for crop in question. Below are the main variables to consider in soil analysis.

Soil permeability: soil analysis provides data on soil permeability. Soils with low permeability may require a drip irrigation system with controlled water dosing to prevent loss and runoff.

Water retention capacity: the soil's ability to retain water is a key consideration. Soils with low retention capacity may require more frequent but lighter irrigation, while soils with high retention capacity may benefit from deeper, less frequent irrigation.

Soil structure: the structure of the soil, which can be sandy, clayey, silty, or a combination of the above, will influence the rate at which water passes through it. Drip irrigation systems can be adjusted to optimise this flow rate.

Soils with a sandy texture have larger particles, allowing for rapid drainage. Water, therefore, spreads more quickly in sandy soils due to their increased permeability. However, there is a risk of severe loss if irrigation is not well managed.

Clay soils have smaller particles, which create a more compact structure. In such soils, water spreads more slowly due to lower permeability. Also, surface pooling can occur if irrigation is too intense.

Silty soils are a balanced mix of sand, clay and silt, providing good drainage and a moderately compact structure. In silty soils, water distribution is generally balanced, with moderate permeability.

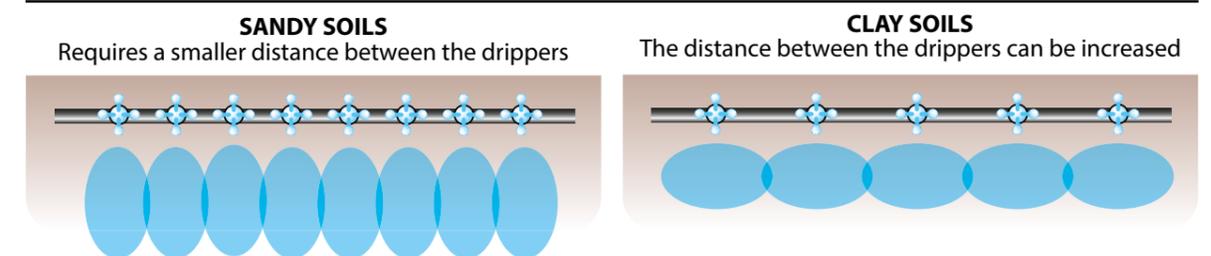
Root depth: the depth to which plant roots extend is crucial. A soil test can reveal this information, helping to ascertain how deep the drippers need to be placed to reach the roots.

Soil nutrient content: soil testing can also assess the nutrient content. This information can be useful when deciding which fertilisers to use in an irrigation system.

Soil pH: this is another crucial aspect to consider. Some crops thrive in more acidic or alkaline conditions; therefore, the irrigation system must be adapted to meet these requirements.

Ground topography: a soil test can also provide information on the land's topography, which affects water distribution and placement of the drippers.

Ultimately, soil analysis guides the design of a customised drip irrigation system, allowing for more precise, targeted management of water resources, so as to optimise crop growth.



Insights into certain soil characteristics

Soil is not made up of particles of equal size, but rather of varying nature and size.

Soil texture, or granulometry, analyses the percentage distribution in weight of solid soil particles based on their size ranges. This variability in particle size gives the soil distinctive chemical, physical and biological properties, influencing factors such as permeability, water retention capacity and fertility.

Particle size classification, based on conventional scales such as the Atterberg limits (adopted by the IASS), makes an initial distinction between gravel (particles > 2 mm) and fine soil (particles < 2 mm).

The different proportions of these fractions determine the soil's textural class and influence its behaviour.

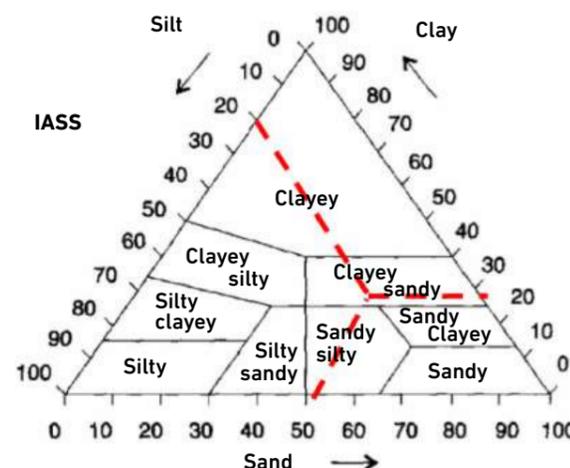
The specific surface area of a soil, i.e. the total surface of the particles per unit of mass or volume, is a key parameter in determining its physical and chemical properties. The specific surface increases as the fineness of the particles increases. This means that clayey soils, with very small particles, have a much higher specific surface area than sandy soils.

