

## Sub-Surface Irrigation:



# Is it really worth it?

The concept of Sub-surface irrigation – also called sub-irrigation and abbreviated SDI - was invented in the second half of the 19th century in Northern Europe as a new branch of the studies on drainage.

The technique was thereafter improved in California and then exported and applied in Italy at the beginning of the 20th century. In the meantime it has evolved a lot! Early drip emitters and tubing were somewhat primitive in comparison to modern materials, which caused major problems, such as emitter plugging and poor distribution uniformity. As plastic materials, manufacturing processes, and emitter designs improved, SDI became more popular but emitter plugging caused by root intrusion remained a problem. Initially, SDI was used primarily for high-value crops such as fruits, vegetables, nuts, and sugarcane. As system reliability and longevity improved, SDI was used for lower-valued agronomic crops, primarily because the system could be used for multiple years, reducing the annual system cost. Design guidelines have also evolved to include unique design elements for SDI, including air entry ports for vacuum relief and flushing manifolds. Specific installation equipment and guidelines have also been developed, resulting in more consistent system installation, improved performance, and longer life. The last EIMA Fair in Bologna has been a great opportunity to learn about the latest developments on Subsurface Drip Irrigation techniques and systems in open field and greenhouses. A Conference on the topic was held under the patronage of SOI (Italian Horticulture Society), the sponsorship of Mazzei AirJection®, Irritec& Siplast®, Osmosistemi and New Ag International. Discussions were moderated by Bologna University Prof. Giorgio Gianquinto Prosdocimi. Lorenzo Della Rovere & Silvio Fritegotto from PROFi s.r.l (www.fertirrigazione.it), the company that organized the meeting, have the story.



Silvio Fritegotto



Lorenzo Della Rovere



All pictures courtesy of Prof. I. Sri

**S**ub-surface drip Irrigation is defined as "application of water below the soil surface through emitters, with discharge rates generally in the same range as drip irrigation." Because it protects soil structure and aeration, sub-irrigation is considered a rational technique for supplying water to open field crops. Moreover, the method allows enlarging the irrigated surfaces as a consequence of the low maintenance costs. The technique can be carried out both in extensive and intensive cropping systems. In the first case, the height of the groundwater table is controlled by introducing water into the drains. The pre-requisites to extensive sub-irrigation are: a superficial groundwater table, the presence of an impermeable layer into the soil profile, and a high soil hydraulic conductivity. In the intensive cropping systems, plastic pipelines are laid near the plant roots. Water diffusion into the soil depends on texture characteristics: it is high in clay and low in sandy soils.

Conversely, water flow is high in sandy and low in clay soils. In loamy soils, diffusion and flow are well balanced. Surface and sub-irrigation require the same equipments. Particular attention must be paid to water filtration, in order to avoid flow interruption inside the pipelines without the possibility of monitoring these failures.

### A NUMBER OF AGRONOMIC ADVANTAGES

They were clearly highlighted by Domenico Palumbo of the Council for Research in Agriculture - Experimental Agronomical Institute, Bari, Italy. The main advantages are the absence of soil evaporation, run-off and wind drift. Indeed, the technique maximizes the water use efficiency. Moreover no soil crust or soil surface compression occurs. As the consequence of the closeness between pipelines and roots, the nutrient use efficiency reaches the highest performances. Finally, plant diseases (fungi and bacteria) and weeds occur less frequently

and may be controlled more easily.

As to the wastewaters, sub-irrigation represents a promising agronomical strategy because the aerial parts of plants are not in touch with the water that could be contaminated by pathogens.

Another advantage consists in irrigating while simultaneously doing something else in the field, as well as the protection of buried pipelines from UV radiation, temperature fluctuations, soil tillage, animals, and vandalism.

From an environmental standpoint, sub-irrigation needs less water volume, which implies water savings and the reduction of salt accumulation into the soil and in groundwater tables.

On the other side, some disadvantages of sub-irrigation in the open field have to be underlined. Firstly, soil depth tillage is reduced due to the presence of the pipelines buried close to soil surface. Secondly, during the early crop stages, a supplementary surface irrigation system could be required if the young roots do not reach the soil zone wetted by capillary water. Finally, the pipelines could be clogged by roots (from crops or weeds) or by air bubbles: these events can be monitored only through frequent and accurate cleanings of the irrigation equipment.

