5.6 Drip irrigation: design, installation and management

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Key points

- A system designed by a row crop engineer who is experienced, preferably in cotton, is critical to achieve the potential water savings and flexibility in crop management that drip irrigation can offer.
- A well-planned maintenance program is essential to maintain proper system operation.
- It is important to monitor and control the quality of water used with the drip system, which determines the frequency of flushing required.
- Drip allows accurate application of water and fertiliser to suit crops' requirements and flexibility in field operations, but the management requirement is higher than conventional surface systems.

Drip irrigation has the ability to optimise water and fertiliser use in row crops. When crops are irrigated daily with small volumes, the potential yields can be increased and maintained, or crops can be finished faster in short season areas.

Drip irrigation is a relatively new technology. It has been used in row crops for just 20 to 30 years. In Australia, drip has become the standard irrigation method in high value permanent crops. Worldwide it is becoming more widely used in row crops.

The widespread adoption of this technology has been largely restricted by high costs involved in setting up a system. With the increasing pressures on growers to increase water use efficiency and maximise production, drip will definitely play a role in many developments.

Drip irrigation is a system of pressurised water run through tubes placed in the field. Emitting devices are placed at intervals along the tube, so water is distributed uniformly. In most row crop situations today this tube is buried, and known as **subsurface drip irrigation** (SDI).

With SDI, water is placed into the plants' root zone, and therefore losses due to evaporation and run-off are minimal. The uptake of the applied water can be very efficient with accurate management, as water is applied daily with fertiliser added as required.

The system capacity is measured in millimetres per day. Systems are most often designed to replace the peak potential daily use of the crop, around 12 millimetres per day. Systems should not be designed for a lower supply rate because the risk of under-supply is increased if rain doesn't arrive as expected. Each day the grower can alter the applied water to keep soil moisture levels in optimum range. Soil moisture levels can also be manipulated to influence crop growth habit.

The practice of fertigation, or irrigation with fertiliser added, is as important as water is with drip irrigation. Soluble fertilisers are taken up faster and more effectively, and fertiliser can be added daily, reducing leaching and soil losses. Drip has the ability to apply very small quantities of elements, uniformly and precisely as required with irrigation water.

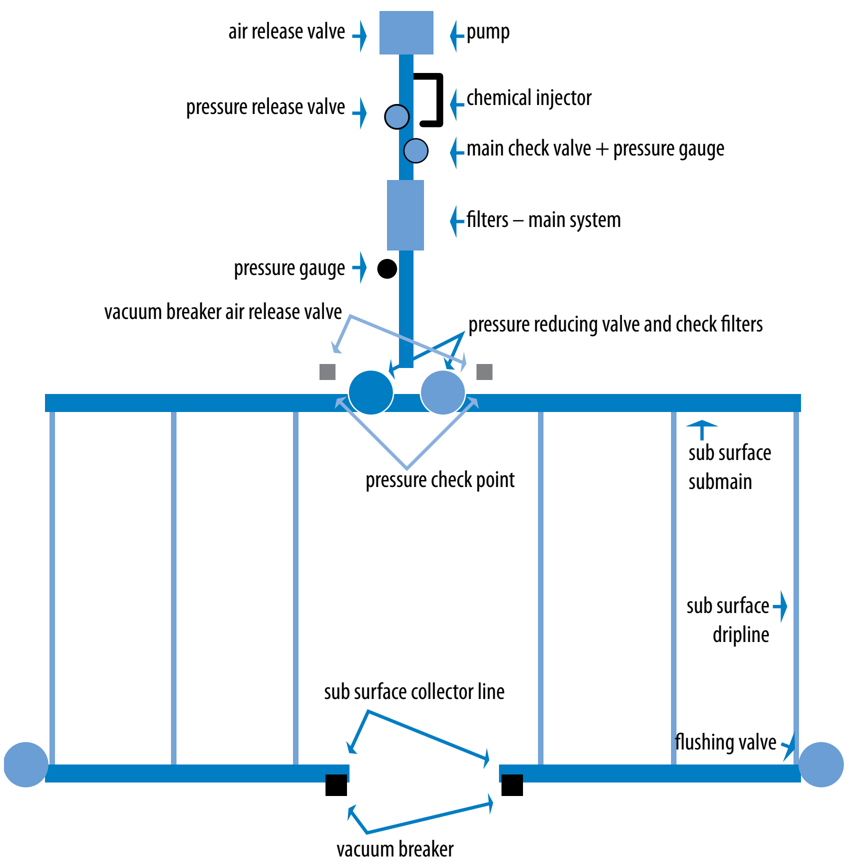
For further information, refer to WATERpak chapter 5.8.