To give an idea of how much the specific surface increases as the size of the particles decreases, consider that a solid cube with a side length of 1 cm and a volume of 1 cm³ has a specific surface of 6 cm². A million cubes with edges of 0.1 mm have a surface area of 600 cm².



Soil section showing the formation of the wetting bulb

Particle size classes	Particle diameter
Rocky	> 2 mm
Stones and pebbles	> 10 mm
Gravel	5-10 mm
Chippings	2-5 mm
Fine soil	< 2 mm
Coarse sand	2 – 0.2 mm
Fine sand	0.2 – 0.02 mm
Silt	0.02 – 0.002 mm
Clay	< 0.002



Let's now analyse how soil characteristics change depending on the content of each component.

Prevalently rocky soils: soils with more than 40% stones are classified as prevalently rocky. A high content of coarse fragments gives these soils an incoherent structure, reduced water retention capacity, and limited permeability. These characteristics hinder agricultural activities, root development in plants, and the growth of underground organs (such as potato tubers, beetroots, etc.).

Sandy soils: due to their coarse grain size, sandy soils offer a loose, aerated structure that facilitates root penetration and soil aeration. In general, they are easy to work with, whether dry or moist. They allow air to circulate; however, excess air, along with the oxidative processes it causes, promotes the rapid mineralisation of organic matter. Also, these soils' high permeability leads to rapid water percolation and, consequently, the leaching of nutrients. The poor capacity to retain water and nutrients makes these soils less fertile compared to other types of soil. Despite these limitations, with careful management, especially as regard irrigation and fertilisation, these soils are excellent, particularly for horticulture.

Clay soils: clay has colloidal properties, and soils with a predominance of clay are classified as heavy or hard soils.

Clay soils, characterised by a predominance of fine particles, have a high specific surface area, which gives them a sizeable cation exchange capacity. This property allows them to retain a significant amount of water and nutrients, making them potentially fertile. However, microporosity and particle cohesion limit the permeability and aeration of these soils, increasing the risk of waterlogging and root asphyxia. Working with clay soils requires special attention, as their plasticity varies significantly depending on the water content.

Silty soils: silty soils, characterised by an intermediate grain size between that of sand and clay, have a complex balance of properties. The coarser silt particles tend to behave like sand, with difficulty aggregating and poor structural stability, while the finer particles behave like clay, limiting aeration and permeability. Excess silt can lead to poorly structured soils, which are prone to pulverisation in dry conditions and compaction in wet conditions.

POROSITY

Soil is composed of solid particles that create empty spaces called pores. Porosity (p) is the ratio of the volume of voids to the total volume of soil, and is expressed as a percentage. In other words, it expresses the percentage of voids within a given volume of soil.

The average porosity of soil is around 50%, although lower in sand (30-40%) and higher in clay soils (55-60%). Soil pores fill with air and water and are crucial for biological processes such as root absorption and respiration.

The size of the pores depends on the size of the solid soil particles. Microporosity (a few micrometres) retains water, while macroporosity (more than 8 µm) allows rapid water flow and promotes drainage. A balance between microporosity and macroporosity (ideally 50% each) is essential for plant life.

Excessive macroporosity in sandy soils leads to poor water retention, but is not harmful if there is a constant water supply. Excessive microporosity in clayey soils causes drainage problems, excessive water retention, and lack of oxygen to the roots, promoting the growth of harmful microorganisms. Soil structure is crucial for restoring fertility in these conditions.

STRUCTURE

Soil structure refers to how particles are arranged in the soil. There are two main types of soil structure:

- a) Single particle structure: the soil particles, such as silt, clay or sand, are separate from one another, creating complete dispersion. This results in two situations: with large particles (sand), the pores are large, while with small particles (silt or clay), microporosity mainly occurs. Sandy soils have this type of structure, leading to issues such as poor water retention and low chemical fertility.
- b) Crumbly or granular structure: due to their colloidal properties, finer soil particles can join together to form clumps or granular structures. This creates microporosity within the clumps and macroporosity between them.

In fine-grained soils, this structure adequately balances water and air in the soil. Moreover, it favours microbial activity, the transformation of organic matter, and the availability of nutrients. This structure makes soils more fertile, providing better water and air retention, which in turn helps facilitate root growth and reduce soil erosion.

In short, soil structure is crucial for plant health and varies depending on the type of soil. The transition from a single particle structure to a granular structure is particularly beneficial in fine-grained soils.



