

Irrigation Efficiency

By LANCE PENDERGAST (Qld DAFF)

Plant response to water

Too little – water stress

Cotton has an indeterminate growth habit (that is, it is a perennial that keeps growing), and therefore, under favourable conditions, the number of leaves, new nodes, fruiting branches and squares can increase rapidly, unlimited by a phenological time frame, and continue to be produced while conditions remain favourable.

During the pre-flowering stages of growth, production of carbohydrates (through photosynthesis) exceeds demand, and as a result vigorous vegetative growth occurs. As plant growth continues, the demands for carbohydrates by the component plant parts such as bolls increase, and production becomes limited by environmental conditions. Boll growth exerts large demands for carbohydrates and it is through the balance between boll demand and leaf production that vegetative growth is restricted.

Water stress can restrict both vegetative and boll growth. It has been shown that no matter what degree of water stress is imposed on a crop, the proportionality between vegetative growth and boll development remains relatively constant. Similar results have been achieved with crops receiving different amounts of nitrogen. This

FIGURE 1.

The changing scale of water use by the cotton plant as it moves into each stage of growth

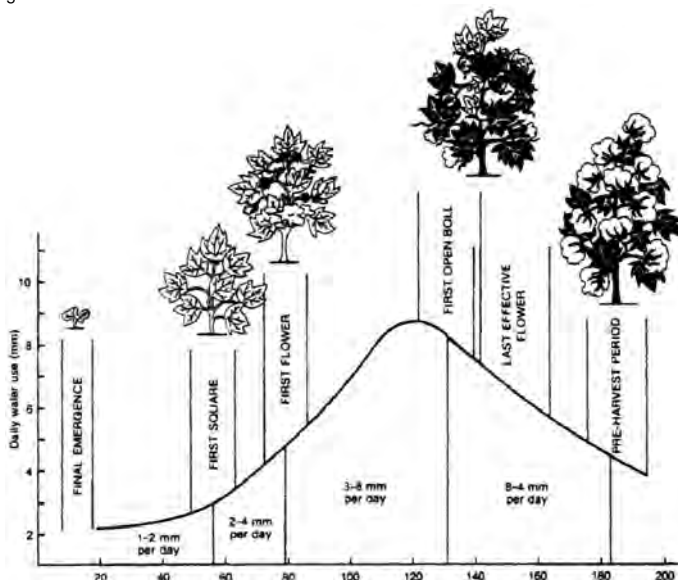


TABLE 1:

Yield loss (%) per day of water stress (extraction of >60% plant available water) (WATERpak Table 3.1.3)

Growth stage	Past conventional*	Bollgard#
Squaring	0.8	1.1
Peak flowering	1.6	1.7
Late flowering	1.4	2.7
Boll maturation	0.3	0.69 [^]

[^]14 d post cut out
Source: Yeates et al. 2010#; Hearn and Constable 1984*

implies that, independent of water or nutrient supply, the plant will always attempt to form a balance between vegetative growth and boll development.

Too much – water logging

The major and immediate effect of waterlogging is a reduction in the transfer of oxygen between the roots and the soil atmosphere. Plant roots may become so oxygen deficient that they cannot respire normally. As a consequence, root growth and absorption of nutrients is decreased leading to less overall plant growth. A reduction in node numbers leads to a reduction in the number of fruiting sites and consequently a reduction in the number of bolls produced.

Cotton is most susceptible to waterlogging during the early stages of flowering as this is when the plant is setting the fruit load that will dictate final yield. As the plant gets older there will still be effects there but they won't be as severe because the fruit is basically established on the plant.

Plants exposed to rainfall induced waterlogging may also suffer from the reduced sunlight availability associated with overcast conditions. Under these conditions the plant cannot fix enough carbon to maintain normal functions and may shed fruit as occurs under any other form of stress.

