Vol 23, No 4, page 30 July-August, 2002 The Australian Cottongrower

Comparing systems for cotton irrigation

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The Australian cotton industry is dominated by furrow irrigation. Only four per cent of the total cotton crop is grown using large mobile irrigation machines (LMIMs) and less than two per cent is grown using subsurface drip irrigation (SDI).

It is likely SDI and LMIM will increase over the next few years, but these systems are unlikely to be a panacea for all irrigated cotton. A significant proportion of the Australian cotton industry will remain surface irrigated for some considerable time.

Even in situations where furrow irrigation is the preferred method there are benefits from better in-field management. As Brian Hearn has pointed out, there is a triple bonus for getting irrigation management right:

• Minimising yield losses from waterlogging;

• Saving water lost below the root zone — increasing water use efficiency and allowing more cotton to be grown; and,

• Conserving the resource base by minimising the risk of salinity and so enhancing sustainability.

What are your options?

For cotton growers who are currently surface irrigating the options are:

• Do nothing — remain with existing furrow design and management;

• Invest in precision surface irrigation — including improved monitoring to optimise surface irrigation management practices — and/or redesign fields;

• Invest in either centre pivot or lateral move machines; or,

• Invest in a drip irrigation system.

Factors influencing system selection

In recent surveys growers gave the following reasons for chosing the irrigation system:

• Water savings; labour savings;

• Uniformity of water application;

There is mounting evidence that on many farms, surface irrigation performance is highly variable.

TABLE 1: Some factors that typically influence irrigation design and management decisions

Factors	Examples
Agronomics	Crop responses to climatic and soil moisture variables; crop establishment, waterlogging, potential to utilise regulated deficit irrigation, cultural benefits (ie timing/nature of spraying), cultivation benefits, fertigation/chemigation benefits.
Engineering	Application efficiencies, distribution uniformity, ability to utilise in-season rainfall, hydraulic design limitations on pumps, pipes and storages, supply capacities.
Environment	Climate, soils, topography.
Social	Skills, experience, education, labour availability.
Economic	Capital costs/availability, operating costs, maintenance requirements/costs, returns from product.
Historical	Existing infrastructure, previous farming systems.
Hydrological	River flow regimes, groundwater issues; surface flow harvesting.
Regulatory policy	Legislation on access to river, surface and groundwater.
Admin. procedures	Licence requirements, ordering of water supplies.

• Reduced crop waterlogging;

• The ability to automate the system; increased yield; and,

• Fertigation/chemigation opportunities.

Removing the need for extensive surface irrigation earthworks and more options to grow crops other than cotton also influenced selection.

Growers often believe that the type of irrigation system is the factor that has most bearing on potential yield and irrigation efficiency.

But while the choice of system can provide a range of benefits, including energy, labour and capital efficiencies, it is the management practices that have the greatest effect on the yield and water use efficiency. Just as it doesn't matter whether you buy an esky or a fridge, if you leave the door or lid open the beers will be hot!

To effectively compare irrigation systems requires both systems to be operated in an optimal state. This rarely happens under commercial cotton-growing conditions and problems with comparisons have been compounded by inappropriate LMIM design and installation over the past 30 years. A lack of appropriate agronomic skills for SDI management has also muddied the water.

Despite these limitations, it is still possible to make some comparisons between systems. (See Table 2 for a summary of factors that should be considered in system selection.)

Yields and water use efficiency

Yields and crop water use efficiencies (CWUEs) of irrigation application systems are primarily influenced by management strategy, system capacity and water availability.

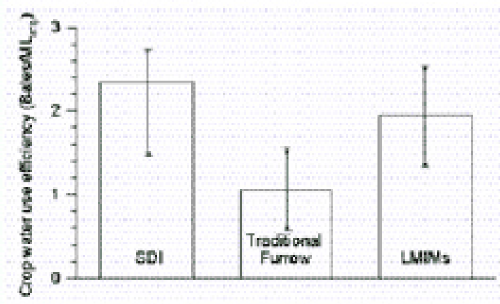
In surveys, growers indicated crop water use efficiencies for surface irrigation fields ranging from 0.6–1.6 bales per irrigated megalitre (Figure 1).

