Chapter 7. Fertigation equipment – Irrigation

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7.1. Introduction

7.1.1. These techniques concern the issue
- More efficient use of water
- More efficient use of fertiliser
- More efficient use of chemicals
- Minimising the impact to the environment by nutrient discharge

7.1.2. Regions
All EU regions.

7.1.3. Crops in which the problem is relevant
All crops.
For all crops and cropping systems, it is important to maximise water and nutrient use efficiency while minimising impacts. Proper design and management of the system are always necessary.

7.1.4. Cropping type
All cropping types.
As irrigation and fertigation systems for soil-grown crops are different from soilless systems, the demands for irrigation and good nutrient management are different, as well as the requirements for the design and management of the systems.

7.1.5. General description of the issue
Micro-irrigation is an irrigation method that slowly applies water to a small area or volume of growing medium (soil or substrate). Drip irrigation is the most widely used for of micro-irrigation; specialised sprinkler systems are another form. With micro-irrigation, water is generally applied close to the plants. A network of valves, pipes, and tubing transports water over the soil surface, or in some cases below the soil surface, to close to the plants where an emitter transfers the water to the soil surface or to the crop root zone.
The total surface area irrigated with drip irrigation for intensive vegetable and ornamental production and for fruit tree production systems in the European Union is continually increasing, particularly in the Mediterranean countries. For intensive vegetable and ornamental production, and the more intensive fruit production systems (e.g. stone fruits), drip irrigation and fertigation are used together. All substrate-grown and many open field crops are irrigated with drip irrigation on the expectation that yields may be higher and that water use will be reduced compared to other irrigation methods. The particular characteristics of the drip irrigation system adapted for an individual cropping situation depend on the type of cropping system (protected vs. open field; soil vs. soilless), the crop type (fruit, vegetable, ornamental), the crop species, and the water source.
Acceptable irrigation uniformity is an essential factor for the effective use of drip irrigation in intensive horticultural and fruit crops. Uniformity of application does not guarantee high
irrigation efficiency, but water and fertiliser use efficiency decrease with reduced uniformity of application.

### 7.1.5.1. Sub-Issue A: Designing the irrigation system. Limitations and components selection

A relatively even distribution of irrigation within a crop is essential. Despite the theoretical benefits of micro-irrigation systems, correct design is necessary to evenly distribute irrigation on a field or in a greenhouse. For example, in open field, soil-grown vegetable crops, it is common to install drip irrigation systems on sloping fields. Special care should be taken with the design (e.g. following contour lines, length of laterals, etc.) and the selection of emitters, to avoid waterlogging at lower elevations. Pipe ageing also affects water distribution within a field. One possible solution is the use of thin-walled dripper lines which have a lower cost and are disposable, making it possible to use new dripper lines with each crop cycle.

Subsurface drip irrigation (SDI) may solve some of these issues. SDI applies water at some depth (depending on the crop) directly to the root zone. It is one of the most advanced methods currently in use and has several advantages, including the possibility of using treated wastewater since it is not applied to the soil surface thereby preventing possible contamination of fruit or vegetable crops. SDI also prevents water loss through evaporation. However, as the system is relatively complex, it is more suitable for medium to large-scale production.

Clogging of the emitters (both in surface drip and SDI) may be one of the limitations of drip irrigation due to the accumulation of particles, organic matter, bacterial slime, algae, or chemical precipitates. Root intrusion can be an added problem in SDI. Newly developed emitters with turbulent water flow may perform better than self-compensating emitters when using water with higher biological loads. Also, drip lines and emitters treated with chemical products to prevent root intrusion are being developed.

### 7.1.6. Brief description of the socio-economic impact of the issue

Some difficulties are faced when using more sophisticated irrigation methods, for example, SDI. Requirements for skilled labour, careful design of the system and good management of irrigation and fertilisation are required to maximise efficiency and to avoid emitter clogging. SDI has a high initial investment cost compared to some alternative irrigation systems. Such large investments may not be warranted in areas with uncertain water availability.

Additionally, as consumers, particularly those North-West European countries, become more environmentally conscious, they are likely to require that the products that they purchase are produced with minimal negative environmental impact.

The use of combined drip irrigation and fertigation systems can reduce fertiliser applications which will reduce growers’ variable costs, and contribute to the profitability of their enterprises.
7.1.7. Brief description of the regulations concerning the issue

7.1.7.1. European level
The current European Union Directives for that affect crop water management (Nitrate Directive, European Water Framework Directive) demonstrate that the European Commission is moving towards agricultural systems in which reduced water use and enhancing the quality of natural water bodies are major priorities. These Directives have given rise to national and regional legislation to protect natural water bodies. Growers are increasingly having to deal with legislation affecting on-farm water and nutrient management. In countries like The Netherlands, Germany, Belgium, etc., growers of soil-grown crops are being increasingly required to reduce fertiliser use to meet the national or regional criteria regarding contamination of natural water bodies. There is an ongoing tendency, in these countries, to more strictly apply this legislation. Additionally, it is probable that there will be increasingly strict application in other EU countries, over time.

7.1.7.2. Country level
The European Union Directives have been transposed to national level since legal responsibility for agriculture and the environment are shared both by the EU and the member states’ governments.

7.1.7.3. Regional level
In those countries with decentralised administration, regions have developed their own regulations for the use of water and fertilisers, in conjunction with national and EU legislation. At the regional level, authorities may limit water consumption for agriculture due to drought.

7.1.8. Existing technologies to solve the issue/sub-issues
The general approaches of the existing technologies can be organised into the following categories:

*Irrigation equipment: materials*
- Irrigation Pipes
- Drip emitters and drip lines
- Thin-walled dripper lines (irrigation tape)
- Drip pipes and drippers with anti-microbial and anti-roots functionalities

*Irrigation equipment: design and management*
- Installation of drip irrigation systems on sloping fields
- Adaptation of drip irrigation systems to water with high biological loads

*Irrigation equipment: systems*
- Subsurface drip irrigation (SDI)
7.1.9. Issues that cannot be solved currently

Growers that switch to pressurised irrigation systems (drip, sprinkler) from surface or ebb and flow systems have to ensure that they well-designed systems combined with an adequate selection of materials and equipment. Both the design and the materials used are critical to achieving good standards of water use efficiency and uniformity. Issues such as non-optimal water quality, coarse soils or topographical constraints can impede the adoption of pressurised irrigation. Additionally, the high investment costs and the necessary on-going maintenance of the equipment may be issues for some growers. Clogging of emitters and lack of uniformity of water and nutrient supply are two major issues in relation to irrigation materials. These can be important problems where design, component selection, maintenance, and management are inadequate. However, if these issues are adequately addressed, clogging and lack of uniformity can be minimised.

