DPI&F note

Sub-surface drip irrigation:

Advantages and limitations

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The objective of good irrigation management is to provide water to the plants when needed. Sub-surface drip irrigation (SDI) is the placement of permanent drip tape (trickle) below the soil surface, usually at a depth of between 20 and 40cm. Emitters along this drip tape emit water during irrigation.

There has been a rapid adoption of this technology by central Queensland irrigators since it was first installed in lucerne at Biloela in the early 1990s. Declining groundwater reserves in the Callide Valley provided the impetus for this development as a means to efficiently utilise diminishing water supplies. Over 600 ha of SDI have been installed since 1994.

A range of crops have been successfully grown with SDI – cotton, cucurbits, lucerne, maize, mungbeans, navy beans, sorghum and wheat.

There are a number of advantages and limitations of SDI systems that need to be considered by irrigators before investing in the system.

Advantages

There are several advantages reported and observed with the use of SDI.

Irrigation

There is a high degree of water application control with the potential for high uniformity of application. For new systems this distribution uniformity (DU) can be very high (93% or higher) compared with that experienced for sprinkler (60% to 80%) and surface (50% to 60%) irrigation.

The high frequency of irrigation with SDI allows maintenance of optimum soil moisture content in the root zone. This is important where salty water is used and with shallow rooted crops. With surface and sprinkler irrigation the fluctuation in soil water potential is greater, increasing the stress on the crop – the importance of this varies between crops.

Compared with sprinkler irrigation it is possible to irrigate regardless of wind conditions. Lower pressures are generally needed and lower flow per unit area, requiring smaller diameter mains and laterals.

Land levelling sufficient to enable drainage is required for SDI. This should be less than that needed for surface irrigation. SDI can be installed on a range of paddock sizes and shapes.

SDI maintains soil surface structure more effectively than other irrigation types and makes it easier to allow for rainfall events or "catch up", provided there is sufficient system capacity.

A well maintained SDI system requires less labour to operate than alternative systems.

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Crop agronomy

The partial soil wetting provided by SDI has several benefits:

- Improved efficiency of nutrient uptake at the fringes of the wetted soil volume;
- Less water lost from soil surface evaporation;
- Less weed germination and growth;
- Unrestricted travel for field operations such as spraying and harvesting;
- In some row crop situations better use of rainfall as there is always a dry zone between laterals for infiltration.

Applying water through SDI maintains dry crop foliage. The benefits include reduced incidence of foliar disease, reduced loss of applied pesticides, reduced evaporation losses direct from the crop canopy and less leaf burn where saline water is used for irrigation.

Saline irrigation water applied through SDI will have less effect on crops than if applied through surface or sprinkler irrigation. This is due to:

- No foliage absorption of salt;
- High frequency drip irrigation reduces the effect of increased salt concentration of the soil solution between irrigations compared to the lower-frequency of surface and sprinkler irrigation;
- Leaching of salts from the active root zone to the outer part of the wetted soil volume.

Fertigation (the application of fertilisers in solution) can be used with SDI. The possible benefits include:

- Savings in labour;
- More efficient use of nutrients and less risk of nutrient leaching;
- Enhanced timing of nutrient applications to match crop requirements according to development stage and crop condition.

Water use efficiency

Usually SDI water use savings range from 0 to 50% when compared with traditional irrigation systems (Camp, 1998). In situations where water savings are not made there is often a significant yield increase resulting in improved production per unit of irrigation water – improved water use efficiency (WUE).

For spray irrigated the lucerne in the Callide Valley the long-term WUE is 1.37 t/ML. The WUE for SDI lucerne grown by Trevor and Lyn Stringer at Biloela can be seen in Table 1, along with a direct comparison between SDI and spray irrigated lucerne on the Biloela Research Station. Here the improvement in WUE of SDI compared with spray irrigation has been 43% in 1996-97 and 95% in 1997-98. SDI and furrow irrigation comparisons for cotton are given in Tables 2 and 3.

Yield improvement

Improved yields have been a feature of SDI installations. For lucerne the yield improvement was 13 and 34% for 1996-97 and 1997-98 respectively. For cotton the yield change ranges from 0 to 21%.

Table 1 SDI and spray irrigated lucerne comparisons

		Subsurface Drip				Handshift Sprinkler Irrigation			
Grower	Year	Yield t/ha	Irrigation ML/ha	Rain mm	WUE t/ML	Yield t/ha	Irrigation ML/ha	Rain mm	WUE t/ML
Stringer	94-95	24.95	12.19	294	1.65				
Stringer	95-96	26.45	11.19	543	1.59				
Stringer	96-97	22.98	6.91	647	1.72				
Biloela RS	96-97	21.23	5.59	720	1.66	18.88	9.03	720	1.16
Biloela RS	97-98	16.98	6.48	400	1.62	12.68	11.30	400	0.83

Table 2 SDI and furrow irrigated cotton comparison from commercial areas at Biloela

		Subsurface Drip				Furrow Irrigation			
Grower	Year	Yield bales/ha	Irrigation ML/ha	Rain mm	WUE bales/ML	Yield bales/ha	Irrigation ML/ha	Rain mm	WUE bales/ML
Grower B	95-96	10.13	4.69	430	1.13	8.40	5.68	430	0.84
Grower C	95-96	8.65	2.17	430*	1.34	8.65	5.43	430[2]	0.89
Grower B	96-97	9.26	3.71	364	1.26	8.89	5.19	364	1.01
Grower B	96-97	10.32	3.71	364	1.40	8.89	5.19	364	1.01