Design of drip systems

A drip system contains some standard components (Figure 5.6.1), but each system is tailormade to the fields' requirements. Soil, water and farming systems all play a part in the system's specifications. As a result it is difficult to compare outcomes.

It is important that a prospective user of drip irrigation assess their aims and goals prior to a system being designed.

Figure 5.6.1. A typical drip irrigation system design



SDI systems require the following components:

Pump – carefully selected for performance and safety, an SDI pump's performance curves will often be 'flat' with maximum pressures below that of the pipelines.

Filtration – variety of filtration methods, sand media or disc filtration being the most common. Nearly all are automatic flushing. Micron or 'fineness' of the filters is determined by the drip tube manufacturer – they do not all have the same requirements! (Figure 5.6.2).

Pressure gauge – to check pump output pressure and pressure after filters; difference between the two is how blocked filters are.

Fertiliser injector – pumps or venturis for fertiliser injection and maintenance.

Water meter – for performance checks and safety.

Controller – an electronic computer runs field valves and system safety; also turns pump off and sometimes on.

Mainlines – Mostly PVC, designed for cost-effective movement of water to fields.

Air valves – very important that these are installed and working. Trapped air can compress, releasing at pressures much higher than pipes are designed for. Air valves are located at all valves and high points in mainline, and must release air whilst under pressure; they are often dual purpose air/vacuum release.

Valves – mostly hydraulic regulating valves, these reduce pressure from mainline to suitable operating pressure for drip lines. Require pressure check points either side for setting valves and checking performance.

Vacuum release valves – these are important to let air back in after system shut down, are located downstream of valves and at all ends of submains and flush collection manifolds, and prevent air including mud being sucked back into emitters.

Submains – critical to system uniformity, drip tube is connected to these; they are positioned after valves, so pressure differences relate to dripper flow rates.

Drip tube – the real key to system operation. Various flow rates, spacing of emitters and diameter of tube. These attributes all play a part in run lengths and costs and uniformity, and can be confusing. Should be determined by soil types and uniformity and flushing ability. Wall thickness is also an issue; a thicker wall is more resilient to damage.

Emitters – not all emitters are the same: they vary in clogging resistance, CV (coefficient of variation, that is, emitter uniformity), size of flow path, ability to clean inlet filter, length of labyrinth (shorter path means more efficient, more turbulent and easier to clean). Beware of low flow rate emitters in long-term systems.

Flushing manifold – the collection pipe where drip tubes are connected, these are opened for flushing out dirt. They are not necessary but greatly reduce maintenance times. Also, they have more vacuum release points.

Figure 5.6.2. Filtration equipment

An experienced, qualified irrigation designer should design all drip systems. For cotton systems they should be experienced in row crop designs and have a record of successful projects. The designer should consult with growers and consultants to ensure the project has the highest chance of success, fitting with farm infrastructure and long-term farm plans. To do this the designers must have adequate information to work with. This will include: accurate GPS maps and contour maps showing 0.5 m variations in slope, field layout and size, access and roads, soil properties and possible changes in soil types. If field conditions are variable, this detail will enable the designer to develop a system that will allow separate within-field management. A detailed soil survey may also be useful.

Almost all SDI row crop systems use non-compensated emitters, meaning the output changes with pressure. Uniformity is a major issue in design and can be complex. Systems can be designed much more cheaply if uniformity is compromised. This makes management very difficult always having to manage for the 'middle or dry' areas. Uniformity is measured in a few ways, the most accurate being **field flow variation (FV)**. This is represented as a percentage, for example, FV ±7% means all emitters in the block or valve will perform better than 7% either side of the specified flow rate of the design. Few row crop designs are adequate beyond ±7% FV. It is important to compare similar uniformity measurements, as it is easy to confuse them.