DEPTH AND SPACING IN A SUB-SURFACE IRRIGATION SYSTEM

As mentioned previously, in addition to collecting data on the availability and quality of the water and the type of soil, the initial phase of designing a sub-surface irrigation system also involves gathering data on the cultivated species, plant spacing, soil configuration and slope gradients. During this phase, it is important to consider the depth and spacing between the irrigation points to ensure the soil horizon accessed by the roots is adequately watered.

The depth is determined using water diffusion models, which consider both horizontal capillarity and vertical gravity. The size and shape of the irrigated area depend on the soil's hydrological characteristics. However, these models only provide general information and must be supplemented by considering the specific needs of the crop and the roots' absorption capacity.

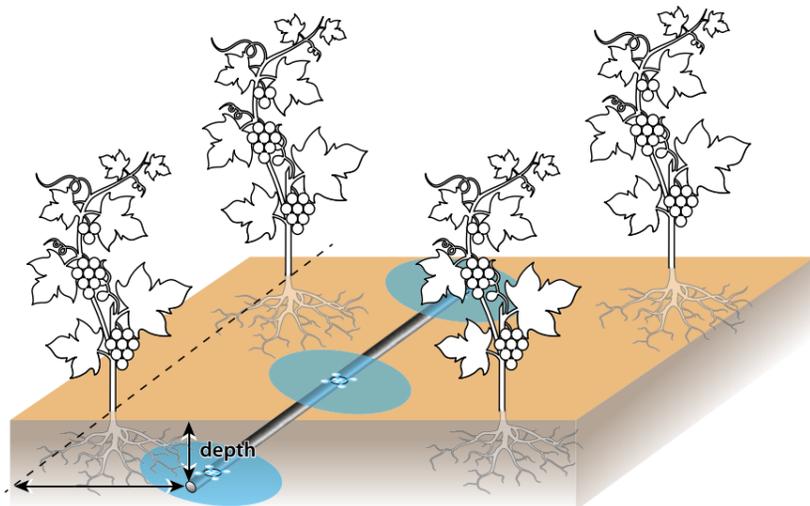
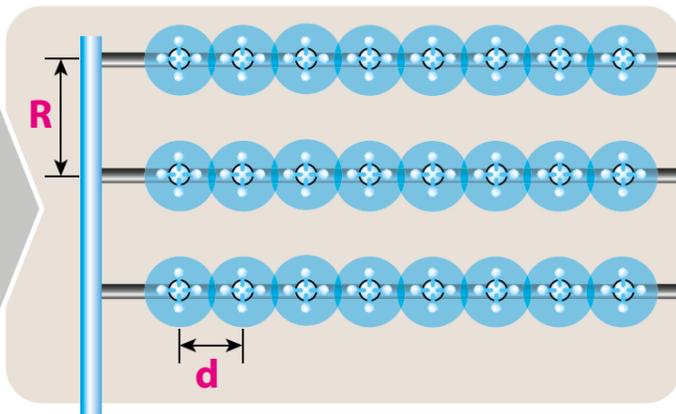
In optimal soil conditions, the installation depth for fruit orchards goes from 30 to 40 cm. In sandy soils or those with a high presence of gravel, the depth can be reduced to prevent excessive water loss due to percolation. Consequently, the choice of rootstock is critical in this context.

The spacing between the drip lines must be designed to ensure uniform moisture distribution in the root zone. In fruit orchards with rows more than four metres apart, we recommend the use of double drip lines to create two humid strips on the sides of the plants, as this promotes better root development. For young plants, solutions may include the asymmetric installation of two drip lines or the use of lightweight surface drip lines during the first year of growth. These measures reduce the risk of crop failures and minimise the need for emergency interventions using traditional methods such as water tankers.

Different species have varying root expansion capacities, depending on the distance of the drip lines from the trunk. For example, the peach tree develops a larger root system when the drip line is placed at a certain distance (120 cm) from the plant, while the pear tree concentrates its root mass at a shorter distance, regardless of the position of the drip line. It is important to strike a balance between watering the majority of the roots and the risk of compaction caused by the roots themselves. The shorter the distance from the trunk, the greater the risk of strangulation. In viticulture, burying the drip line in the centre of the inter-row has proven effective for plants that have already developed their root system. If the soil is excessively draining, it is advisable to bury the drip line on one side, at a depth of approximately 30-40 cm.