* Accurate rainfall figures unavailable so rainfall for Grower B used to estimate WUE

Table 3 SDI and furrow irrigated cotton comparison demonstrations – 2000-01 to 2002-03

	Subsurface Drip				Furrow Irrigation			
Year	Yield bales/ha	Irrigation ML/ha	Rain mm	WUE bales/ML	Yield bales/ha	Irrigation ML/ha	Rain mm	WUE bales/ML
Dalby (1m beds)								
2000-01	10.0	4.50	396	1.18	7.98	5.30	396	0.86
2001-02	8.78	4.20	440	1.02	8.20	5.60	440	0.82
2002-03	10.1	2.90	608	1.12	9.80	5.60	608	0.84
Moree (2m beds & 40cm deep tape)								
2000-01	7.36	3.73	150	1.41	7.80	6.00	150	1.04
2001-02	7.42	3.29	184	1.45	6.80	5.85	184	0.88
2002-03	8.37	2.60	62	2.60	10.18	7.27	62	1.29

(**Source:** T-Systems Australia Pty Ltd)

The above advantages are “typical” and not necessarily universal. Success with SDI is a function of good design, good installation, good maintenance and good crop management.

Limitations

Emitter clogging

The high distribution uniformity inherent in a well-designed SDI system can be readily destroyed through emitter clogging. The orifice diameters of emitters are usually 0.5 to 1 mm^2 and are susceptible to clogging by root penetration, sand, rust, microorganisms, water impurities and chemical precipitates. This clogging is usually the result of insufficient water filtration, lateral flushing and/or chemical injection.

Root penetration has generally only been observed in perennial crops like lucerne where the soil has dried out around an emitter and the roots penetrate the emitter seeking water. On system shutdown water will flow to the lowest point in the field. If air is not allowed to enter the system by means of an air/vacuum release valve a vacuum will be created and soil is sucked back into the emitter. On undulating fields it is possible for this to occur throughout the field resulting in emitter clogging. The soil dries out around these emitters and roots penetrate the emitter seeking out water and further blocking the emitter. This problem is avoided through:

- proper design (including the strategic location of air/vacuum release valves)
- field preparation (levelling to drain)
- high frequency irrigation that produces a permanently saturated soil zone around the emitter – this discourages root growth.
- chemical treatments - there are no herbicides registered in Australia to prevent root intrusion.

Root hairs that have penetrated an emitter can be burned out with hydrochloric acid.

Sand is readily removed from water using centrifugal separators. Suspended organic matter and clay particles can be separated with gravel filters, disk and screen filters. If the supply water has more than 200 mg/L suspended solids than a settling reservoir is recommended before the enter enters the filtration unit – above this level the filter system will be overloaded resulting in excessive backflushing.

Bacterial slimes and algae growing on the interior walls of the laterals and emitters can combine with clay particles in the water to block the emitters. Bacterial precipitation of sulphur and iron is a further problem. These must be treated with chlorination.

Chemical participates causing emitter clogging include:

- iron oxide – where the iron concentration is greater than 0.1 mg/L in irrigation water. Iron bacteria further exacerbate the problem.
- manganese oxide – where the manganese concentration is greater than 0.1 mg/L in irrigation water.
- iron sulphide - where the iron and sulphide concentrations are greater than 0.1 mg/L in irrigation water or nutrients containing iron are injected into sulphide-bearing water.
- carbonates – resulting from bicarbonate levels above 2 meq/L in water with a pH of 7.5 or higher, and there is calcium at similar levels or a fertiliser containing calcium is injected into the system.

Salt accumulation

When saline water is used salts accumulate at the wetting front. In SDI this results in an accumulation of salt above and mid-way between the laterals. Where there is insufficient rainfall to move salt below the root zone this accumulation will affect the growth of the current crop (even a relatively salt tolerant crop like lucerne) or the establishment and growth of subsequent crops.

Mechanical damage

SDI laterals must be installed at the required depth below the ground surface along the full length of the field. To achieve this cross-rip the field and ensure that the turn-out area at the end of the lateral run is the same level as for the field (otherwise the lateral will be installed at different depths at the end of the field.

Mice damage can be significant on cracking soils used to grow grain crops. Do not let these soils crack open between crops by using some irrigation water to keep the soil about the lateral closed up.

Insect damage has been a significant problem on some SDI sites. There are a number of possible insects that chew through SDI tape. Damage has resulted from crickets, earwigs, false wireworm larvae and white-fringed weevil larvae. Care needs to taken in choosing and preparing the field for SDI, in its installation and maintenance in order to minimise the negative effect of insect damage. There are no insecticides registered in Australia for the control of insect pests for SDI systems.

Crop establishment

Soil type and the depth of placement of the SDI laterals will determine the ability of the system to wet the soil surface to aid crop establishment. In most situations crops cannot be established using SDI alone. Where it has been installed on farms with existing sprinkler or furrow irrigation systems these have been used to establish the crop. In some situations the SDI system has been used to pre-irrigate the crop and fill the soil profile, with planting following rainfall. Using SDI to fill the profile prior to crop establishment runs the risk of deep drainage as water is being released below the soil surface – this can negate the possible benefits of the system in improving crop WUE.

Soil structural effects

In certain soils the use of high quality water through SDI has resulted in increasing clay content, exchangeable sodium percentage and calcium:magnesium ratio away from the emitter. The result is a decrease in the lateral spread of water from the emitter during irrigation and a smaller effective root volume.

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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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