Installation of drip systems

Good installation can improve performance and longevity. Extreme care and high levels of supervision are required to ensure systems are installed correctly and best suit the farm and the grower. Often problems can be avoided if small changes are made to placement of flush points and other equipment. There should be almost no aboveground components within fields, locating flushers and valves beyond fields, or they can at least be grouped and protected.

Accurate injection of tube is also critical and specialised equipment is available for placement (Figure 5.6.3). Emitters should always be positioned facing upward and into loose soil. Bed preparation and pre-ripping can make accurate depth and location much easier (Figures 5.6.4 and 5.6.5). The use of global positioning satellites (GPS) is now considered essential, making relocation of beds possible over time.

Figure 5.6.3. Tube installation equipment

Figure 5.6.4. Depth of tube placement is critical

Figure 5.6.5. Placement within bed system prior to sowing

Drip tube connections should be perfect. Risers from pipelines should be accurately drilled. Extreme care is needed filling trenches. The system should be pressurised and loose fill delicately pushed into trenches to prevent movement and kinking of risers or tube.

Accurate depth and straight trenches with smooth, soft floors will allow good support of pipes (Figure 5.6.6). PVC pipe, elbows, reducers and ends should be adequately thrusted to prevent movement, following the pipe manufacturer's instructions. Valves and command tubing should be supported if required, and protected from machinery and animal damage. Control systems need to be electrically protected from both supply and lightning.

Figure 5.6.6. Trench construction

Photograph all major valve assemblies and pipe junctions before backfilling. This is a big help if they ever need repair.

Maintenance of drip systems

Like any complex system or machine, drip systems need maintenance to prevent breakdowns and loss of performance.

Maintenance requirements need to be included in the design. Drip tube sizes and run lengths are often determined by flushing capability. Keeping systems clean, particularly on silty river water, is the key to emitters' longevity. The tube and emitters don't degrade or break down. If kept clean, very long life can be expected – often, with the high cost of establishment, 10 years or more. There are systems that have been well maintained that are beyond this age and performing as new.

Maintenance is largely preventative, with silt and organic matter needing to be removed with water. Inlet water pressure to tubes may need to be raised to achieve scouring velocity in the tube once ends are opened. This will be indicated on the design. Frequency of flushing is determined by water quality. Monitoring system flow rates on the water meter can reveal emitter clogging.

Flushing needs to be commenced from the pump onwards. Ensure filters are cleaned well and pressures set. Progress systematically, cleaning mainline, submains, then drip lines.

In most situations additives such as chlorine and acid may need to be used. Chlorine kills algae and can loosen up bonded organic matter, enabling it to be flushed out afterwards. It is important to understand there is no particular volume of chlorine that will achieve this task. Silt and organic matter consume chlorine as it proceeds through the system. An injection rate of chlorine can be calculated and must be injected until free or spare chlorine is sampled at the farthest point. Rates of between 5 to 20 ppm chlorine may be required, depending on the severity of the problem. Irrigation suppliers and some manufacturers can supply the necessary technical help to keep this job as cost-effective as possible.

Acid injection is often over-recommended. In other parts of the world, acid is very cheap and can be used in place of chlorine, although high rates are needed. It should really only be used for chemical-based deposits, and works on the basis that solubilities of chemicals change with pH. By dropping the pH of water, these chemicals may become soluble again and can be flushed out.

To accurately calculate the volume of acid required to drop the pH of the irrigation water, simply perform a bucket titration. Get 10 litres of irrigation water; add acid one millilitre at a time and test pH until water drops to desired pH. Using these measurement and system flow rates, an injection rate in litres per hour of acid can be calculated.

ADD WATER TO ACID!

The exception in the use of acid is for root intrusion, where the corrosiveness of the acid is used to break down intruding root material. Very high rates are required and it is very expensive. Prevention is by far the best method.

Strategic use of herbicides is effective in preventing the roots' entry to emitters. When injected late in the irrigation, herbicide stays close to the emitter outlet, making this an unattractive area for the roots to enter. Careful cutting back of water can also reduce the tendency for roots to search for more water.

Before and after addition of acid or chlorine the drip systems should be flushed strongly with water. This reduces consumption of chlorine and buffering of pH by silt and organic matter that are easily removed. Flushing after treatment is important to prevent loosened material attempting to exit through emitters and clogging them.