Depending on the distance between the drip lines and the distance between the individual drippers, the number of drippers required in the irrigated field will increase or decrease

$$\text{Precipitation} = \frac{\text{Dripper Flow Rate (l/h)}}{R \text{ (mt)} \times d \text{ (mt)}} \text{ (mm ????)}$$



Planting depth and spacing are determined based on the soil type and the characteristics of the root system

TORO TEMPUS® AIR, PRECISION IRRIGATION WITHOUT LIMITS



Toro introduces Tempus® Air, a centralised control system that automates your irrigation systems and monitors various environmental parameters via precision sensors.

Irrigation will never be the same again!

Tempus® Air is made up of various modules that can be integrated at any time, enabling you to monitor both the initial requirements of the irrigation system and any later changes or expansions to the irrigated areas. Thanks to its modularity and flexibility, Tempus® Air can meet a wide range of needs.

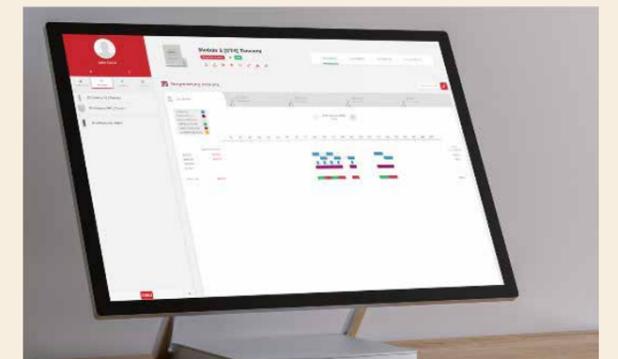
Plug & Play system

Simply connect to a broadband mobile network (3G or 4G) or a Wi-Fi network; the gateways are always accessible remotely, via smartphone, tablet or PC. In turn, the gateways communicate via radio with the field modules using LoRa™ technology, sending and receiving manual commands, irrigation schedules, and readings from the field sensors.

No more cables, no more limits!

The control units and sensor modules – with IP68 protection – are powered by 9V batteries and use LoRa™ technology, enabling coverage of an area over 200 hectares, and all without cables! Indeed, battery power allows you to automate your system without cables, thus eliminating installation costs. Tempus® Air can be controlled remotely, either via the web platform or the MyToroTempus app. In addition, the user can connect locally via Bluetooth.

Furthermore, based on the data collected, Tempus® Air can autonomously manage individual components of the irrigation system, including hydraulic valves, pumps, filters and fertigation systems. Toro Tempus® Air allows you to create an automated, wireless irrigation system.



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TORO

LoRa



The choice of dripper flow rate and spacing depends on the characteristics of the soil and the amount of water needed for proper irrigation. The topography of the land also influences the choice of materials to use. If there are significant variations in level or length, we recommend using the Aqua-Traxx® FlowControl™ drip line with flow control, which minimises the sensitivity of the flow to pressure variations. Alternatively, the Neptune PC Self-Compensating Drip line ensures uniform delivery along the entire row within a working range of 0.5 to 3.5 Bar.

AIR RELEASE VALVES

To ensure proper positioning of the air release valves, during the design process it is important to take the slope gradients into consideration. These valves prevent the drippers from becoming clogged with soil particles drawn in due to the pressure drop that occurs when the system is turned off. Naturally, this risk is greater on sloping terrain. It is advisable to install the air release valves at the highest points of the sectors, while, in the case of sloping terrain, they can be installed at the level of the control unit (if this is located at the higher end of the sector). The control unit can also be used as the location for installing the air release valve on flat terrain, positioning it after the valve and the local filter for the sector.

CLASSIC SYSTEM LAYOUT

From a technical perspective, the difference compared to a conventional surface system lies in the ring sector configuration. Due to the self-cleaning properties of the drip lines, supported by the inlet filter and the turbulent-flow labyrinth system, particles that pass through the central and local filters accumulate at the ends of the lines, in the downstream section of the ring.

Installing a drain valve at this point simplifies the sector cleaning process, eliminating the need to empty each lateral line individually. This approach not only simplifies maintenance, but also promotes better water circulation and more even distribution. The second pipe, placed opposite the supply head, acts as a collector and can be smaller in size. This solution helps optimise system efficiency, while also simplifying the management of cleaning and maintenance operations.

Typically, in a sector with a diameter of 2" and a maximum flow rate of 25 to 30 m³/h, a 40 mm diameter pipe can be used. However, when the sector is large and irregular in shape, it is advisable to install multiple drain valves. This practice facilitates flushing, ensuring better control and more efficient system management.