7.1.10. References for more information


### 7.2. Summary of technologies subsequently presented in this chapter in individual technology descriptions (TDs).

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost Installation</th>
<th>Maintenance</th>
<th>Required</th>
<th>Weaknesses</th>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation pipes</td>
<td>Pipes + emitters between 3000 and 8000 €/ha</td>
<td>Evaluation of irrigation uniformity Anti-clogging treatments</td>
<td>Basic knowledge of pipe maintenance Pressure and flow measuring skills</td>
<td>High initial investment costs</td>
<td>Better control of water flows and pressures More efficient use of water and of fertilisers where fertigation used</td>
<td>Environmental issues regarding the recycling of PVC materials</td>
</tr>
<tr>
<td>Drip emitters and drip lines</td>
<td>0,02-0,03 €/m for low-cost irrigation tapes to 0,2-0,4 €/emitter for pressure compensating emitters</td>
<td>Evaluation of irrigation uniformity Anti-clogging treatments</td>
<td>Maintenance of irrigation networks, good understanding of plant nutrition and water balance</td>
<td>High initial investment, complexity in the agricultural practice</td>
<td>Improvement of crop irrigation practices Increase in yields Very suitable for areas with a limited supply of water</td>
<td>Good quality of water Water pressurising pump, irrigation head unit</td>
</tr>
<tr>
<td>Innovative pipes and drippers for micro-irrigation</td>
<td>Between 1,99 €/Kg (2% additive concentration) and 3,69 €/Kg (6% additive concentration)</td>
<td>Basic knowledge of maintenance of irrigation networks</td>
<td>Recycling of used pipes and drippers. Such service can be provided by the manufacturer company itself</td>
<td>Reduce the algae and diseases in irrigation water Reduce root clogging of drippers</td>
<td>Not yet commercialised</td>
<td></td>
</tr>
<tr>
<td>Thin-walled driper lines (irrigation tape)</td>
<td>600-750 €/ha</td>
<td>Maintenance of irrigation networks Good understanding of plant nutrition and water balance</td>
<td>Pressures above 0,2 MPa cause damage Not recommended for stony or coarse-textured soils</td>
<td>Low cost and disposable thin walled material</td>
<td>Short lifespan New equipment each crop cycle</td>
<td></td>
</tr>
</tbody>
</table>

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### Transfer of INNOvative techniques for sustainable WAter use in FERTigated crops

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost</th>
<th>Installation</th>
<th>Maintenance</th>
<th>Required</th>
<th>Weaknesses</th>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of drip irrigation systems on sloping fields</td>
<td>4 €/lm for pressure compensating drippers and 0,03 €/lm for irrigation tape</td>
<td>Periodic maintenance operations, such as chlorination and acid injection</td>
<td>Maintenance of irrigation networks</td>
<td>Cost, inefficient when medium to low-quality water is used</td>
<td>Compensates pressure changes and varying discharge rates</td>
<td>Irrigation water with high biological loads</td>
<td></td>
</tr>
<tr>
<td>Adaptation of drip irrigation systems to water with high biological loads</td>
<td>Same as conventional turbulent emitters</td>
<td>Periodic maintenance operations, such as chlorination and acid injection</td>
<td>Basic knowledge of maintenance of irrigation networks</td>
<td>Not suited for soilless culture facilities</td>
<td>Suited drippers to avoid clogging or emitter’s flow unbalances</td>
<td>Yearly maintenance. Periodic evaluation of the irrigation uniformity</td>
<td></td>
</tr>
<tr>
<td>Subsurface drip irrigation (SDI)</td>
<td>900-2000 €/ha</td>
<td>Periodic maintenance operations, such as chlorination and acid injection</td>
<td>Basic knowledge of maintenance of irrigation networks</td>
<td>Short lifespan No resale value</td>
<td>Water applied directly to the root zones Applicators placed below the ground surface</td>
<td>Investment not warranted in areas with uncertain water and fuel availability</td>
<td></td>
</tr>
</tbody>
</table>

### Design & management

- **Cost**: Evaluation of the initial investment required for each technology.
- **Installation**: Details on the installation process, including costs and maintenance needs.
- **Maintenance**: Requirements for ongoing maintenance, including costs and operations.

7.3. **Irrigation pipes**

*(Authors: Miguel Giménez\(^{11}\), Rafael Baeza\(^{11}\))*

7.3.1. **Used for**

More efficient use of water.

7.3.2. **Region**

All EU regions.

7.3.3. **Crops in which it is used**

Vegetable crops, fruit crops, extensive crops.

7.3.4. **Cropping type**

All cropping types.

7.3.5. **Description of the technology**

7.3.5.1. **Purpose/aim of the technology**

![Diagram of irrigation pipes](http://www.gokulplast.com)

Figure 7-1. Schematic operation diagram of a pipeline irrigation distribution system (from http://www.gokulplast.com)

All drip irrigation systems consist of three components: 1) the irrigation head (the control equipment and filters), 2) the pipes that convey water to the crop, and 3) the drip emitters. The pipes convey filtered and treated water from the irrigation head to the emitters. Pipes
and fittings form a distribution system that is adapted to the size, shape, and configuration of the irrigated plots. Depending on their function and position within the complete irrigation system, different terms are used to describe the component pipes. Mainlines are all the pipes (main, sub-main) between the irrigation head or water source and the control valves in the irrigation zone. Laterals are the pipes or tubes into which the emitters are inserted.

7.3.5.2. Working Principle of operation

Irrigation pipes are normally made of plastic derived materials, mainly polyvinyl chloride (PVC) or polyethene (PE).

Since PVC is a rather rigid and brittle material, its use is restricted to conditions free from impact or external sources of excessive pressure. It is normally used when the required outside diameters are >50 mm. It should be buried to avoid mechanical or sunlight damage. Because of these characteristics, it is normally used for mains pipes.

A development of PVC is Oriented PVC (PVC-O). PVC-O is made by realigning the PVC molecules when the PVC is produced. This greatly enhances the material properties giving around twice the strength and ten times the impact resistance compared to traditional unplasticised PVC (PVC-U) material. Using PVC-O enables the wall thickness of PVC-O pipes to be reduced by up to 50% while maintaining the same pressure as that of the traditional PVC-pipe. The result is that PVC-O has a larger internal diameter providing greater flow rates for an equivalent outer diameter.

Polyethylene is a flexible and easy-to-use material. Installation is much easier and faster than with PVC and can be mechanised. It is recommended for outside diameters of <50 mm. There are different classes of pipes according to the maximum working pressure (2, 5, 4, 5, 6 bar). Pipes are manufactured with UV and oxidation protection, making them durable to solar radiation without significant damage for many years. PE pipes are resistant to saline water, acid, or alkaline solutions (excluding highly concentrated solutions) and to most substances employed in agricultural applications. Low-density polyethene is normally used for the drip lines in which the emitters located. The high flexibility of low-density polyethylene is an important characteristic for drip lines. High-density polyethylene can be used for other pipes.

The basic characteristics used to classify (plastic-derived) pipes are:

- Pressure rating: Maximum working pressure at 20°C
- Diameter: Outside diameter as stated by the manufacturer
- Wall Thickness: Thickness of the pipe wall as stated by the manufacturer
7.3.5.3. Operational conditions

When using pipes for irrigation, the design of the irrigation system is a relevant aspect since it strongly influences the performance of the system. All pipes and fittings should be properly sized to withstand maximum operating pressures and to ensure that they convey water with the minimal loss of pressure. Crop irrigation requirements, soil type and water quality are some of the key factors that must be considered.