Pumps, filters, valves and control systems also need maintenance. This can most often be carried out in the off-season. Suppliers and some manufacturers can provide advice or a service to do this work.

In summary

Drip irrigation is one of the most powerful agronomic tools available to the grower. It allows accurate application of water and fertiliser to suit crops' requirements and push plants to achieve their potential. Field access is increased with no flooded period. Labour costs can be reduced, with large areas being centrally controlled. Grower lifestyle can be improved with planned tasks and little odd hours or heavy work. Complex fertiliser regimes or watering strategies can be implemented easily. Drip systems can be designed to suit irregular fields and difficult soil types. Many current systems are purchased for this reason alone.

As demand increases for higher crop production with efficient use of resources, drip irrigation will provide the ability to accurately manage crops to achieve the forward-thinking grower's goals.

The best way to determine if drip irrigation is suitable for your situation is to talk to other growers who are using this system. Your local extension officer should be able to connect you to such growers. Some examples of growers who have used drip irrigation for cotton are available online and in the case studies that follow.

Case study 1 - evaluating drip irrigation: Lower Namoi Valley

Steffan Henggeler

Integra Management Systems

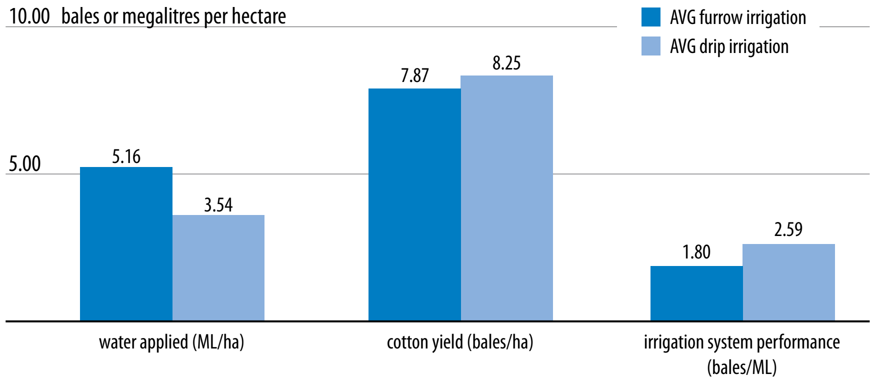
Irrigation system performance

The drip system installed at Auscott Narrabri worked very well with only minor technical problems. One of the issues we faced was that the lines and at the head ditch end of the field were not buried deep enough and therefore dug up a couple of times while scarifying the rotobuck area. Diligence when installing drip systems is crucial.

The system performed well and even issues such as watering up after planting were not a problem in our soils.

The yield results over the four trial years were quite consistent, with small variability only. The fourth trial year (1999-2000) is not included in Figure 5.6.7 but has performed very similar to the average of the first three years: because it was a cool season, water savings were not quite as high, but still around 20%. Yield difference was 0.395 bales/ha before ginning in favour of drip, and therefore pretty much the same as the 3-year average.

Figure 5.6.7. Increased irrigation performance of drip irrigation compared to furrow irrigation



(Note: No measurement of deep drainage or evapotranspiration)

It should be noted that both yields and furrow irrigation performance have increased dramatically across the industry since 2000 and will most likely continue to do so in the future. Therefore, it is imperative that growers considering investment in alternative systems investigate the recent performance of these systems by talking to other users and searching for up to date research and trial results.

While the system itself performed technically very well, the necessary yield differences to pay for the additional capital investment for drip irrigation were not achieved under the soil and climatic conditions of our trial.

For this reason, the drip system was moved from Auscott Narrabri to Auscott Warren, where it is very successful on a red soil. The yield difference achieved in the first year on red soil of 1.73 bales per hectare made drip irrigation a valuable investment at this site.

Additional benefits

Substantial water savings (20% to 30% of applied water) were achieved using drip versus furrow irrigation, even on heavy clay soils. Those savings are likely to be even higher on lighter soils.

However as furrow irrigation performance across the industry has increased, the water savings offerred by alternative systems may not be as large as they once were. Recent research into CPLM systems has indicated the magnitude of water savings has decreased (see WATERpak Chapter 5.5) and the same may be true of drip irrigation systems.