In addition to the immediate physiological impacts of waterlogging on the crop, there are also significant impacts on nutrient availability and uptake. Waterlogging increases the rate of denitrification and plant uptake of Nitrogen (N), Iron (Fe), Zinc (Zn) (reduced) and Manganese (Mn) (increased) are directly affected by a decline in soil oxygen. Irrigation strategies designed to avoid potential waterlogging events not only contribute towards improved yield and water use efficiencies but can also benefit crop nutrient efficiencies. Waterlogging also tends to decrease the plants ability to regulate sodium uptake and, although cotton is reasonably tolerant of salinity, exposure to increased concentrations does impinge on yield potential.

Optimized irrigation system designs allow delivery to the head-ditch, run-times and tailwater collection / return such that exposure to waterlogging and deep drainage are minimised.

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Monitor to manage – irrigation efficiency

Water is a production tool just like any other management input. Regardless of how growers manage their water or how much water is available the goal is to optimise water use efficiency (WUE). Improving water use efficiency involves a whole farm water management plan.

The first step is to have a water budget. Water budgets consist of components such as crop/plant requirements, and potential water sources. Budgeting requires knowledge of all water sources; fallow rainfall and fallow efficiency, reliable in-crop rainfall, irrigation allocation and reticulated water. Water losses, such as by deep drainage and leaching in-field and through evaporation and seepage from on-farm storages and channels, should also be considered.

In the planning process, decisions about cropping and what area to sow can be made seasonally, dependent on expected water availability. Tools such as CropWaterUse – a web based application is available to help growers calculate the theoretical daily and seasonal water use of a crop. (<http://cropwateruse.dpi.qld.gov.au>)

The overall production target must suit the type of irrigation system and the available water resource.

A successful philosophy to follow from the start is 'measure to manage'. The use of both water meters and soil moisture probes enables the fine tuning of management strategies that can lead to improved efficiencies. There is also benefit in monitoring crop response such as NAWF. Refer to Chapter 5.

Dryland growers can use HowWet?, a Windows based program which uses farm rainfall records to estimate how much plant available water has been stored in the soil and the amount of organic nitrogen that has been converted to an available form during a fallow (non-crop period). HowWet? tracks daily evaporation, runoff and soil moisture using estimates of weather conditions and rainfall input by the user. Accumulation of available nitrogen in the soil is calculated based on soil moisture, temperature, soil type and age of cultivation.

<http://www.apsru.gov.au/apsru/Products/HowWet/how%20wet.htm>

BEST PRACTICE

- Monitoring the conditions, the plant, and soil moisture will help in scheduling irrigations to meet crop demands and avoid plant stress.

Pre irrigation

The decision for the cotton grower to pre-irrigate or water up the crop is, like so many others, a decision that has to be made specifically to suit a particular farm. In certain situations it can be beneficial to combine the two options: pre-irrigate to plant into moisture and give the crop a quick watering to ensure good plant stands (WATERpak page 91).

Every farm is different and a range of questions need to be considered before making a decision e.g. is it likely to rain before/during/after planting?, what are the implications associated with the different tactics in relation to seedling disease and weed control, am I set up for dry or moisture planting?

Scheduling in-crop irrigations

Irrigation scheduling is the decision of when and how much water to apply to an irrigated crop to maximise crop productivity. Good scheduling should provide plants with water that is within a desired range and should limit over or under irrigation so that balanced growth is achieved. For Bollgard II varieties insufficient available water prior to and during flowering will reduce plant size and lead to early cut-out while too much water can lead to rank growth or waterlogging.

The first irrigation plays an important role in setting up for plant growth, fruit retention, fibre quality and boll weight. Its timing is perhaps the most difficult irrigation scheduling decision as it is a balancing act between not stressing the plant while stored water is fully explored by the developing root system.

The demands of high fruit retentions afforded by Bollgard II cotton, in conjunction with tight water scenarios which growers and consultants have been faced with for the past few seasons, has seen the timing of first irrigation become a key management issue.