Consideration of the agronomic requirements determines the gross irrigation volume to be distributed by the network in periods of maximum demand and is equivalent to the maximum crop requirements modified by an application efficiency factor and a drainage factor. The hydraulic design establishes the dimension, distribution and optimal working conditions of the pipes and fittings to comply with the agronomic requirements. The calculation of the pipe diameters considers the emitters’ working pressure and the pressure losses due to water transport friction along pipes and fittings. There are many spreadsheets available to enable such calculations. In addition to the pipe distribution system being designed to provide the flow rate necessary for normal irrigation, it must also have the capacity for a sufficient flow rate that ensures that the water velocity is sufficiently high for proper flushing velocities in the system (minimum 0.3 m/s).

In the Almeria region, the average irrigation sectors (maximum area irrigated in one single event) occupies an area of 5100 m², and the average area of irrigation subunits (maximum area in which irrigation pressure can be managed by closing or opening valves) occupies an area of 1034 m². The required maximum flow rates for irrigation sectors and subunits are 30.6 m³/hour and 6.2 m³/hour, respectively. Therefore, recommended diameters according to these flow rates are 90-110 mm for irrigation sectors and 50 mm for irrigation subunits.

Expansion and contraction that occurs under normal on-surface operating conditions should be considered to avoid possible damage. It is important to double check that all fittings are secure, particularly in subsurface distribution systems.

7.3.5.4. Cost data

The cost of an installation depends on the location, supplier, quality, size, crop, and plant density. A rule of thumb that is specific for the Almeria region is that the cost of pipes and emitters for one hectare of a greenhouse crop is approximately 3000-8000 for turbulent and
pressure compensating emitters, respectively. Plant density should be around 2 plants/m² with one emitter/m². Additionally, the cost of pipes and fittings for the irrigation head unit would be between 1000 and 2000 €/ha.

7.3.5.5. Technological bottlenecks

No technological bottlenecks.

7.3.5.6. Benefit for the grower

**Advantages**

- Better control of water flows and pressures
- More efficient use of water and of fertilisers where fertigation used
- Easily installed and maintained

**Disadvantages**

- There are some environmental issues regarding the recycling of PVC materials
- More expensive installation costs compared with surface or furrow irrigation methods

7.3.5.7. Supporting systems needed

Irrigation head unit and pumps. Where a continuous supply of water is not available, water storage facilities on the farm may be required.

7.3.5.8. Development phase (delete as appropriate, add additional information if needed):

Commercialised.

7.3.5.9. Who provides the technology

Many distributors and suppliers.

7.3.5.10. Patented or not

This technique is very general and is not patented.

7.3.6. Which technologies are in competition with this one (can be referred to another technology sheet)

Surface irrigation.

7.3.7. Is the technology transferable to other crops/climates/cropping systems?

Already in general use in many regions.

7.3.8. Description of the regulatory bottlenecks

The adoption of more sustainable irrigation strategies is encouraged policy objectives at EU level, as expressed in the 6th and 7th Environmental Action Programmes and the Water Framework Directive. These policy objectives aim to promote that the rates of extraction...
from water resources are sustainable over the long term and to promote sustainable water use based on a long-term protection of available water resources; national, regional, and local authorities need, among other things, to introduce measures to improve the efficiency of water use and to encourage changes in agricultural practices necessary to protect water resources (and quality).

7.3.9. Brief description of the socio-economic bottlenecks

Pipes may be associated with high initial investment costs when initially installing the irrigation systems. Additionally, the use of pipes and pressurised water introduces complexity into farming practice which requires a good understanding of hydraulics and crop water requirements.

7.3.10. Techniques resulting from this technology (add as many needed)

Pipes are used in the sprinkler, drip, and subsurface irrigation.

7.3.11. References for more information


7.4. Drip emitters and drip lines

(Authors: Rafael Baeza\textsuperscript{11}, Miguel Giménez\textsuperscript{11}, Milagros Fernández\textsuperscript{11})

7.4.1. Used for

- Preparation of irrigation water
- More efficient use of water
- Minimising the impact to the environment by nutrient discharge
- More efficient use of fertiliser

7.4.2. Region

All EU regions.

7.4.3. Crop in which it is used

All crops.

7.4.4. Cropping type

All cropping types.

7.4.5. Description of the technology

7.4.5.1. Purpose/aim of the technology

Drip irrigation is the high-frequency application of small volumes of water in localised areas forming “wetted bulbs” along crop lines. When these wetted bulbs overlap they form a “wetted strip”. With good management, drip irrigation provides high application efficiency of irrigation water. Other advantages of drip irrigation are high uniformity of water distribution, improved control of water content in the root zone, enhanced capacity to manage salinity in the root zone enabling better crop performance with poorer quality water, reduction of labour costs and improved fertiliser use efficiency when combined with fertigation. The core elements in drip irrigation are the drip emitters. The emitters are installed on the pipe and act as small throttles, assuring that a uniform rate of flow is emitted. Different models of drip emitters are available that enable use with large variations in crop types and cropping conditions. To ensure maximum irrigation uniformity and water use efficiency, it is necessary that the most appropriate emitters are selected for the crop type and local conditions. Pipe and emitter technical features and specifications determine what conditions and cropping are better applied. Parameters like length and shape of the labyrinth path, flow rate, presence of a pressure-compensating silicon diaphragm, anti-drain systems, or physical root barriers define their optimal range of applications. Normally emitters and drip lines are on-surface but in a much smaller percentage of crops, sub-surface drip irrigation (SDI) is used where the drip line is buried.

7.4.5.2. Working Principle of operation

Examples of common layouts of drip emitters and driplines have been explained in other sections of this chapter (see Irrigation Pipes or SDI). Mains, sub-mains, and laterals are installed, mostly on the soil surface, to convey water and nutrients to the crop in the most...
uniform and efficient way. Design of the irrigation layout should consider not only crop needs or issues related with the water quality of soil physical properties but also the hydraulic calculations to determine the most suitable materials for the required pressures and water flows.

Drip emitters ‘manufacturers should provide information on the technical features of their range of products. Not every drip emitter is suitable for every situation. This information is, in the case of big manufacturers, well developed and available in their internet web pages. Information should include data about flow, working pressure ranges, recommended filtration, and some hydraulic parameters that express to what point the flow rate changes with pressure. Besides, information on the maximum recommended lateral length at different inlet pressures and different slopes might also be very useful. The hydraulic design of dripper and pipes determines to what crops or cropping systems are more suitable. As an example, a dripline could be tagged as adequate for on-surface multi-seasonal row crops while a second one would be more suitable for sub-surface seasonal crops.

Type of drip emitters

Depending on how emitters are assembled to the lateral mains, they can be classified as:

- **In-line emitters, driplines, or dripper lines**: Emitters are inserted and welded into the pipe or tubing during the manufacturing process, so emitter and pipe form a single piece of equipment. The emitters are uniformly spaced along the tube, often several different spacing options are available. The primary advantage of drip lines is ease of installation due to the preinstalled emitters. However, in some cases, they are just inserted between short pipe sections (0.4 and 0.5 m distance) so they can be manually extracted by pulling apart both sections of the pipe where the emitter has been intercalated. This is good for maintenance because they allow manual de-clogging of the emitters but as they are fitted with barbed joints high temperatures may easily cause accidental split opening.