Drip irrigation allows the usage of ground rigs all season (except after rain) and therefore reduces the risk of off-target chemical drift as well as decreasing insecticide cost early in the season (banded sprays).

Drip reduces the need for physical labour and therefore potentially reduces the chances of workers compensation costs. It also suits an older workforce (experienced irrigation operators with reduced physical abilities).

Drip reduces soil erosion and therefore decreases de-silting costs. It is also better suited to zero-till farming systems than furrow irrigation because it avoids waterlogging.

Financial considerations

Drip systems should probably be installed on land not previously developed for irrigation, because when considering the capital put into development, you do not work with the full development cost, but only the difference between the cheapest option (for example, furrow irrigation) and drip irrigation.

The capitalisation of water savings (in our case, around 1.5 ML/ha @ $1200/ML) needs to be taken into account to be able to justify drip irrigation versus other irrigation systems.

To capitalise on the great expense, soils should be chosen for new systems that favour drip irrigation and are less suitable or even unsuitable for furrow or lateral move. This will increase the yield benefit and therefore the return on capital, hence the recommendation to move our drip project to Warren.

Choose a field protected from flood and other external influences to protect invested capital.

Centre-fed systems are less expensive than side-fed systems, mainly due to decrease in cost of laterals.

Issues when considering drip irrigation in cotton

Some design specifics for the Auscott trial site:

- 1 lateral tape around 25 cm deep every 2 metres, in the middle of the wide bed
- 1 dripper/50 cm @ 1.1 L/h

Design of filtration to take muddy water out of a channel

The maximum row length for 35 mm tape seemed at the time to be 700 metres. No valves, fittings or joiners are in the field. The problem is not system uniformity while the system is applying water, but to achieve water flows fast enough when flushing the system when longer than 700 m. Using long run length therefore demands less frequent irrigations to minimise the filling and emptying times of the lines as the main source of bad uniformity in 35 mm tapes.

To my knowledge, it is still doubtful to date (2002) if 700 metre drip tapes are successful.

Centre-fed systems require a tail drain in the middle of the field to allow access to submains and fittings during the season and still drain off stormwater. Practically, it means that fields are split in half to a maximum length of 400 to 450 metres.

Do not under-design a system in regards to its capacity to save on initial capital costs! The system needs to be designed to be able to grow the highest yields possible to make it worthwhile. The Auscott trial system was designed to supply 13 mm per day.

EnviroSCAN® tubes proved themselves very well suited for scheduling water applications. Soil moisture can be monitored on a regular basis to avoid deep drainage. In our heavy clay soils, 6 hours application per irrigation and section was ideal to keep the water in the root zone. On lighter soils the optimal application time is likely to be shorter.

The installation of a good fertigation injection system is very important. Evidence from other drip systems suggests that spoon-feeding of nutrients through drip could give additional yield benefits we have not yet explored in our trial. We installed a very simple and cheap but effective system using a mixing drum, separate water supply through a float valve and a fire fighter to inject fertilisers.

Absolutely crucial are a well-designed maintenance system and a maintenance procedure to avoid silt and algae build-up as well as root intrusion.

The quality of the installation will make or break a system. Purchasing a fully installed system should be considered instead of doing some of the critical jobs yourself. This approach clarifies the responsibilities when potential system faults occur.

All parts and fittings have to be checked by the owner of the system for leaks, kinks and so on before trenches are filled in. Avoid being caught by rain while the trenches are still open. The order of installation of the different system components is also very important: **laterals last.** Laterals have to be filled with water as soon as possible after installation to reduce the risk of insect damage.

Suppliers and installers offer after-sale service to get the system working to its full potential (irrigation scheduling, fertigation and maintenance).

Case study 2 - evaluating drip irrigation systems: Yambocully

Peter Cross
Corish Farms, Goondiwindi

We decided to give subsurface drip a try after hearing about the water savings to be made and looking at some of the systems in the Macquarie Valley.

The area we were looking at to develop was a ridge in the middle of the farm. This area was impractical to develop for furrow irrigation because of the amount of soil to be moved and the number of point rows we would create.

Our reasons to go ahead with subsurface drip were:

- water savings to be had
- use of land inside developed area
- keen to give it a go
- potential for higher yields.