Growers using LMIMs, who had plenty of available water and an adequate system capacity, typically reported yields similar to, or greater than traditional surface irrigation.

LMIM growers with limited available water or undersized machine capacities reported lower yields compared to traditional surface irrigation. But these growers would not have had enough water to fully irrigate the cropped area using surface irrigation.

The average yield for growers using LMIMs was 0.5 bales per hectare less than furrow. But growers using LMIMs reported applying on average 3.1 megalitres of irrigation water less

FIGURE 1: Crop water use efficiency (bales per irrigated megalitre) for subsurface drip irrigation, traditional furrow and large mobile irrigation machines from grower surveys



Cross bars represent highest and lowest values reported by growers

TABLE 2: Comparison of irrigation application systems as used in the Australian cotton industry (modified from Burt et al., 1999)

	Furrow	Precision furrow	Centre pivot	Lateral move	Subsurface drip
Land					
Odd-shaped fields	0	0	–	–	+
High water table	–	0	0	0	+
Undulating slopes	0	0	+	+	+
Steep slopes	–	–	0	0	+
High infiltration soils	–	0	+	+	0
Low infiltration soils	0	0	–	0	0
Highly non-uniform soils	–	–	+	+	–
Low water holding cap. soils	0	0	+	+	+
Saline soil	–	–	0	0	+
Poorly drained soil	–	0	0	0	0
Highly erodible soil	–	–	0	0	+
Low bearing capacity soil	0	0	–	–	+
Water supply					
Ground water supply	0	0	+	+	+
High sediment load	0	0	0	0	–
Small rate of flow available	–	–	+	+	+
Climate					
Ability to use in-season rainfall	–	0	+	+	+
Windy conditions	0	0	–	–	0
Social/institutional conditions					
Low labour availability	–	–	+	+	+
Low manage. skills available	0	–	–	–	–
Little technical assist. available	0	–	–	–	–
Automation potential	–	–	+	+	+
Agronomy					
Germination/crop establishment problems	0	0	+	+	–
Waterlogging	–	0	+	+	+
PRD/deficit irrigation	–	0	+	+	+
Fertigation/chemigation	0	0	+	+	+
System characteristics					
Crop risk from system breakdown	+	+	0	0	–
Installation complexity	+	+	+	+	–
System robustness	+	+	0	0	–
Labour and manage. time req.	–	–	+	+	+
Environmental concerns					
Land transformation	–	–	0	–	0
Chemical use/movement	–	–	0	0	+

(0) indicates limited or no influence on selection, (+) indicates possible reason for preference, (–) indicates possible reason for choosing alternate method

than fully irrigated surface systems resulting in CWUEs ranging from 1.35 to 2.6 with an average of 1.9 bales per irrigated megalitre.

The potential to apply smaller volumes on preseason irrigations, improved crop germination, better use of in-season rainfall and the ability to use deficit irrigation strategies have all been cited as reasons for the lower irrigation water use and increased CWUE with LMIMs.

Yields achieved on SDI blocks are most influenced by growers' water management strategies. Where growers focus on maximising yields (that is, growers were trying to grow large crops to pay for the SDI system) improvements of up to 2.7 bales per hectare over surface irrigated fields have been achieved.

But where growers focus on saving water to increase their production area on other fields using the saved water (that is, growers were 'water short'), the yields of the SDI fields are similar to surface irrigated fields.

In all cases, growers have reported an increase in crop water use efficiency with an average increase of 1.29 bales per irrigated megalitre.

All cotton growers using SDI reported a decrease in water use (an average saved of 2.56 megalitres or 38 per cent of applied water) compared to traditional furrow irrigated systems. But the water saving differential was much smaller where the surface irrigation had already been optimised.

