

DPI&F note

Sub-surface drip irrigation:

Crop management

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Crop choice

Sub-surface drip irrigation (SDI) has been successfully used with a range of field crops in Australia – these include row-crops (cotton, maize, sorghum and mungbeans) and broadacre crops (lucerne, millet, wheat).

If intending to grow lucerne with SDI it is advisable to grow another crop immediately following installation of the SDI system. This enables the field to be levelled through cultivation. If this is not done then the uneven surface caused by installation of the laterals will make it very rough on cutting, raking and baling equipment at the end of the block. This is achieved by installing SDI during winter and follow this with a short season crop like millet in spring, allowing enough time for seedbed preparation for lucerne planting in the following autumn.

Crop establishment

Generally crop establishment is achieved with an alternative irrigation system to the SDI system. In the absence of rainfall to fill the root zone prior to planting the SDI system is used to pre-irrigate the field.

Furrow irrigation has been used to pre-irrigate row-crops where the two metre lateral spacings are used – this configuration has been unable to irrigate adequately across seedbed for the crop to be planted on one metre rows. In other instances row-crops have been planted following rainfall. Another limitation of these two metre lateral configurations is the risk of planting the crop rows “off-target” to the drip tape. The result can be an uneven crop with alternating crop rows of good and poorer growth and maturity. This problem is now largely overcome through the use of GPS guidance technology. These problems are not of concern where one-metre configurations are used, but this is at a higher capital cost.

For broadacre crops lateral spacings closer to one metre are generally used – the most appropriate spacing for your soil type should be determined during the planning of your system. On some soil types pre-irrigation with SDI adequately wets the seedbed for crop establishment. The depth of lateral placement also affects the success of this. With a crop like lucerne, which requires surface moisture for establishment, most irrigators use an existing sprinkler irrigation system to establish the crop. Once established irrigation reverts to the SDI system. The need to have an alternative irrigation system available to establish the crop is generally not a problem as most SDI systems are installed by irrigators with existing sprinkler systems.

Irrigation management

Irrigation management with SDI is very different from that with traditional irrigation systems. SDI systems are designed for high frequency irrigation. Also, the volume of soil irrigated is less than with other systems. The technical skills necessary for proper system operation and maintenance are also greater than for other irrigation systems. Only very astute managers can successfully use SDI.

There is a small margin for error irrigating with SDI as the crop is operating with limited water and nutrient storage, particularly where wider lateral spacings are used in row crops. This limited capacity is the reason for the high efficiencies that can be achieved with SDI. The success of SDI is dependent on precise

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information on crop water use, soil water status and system delivery to meet the correct timing and amount of water and nutrients, and limit losses through deep drainage.

Irrigation scheduling

Scheduling the timing and amount of irrigation to achieve optimal crop performance is often limited by irrigation system limitations. One of the key advantages of a properly designed SDI system is that irrigation scheduling becomes a reality – the result can be increased yield and reduced water use, leading to improved water use efficiency.

The two most important factors for design and irrigation management are the peak water requirement and seasonal water use. The peak water requirement is the irrigation application rate needed to meet the largest crop water requirement. For Australian conditions this figure can be estimated using the Bureau of Meteorology Average Point Potential Evapotranspiration maps (<http://www.bom.gov.au/climate/averages/climatology/evapotrans/et.shtml>). The minimum capacity (Q_{\min}) is found using:

$$Q_{\min} = \frac{ET_{\text{peak}} \times A \times 1,000,000}{T \times E_a}$$

where

Q_{\min} = the volumetric flow rate for the block (L/hour)

ET_{peak} = peak water requirement (mm/day)

A = area of block (ha)

T = irrigation “on” time available (hours/day)

E_a = irrigation efficiency of SDI system (%)

Example

For a lucerne crop growing a Biloela in January the average point potential evapotranspiration is 270mm (8.7 mm/day). The peak requirement is likely to be 12 mm/day (based on experience). For a 5 ha SDI block irrigated with a 12-hour shift and an irrigation efficiency of 90% the minimum capacity is given by:

$$\begin{aligned} Q_{\min} &= \frac{ET_{\text{peak}} \times A \times 1,000,000}{T \times E_a} \\ &= \frac{12 \text{ mm/day} \times 5 \text{ ha} \times 1,000,000}{12 \text{ hours/day} \times 90\%} \\ &= \frac{60,000,000}{1080} \\ &= 55,556 \text{ L/hour} \end{aligned}$$