Summary of our experience

Negatives of drip:

- high capital costs of installation
- potential problems of wet harvest
- some soil types are hard to wet up
- life expectancy of tape is unknown
- thin walled tape is prone to insect damage

Positives of drip:

- lower water use – 35% to 40% less than furrow irrigation
- higher yields
- less crop stress due to waterlogging
- able to use rainfall more effectively
- fewer OH&S issues – for example, less manual handling, less chemical contact when watering while spraying
- lower labour costs
- better soil tilth (in our case)
- fewer workings
- fertigation – feed as you need
- greater ability to use stored water at the end of the crop
- use ground unsuitable for furrow irrigation

Must haves:

- natural drainage
- system that can deliver peak daily water use of crop
- good distribution uniformity
- good filtration
- soil moisture monitoring tools
- maintenance program
- correct installation (use a guidance system)
- position valves to suit soil types and slopes

The system has worked well for us, especially the second installation with heavier tape. We have achieved a water saving over the last 4 years of 35% to 40%.

This has enabled us to grow 2 bales of cotton for every megalitre of water applied consistently.

Drip versus furrow irrigation: 1999–2000 and 2000–01 seasons

Introduction

The two seasons were very different, with 1999–2000 having almost perfect growing conditions, which produced some very high yields, while 2000–2001 was almost the opposite with some very low to moderate yields. This was caused by some adverse climatic conditions – an extremely wet November, followed by a very hot January and another very wet period in January/ February. However, there were still some significant differences between drip and furrow irrigation fields.

Outcomes

The main difference between furrow and drip irrigation was still the water saving (Table 5.6.1) plus a small increase in yield under drip irrigation (Table 5.6.2). Table5.6.3 notes the increase in bales produced per megalitre with drip.

Table 5.6.1. Water savings made under drip irrigation

Megalitres of water applied ML/ha		
Season	Furrow	Drip
1999-2000	7.0	4.2
2000-2001	7.2	5.0
Average	7.1	4.6

The increase in water usage under drip in 2000-01 was caused by the very dry winter, with drip using 1.6 ML/ha to wet up at planting time.

Table 5.6.2. Yields for both seasons under furrow versus drip irrigation

Average yields Bales/ha		
Season	Furrow	Drip
1999-2000	9.02	10.34
2000-2001	7.7	8.1
Average	8.36	9.22

Table 5.6.3. Bales per megalitre produced for both seasons: furrow versus drip irrigation

Bales/ML		
Season	Furrow	Drip
1999-2000	1.28	2.46
2000-2001	1.08	1.6
Average	1.18	2.03

Case study 3 - Oxygation: using aerated irrigation water for drip irrigation

Lance Pendergast
DAFF Queensland, Emerald

Oxygation is a term used to describe the use of aerated water (at the rate of 12 per cent air by volume of water), for subsurface drip irrigation. Positive effects of oxygation were noted consistently on lint yield over a number of seasons without the need for additional water application.

A long-term oxygation field study from 2004 to 2012 on a vertisol soil at "Nyang" Emerald measured the effects of oxygation on cotton lint yield, quality and water use efficiency (WUE), as well as long-term changes in soil chemical, physical and biological properties.

The trial aimed to determine the longer-term effect of oxygation and evaluate aeration uniformity and crop performance along the lateral row length.

In the first two seasons the effect of oxygation was quantified at two irrigation rates (85 per cent and 105 per cent of crop evapotranspiration (ET_c). In 2006/07 there was insufficient water for the trial due to drought. In the 2007/08 and 2008/09 seasons only one irrigation rate (85 per cent ET_c) was tested. In subsequent seasons, the irrigation rate was increased to 100 per cent.

Positive effects of oxygation were noted consistently on lint yield over a number of seasons. Yield increased with oxygation in all trial years when irrigation rate was maintained at 85 per cent of ET_c or above. An increase in WUE was associated with higher yield in the oxygation plots for the same amount of irrigation water applied. Yields in all years benefitted from oxygation, although the difference was not statistically significant in every year. The average yield increase across all years was 14.7 per cent (Table 5.6.4).