EXAMPLE OF A SUB-SURFACE IRRIGATION SYSTEM

Let's now examine an example system to understand the materials and sizing involved in a sub-surface drip irrigation system.

The product we will use for irrigation will be the Toro Aqua-Traxx® PBX tape. The use of tape in a sub-surface irrigation system solves the root issue for two reasons: the first is that it closes when the irrigation

is turned off; the second is that the roots do not attempt to invade the irrigation system, as the tape empties and remains dry.

The system will be used to rotate biomass crops such as corn, alfalfa and wheat. The rotation of crops with varying row distances or even without rows (such as alfalfa) requires a different irrigation approach compared to the typical irrigation strips used for row crops. In this case, the irrigation approach will focus on balanced and complete wetting of the entire soil area. To achieve this, we will use a tape with a spacing of 50 cm, which will be placed 1 metre apart between the rows.

The Aqua-Traxx® PBX, will be installed at a depth of 40 cm for the secondary lines, while the main lines will be installed slightly deeper at approximately 50 cm.

The land designated for cultivation covers approximately 40 hectares, which will be divided into 12 sectors, each measuring 3.3 hectares.

The first data we need is the crop's water requirement. In this specific case, we have a requirement of approximately 40 mm per week, which is equivalent to approximately 40 l/m² per week and 5.7 l/m² per day.

We will use an Aqua-Traxx® PBX tape with a diameter of 22 mm and a thickness of 12 mil to minimise the risk of damage caused by animals. As mentioned previously, the Aqua-Traxx® PBX that we will use will have a spacing of 50 cm, a flow rate of 0.87 l/h, and a distance of 1 m between the lines.

With a row spacing of 1 m, the chosen tape will deliver 1.74 l/h/m² to our crop. Considering the crop's average water requirement, this results in an average daily operation time of approximately 3 hours and 15 minutes.

To irrigate the entire crop, we will use a pump with a capacity of approximately 3000 l/min, which will allow us to irrigate 3 sectors simultaneously, operating for around 13 hours per day.

Each sector will have a 3' loading valve, with a flow rate of approximately 1000 l/h, and 2 drain valves.

Release valves also play a fundamental role for the correct functioning of the system: at the beginning of each sector, we will install a 2-inch, double-acting air release valve. This will allow the air in the main pipe to be completely released at system startup and will help prevent the tape from collapsing when the system is shut down. At the end of each sector, we will instead install a 1-inch, single-acting air release valve with a solenoid valve.

Finally, another component to ensure the smooth operation of a sub-surface irrigation system is the installation of a Mazzei venturi air injector for each sector. In our case, we will use a 3-inch Mazzei AIRJECTION injector.

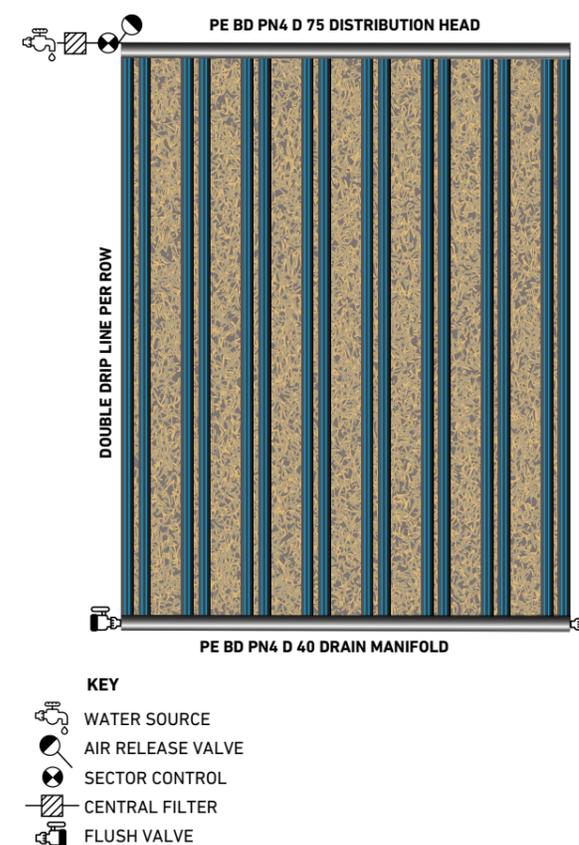
Insufficient soil aeration reduces the roots' ability to absorb water and nutrients effectively. When the soil becomes saturated, it can trap metabolites, ethylene and carbon dioxide within the root zone, leading to negative effects on plant growth and size due to high concentrations of these substances.