The actual system capacity should exceed Q_{\min} to meet irrigation demand and allow flexibility in scheduling irrigations. The frequency of irrigation depends on the water holding capacity of the soil. Soils with greater water holding capacity (for example, medium clay alluvials) are generally irrigated less frequently as they have sufficient buffer capacity to meet crop demand for several days compared to lower water holding capacity soils (for example, sandy loams) with less buffer capacity. The lighter textured soils may need to be watered daily with applications closely matching daily crop demand and as a way to minimise deep drainage losses. Crop demand also drives the irrigation frequency. A fully grown cotton crop in January will have a much greater demand than a lucerne crop which has recently been cut at the same time.

In heavier alluvial soils lucerne is generally irrigated every three to four days during summer with an application totalling around 30mm. During the cooler parts of the year demand is lower and irrigations are more likely to be on a weekly to fortnightly basis.

In SDI crops estimates of crop evapotranspiration (using weather station data) and soil moisture monitoring tools should be used to aid irrigation scheduling decisions. This is particularly important during the first season using SDI.

Soil water monitoring

There is a range of soil water monitoring tools that have been used in SDI crops – neutron moisture meters, capacitance probes (Diviner 2000, EnviroSCAN, C-Probes and GOPHER) and tensiometers. Properly located the information from these tools together with crop observations give a good indication of when to irrigate SDI crops.

The wetting pattern created by water released by the SDI emitter is a function of the emitter hydraulic characteristics and soil hydraulic properties. In a properly designed and maintained system the variation in emitter hydraulic properties along and between laterals should have only minor impact on this wetting pattern. Soil hydraulic properties are generally related to soil texture and structure. General the sandier a soil the greater the depth penetration of water due to gravity and the narrower the sideways movement of water from the emitter. This lateral movement is generally greater with finer textured soils like clays while downward movement is less. As a consequence, laterals are spaced more widely in finer textured soils and narrower in coarser textured soils to ensure adequate horizontal movement of water where this is required (in broadacre crops for example). The wetting pattern produced by SDI can be modelled using Wetup, a software program developed by CSIRO and available for download at www.clw.csiro.au/products/wetup. The best approach to determining the wetting pattern is to characterise it using the pit method described earlier.

Table 1 Suggested location for neutron moisture meter or capacitance probe access tubes to aid irrigation management in crops irrigated with SDI

Crop	Lateral Configuration	Location of Access Tubes	Purpose
Row crops (planted on 1m spacings)	1m lateral spacing	In crop row next to emitter	Indicate wettest part of the soil profile and most likely deep drainage site.
		Halfway between laterals and halfway between adjacent emitters	Indicates driest part of the soil profile
	2m lateral spacings	Halfway between crop rows and adjacent to emitter	Wettest part of the soil profile and most likely deep drainage site
		In crop row (adjacent to emitter which should be 500mm away)	Indicates water from emitter received directly below crop
Broadacre Crops	1m lateral spacings	Adjacent to emitter	Indicate wettest part of the soil profile and most likely deep drainage site.
		Halfway between laterals and emitters	Should indicate driest part of the soil profile

Knowledge of how water moves from the emitter determines the best location to place soil water monitoring tools. For example, locating the tools adjacent to the emitter will monitor the wettest part of the profile, while locating them halfway between laterals and adjacent emitters will monitor the driest part of the profile. Installing access tubes to a depth of 1m will cover the active root zone of most irrigated crops (including lucerne). However, monitoring the profile to a depth of 1.5m may be useful to assess deep drainage that could be occurring if the SDI crop is over-irrigated (if the readings at depth are in the saturated moisture range than deep drainage may not show up particularly in heavier textured soils as the deep drainage moves past the soil moisture sensor without altering the soil water content).