- **On-line emitters**: Assembled and pinched on the lateral mains. To install the emitters a hole is made on the lateral piping and the barbed emitter inlet is pushed into the hole and the barb locks it in place. The diameter of the main does not limit the election of emitters of different sizes which makes the adoption of new emitters easier. This type of assembly is adequate for irregular plant densities since it is manually done. However, laterals with pre-installed on-line emitters are commercially available and are widely used in soilless and container cropping drip irrigation systems.
Other features also relevant to classify emitters:

- Length of the labyrinth path: Long path emitters are more expensive and maintain uniform and low flow rates. Short path emitters are cheaper and adequate for low-pressure systems where other types will not work at all. The latter is more due to clogging, especially if water quality is not good enough. Their flow performance is poorer

- Method to control flow rate and pressure: Turbulent-flow emitters work by running the water through a labyrinth resulting in water turbulence which reduces the flow rate and pressure, and clogging. Diaphragm emitters use some type of flexible diaphragm to reduce the flow and pressure. They wear out eventually, but they are much more accurate in controlling the flow rate and pressure. Besides, the show anti-leak properties so when the irrigation pulse stops irrigation water remains in the pipe and there is no extra flush of water. Combined emitters are commercially available and have the advantages of these two methods. Drip emitters with constant flow rates regardless changes of water pressure are called pressure-compensating

- Emitter sensitivity to clogging: Emitter sensitivity to clogging strongly depends on the minimum diameter of water passage inside. Emitters are then classified in:

<table>
<thead>
<tr>
<th>Minimum diameter (mm)</th>
<th>Clogging sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.7</td>
<td>High</td>
</tr>
<tr>
<td>0.7-1.5</td>
<td>Medium</td>
</tr>
<tr>
<td>&gt; 1.5</td>
<td>Low</td>
</tr>
</tbody>
</table>

7.4.5.3. Operational conditions
Adequate uniformity and efficiency of irrigation can only be achieved if the technical features of emitters are suitable for the specific conditions of the crop. Firstly, the flow rate

and layout of emitters should be considered in relation to the crop type and crop layout. The objective is to form wetted bulbs or strips that are adapted to the crop root system. The size of the wetted volume of soil will depend on soil texture and structure, the flow rate of the emitter, and the volume of each irrigation pulse.

There are different types of drippers commercially available. Pressure-compensating and anti-drain drippers are recommended for soilless crops or any other cropping systems requiring short and frequent irrigation pulses. On the contrary, if water used for irrigation presents high biological loads, emitters should allow complete drainage of the main circuit after each irrigation pulse. In this case, turbulent emitters, in which the applied water passes through a labyrinth structure, are recommended.

Water with high concentrations of suspended particles requires emitters specifically designed to prevent clogging, so that minimum diameter to ensure water passage should be considered.

Drip lines are recommended in layouts in which laterals are extended and retired in each cropping cycle. If this is the case and water presents high biological loads and/or suspended particles, one-use irrigation tapes may be the most suitable material.

Emitters with a low variability (measured as the “coefficient of variation”) should be selected to ensure maximum uniformity of irrigation.

**7.4.5.4. Cost data**

Investment costs depend much on the choice of material. Prices go from 0,02-0,03 €/m for low-cost irrigation tapes to 0,2-0,4 €/emitter for anti-drain pressure compensating emitters.

**7.4.5.5. Technological bottlenecks**

Most of the bottlenecks experienced are associated with the use of emitters with inadequate characteristics for the local conditions which can hamper their operation. Suitable materials have been developed to avoid the entrance of soil particles and roots, clogging due to low-quality water, or unwanted leakage causing irrigation inefficiency. However good maintenance practices are always recommended. In the case of continuous machinery passing cheaper materials made with thin walled PE are available if frequent replacement is required.

**7.4.5.6. Benefit for the grower**

**Advantages**

- Allows high-frequency irrigation
- Low pressure is sufficient
- Requires low volumes of water and fertilisers
- Suitable for using recycled water
- More uniform distribution of water and fertilisers
- Efficient and precise technique
- Reduces evaporation and runoff losses
- Easily adaptable to small and odd shaped parcels
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- Requires minimal land grading
- Reduces the relative humidity in the crop canopy
- Reduces disease pressure
- Less groundwater contamination and leaching of nutrients
- Suitable for high return value crops such as vegetable and horticultural crops
- Can increase yields and decrease nutrient, pesticide, and labour requirements
- Limits deep water drainage
- Increases infiltration and storage of water on drier, less encased soils
- Possible on sloping or irregularly shaped land areas that cannot be flood irrigated
- High Fertiliser efficiency: application at any time and any dosage without wetting plant foliage; any water-soluble fertiliser may be injected
- Yields are typically increased

Disadvantages

- High initial system cost
- Power costs
- Difficulties with emitter uniformity
- Careful system design is essential
- Soil salinity issues must be addressed as well as the effects of excess calcium carbonate dissolved in the irrigation waters
- Emitter clogging will affect distribution uniformity
- Algae growth and scale build-up (CaCO₃) must be controlled
- Provisions must be made for utilising the flush water, same as with all systems that use filters
- Water must be available on a regular basis
- Problems with deficit irrigation strategies during the early stages of cultivation may result in limited bulb size and root entry in the dripper
- The depth of drip line installation limits soil tillage

7.4.5.7. Supporting systems needed
The irrigation system may need to be adapted to facilitate the application of this technology.

7.4.5.8. Development phase
Commercialised.

7.4.5.9. Who provides the technology
Manufacturing companies working in the irrigation sector.

7.4.5.10. Patented or not
This technology is not patented. SDI is a generic technology.

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7.4.6. Which technologies are in competition with this one
Sprinkler irrigation systems and surface irrigation systems. Both provide less control of the wetted bulb and are less efficient in terms of water and fertiliser use.

7.4.7. Is the technology transferable to other crops/climates/cropping systems?
Yes, when compared to rain-fed agriculture, irrigation can significantly increase and stabilise crop yields and farm incomes from season to season, reducing farming risk. It is a very suitable technology for arid, semi-arid, hot, and windy areas with limited water supply. Also for controlled environments like greenhouses. It is commonly used in situations including row crops, orchards, and vines.

7.4.8. Description of the regulatory bottlenecks
No relevant European directives or regulatory bottlenecks at European level. Being a system with a great efficiency in the applied water is integrated within the directive of efficient use of irrigation.

7.4.9. Brief description of the socio-economic bottlenecks
Drip lines may be associated with high initial investment costs when reclaiming or adapting land from rain-fed to irrigated agriculture. Besides, drip irrigation introduces complexity in the agricultural practice and a good understanding of plant nutrition and water balance is required.

7.4.10. Techniques resulting from this technology
Subsurface drip irrigation supplies irrigation water and nutrients directly to the root zone.