System performance

It is often claimed that application efficiency of well designed and managed surface irrigated cotton is over 80 per cent, but there is increasing evidence that on many farms surface irrigation performance is highly variable. In-field measurements on over 180 irrigation events under commercial conditions have found application efficiencies of single irrigations ranging from 35–100 per cent with seasonal efficiencies commonly between 60–85 per cent.

One of the major reasons for low efficiencies of furrow irrigated fields is low uniformity. But both uniformities and efficiencies can often be increased by using more appropriate inflow rates and by pulling siphons earlier to reduce potential deep drainage losses.

These types of simple, low cost improvements — provided by the surface irrigation model SIRMOD — have been found to improve individual application efficiencies by as much as 30 per cent and seasonal application efficiencies by up to 15 per cent.

The uniformity of water application using SDI and LMIMs is normally much higher (distribution

Fertigation and chemigation is easily achieved with both SDI and LMIM systems.

Lepa socks and bubble emitters can give high application efficiencies.

uniformity greater than 90–95 per cent) than for furrow systems (distribution uniformity from 60 to 90 per cent) and should mean less in-field yield variations with these systems.

Similarly, while efficiencies are strongly influenced by management practices, well managed SDI and LMIMs commonly produce application efficiencies in excess of 90 per cent. Low pressure, static plate sprinklers on LMIMS typically operate at 80–90 per cent application efficiency while moving plate sprinklers have application efficiencies up to 95 per cent. Low energy precision application (LEPA) socks and bubbler emitters have been found to have application efficiencies up to 98 per cent per cent where surface run-off is controlled with furrow dikes.

Waterlogging

Inappropriate surface irrigation that causes waterlogging can lead to losses of up to one bale per hectare. Yield losses can be as high as two to three bales per hectare in extreme cases. Laser levelling (and regular relasering), using appropriate furrow lengths, flow rates and siphon pull times are vital to reduce irrigation induced waterlogging in surface irrigation.

Irrigation induced waterlogging is not commonly found with SDI or LMIMs.

Waterlogging from irrigation before a rainfall event is much more common with surface irrigation than with SDI or LMIMs.

The ability to apply smaller volumes of water using SDI and LMIMs when rainfall is predicted reduces the potential for root zone waterlogging and provides a higher chance of ‘capturing’ rainfall for crop use.

Although neither SDI or LMIMs require laser levelling of fields, fields must still be ‘cut to drain’ to minimise surface water ponding from rainfall.

Capital costs

Laser levelled surface irrigated fields generally have set up costs ranging between $500–$1800 per hectare.

LMIMs typically cost between $1700 and $2500 per hectare to set up and have a life expectancy of more than 20 years depending on water quality and operational conditions.

Centre pivot machines often cost between 10 to 15 per cent more in capital costs than lateral move machines on a per hectare basis because larger areas are normally irrigated with each lateral move.

The capital cost of SDI systems is comparatively high ($3500–$4500 per hectare) and the life expectancy of the tape is less than 10 years. Only 10 per cent of growers using SDI achieved a yield increase of at least 2.5 bale per hectare, which has been estimated as the difference required to economically justify a move to SDI.

So the economic benefits of moving to SDI for many growers are marginal, particularly if surface irrigation efficiencies are already high. Low cost ($1500–$2000 per hectare) 'temporary' drip systems have recently been trialled and could prove to be more economically attractive.

Labour

A major driver in adoption of LMIMs and SDI is substantial reduction in labour costs compared to furrow. But while labour requirements for these systems can be as little as 10 per cent of traditional surface irrigation systems, the level of agronomic management skill required is much higher.

The majority (76 per cent) of LMIMs in the cotton industry are centre pivot machines. A factor to consider in LMIM selection is labour requirement, with lateral moves typically requiring 50–80 per cent more labour to manage (including channel/hose changes, guidance system maintenance, re-fuelling operations) compared to centre pivots.