Simply put, plant roots need air to breathe. Without adequate oxygen, soil can become anaerobic, which hinders nutrient availability, reduces plant growth and decreases crop yields.

AirJection technology provides a direct supply of essential oxygen to the root zone during irrigation, enhancing aerobic activity in the soil and promoting better root respiration. AirJection efficiently mixes atmospheric air with irrigation water at optimal levels, delivering it directly to the root zone. By delivering essential air components (oxygen and nitrogen) directly to the roots, this innovative approach leads to improved crop yields, enhanced water use efficiency, and greater fertiliser effectiveness.

Since 2000, numerous studies have been conducted using AirJection technology. The data from these studies, and from other grower installations, consistently demonstrate that the commercial adoption of AirJection technology can increase crop yields by 13% to 35%, due to enhanced plant performance and improved soil conditions.

CLASSIC RING PLAN FOR SUB-SURFACE IRRIGATION



AUTOMATION AND SENSORS

Since sub-surface irrigation systems use water differently from surface irrigation systems, the operator may need to amend the current irrigation management protocol or introduce new procedures to ensure optimal performance. Pressure gauge and water meter readings become extremely important indicators of the health of a sub-surface irrigation system. Additionally, other management issues, such as fertiliser and herbicide application schedules, may require adjustments to fully leverage the system's strengths. Finally, sub-surface irrigation systems can influence the answer to a key question in irrigation scheduling: how much water should be applied and how often.

IRRIGATION SCHEDULING

Sub-surface drip irrigation systems differ from traditional irrigation and other systems insofar as they do not fully saturate the soil. While irrigation water is distributed evenly along the drip line, in sub-surface irrigation, this line is placed between two rows of crops, meaning that, while the plants receive an equal amount of water, wet and dry areas are created in the field. Consequently, this irrigation technique requires precise scheduling based on soil moisture monitoring, which can be done manually or using sensors. These systems are compatible with irrigation strategies based on evapotranspiration (ET).

IRRIGATION FREQUENCY

Sub-surface irrigation systems typically irrigate a smaller area than other systems, which can limit expansion of the crop root system. In these circumstances, crops may benefit from more frequent irrigation.

SYSTEM MONITORING

These systems do not provide many visual indicators of their performance. Relying solely on visual indicators of crop stress could lead to yield losses and damage to the system. This is why it is crucial for the system to be equipped with a flow meter and pressure gauges to monitor performance. Each irrigation zone should have clearly defined flow and pressure operating standards. A monitoring programme enables the detection of any changes in performance.

Moreover, keeping accurate records is essential for assessing the health of a sub-surface irrigation system. Flow and pressure readings establish operating conditions in line with design specifications, allowing for the identification of any changes or trends in performance over time.



INSTALLATION AND MAINTENANCE OF A SUB-SURFACE IRRIGATION SYSTEM

MAZZEI AIRJECTION® IRRIGATION TECHNOLOGY

Improves crop yield, water use and fertiliser efficiency

Air and water are essential ingredients for the development of root systems in agricultural crops. Poor soil aeration decreases the roots' ability to absorb water and minerals effectively. When soils become saturated, they can trap metabolites, ethylene and carbon dioxide within the root zone, leading to negative effects on plant growth and size due to the high concentrations of these substances. Oxygen is vital to the survival of beneficial soil microorganisms that help improve the physical properties of the soil and facilitate processes such as nitrification and ammonification.

Simply put... plant roots need to breathe. Without adequate oxygen, soil can become anaerobic, which hinders nutrient availability, reduces plant growth and decreases crop yields.

The challenge of getting the right amount of air to the root zone efficiently and effectively has been solved by Mazzei's AirJection technology.

Mazzei's AirJection technology, integrated into a Toro sub-surface irrigation system, effectively combines atmospheric air with irrigation water at optimal levels, supplying essential air components (oxygen and nitrogen) directly to the roots.

Since 2000, the Center for Irrigation Technology at California State University, Fresno, has conducted numerous tests using AirJection

technology. Data from these trials, including those from agricultural installations and other academic institutions, consistently demonstrate that the commercial adoption of Mazzei AirJection technology in sub-surface irrigation systems can increase crop yields by 13% to 35%, due to enhanced plant performance and improved soil conditions.

MAZZEI AIRJECTION® IRRIGATION TECHNOLOGY

1. Significantly increases:

- Root mass
- Sugar content
- Germination
- Crop yield
- Fruit density

2. Improves water use efficiency

3. Achieves earlier ripening in most crops

4. Increases plant salinity tolerance

5. Improves late-season yields

6. Reduces fertiliser application rates

INSTALLATION OF A SUB-SURFACE IRRIGATION SYSTEM

The following guidelines offer general recommendations and tips for burying drip lines and tapes, and for the subsequent inspection of a sub-surface irrigation system.