As a conclusion, sub-irrigation in open field is an agronomical technique that merits to be considered by growers and agronomists. The lack of information about this irrigation method will be overcome only through constant and repeated demon-

strative and experimental activities.

### THE BENEFITS OF ALSO INJECTING AIR!

This was the topic discussed by D.ssa Lucia Bortolini, from the Irricentre at Padova University. The input of air into the ground through an irrigation system is a technique for improving the production capacity of anoxic soils, fine-textured soils, and/or salty soils. In these soils, the crops can show signs of intolerance by wilting, chlorosis, insufficient development, increased susceptibility to illness, etc. An injection system recently introduced by Mazzei to the market, called AirJection® Irrigation, is able to inject microbubbles of air into the water feeding the SDI system. It contains a venturi-type injector, designed specifically to create microbubbles, inputting air directly into the water and delivering it to the soil through the lines of the underground microirrigation system. The air injector(s) can be installed at the main line or on each row. In the case of a completely buried system, the individual injectors' suction ports should be linked to a common air tube, vented to the surface.

The loss of pressure, naturally associated with this device, requires that the pressure at the inlet of the injector be at least 2 times greater than the pressure at the outlet of the injector. At the same time, however, the device can operate as a pressure regulator, eliminating the need for a regulator valve in the system. The experiments with the system of air injection conducted in Italy, in Australia

and the United States on a variety of crops such as bell peppers, melons, cauliflower, corn, zucchini, strawberries, cotton, and grapes show that a minimum of 10% increase in yield is achieved on most crops tested and sometimes much more. The tests recently conducted in Italy by Dr Bortolini have demonstrated that the effect of air injection is seen more intensely on crops in which (1) there are conditions of soil water saturation,(2) the beds are under

the abundance of air in the rhizosphere and the higher level of dissolved oxygen in the water, which among other things, improves the absorption of nutrients by the roots. It is noted, moreover, that there are positive results in the irrigation system itself, such as a reduction in the formation of algae in the tubing due to the oxygen, and the suspension of solids due to microbubbles, which reduces the possibility of emitter clogging.

The system presents some disadvantages linked to the possibility of root intrusion into the emitters, an inconvenience typical of subsurface irrigation, but controllable with various types of mechanical solutions (for example: emission through a leak) or chemical solutions (for example: Treflan-impregnated emitters). The air injection could, however, create undesired precipitation in the water, a consequence of aeration (oxygenation) of the water, causing the oxidation of reducing compounds, such as iron in well-water.

#### ALSO INTERESTING IN HYDROPONICS

The sustainability of soilless systems nowadays is under discussion for "open cycle" systems, where excesses of the nutrient solution (NS) leaching from the substrate are released into the environment. For a drainage percentage of 20-30%, as an attempt to wash the remaining nutrient salts out of the substrate, the respective volume of NS released into the environment can reach 2,000-3,000 m<sup>3</sup>/ha every year, with a waste of fertilizers up to 8 t. With sub-irrigation systems, the NS is not leached or discharged into the environment and for this reason they are also indicated as "zero runoff



sub-irrigation" systems (ZRS). The most used ZRS systems are: "ebb-and-flow benches", "flood floors", "capillary mat" and "trough-benches". This was the topic presented by Prof. Pietro Santamaria from the Dipartimento di Scienze delle Produzioni Vegetali at Bari University.

According to Prof Santamaria, ZRS systems have several advantages compared to the traditional hydroponics systems: uniformity in NS supply, lower sub-

strate compression and significant water and fertilisers saving. From a survey in the USA, it has been pinpointed by the farmers that ZRS systems allow: (1) savings in labour (as required for the control and maintenance of drippers), (2) higher plant uniformity and (3) higher yield compared to the traditional irrigation systems.

ZRS systems have been studied and proposed mainly for growing small-sized ornamental potted plants, characterised by short growing seasons with limited water and nutrient requirements. In the Experimental Farm "La Noria" Santamaria studied some aspects of the trough-benches technique as well as its performance results for growing cherry tomato.