Table 5.6.4. Lint yield (bales/ha) was generally higher in oxygation plots

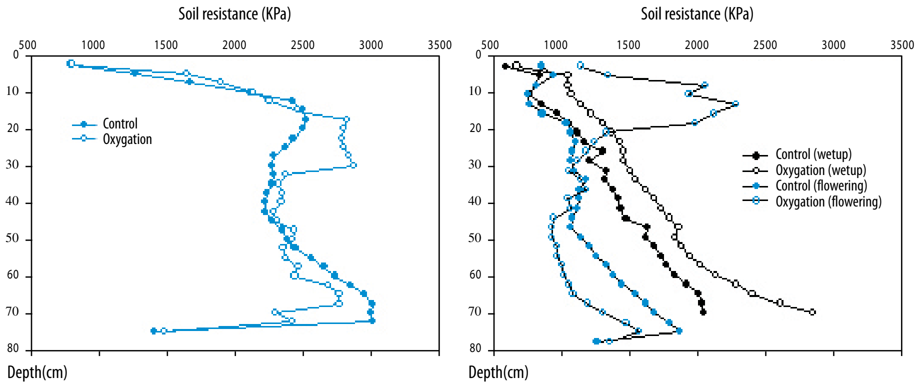
Treatment	2004/05	2005/06	2007/08	2008/09	2009/10	2010/11	2011/12	Combined
Oxygation	9.32	9.33	8.84	6.90	9.11	9.04	11.21	9.10
Control	7.35	8.02	7.89	6.47	8.33	7.71	10.62	8.05

A number of controlled environment studies suggested that the aeration can be non-uniform along the drip lateral. Intensive plant sampling and data collection along the length of drip line was conducted in a number of seasons.

Field data from the trial in 2005/06 suggest that there is no major difference in terms of benefit of oxygation along a drip line until beyond 165 metres from the start of the drip line.

Likewise in 2008/09 and 2011/12 there was no differential effect of oxygation according to distance from the air injection point, although in both the latter years there was an indication of a positive effect further from the injection point.

Figure 5.6.8. Soil compaction was often higher in the oxygation plots.
Left – at the end of the 2008 - 09 season.
Right – during wet up and flowering stages in 2010-11.



We did find effects of oxygation on soil penetrometer resistance, which increased with oxygation due most likely to the more effective water uptake and drying of soil with oxygation (Figure 5.6.8). Soil biological activities (as indicated by increased fluorescein) were enhanced (Table 5.6.5) in the oxygation treatment compared to the control.

Table 5.6.5. Effect of long term oxygation on soil biological properties, Nyang, Emerald

Treatments	Fluorescein (µg /g dwsoil/h)	CFU bacteria (Log)	CFU fungus (Log)	Soil respiration (g com m-2h-1)
Oxygation	46.49±0.87	5.81±0.061	3.50±0.106	0.890 ± 0.079
Control	42.68±0.79	5.93±0.055	3.51±0.051	0.698 ± 0.041
Furrow	36.32±1.38	5.96±0.062	3.22±0.100	

NB: Amount of fluorescein produced by the hydrolysis of fluorescein diacetate (FDA) is directly proportional to the microbial activity in the soil (Swisher and Carroll, 1980)

A simple economic analysis (Tables 5.6.6 and 5.6.7), indicates a return on investment of $562.50 per hectare per year, giving a payback period of a little over two years.

Table 5.6.6. Details of cost to retro-fit air injection to 0.4 ha plots at current site

Item	Unit	Price ($)	Cost ($)*
Venturi injector	1	265	265
PVC elbows	4	10	40
PVC t-pieces	2	10	20
Valves	2	45	90
Pressure gauges	2	30	60
TOTAL			**475**
Cost of oxygation 1 ha (475 x 2.5)			1187

* Costs would be less if installed with new system

Table 5.6.7. Details of returns per ha at current site

Yield (control)	Yield (Oxygation)	Yield difference (bale/ha)	Cotton price ($/bale)	Return on investment ($/ha/year)
8.05	9.10	1.05	500	525
Return to investment, yrs (1187/525)				2.26yrs

Further Information

Irrigation Australia

NSW DPI

Pendergast, L. (2012). Benefits of aeration of subsurface drip irrigation water – field evidence on CQ highlands vertosols. PhD thesis, CQUniversity, Rockhampton, Australia, pp245.

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