Irrigating too early can increase potential for exposure to waterlogging. Irrigating too late will incur yield penalties due to the impact of stress on plant development. Like many crops cotton has stages of development at which it is particularly sensitive to stress. Irrigation scheduling should strive to avoid exposure to stress during flowering and early boll filling stages. Research by Steve Yeates and Dirk Richards, CSIRO, in both BollgardII® and conventional cotton, has shown similar losses in yield attributed to being late on the first irrigation. Delaying the 1st irrigation will place the plant under stress which will impact on the performance of the crop. Results have shown a dramatic reduction in yield (up to 23%) due to stress in the lead up to flowering. Recent research by Marcelo Paytas and Steve Yeates has shown for BollgardII crops that when conditions are hot and dry irrigation up to 2 weeks prior to flowering on clay soils will increase yield provided there is no water stress after flowering.

It is important to tailor your irrigations to meet the needs of high retention crops to optimise yield and water use



efficiency. High boll load early in flowering can lead to premature cut-out and lower yields.

Subsequent irrigation scheduling

One of the most important things besides monitoring your soil moisture is monitoring crop development. Keep a check on squaring nodes, first position retention and NAWF. Use the CottASSIST Crop Development Tool to help keep track of how the crop is progressing.

Research by Yeates has shown that low deficit scheduling or frequent watering eg 40 to 50mm deficit or 6 to 7 day intervals (Wee Waa clays) increased Bollgard II yield by 17% and WUE by 8% when conditions were hot and dry during flowering. Trials showed where mild growing conditions were experienced, generally associated with higher in-crop rainfall and less evaporative demand, scheduling irrigations to a greater deficit maximised yield and WUE, by allowing the opportunity to capture more in-crop rainfall rather than irrigating at a 40mm deficit. Irrigation scheduling based on small deficits requires skill and a system that can apply water quickly. Otherwise application efficiencies will be lower and the crop waterlogged.

When irrigation water is limited, save water for the flowering period. Bollgard II crops with high fruit retention are most susceptible to water stress late in flowering and at Cut-out. Yeates and Richards have measured a yield decline of 2.7% per day of stress compared with 1.2% per day for conventional cotton at this stage of growth.

Scheduling: Final irrigation

Ideally the last irrigation will provide sufficient water to optimise final yield and fibre quality, adequate soil moisture to facilitate efficient take-up and function of applied defoliant, and a soil profile that is sufficiently dry enough to enable harvest without causing soil compaction.

End of season water requirements can be estimated from the date of the last effective flower (“cut-out”). Although location specific it takes about 50 days from cut out to maturity. Given reduced daily water use late in growth and a full profile, a crop should be able to rely on stored soil water for up to 30 days, on most clay soils depending on the rate of evapotranspiration experienced. Hence irrigation water is required for the first 20-25 days after last effective flower – possibly two irrigations would be required during this time. The last harvestable bolls take 600 to 650 day degrees to reach maturity. Crop water use during this period will vary, at the time of first open boll, water use may be 5–7 mm/day, and may decline to around 3–4 mm/day prior to defoliation.

There are a number of methods available to accurately time final irrigation and defoliation: Measuring Nodes Above (last) Cracked Boll (NACB), is most commonly used, (refer to FibrePAK). On average, bolls will sequentially open at a rate a node every three days. This will depend on a number of factors, particularly climatic conditions.

The prime objection of the last irrigation is to ensure that boll maturity is completed without water stress, (WATERpak pg 93). Once a boll is 10–14 days old, the abscission layer responsible for boll-shed cannot form. Consequently late water stress (beyond cut out) does not significantly reduce boll numbers and therefore yield. However, fibre quality can be more seriously affected by late water stress. Crops that come under stress prior to defoliation (60% bolls open or 4 boll carrying NACB), can suffer some fibre quality reduction, especially micronaire. The degree of reduction obviously increases the earlier the stress occurs.