The type of crop and system configuration needs to be considered when locating the soil water monitoring equipment. Table 1 summarises possible locations and their purpose for different crop types and lateral spacings. It is important that several sites are monitored in each block – the ideal would be at least three sites with two access tubes at each site covering the likely soil moisture extremes as described in Table 1. If tensiometers are used it would be best to locate these closest to the laterals in pairs – a deep tensiometer (90cm) to monitor soil water changes at depth and a shallower one in the active root zone (60cm). Tensiometers should not be located in the driest part of the root zone (between the laterals) as it could be too dry for them to function properly.

In lucerne access tubes should be installed below ground level to avoid damage from cutting, raking and baling. One way to do this is place the tube inside a section of PVC pipe 100mm high inserted below ground level. Tensiometers can be installed in a similar fashion. Mark the location of the access tubes to aid locating them when taking readings.

Cropping practices interaction

The frequency of irrigation with SDI can result in a number of interactions with cropping practices not experienced with other irrigation systems. With row crops it is generally possible to carry out practices like spraying during SDI irrigation. This is particularly so with 2m lateral configurations. On 1m configurations some growers have found that surface wetting has made it difficult to spray without slipping onto the plant line. This has only occurred with shallow installations on some soil types where water surfaces during irrigation.

With lucerne, irrigations on shallow installations should be delayed prior cutting to avoid soil surface compaction from trafficking. This is less of a problem with deeper installations and on some soil types.

Salinity management

Water with higher salinity than that suitable for sprinkler irrigation can be used for SDI as the salt is leached away from the emitter to the outer margin of the wetted soil volume. As a result the root zone for row crops has lower salinity. However, this leads to an accumulation of salt midway between drip laterals and above the drip tape. Without adequate leaching this can significantly affect the growth of broadacre crops including lucerne despite its relatively good salinity tolerance. It shows up as poor growth midway between laterals.

Narrower emitter spacings along laterals helps minimise salinity build-up there. The shallower the tape the smaller the amount of rainfall or sprinkler applied water needed to carry salts below the drip tape, and the shallower the high salinity zone above the drip tape.

Water applied for leaching must leach the salts below the depth of the drip tape – below this depth the water applied by SDI will move the salts further downwards. To aid in the leaching of accumulated salts the SDI system should be used during rainfall events exceeding 12mm.

Nutrition

All SDI systems should include fertigation equipment – used to supply nutrients to the crop through fertilisers dissolved in irrigation water. The benefits over conventional fertiliser application include:

- More uniform application of nutrients
- Nutrient supply can be matched to crop demand at different growth stages
- More efficient application of nutrients through reduced losses. This could lead to reduced fertiliser use.

Use soil and tissue analyses to determine nutrient requirements. The choice of fertilisers to use depends on solubility, cost per unit of nitrogen, phosphorus or potassium, convenience and availability.

It is important that any fertilisers used in SDI systems are soluble. Dry fertilisers may have coatings that reduce their solubility – if used they can cause sludges or surface scums which could enter the drip system. Always check the solubility of any fertiliser product you are considering using. Also check the compatibility of fertilisers and chemicals you may intend using in the system. Adverse reactions from mixing chemicals include the creation of toxic gases, precipitates, slimes, phytotoxic mixes, and heat generation. Always perform a 'jar test' before using a chemical – add the chemical to the irrigation water to be used and check for any precipitates or cloudiness produced. Chemical mixes can be tested similarly. Use higher concentrations than expected in the system to allow for injection inaccuracy.

Urea is commonly used as a source of nitrogen in fertigation because of its solubility and lower cost compared to specialised mixtures such as calcium nitrate. Water cools when nitrogen fertilisers are added, reducing their solubility below that expected.

Care must be taken with injecting phosphorus fertilisers – irrigation water with calcium concentrations exceeding 2 meq/L can result in calcium phosphate precipitation that will clog emitters.

Potassium fertilisers have low solubility except for potassium chloride – the effect of chloride on the crop needs to be considered.

Monitor the effect of fertilisers applied through SDI on soil pH. Ammonium based fertilisers are acidifying. When applied to the restricted soil volume typical of SDI acidifying effects can be rapid. Choose products and rates that match crop requirements.