Operating costs

Pumping and maintenance costs of pressurised application systems are commonly seen as a major barrier to their adoption. But modern LMIMs typically operate with nozzle pressures between 70 kPa (10 psi) and 138 kPa (20 psi) and require no more than 240 kPa (35 psi) at the system centre.

Fuel costs of these machines typically range from $13–$25 per megalitre. SDI systems also operate at low emitter pressures (that is 70–138 kPa) and have comparable pumping costs.

Agronomic control and management

SDI and LMIMs provide substantial benefits in timing of operations such as groundrig spraying and cultivating. These systems can apply smaller irrigations than furrow systems so the time between irrigation and a field operation can be relatively short.

Concerns over LMIMs affecting boll formation and lint quality are unfounded. No Australian grower using LMIMs reported reduced lint quality. The use of low energy precision application emitters (that is, socks and bubblers) on these machines means that the irrigation water is applied beneath the plant canopy and the flowers and bolls are not routinely wet.

Where overcrop sprinklers are used, applying irrigation water no more than every third day to a particular part of the field means that the flowers and bolls are able to completely dry between irrigations.

Fertigation and chemigation

Fertiliser is normally applied to surface irrigation systems through distribution channels (for instance, water run urea). But problems with undissolved fertiliser, denitrification and non-uniformity of surface irrigation mean that the effectiveness of applying fertiliser in this way is often questionable.

By comparison, fertigation and chemigation can be easily implemented using both LMIMs and SDI systems. The injection systems used to mix fertilisers and chemicals into irrigation water for application by LMIMs and SDI systems can be accurately controlled and the high uniformities of application ensure that the fertiliser/chemical is evenly applied to the crop. LMIMs have the advantage of being able to apply chemicals onto the crop canopy with very small volumes of water. LMIMs can also be fitted with a separate chemical distribution pipeline so the crop can be sprayed without the chemical being mixed with irrigation water.

Other factors

One advantage of LMIMs is being able to change the application method (spray plates or LEPA) and water volume applied. Using spray plates, water can be applied to the soil surface providing high germination rates with relatively small application volumes compared to SDI or surface systems.

A major benefit of lateral move machines over centre pivot machines is their ability to fully irrigate fields that have already been developed as square or rectangular blocks. There is also a perceived ease of use with LEPA systems.

More than three-quarters of growers using LMIMs have reported experiencing some wheel rutting problems during the first few years of LMIM operation due to inexperience and poor machine design. The majority of growers have overcome these difficulties through a range of machine modifications and management practices including the use of boom backs, half-throw sprinklers, reduced flow rates near towers, double length LEPA hoses or the application of lighter irrigations until the wheel tracks are firm.

Nearly all SDI irrigators have experienced some problems in the design, installation, operation, maintenance or management of their systems. But most growers acknowledged that with the benefit of experience none of these issues should have been a problem.

A number of SDI systems in the cotton industry appear to have been installed with inadequate flushing main capacities and/or with flushing valves which restrict flushing water flow rates.

Germination also remains one of the biggest challenges for SDI users, especially when used on an alternate tape line spacing (that is, tape spacing is twice crop row spacing).

Conclusions

Many surface irrigation systems in the cotton industry have highly variable performance and may not be as efficient as commonly perceived.

This should be seen as an opportunity to improve production by modifying management and/or design practices which minimise crop waterlogging and improve application efficiencies.

But there is a wide range of farm specific factors which need to be considered when deciding whether to improve the performance of the existing surface system or invest in alternative irrigation infrastructure.

In most cases where the main objective is an improvement in application efficiency and/or a reduction in irrigation induced waterlogging, the most cost effective option will to improve the performance of the existing surface irrigation system.

If a grower wants the greater control and flexibility of irrigation management offered by LMIMs or SDI systems, the comparatively lower cost and longer life expectancy of LMIMs are probably more attractive. On the other hand, SDI allows extra flexibility in design layouts with additional environmental and management benefits.

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