Scheduling: With limited water

More recently, in the face of reduced water allocations that preclude normal (full) irrigation practises, irrigators have also employed skip row strategies into their production systems. (CSD, 2009). As with dryland production, the number and timing of irrigations in skip row planted cotton will vary with location, soil type, previous history, and weather conditions, with the interval between irrigations increased with skip row plantings. Ideally the irrigation deficit used should be the same as for normal planting configuration. See Furrow irrigation considerations and configurations.

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For more information the following resources and tools are available at https://www.mybmp.com.au/auth_user/grower_tools_and_resources.aspx

- WATERpak
- FIBREpak
- CottASSIST Crop Development Tool



(Photo: Cotton Australia: Karen Sullivan)

Monitor to manage – whole farm water balance

By **JIM PURCELL** (Aquatech Consulting)

A successful and profitable irrigation enterprise is one that manages precious water at both the crop root zone level (soil moisture monitoring and irrigation scheduling) and at the whole farm level (how much water do I have? what are my losses? and therefore how much do I have left for crop production?).

This section discusses the whole farm water management area. The tools for whole farm water balance have progressed greatly in the last 10 years. The use of commercial tools and water management consulting services has steadily grown as irrigators strive to improve their profitability with less water.

Below is a step by step process to better manage water at the whole farm level. In summary:

Phase 1

- Measure and record the basics.
- Complete a simple seasonal whole farm water balance
- Review the results.
- Fix the easy stuff.
- Repeat until happy.

Phase 2

- Stop at Phase 1 if you are happy with your WUE or move to daily water balance. Daily water balance allows prediction forward of water requirements before and during the season.

Phase 1 – Seasonal whole farm water balance

Step 1 – Measurement

Measurement is essential for any good management and water management is no different. To achieve good measurement start with the following:

- Ensure all water meters are installed correctly and measuring accurately. Check them with another meter.
- Survey all storages to establish accurate depth to volume to surface area characteristics. Ensure all tailwater and buffer storages are included. Storage surveys can now be done with water in the storages!
- Fit storage meters in all storages. Gauge Boards are a start but don't really do enough. It is very difficult to measure the volume of a stormwater harvesting event with gauge boards unless the gauge boards are read just before and just after each event and recorded. Irrimate™ Storage Meters have been developed over the last 5-6 years. They read and log water level, storage volume and water surface area at any required interval (normally 30 minutes but can be changed). This not only allows water volume to be accurately monitored in real time but also provides flow rates

into or out of the storage. A storage meter also records the water surface area which allows the calculation of water volume loss from seepage and evaporation. Telemetry is now optional with information available by internet (read your storage volume, depth and surface area with your mobile phone or laptop while on a holiday overseas!).

- Take strategic measurements of soil seepage characteristics and storage and channel evaporation characteristics. This allows calculation of the seepage and evaporation losses in each storage, channel and drain. Irrimate™ Seepage and Evaporation Meters can be hired from Aquatech Consulting or any Irrimate™ Agent. These meters measure both seepage and evaporation characteristics. It is not necessary to measure every storage or every channel and drain to get meaningful results. Default values are available without measurement as a start.

Step 2 – Record keeping

The next step is basic record keeping. The aim is to record enough basic information to calculate how much water the crop actually needed during the particular season and how much water was made available to grow that crop.

In simple terms, the total measured available water, less the calculated actual crop water requirements for the season, equals the water lost to production. It should always be remembered that it is impossible to produce an irrigated crop without some losses. The real question is "How much water did I lose and how much could I save and use to increase production and profit?"

To establish this, it is necessary to be able to split up the total water lost to production into components:

- Storages losses (wet-up, seepage and evaporation).
- Channel system losses.
- Drainage system losses.
- In-field losses.
- Operational losses (stuff-ups resulting in water lost out of the system).

The records needed for a seasonal whole farm water balance include:

- Meter readings from all inflows – (river, scheme channel and/or bores).
- Storage volumes at the start of the season.
- Storage volumes at the end of the season.
- Harvested water volumes (land surface diversions) measured using the Irrimate™ storage meters or similar.
- Rainfall on fields.
- Field number or name and area.
- Crop yield.
- Reference Evapotranspiration for each day during season based on weather data (automatically provided in WaterTrack™).
- Field soil type (menus provided).