7.4.11. References for more information
7.5. Innovative pipes and drippers for micro-irrigation

(Authors: Jadwiga Treder, Federico Tinivella, Waldemar Treder)

7.5.1. Used for
More efficient use of water.

7.5.2. Region
All EU regions.

7.5.3. Crop in which it is used
- Vegetables
- Ornamentals
- Tree fruit

7.5.4. Cropping type
- Soil-bound
- Protected
- Open air

7.5.5. Description of the technology

7.5.5.1. Purpose/aim of the technology
The RIGA project (www.rigaproject.eu) funded in the frame of the CIP-Eco-innovation scheme has developed new irrigation systems with anti-microbial and anti-roots (trifluralin free) functionalities to pursue the following objectives:

- To reduce the algae and diseases in irrigation water, which may cause biofilm formation inside the tubes, by the addition of anti-microbial additives, according to the biocide standards: 98/8/CE and RD 1054/2002, in the extruded micro-irrigation pipes
- To reduce the clogging of the drippers by roots, using additives with low toxicity as an alternative to trifluralin. Drippers will be impregnated with these additives during the manufacturing process through injection

7.5.5.2. Working Principle of operation
Micro-irrigation, also known as drip irrigation (Figure 7-4) or trickle irrigation is an irrigation method that applies water slowly to the roots of plants. This is done by depositing the water either on the soil surface or directly to the root zone, through a network of valves, pipes, tubing, drippers, and emitters. Of the various forms of micro-irrigation, drip irrigation is the one most widely used because it can save water and reduces the use of agrochemicals.
However, despite the benefits that micro-irrigation systems present, there are some limitations:

- The clogging of the emitters. Soil particles, organic matter, bacterial slime, algae or chemical precipitates can easily clog the small openings. The micro-irrigation systems require very exhaustive filtration, even with a good quality water supply.

- The prevention of root intrusion that leads to the collapse of the water emitters. Current systems with inbuilt anti-root chemical treatments are available. However, most of these chemicals are based on trifluralin which has a high toxicity to fish and...
other aquatic organisms and is not approved for use as a plant protection product in Europe.

Pipes and drippers already containing anti-root and antimicrobial additives that are added through the extrusion and the injection processes respectively, can ensure a constant flow during the crop cycle and avoid dripper clogging due to the formation of biofilms inside tubes or the penetration of roots into the drippers.

7.5.5.3. Operational conditions
The operational conditions are the same as the ones adopted for traditional pipes and drippers.

7.5.5.4. Cost data
Since the technology is still at a pre-commercialisation stage, costs are provided as €/Kg of the product according to manufacturers’ calculations. Costs are referred to pipes already extruded with drippers (1 dripper every 15 cm). They vary between: 1,99 €/Kg (2% additive concentration) and 3,69 €/Kg (6% additive concentration).

7.5.5.5. Technological bottlenecks
No technological bottlenecks are encountered.

7.5.5.6. Benefit for the grower

*Advantages*
- Longer duration of pipes and drippers
- Reduction in water consumption
- Reduction of the amount of plastic waste to be collected and recycled
- Reduced environmental impact

*Disadvantages*
Slightly higher costs of the final product compared to traditional polyolefins.

7.5.5.7. Supporting systems needed
Mainly a service dedicated to the collection of used pipes and drippers in order to facilitate the recycling of plastic. Such service can be provided by the manufacturer company itself.

7.5.5.8. Development phase
Field tests.

7.5.5.9. Who provides the technology
- Galloplast, Spain ([www.galloplast.com](http://www.galloplast.com)): additive masterbatches
- Irritec, Italy ([www.irritec.com](http://www.irritec.com)): pipes and drippers manufacturing

7.5.5.10. Patented or not
Both additives (antimicrobial and anti-root) are patented.
7.5.6. Which technologies are in competition with this one
Traditional pipes and dripper used for micro-irrigation based on standard polyolefin.

7.5.7. Is the technology transferable to other crops/climates/cropping systems?
With some adaptations/modifications, the technology can be easily transferred to plants grown in pots/containers.

7.5.8. Description of the regulatory bottlenecks

7.5.8.1. Brief description of the European directive and implications for growers at European level
- Directive 2008/98/EC on wastes
- Directive 1999/31/EC on landfill of wastes

7.5.8.2. Implementation at the country level
- Directive 2008/98/EC adopted in Italy through the Legislative Decree n° 205 on 03/12/2010
- Directive 1999/31/EC adopted in Italy through the Legislative Decree n° 36 on 13/01/2003

7.5.8.3. Implementation at the regional level
- Resolution n° 14 on 25/03/2015 of the Regional Council with regards to waste management

7.5.9. Brief description of the socio-economic bottlenecks
The main issue related to the market introduction of the innovative micro irrigation pipes and drippers could be its cost compared to current polyethylene systems. The difference in the final cost is mainly attributed to the price of the new additives: it was demonstrated that the cost increase is around 10-15% regarding the final cost of the product. This could be a restraint in crops with short cultivation cycle (lower than 5 months) and where the pipe reuse is complex.

7.5.10. Techniques resulting from this technology
This technology is still in a pre-commercialisation phase. Therefore, the new pipes and drippers will be distributed according to the commercial agreements defined among project partners and on the basis of the commercial requests received by the manufacturers.
7.5.11. References for more information


[8] www.galloplast.com
7.6. Thin-walled dripper lines (irrigation tape)
(Authors: Rafael Baeza, Milagros Fernández, Elisa Suárez-Rey)

7.6.1. Used for
More efficient use of water and fertilisers.

7.6.2. Region
All EU regions.

7.6.3. Crop in which it is used
All crops.

7.6.4. Cropping type
- Soil-bound
- Protected
- Open air

7.6.5. Description of the technology

7.6.5.1. Purpose/aim of the technology
Counter deficient facilities that lack proper maintenance or aged irrigation networks with low cost and disposable thin walled dripper lines, making it possible to use a new material each crop cycle.

7.6.5.2. Working Principle of operation
An acceptable uniformity of irrigation distribution is an essential factor for the proper development of intensive horticultural crops. While the uniformity of distribution does not guarantee high irrigation efficiency, a lower uniformity decreases the efficiency of the applied water and fertiliser. Studies carried about by IFAPA on horticultural crops grown under Mediterranean greenhouses and conventional thick-walled dripper lines shown that a high percentage of facilities have no acceptable coefficients of uniformity (Figure 7-7).

![Distribution uniformity (%)](image)

Figure 7-7. Distribution Uniformity (%) obtained in a sample of 80 grower facilities (Methodology Merriam and Keller) (Baeza et al. 2010)
Irrigation uniformity undergoes a progressive decrease because of chemical scaling and develops sedimentation with biological colonies. If the available material has a low cost and low coefficient of variation, you can use such materials for one or two growing cycles, thereby ensuring distribution uniformity. Currently, there are inexpensive irrigation tape types (0.03-0.06 €/m) on the market with a pretty good manufacturing quality. A recent study by IFAPA with a sample of 13 different irrigation tape types shows that there are types of high-quality manufacturing (Figure 7-8).

![Figure 7-8. Classification of tapes studied as manufacturing coefficient of variation (CV). Class A (CV <5%), Class B (5 <CV <10) (Baeza et al. 2016)](Image)

### 7.6.5.3. Operational conditions
- These tapes do not allow for irrigation at high pressures (pressures above 0.2 Mpa can damage the material)
- Installing this type of materials is not recommended in farms with high presence of stones or other heavy elements

### 7.6.5.4. Cost data
The cost of these materials is about 20-25% of the cost of conventional irrigation pipes. The costs of labour, required to remove and replace the lines annually or biennially should, however, be considered together with a regular maintenance.