1. Storing the material

- Set up a sheltered area for storing the drip lines. These must not be exposed to sunlight, as this could cause damage to the material.
- Assigned personnel should handle the reels wearing gloves, taking particular care not to damage the material during handling.

2. Carrying out the excavations

- The width of the excavations should facilitate easy connection between the delivery head, the drain manifold and the drip lines, with minimum dimensions determined by the diameter of the piping.
- The excavations must be carried out using suitable means, taking care to avoid damage to the pipes. It is advisable to remove roots and to pile the excavated material along the side of the trench.
- At the bottom of the trench, prepare a sandy bedding layer to provide a flat surface for the piping to rest on. The thickness of the bed must be proportionate to the diameter of the piping.
- The dig depth depends on the depth of the drip lines. A greater depth is advised for drainage manifolds, to facilitate water runoff after irrigation.
- To prevent wall collapses while the tractor passes with the subsoiler, dig the trenches after the sub-surface irrigation lines have been laid.



- If the burying direction is fixed and requires an idle tractor pass, it is preferable to dig beforehand to facilitate insertion of the subsoiler. In cases where an idle tractor pass can be avoided, perform two small excavations at the tops of the rows before burying the lines.

3. Preparing the subsoiler

- Adjust the machine.
- Install the reel unwinder device and insert the drip line reel, adjusting the subsoiler.
- Conduct a few test runs before burying the lines to monitor depth and functionality.



4. Burying the drip lines

- Once the subsoiler has been positioned correctly, start burying the drip lines. To prevent dragging, it is essential to secure the outer vertex, but this becomes less critical after a few metres.
- While burying the drip lines, monitor the depth to ensure the reel unrolls smoothly.
- The tractor should proceed at low speed to avoid jerking.
- At the end of the reel, load the reel holder and halt operations before the last part of the drip line runs into the pipe holder.
- Make sure to connect the new reel smoothly, without jerking the line.



- At the end of the row, move forward and make a cut, leaving one metre of drip line above the ground to facilitate subsequent connections.
- When necessary, the underground connection between drip lines is made using specific connectors to avoid kinks.

5. Connecting the drip lines to the pipes

- After burying, place the distribution heads and drainage manifolds at the bottom.
- Connect the drip lines to the pipes using brackets, fittings or rubber connectors.



6. Installing the air release valves and the drain valves

- The air release valves - essential in sub-surface irrigation to prevent the risk of soil suction around the dripper and potential system clogging - should be positioned at the highest point of the upstream sector. In perfectly flat terrain, the air release valve can be placed at any vertex of the ring sector or, as per the designer's instructions, on the control unit, immediately after the manual or automatic valve. In many cases, it is advisable to divide the air release valves appropriately for each sector.
- The drain valves should be installed at the downstream vertex of the sector, to help flush the entire system. These valves, which can be manual, automatic or end-of-flow, can be located on the surface or housed in a pit. Installing valves at each vertex of the sector helps improve safety and simplifies flushing operations.

7. Installing the control units

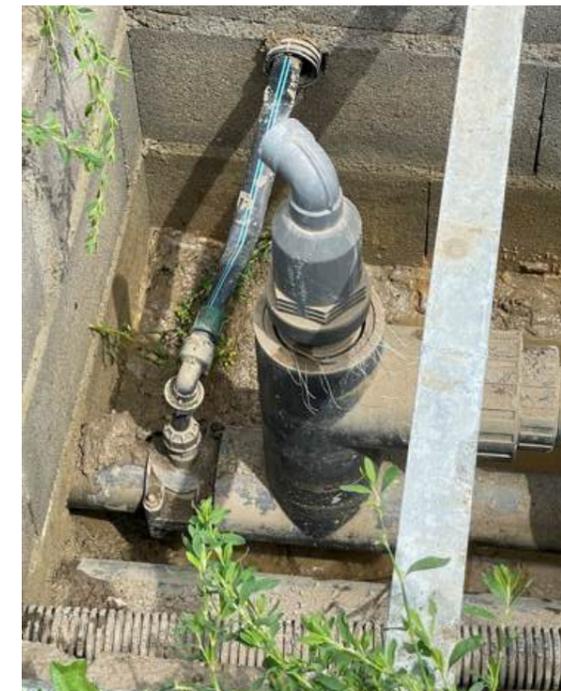
- To position and sequence the control units correctly, carefully follow the designer's instructions.
- Anchor the control units with thrust supports to resist hydrostatic forces.