In the trough-benches system, the NS movement inside the pot occurs only in upward direction, which is promoted by: 1) the evaporation process from the substrate surface, and 2) plant transpiration. The unabsorbed mineral salts are subjected to a low but continuous movement of water towards the top layer of the substrate. As a result unused salts progressively migrate in the top layers increasing the salinity in the top portion of the substrate where there is no root growth. The ionic

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**DOMENICO PALUMBO**

mulch and/or it is difficult to cultivate among the rows, and (3) it is possible to couple fertilizer application (fertigation). The obtained increase in crop yield easily compensates for the installation costs of the AirJection® injectors installed with the subsurface microirrigation.

The advantages are linked to

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**LUCIA BORTOLINI**

composition of the aqueous extract of the pot substrate analysed after 2 months of tomato growing showed an ion concentration and ion ratios quite similar to those of the NS in the bottom layer, while in the middle and the top layer the concentrations of N, K<sup>+</sup> and Mg<sup>2+</sup> were lower. Conversely, those of Na<sup>+</sup>, Cl<sup>-</sup> and Ca<sup>2+</sup> were higher compared to that of NS.

By using the sub-irrigation technique the composition of the recirculating NS (the NS that returns to the reservoir after the irrigation practice) remains unaltered; then the NS management is easier, merely to control the pH and EC.

### A TECHNIQUE STILL QUESTIONED WHEN IT COMES TO USE SALINE WATER IN PROTECTED CROPPING

As indicated above, in protected horticulture closed-loop aggregate (substrate) cultures with drip (top) or

bottom irrigation (trough or ebb-and flow bench systems) are increasingly used since they can minimise water use and limit the environmental pollution resulting from nutrient runoff. In these systems, the nutrient solution drained from the growing medium is collected and recirculated after proper adjustment of pH and nutrient concentration, the latter being generally assessed by measuring electrical conductivity (EC). Other advantages of this technique are the labour saving for the irrigation and the possibility of a strong automation of the plant spacing during the growing cycle and during the commercialization. Nevertheless, some disadvantages have been an hindrance to the full commercial expansion of these irrigation systems such as the high investment costs and the need of a good quality of the irrigation water source.

In order to understand better the interaction of the use of saline water (EC = 1.5 dS/m, with 10 mM of NaCl) and the irrigation system (sub-irrigation or normal drip irrigation) on the growth and the yield of the potted horticultural crops, two different experiments on geranium and tomato, (respectively a medium sensitive and a medium tolerant crop to salinity) have been conducted by Luca Incrocci and Alberto Pardossi from the Dipartimento di Biologia delle Piante Agrarie, at the University of Pisa.

### HEARD ON THE SPOT



Courtesy of Prof. L. Sfr

*“The application of subirrigation on protected crops may cause problems when it comes to using saline water.”*

**LUCA INCROCCI**

In both experiments, they compared the growth and the plant yield on two closed-soilless systems that differed only by the irrigation system used (sub-irrigation versus the traditional drip irrigation). The changes of the recirculating nutrient solutions and of the growing substrate were also investigated.

The results obtained showed that the composition and EC of the re-circulating nutrient solution changed slightly in the sub-irrigation treated plots whereas in the normal drip treatments there was a fast water salination with the consequence of periodical flushing: for example, in the drip irrigation treatments, the nutrient solution was discharged in six different occasions for tomato (cycle length of 92 days) and two times for

geranium (cycle length of 120 days) with subsequent loss of water and fertilisers, while no change was necessary on the sub-irrigation treatments. Nevertheless, the substrate analysis confirmed that this lack of salt build-up on the nutrient solutions of the sub-irrigation treated plots, was substituted with a harmful salt accumulation in the upper region of the substrate, which was associated with high Na<sup>+</sup> content as a consequence of the upward nutrient solution movement in the substrate, coupled with selective mineral uptake by the roots. No significant influence of the irrigation method (normal drip or sub-irrigation) on total fruit yield and quality was observed in tomato culture; nevertheless, the sub-irrigation treatment produced a fruit weight reduction of 25% on the last truss harvested.

Also in geranium the two systems did not show relevant differences on the leaf area and on the total dry weight. However the salt accumulation occurred in the upper part of the pots had strongly reduced the shelf life of the geranium plant obtained by sub-irrigation mainly due to the fast dissolution of these salts as a consequence of the traditional drip or aspersión irrigation systems adopted by the final consumers.