### 7.6.5.5. Technological bottlenecks
Not detected.

### 7.6.5.6. Benefit for the grower
**Advantages**
- Ensures high irrigation uniformity distribution
- Reduces initial investment
- No high levels of technical knowledge for handling required

Technology developed widely and readily available

**Disadvantages**

- Not suited for soilless culture facilities
- Not suited for farms with high presence of stones or other coarse materials
- More sensitive to farm operations and machinery
- More sensitive to insects or animals damaged

**7.6.5.7. Supporting systems needed**
There are no supporting systems required.

**7.6.5.8. Development phase**
Commercialised.

**7.6.5.9. Who provides the technology**
Manufacturers and distributors of irrigation systems.

**7.6.5.10. Patented or not**
Yes, this technology is patented.

**7.6.6. Which technologies are in competition with this one**
Conventional irrigation pipes of a thick wall.

**7.6.7. Is the technology transferable to other crops/climates/cropping systems?**
Yes.

**7.6.8. Description of the regulatory bottlenecks**
There are no regulatory bottlenecks.

**7.6.9. Brief description of the socio-economic bottlenecks**
There are no socio-economic bottlenecks.

**7.6.10. Techniques resulting from this technology**
None.

**7.6.11. References for more information**


Transfer of INNOvative techniques for sustainable WAter use in FERtigated crops

Congreso Nacional de Riegos. León, Spain. 15-17 June 2015. Asociación Española de Riegos y Drenajes


7.7. Installation of drip irrigation systems on sloping fields

(Author: Rafael Baeza\textsuperscript{11}, Elisa Suárez-Rey\textsuperscript{11})

7.7.1. Used for

- More efficient use of fertiliser
- More efficient use of water
- Minimising the impact to the environment by nutrient discharge

7.7.2. Region

All EU regions.

7.7.3. Crop in which it is used

All crops.

7.7.4. Cropping type

Open air.

7.7.5. Description of the technology

7.7.5.1. Purpose/aim of the technology

Counter the pressure change and varying discharge rates along the drip line when this type of irrigation is applied on sloping fields.

7.7.5.2. Working Principle of operation

In open field vegetable production, it is common to install drip irrigation systems on sloping terrain. In these systems, the irrigation uniformity can be high when the system is evaluated when fully operating. However, an elevation change of 0.7 m will cause a 0.07 bar change in pressure in a drip line. For example, a drip tape on a 5\% sloped plot, would have a change in pressure of about 0.4 bars along with a 91 m distance. Assuming the drip tape was medium flow tape (5 L/h/m) and the pressure at the manifold was 0.7 bar, then 25\% more water would be applied at the lower end of the field compared to the top of the slope.

The land slope can have either a positive or a negative effect on the emitter discharge rate along the lateral drip line (Figure 7-10) in surface irrigation. Drip lines running uphill always result in increasing pressure losses along the drip line and thus lower system uniformity. When the downhill slope is too high, the emitter discharge rate at the end of the drip line becomes unacceptably high. In the example shown (Figure 7-9), the optimum slope is 1\% downslope, but this will vary with drip line and emitter characteristics.
Irrigation Uniformity is normally measured when the flow rate from the drip emitters has become even (air flushed out and constant pressure). This method does not consider the charge/discharge periods. In case of short irrigation pulses (frequent in soilless culture) it is common to find apparently good irrigation uniformity percentages whereas the situation is completely the opposite. It is strongly advised to consider the whole irrigation pulse when evaluating such irrigation systems.

In poorly designed and/or maintained irrigation systems irrigation uniformity can drastically decrease if the evaluation includes the processes of manifold water charge and discharge, as they may cause irregular water flow from the emitters when irrigation pulses finish. Those emitters at the bottom of the slope give higher outputs than those at the top since the irrigation system drains downwards. Furthermore, in sandy soils and to improve irrigation water use efficiency, it is necessary to increase the frequency of irrigation by using less volume of water per pulse. However, this increases the number of discharges from the irrigation pipes. The low uniformity in the distribution of irrigation water creates negative impacts on the crop and the environment because of waterlogging in the lowest ground levels of the farm as a consequence of the discharge of the lower emitters (due to drain off) whilst those at the top have stopped emitting water. Irrigation uniformity on sloping sites can be significantly improved by following some simple guidelines on design and maintenance.
Possible solutions are:

- To install irrigation laterals following contour lines
- To increase the length of irrigation pulses and reduce frequency
- To install anti-leak emitters
- To reduce laterals’ length
- To install electro valves; thus, avoiding the discharge of the irrigation pipes when irrigation has finished
- To bury tertiary lines, keeping them to a lower height than the first irrigating emitters, thus avoiding their discharge when irrigation is finished
- To use pressure compensating emitters in fields with elevation differences of 1.5 m or more within a zone. Pressure compensating emitters apply a more uniform rate of water on slopes and equalise pressure differentials created by the elevation differences when compared to a standard emitter
- Areas of a field at different elevations should operate as separate sub-units with separate pressure regulators
- To locate drip-lines parallel to the contour of slopes whenever possible
- Since subsurface runoff can occur in areas with a slope larger than 3%, consideration must be given to drip-line density from the top to the bottom of the slope. The drip-line on the top two-thirds of the slope should be placed at the recommended spacing for the soil type and plant material in use. On the lower one-third, the drip-lines should be spaced 25% wider. The last drip-line can be eliminated on slopes exceeding 5%. For areas exceeding 3 m in elevation change, zone the lower one-third of the slope separately from the upper two-thirds to help control drainage

7.7.5.3. Operational conditions

The use of anti-drain emitters is limited to the differences in height within the irrigation sector.
7.7.5.4. Cost data
Installation costs would be increased with the incorporation of electro-valves and anti-drain emitters. This cost is variable depending on the size and design of the irrigation system within the farm. An approximation could be 0,4 €/lm for pressure compensating drippers and 0,03 €/lm for irrigation tape. The cost of an electro-valve of 50 mm diameter is approximately 100 €.
Yearly maintenance or inputs needed are low. If anti-drain emitters are installed, periodic revision is needed since their failure may induce the discharge of water in some part of the irrigation network.

7.7.5.5. Technological bottlenecks
Anti-drain emitters may undergo reduction of their closing capacity after some time of use.

7.7.5.6. Benefit for the grower
Advantages
- Increased irrigation uniformity
- Increased water and nutrient use efficiency

Disadvantages
Cost, inefficient when medium to low-quality water is used.

7.7.5.7. Supporting systems needed
None.

7.7.5.8. Development phase
Commercialised.

7.7.5.9. Who provides the technology
Installation irrigation and fertilisation companies.

7.7.5.10. Patented or not
Not patented.

7.7.6. Which technologies are in competition with this one
Land levelling (high cost in large size farms).

7.7.7. Is the technology transferable to other crops/climates/cropping systems?
Yes.

7.7.8. Description of the regulatory bottlenecks
There are no regulatory bottlenecks.

7.7.9. Brief description of the socio-economic bottlenecks
High costs associated with land levelling for large size farms.
7.7.10. Techniques resulting from this technology

Not applicable.