- Field soil moisture deficits (mm) at the start of the season and end of season (estimated or from soil probes if available).
- Crop emergence date and end date (when crop stops transpiring e.g. cotton defoliation).
- Dates of each field irrigation.

Step 3 – Seasonal water balance

The whole point of completing a whole farm water balance is to find out where water is being lost, whether those losses are ok and what is required to reduce the losses and increase production.

The Seepage and Evaporation Assessment with an Irrimate™ Meter allows the calculation of soil seepage losses from storages, channels and drains. Similarly, the measured evaporation characteristics from the same measurement allow calculation of evaporation from storages, channels and drains. If a farm has two different soil types, then it “may” be necessary to complete a second Seepage and Evaporation Assessment in each soil type.

Calculation of actual crop water requirements is based on daily Reference Evapotranspiration (Eto) values for particular farm and season and crop factors. Eto can be sourced from a weather station on the farm or normally from the Bureau of Meteorology SILO database. If WaterTrack™ is used for the whole farm water balance, the program automatically obtains and updates daily Eto from the Bureau of Meteorology. All that is required is to provide the farm Latitude and Longitude from Google Earth.

Step 4 – Review the results

All irrigation farms will lose water; it is inevitable. The question is “Where are the losses and are they OK?”

WaterTrack Divider™ will complete a simple seasonal water balance and provide Water Use Efficiency Indices required for *myBMP* and Water Management Plans.

Irrigation consultants can advise whether the losses are typical, good or bad and can advise on the type of works and cost to reduce losses. WaterTrack Divider™ even provides a basic economic calculator. This can determine if the proposed capital works are economic and how long the pay back period is from the extra production.

There is a network of commercial consultants from Emerald, Queensland to Keith in South Australia who can provide the equipment, software and consulting support to their clients in Water Management. Experience is showing significant increases in farm profit from increased water use efficiency.

Step 5 – Repeat seasonal water balance next season and so on, until happy with reduced losses and water use efficiency performance

For more detailed accuracy and predictions undertake Phase 2.

Phase 2 – Daily whole farm water balance

Step 6 – Comprehensive daily whole farm water balance

Rather than waiting until the end of the season to check how water management went, it is also possible to set up the daily water balance model, WaterTrack Optimiser™.

WaterTrack Optimiser™ models each element of an irrigation farm in sections and in individual fields daily. The computer model replicates each action taken by the irrigator in their daily routine and calculates the losses in each segment of channel and drain, each storage and each field daily.

The results are much more comprehensive than those achieved by completing a seasonal water balance but more effort is required with data collection and data entry. Essentially, every action done with water on the farm is also done on the computer.

The value of the extra effort is the ability to manage water at each irrigation and make changes then rather than waiting until next season. WaterTrack Optimiser™ also allows forward prediction at any time to check whether there is enough water available (including losses) to completely irrigate those fields in production.

Typically, prediction is done:

- Before planting.
- Mid November or early December to decide which fields shall remain irrigated.
- As many times as required in February to determine which fields shall be finished.

The effort required to complete this modelling can result in very significant profit increases by maximising the yield potential of the remaining water. Most irrigators use commercial consultants to complete this modelling. The consultant is then able to work with the irrigator on alternative strategies.

Further information on whole farm water balance can be found at www.myBMP.com.au

For more information reference waterpak contact: Aquatech Consulting 02 6792 1265 (www.aquatechconsulting.com.au, www.irrimate.com.au or www.watertrack.com.au)