8. Flushing, pressurising and testing the system

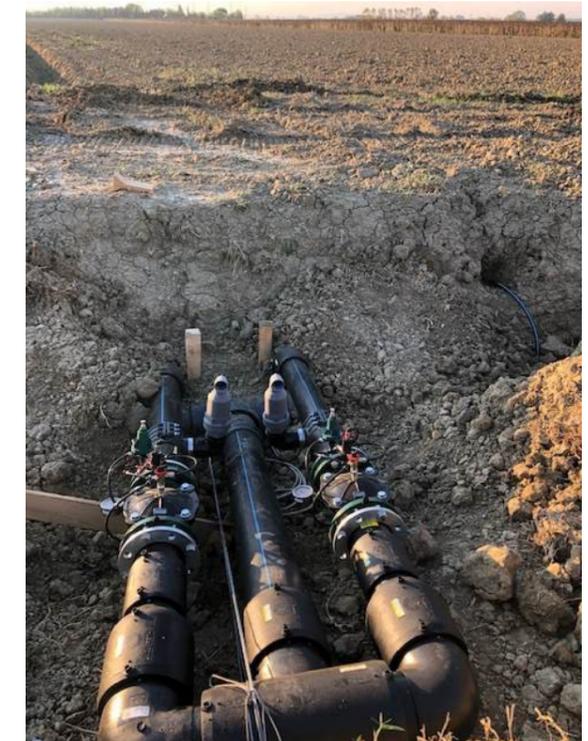
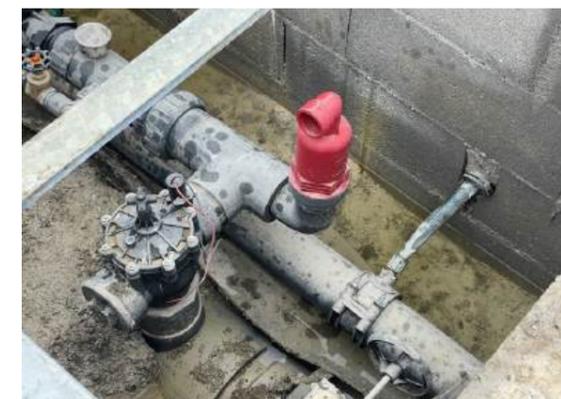
- Fill the water lines, opening the drain valves to remove any foreign material.
- Close the valves and increase the pressure to the operating level, checking that the filters are functioning correctly.
- Maintain the test pressure for at least 4 hours and check the exact operating pressure.

MAINTENANCE OF A SUB-SURFACE IRRIGATION SYSTEM

As with any micro-irrigation system, proper maintenance of a sub-surface system is essential to ensure optimal performance throughout the irrigation season. Particular attention should be given to initial activation after the winter downtime, especially in the spring, to prevent clogging issues caused by suspended materials such as iron, manganese and calcium, which can block the narrow openings of the drippers.



The initial check should focus on the central filtering station. We recommend checking the operation of the sand filters by activating the manual or automatic backwash system and monitoring the control units and automatic valves. Furthermore, it is advisable to perform maintenance on the filter media by stratifying the grit from coarser to finer particles and removing any impurities that may have accumulated over the winter. The mesh and disc



filters should be disassembled and thoroughly cleaned to prevent pressure loss and scale buildup.

After checking the central filter, it is advisable to flush the connection pipes under pressure so as to expel sediment or impurities that may have accumulated during the period of inactivity. For white PVC pipes, it's also recommended to carry out preventive chlorination to eliminate any algae that may have developed in isolated sections of the system.

Subsequently, you should check the sector control units to ensure the correct operation of valves, filters, pressure regulators, pressure gauges and electrical automation devices.

After these operations, water can be introduced into the irrigation sectors to flush out the final sections, where impurities typically accumulate. This operation should be carried out after opening the drain valves.

In the event of a risk of clogging due to various deposits, it is advisable to inject an acidic solution, such as orthophosphoric acid, to lower the pH. After a period of operation, close the system and flush it with pressurised water. Repeat this operation several times to ensure proper functioning of the irrigation system.







TORO[®]

I.S.E. S.r.l.
Via dell'Artigianato, 1-3
00065 Fiano Romano (Rome) - Italy
Tel. (+39) 0765 40191
Fax (+39) 0765 455386
www.toro-ag.it