7.7.11. References for more information

7.8. Adaptation of drip irrigation systems to water with high biological loads
(Authors: Rafael Baeza\textsuperscript{11}, Milagros Fernández\textsuperscript{11}, Elisa Suárez-Rey\textsuperscript{11})

7.8.1. Used for
More efficient use of water and fertilisers.

7.8.2. Region
All regions.

7.8.3. Crop in which it is used
All crops.

7.8.4. Cropping type
All cropping types.

7.8.5. Description of the technology

7.8.5.1. Purpose/aim of the technology
This document aims to provide decision support to choose the best-suited drippers to avoid clogging or emitter’s flow unbalances when the quality of the irrigation water is low. Besides from suspended solids, agglomeration of inorganic or organic fine particles with microbial biomass and products developing inside pipes and emitters is a major problem in irrigation distribution systems. This problem is aggravated when nutrients are added to the irrigation water (fertigation) as these nutrients are a source of food for microorganisms in the water, thus increasing the biomass.

7.8.5.2. Working Principle of operation
Clogging occurs with the conjunction of the following circumstances:

- Presence of microorganisms in water
- Presence of nutrients in the water
- Water remnant in the irrigation pipelines

Drip Irrigation users can select from many different types of drippers to suit different watering needs. Drippers, also referred to as emitters, are the end devices which deliver water to plants in a specific manner. The type of irrigation emitter, the design of the irrigation network, operation and maintenance are thereof essential to achieve or avoid the previous three issues. Two major types of emitters may be distinguished. Turbulent flow emitters work by running the water through a path with all kinds of sharp turns and obstacles in it. These larger passages make the emitter less likely to clog up, but the flow is not constant since depends on water pressure. Pressure compensating drippers deliver a precise amount of water regardless of changes in pressure due to long tubing runs or changes in terrain elevations (Figure 7-11). Two works carried out by IFAPA with reclaimed wastewater have shown that emitters with turbulent regime perform better in these conditions than pressure compensating emitters. This is a result of the problems caused by...
the interference of bacterial colonies on the operation of the membranes in these pressures compensating emitters (Figure 7-12).

![Diagram](image1.png)

![Diagram](image2.png)

Figure 7-11. Turbulent (A) and pressure compensating drip emitters (B and C) emitters (http://www.anadoluparkbahceler.com; https://www.planetahuerto.es)

An irrigation network that provokes complete draining of the lines between irrigation pulses and this is the case when turbulent flow drippers are used, increases water transit velocity. A period of post-irrigation with no nutrients in each pulse helps to maintain irrigation uniformity. With regards to equipment maintenance, it is advised to frequently clean the end of irrigation laterals by opening end-line valves and the use bactericides.

![Bar chart](image3.png)

Figure 7-12. Distribution uniformity (%) and dripper type: pressure-compensating (membrane drippers) in orange, non-compensating (turbulent drippers without membrane) in blue.

7.8.5.3. Operational conditions
Turbulent emitters do not perform well with short irrigation pulses. Emitters with a flow of 3 L/h and irrigation pulses of less than 1 L (thus 20’) show a drastic reduction of irrigation uniformity due to the time spent in charging or filling the irrigation manifolds. In the case of lateral pipes e.g. 180 m long and because of this charge/discharge process, 3 minutes are spent just in establishing the right operational pressure conditions. In soilless systems, in which short irrigation pulses are required, it is not recommended to follow these guidelines. Regarding increasing velocity of transit, it would require the design of smaller irrigation sectors to avoid excessive pressure head losses in the network.

7.8.5.4. Cost data
Following these design criteria, operation and maintenance of drip irrigation networks using reclaimed urban wastewater do not increase costs compared to conventional water sources.
- Yearly maintenance or inputs needed
- Periodic evaluation of the irrigation uniformity
- Regular cleaning of the irrigation network by opening the end of the drip lines (flushing)
- Application, if necessary, of bactericides and/or descaling

7.8.5.5. Technological bottlenecks
None.

7.8.5.6. Benefit for the grower
Advantages
- Increases irrigation network durability
- Reduces initial investment
- Reduces power consumption
- Not requiring high levels of technical knowledge for handling
- Widely developed technology and readily available

Disadvantages
- Not suited for soilless culture facilities
- Does not allow small irrigation pulses

7.8.5.7. Supporting systems needed
None.

7.8.5.8. Development phase
Commercialised.

7.8.5.9. Who provides the technology
Companies which install irrigation and fertigation.
7.8.5.10. Patented or not
Not patented.

7.8.6. Which technologies are in competition with this one
- Irrigation networks equipped with high-tech emitters
- Irrigation networks using drip tapes

7.8.7. Is the technology transferable to other crops/climates/cropping systems?
Yes, this decision tool can be applied in all regions when considering soil bound crops.

7.8.8. Description of the regulatory bottlenecks
There are no regulatory bottlenecks.

7.8.9. Brief description of the socio-economic bottlenecks
There are no socio-economic bottlenecks.

7.8.10. Techniques resulting from this technology
Not applicable.

7.8.11. References for more information
7.9. Subsurface drip irrigation

*Authors: Elisa Suárez-Rey*, 11 *Carlos Campillo*, 5 *Mercedes Romero* 11

7.9.1. Used for
- Preparation of irrigation water
- More efficient use of water
- Minimising the impact to the environment by nutrient discharge

7.9.2. Region
All EU regions.

7.9.3. Crop in which it is used
All crops.
Currently on a wide range of grain forage and fibre crops including alfalfa, corn, cotton, tomatoes, sugar beets, potatoes, melons, soybeans and sugarcane and fruit crops.

7.9.4. Cropping type
- Soil-bound
- Protected
- Open air

7.9.5. Description of the technology

7.9.5.1. Purpose/aim of the technology
It is a planned irrigation system in which water is applied directly to the root zone of plants by means of applicators (e.g. orifices, emitters, and porous tubing) placed below the ground surface.

7.9.5.2. Working Principle of operation
A subsurface drip irrigation system (SDI) has a similar design as a common drip irrigation system. The correct design of the installation is one of the most important points due to the practically insurmountable difficulties to modify an installation that is mostly below the ground. A typical system layout consists of a settling pond (where possible), pumping unit, pressure relief valve, check valve or backflow prevention valves, hydrocyclone separator (if a settling pond is not feasible), chemical/fertiliser injection unit, filtration unit equipped with backflush valves, pressure regulators, air vent valves and PVC pipes delivering the water to the crop. The principal protection system for the drip lines is the filtration system (Figure 7-13).
The type of filtration system needed will depend on the quality characteristics of the irrigation water. The piping is 10-60 cm below the ground, depending on crop and soil (capillary attraction). As a rule, depths of between 40-45 cm are recommended in soils with clay texture and 25-35 cm in sandy loam soils. Clogging of drip line emitters is the primary reason for SDI system failure. As a water source, treated grey water or even black water is possible, with the risk of clogging being greater if the influent flow has not properly settled. Therefore, treatment of the water (e.g. a non-planted filter system, constructed wetlands or at least a septic tank) before the settling pond is necessary.

The drip tapes normally come in rolls and are buried with a customised shank that is attached to a tractor (Figure 7-14).