Crop protection

Care should be taken in selecting a block for SDI installation. Do not install blocks with a history of soil borne diseases and difficult insect problems like white-fringed weevil. High yields are required from SDI because of the high investment cost and the presence of difficult soil borne diseases and pests will seriously limit the possible return. Pests like white-fringed weevil not only attack the crop but also the SDI system. There are no pesticides registered in Australia for use through SDI systems. This limits options to control pests and root intrusion. Weed problems are minimised by SDI irrigation, as the soil surface remains dry during irrigations.

Crop performance

An international review of SDI showed that for over 30 crops the yield of SDI irrigated crops was greater than or equal to that for other irrigation methods. Yield improvements up to 50% have been recorded. The yield gains can be attributed to a number of factors:

- Improved timing and greater control over irrigation
- Improved crop nutrition through fertigation
- Improved crop protection through the use of particular pesticides and reduced disease incidence

Often these yield improvements have occurred while reducing applied irrigation volumes. The extent of water savings is determined by the efficiency with which existing system are applying water and the ability of the SDI irrigator to optimise their irrigation management. Savings of water up to 50% have been reported. It is also possible that water use might increase where existing irrigation systems are unable to meet crop requirements – a properly designed, installed and managed SDI system can better meet crop water requirements resulting in similar or slightly increased water use, and a substantial yield improvement.

Table 2 Performance of first SDI lucerne crop grown by Trevor and Lyn Stringer

Year	Irrigation Number		Irrigation Amount		Rain mm	Evaporation mm	Yield t/ha
	Sprinkler	SDI	Sprinkler	SDI			
1994-95	3	59	2.25	9.94	294	2009	25.4
1995-96	0	53		11.19	543	1946	26.9
1996-97	0	23		6.91	647	1820	23.4

This has been the experience with lucerne production in the Callide Valley where yield improvements of 25% have been achieved in SDI irrigated lucerne compared with traditionally sprinkler-irrigated crops. The yield improvement has largely been through an increased number of cuts resulting from the rapid regrowth of SDI lucerne after cutting. With SDI it is possible to irrigate a full lucerne area much more readily than with sprinkler irrigation that has higher labour demand and cannot be used under windy conditions.

Table 2 summarises the performance of the first lucerne crop grown with SDI by Trevor and Lyn Stringer between July 1994 and June 1997 (on 6.4ha).

The performance of this crop compares very favourably with the average sprinkler-irrigated lucerne yields achieved by the Stringers of 20 t/ha. This SDI development is still performing well although installed in 1994 – the result of good maintenance and management practices.

SDI economics

The economics and profitability of SDI depends upon the local conditions and constraints, particularly with respect to water availability and cost. There is a large capital investment in the installation of SDI systems with costs ranging from \$1600 to \$5000/ha. This range is a function of block shape and slope, bore capacity, water quality and lateral spacing. At the lower end of this range this cost is very competitive with alternative irrigation systems like furrow irrigation and sprinkler systems. At the higher end, serious consideration needs to be given to the possible water savings and yield benefits compared to your existing system before proceeding with a SDI development.

The development of SDI is most profitable when:

- The water supply is insufficient to optimise crop performance with existing irrigation systems (but there is an adequate and reliable supply over the life of the project which must exceed 10 years to produce high yielding crops)
- There are a range of higher return crops that can be grown
- The cost of water increases
- The irrigator has the skills and ability to maintain and manage the SDI system to ensure its longevity.

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Further information

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There are an increasing number of commercial irrigators experienced with SDI within Australia across a range of crops. If considering SDI you should discuss this with experienced growers as well as the experienced field staff of the major SDI system suppliers who can put you in contact with experienced SDI irrigators.

Information is also available on the World Wide Web through the Trickle-L Discussion List. This list has over 650 members (irrigators, manufacturers, resellers, researchers, extension personnel) in 35 countries. Details on joining this list can be found at the Microirrigation Forum Web site at www.microirrigationforum.com. This site contains archives of discussions related to drip irrigation (and SDI in particular) that you can readily examine.

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