As conclusions, the sub-irrigation with saline water may simplify the management of the re-circulating nutrient solution in closed-loop systems, but it can be used only with salt tolerant crops and for a short period (not more to three months). On the opposite, drip irrigation produces a fast build-up of salinity on the re-circulating nutrient solution with the consequence of more complication

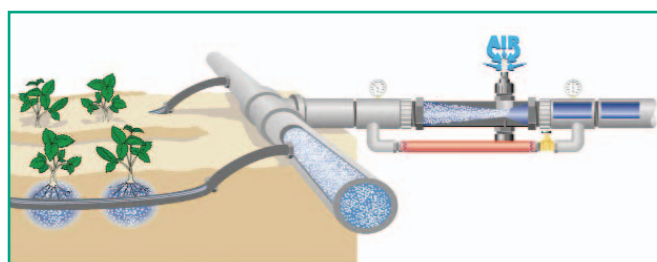
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*“By using the sub-irrigation technique the composition of the recirculating Nutrient Solution in recycled hydroponics remains unaltered; then the Nutrient Solution management is easier, merely to control the pH and EC.”*

**PIETRO SANTAMARIA**



on its nutrient management, but allows avoiding harmful salination of the growing substrate.

### SUB IRRIGATION MATS POSITIVELY TESTED IN ORNAMENTALS AND AROMATIC POT PLANTS PRODUCTION

Tests on the use of sub-irrigation with the aim of saving water have been conducted in the Savona's province, particularly on the Albenga's plain, (famous for its horticultural productions, so-called "primizie"), by the Albenga's section of Italian Confederation Agriculturists (Savona). The main purpose of the project presented in Bologna by Dr. Gianluigi Nario has been the introduction of particular mats for sub-irrigation of ornamentals



and aromatic potted plants. Thanks to their particular structure, such mats allow the water to go up again in the pot by capillarity, from the bottom towards the top. A more uniform wetting of the plants and a greater water and fertilizer saving are obtained in comparison to the traditional methods of sprinkling.

The Ligurian flower-farming production is the result of a process based on a huge employment of energy and water. As well the ornamental and aromatic plants pots are characterized by an elevated rhythm of growth and therefore they ask for a suitable restocking of water and nutrients.

To obtain a correct irrigation technique and the optimization of the water and fertilizing solutions employment it is essential to have a irrigation system able to distribute water to the crops with good uniformity.

In the specific case of the tests conducted in Albenga, the mat for sub-irrigation had three overlapped layers. The first one, IDROFLOOR, is an impermeable background mat for sub-irrigation with transversal micro-canaliza-

tion that favours the rapid and uniform distribution of the water. The second one, called IDROSUB, is a special mat for sub-irrigation realized in synthetic material with high capillarity that guarantees a rapid and

homogeneous distribution of the irrigation water. The third and last layer, called IDROTOP, is a mat of coverage spaced in a way that it optimizes the passage of the water both for fall and for reusable capillarity for many years. This cloth formed by three layers allows a rational management of the irrigation and a reduction of the leaching of the nutrients typical in traditional mats for flower-farming. In all the pilot farms total water savings reached about 50% in comparison to the control plots! The numbers speak for themselves.

### A BIG POTENTIAL FUTURE IN MANY CROPS AROUND THE WORLD

For SDI use on fruit and vegetable crops, tomato (fresh market and processing) is today the most popular, followed by lettuce, potato, and sweet corn. Other crops include apple, asparagus, banana, bell pepper, broccoli, cabbage, melons, carrot, cauliflower, pea, green bean, okra, onion, papaya, rape, squash, and floriculture. For agronomic crops, sugarcane, cotton and corn are the most popular. Others include alfalfa, grain sorghum, peanut, pearl millet, and wheat. Sub-irrigation has a solid future in most cropping systems around the world! As competition for water resources and the need for water conservation increases, applications of SDI should also increase. This technology offers the ability to very precisely place water, nutrients, and other chemicals in the plant root zone at the timing and frequency needed. With proper design, installation, and management, SDI systems can provide good and reliable performance for 10-20 years, concludes moderator Prof. Giorgio Gianquinto Prosdocimi. ■

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*"Thanks to their particular structure, the mats for sub-irrigation of ornamentals and aromatic potted plants that we tested allow the water to go up again in the pot by capillarity, from the bottom towards the top. A more uniform wetting of the plants and a greater water and fertilizer saving are obtained in comparison to the traditional methods of sprinkling."*

**GIANLUIGI NARIO**

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**GIORGIO GIANQUINTO PROSDOCIMI**