**7.9.5.3. Operational conditions**

SDI systems are highly efficient irrigation systems that apply accurate amounts of water directly to the root zone, preventing water loss through evaporation and other negative effects of surface irrigation. This is especially suitable for arid, semi-arid, hot, and windy areas with limited water supply. However, as the system is relatively complex and most likely automated, it is more suitable for medium to large-scale production.
In light textured soils without clay subsoil, deep drainage can be substantial and much closer drip tape spacing is required to ensure adequate irrigation of the areas between dripper lines and to avoid substantial water losses to deep drainage.

It is not advisable that the slope of the dropper lines is greater than 2%, in which case the use of self-compensating drippers will be necessary to minimise the differences in flow between the first and last dropper. This irrigation system is not recommended in plots with significant undulations.

7.9.5.4. Cost data

Investment costs of a subsurface drip irrigation system are between 900-2000 €/ha. The costs vary depending on the water source, quality, filtration needs, and choice of material, soil characteristics and degree of automation. Normal life expectancy is 12-15 years. With good maintenance and high-water quality, the system can be used even longer.

7.9.5.5. Technological bottlenecks

SDI systems are expected to last for many years. As a result, they must be designed, installed, operated, and maintained properly. Common challenges including emitter clogging, root intrusion, vacuum suction and insect, rodent and mechanical damage are difficult to find and repair, all of which may be successfully addressed with proper planning and management. Management time requirements for SDI can be higher than for other irrigation systems, especially the first couple of years when the learning curve is steep. This is because operating an SDI system requires special periodic maintenance operations, such as chlorination and acid injection, which are not required for other systems. Also, applying fertilisers and other chemicals using SDI requires special care and knowledge.

Preventing clogging requires regular preventive maintenance, including proper water filtration, injection of chemicals and flushing. Since the drip tape is buried, supplying water for crop germination can be a problem, especially in sandy soils. In the case of crops where medium-deep tillage is realised, to perform a perfect monitoring of the irrigation line placement to avoid drip line breakage is required. In this sense, to incorporate the lines, tractors with high-resolution GPS-RTK technology are necessary. The guidance systems will be necessary to monitor a correct drip line position to carry out the deep workings of the crop.

7.9.5.6. Benefit for the grower

Advantages

- Allows high-frequency irrigation
- Low pressure is sufficient
- Requires low volumes of water and fertilisers
- Suitable for using recycled water
- More uniform distribution of water and fertilisers
- Efficient and precise technique
- Reduces evaporation and runoff losses
- Easily adaptable to small and odd shaped parcels
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- Requires minimal land grading
- Reduces the relative humidity in the crop canopy
- Reduces disease pressure
- Less groundwater contamination and leaching of nutrients
- Suitable for high return value crops such as vegetable and horticultural crops
- Can increase yields and decrease nutrient, pesticide, and labour requirements
- Limits deep water drainage
- Increases infiltration and storage of water on drier, less encased soils
- Reduced weed growth due to the dryer soil surface
- Possible on sloping or irregularly shaped land areas that cannot be flood irrigated
- High Fertiliser efficiency: application at any time and any dosage without wetting plant foliage; any water-soluble fertiliser may be injected
- Yields are typically increased
- Improved efficiency and management of agricultural operations: lower compaction and soil crusting

Disadvantages

- High initial system cost
- Power costs
- Difficulties with emitter uniformity
- Sizeable personal effort required to understand the anticipated outcome as well as the operation and maintenance
- Requires higher skilled labour than most other irrigation systems
- Difficulty in monitoring and evaluating irrigation events and management of the system
- Possible poor water distribution, infra- and over-watering areas, poor soil aeration, lower yields and high losses by deep percolation in case of bad management
- Careful system design is essential
- Difficulty of adaptation of crop rotations with different distance between lines at the fixed distance between the dripper lines
- Insufficient movement of water to the soil surface, especially in sandy soils, limiting germination and establishment of crops and increasing the application of water to achieve optimum moisture
- High cost of recovery and removal of tapes
- Soil salinity issues must be addressed as well as the effects of excess calcium carbonate dissolved in the irrigation waters
- Filtration is critical
- Emitter clogging will affect distribution uniformity
- Algae growth and scale build-up (CaCO₃) must be controlled
• Provisions must be made for utilising the flush water, same as with all systems that use filters
• Water must be available on a regular basis
• Problems with deficit irrigation strategies during the early stages of cultivation may result in limited bulb size and root entry in the dripper
• The depth of drip line installation limits soil tillage
• Necessary to use a tractor with GPS control systems RTK and automatic steering

7.9.5.7. Supporting systems needed
The irrigation system may need to be adapted to facilitate the application of this technology.

7.9.5.8. Development phase
• Research
• Experimental phase
• Commercialised

7.9.5.9. Who provides the technology
Several suppliers, e.g. Netafim, NaandanJain, Toro.

7.9.5.10. Patented or not
This technology is not patented. SDI is a generic technology.

7.9.6. Which technologies are in competition with this one
SDI is generally a high-tech, automatically operated technology. However, several low-cost and simple methods of subsurface (drip) irrigation like pitcher or bottle irrigation exist that are equally effective for small-scale farming. There are several subsurface techniques used for secondary wastewater treatment such as a leach field or evapotranspiration bed that also provide uncontrolled irrigation to fields.
Other water saving techniques such as regulated deficit irrigation (see relevant TD) or transient deficit irrigation which trigger similar effects on the plant but require different management can also be used.

7.9.7. Is the technology transferable to other crops/climates/cropping systems?
Yes, when compared to dryland farming, irrigation can significantly increase and stabilise crop yields and farm income from season to season, reducing farming risk. This is especially suitable for arid, semi-arid, hot, and windy areas with limited water supply. It is commonly used in situations including row crops, orchards, and vines.
7.9.8. Description of the regulatory bottlenecks

7.9.8.1. Brief description of the European directive and implications for growers at European level

There are no relevant European directives or regulatory bottlenecks at European level. Being a system with a great efficiency in the applied water is integrated within the directive of efficient use of irrigation.

7.9.8.2. Implementation at the regional level

SDI allows the use of recycled water while complying with environmental and public health regulations which prohibit overhead irrigation of certain crops with recycled water.

7.9.9. Brief description of the socio-economic bottlenecks

SDI has a high initial investment cost compared to some alternative irrigation systems. In many cases, the system has no resale value or a minimal salvage value. Such large investments may not be warranted in areas with uncertain water and fuel availability, particularly if commodity price outlook is poor. SDI systems typically have a shorter design life than alternative irrigation systems which means the annualised depreciation costs must increase to provide for system replacement.

Management time requirements for SDI can be higher than for other irrigation systems, especially the first couple of years when the learning curve is steep. This is because operating an SDI system requires special periodic maintenance operations, such as chlorination and acid injection, which are not required for other systems. Also, applying fertilisers and other chemicals using SDI requires special care and knowledge.

7.9.10. Techniques resulting from this technology

SDI is a specialised sub-set of drip irrigation where drip line or drip tape “lateral lines” (tubes buried beneath the crop rows) and supply and flushing “submains” (pipes supplying water to the lateral lines) are buried beneath the soil surface for multi-year use. The technique of burying Bi-Wall drip tape laterals beneath field crops was pioneered in the American Southwest decades ago and has since been implemented by researchers and growers alike.

7.9.11. References for more information


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