Furrow irrigation considerations and configurations

By **LANCE PENDERGAST** (Qld DAFF) & **CSD EXTENSION TEAM**

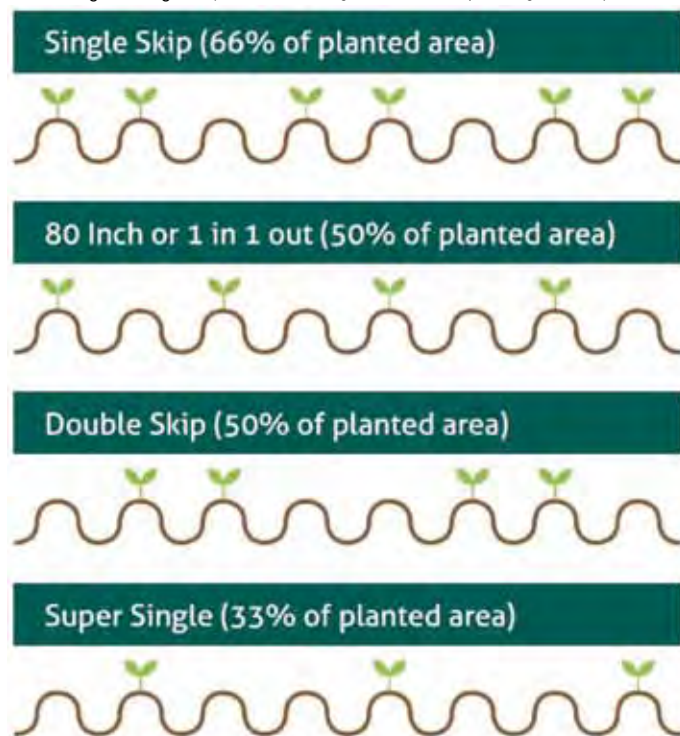
Acknowledgements: **Michael Bange (CSIRO)** and **Dave Kelly (Macpherson Agricultural Consultants)**

Furrow considerations

Furrow irrigation remains the dominant irrigation method in Australia. Typically about 60–70% of the water that reaches the field is used by the crop, and the remainder is recycled as runoff or lost to deep drainage. Over recent years some operators have made considerable improvements in the efficiency of furrow irrigation in response to the increasing demand for limited water supplies. Significant improvements in

FIGURE 1:

Row configuration guide (Source: CSD Getting the most out of skip row irrigated cotton)



BEST PRACTICE

- Measuring field efficiencies will enable informed decisions about management options to improve irrigation efficiencies.
- Wider row spacing configurations can be used to manage risk in dryland and semi-irrigated situations but will limit yield potential. Carefully assess the benefits of reduced costs and improved fibre quality to determine best fit for your system.

water use efficiencies have been achieved through furrow optimisation evaluations using advance meters, siphon meters and SIRMOD.

Optimal furrow irrigation performance requires understanding of application efficiency (amount of water applied in irrigation that is available to the crop for use) and distribution uniformity (how evenly infiltration occurs across the over the field) and the methods for improving both. Adequate management and maintenance of all components between the head ditch and the tail drain is important for furrow irrigation systems. Improving furrow irrigation performance involves careful management of flow rates and irrigation duration and appropriate timing (scheduling) of irrigation events. Refer to monitor to manage irrigation efficiency.

A number of modifications can be made to improve furrow irrigation performance. Design changes include modifying furrow slope and geometry, although these parameters have very little effect on irrigation performance. Changing field length has a larger impact on performance, but typically the most significant improvements are possible through management changes. Increasing or decreasing compaction in furrows will modify the infiltration characteristic (for example, wheel tracks) and can improve efficiencies. The most common changes to improve furrow irrigation system performance are an increase in flow rate and corresponding decrease in irrigation duration. It is vital that measurements are taken before implementing changes so that current performance can be identified and appropriate changes can be implemented. For more information see WaterPak 4.2.

Semi irrigated – Row configurations

There are a range of different configurations being used by growers across the cotton industry in semi-irrigated situations. These include single skip, 1.5m and 2m (60 and 80 inch), double skip, super single and some non-uniform configurations. The positive and negative features of each configuration, including the relative water use efficiencies, depends on the individual situation. What works best in one farming system may not in another due to differences in soil type, environment, cropping history, available equipment, water availability and other factors.

Growers contemplating:

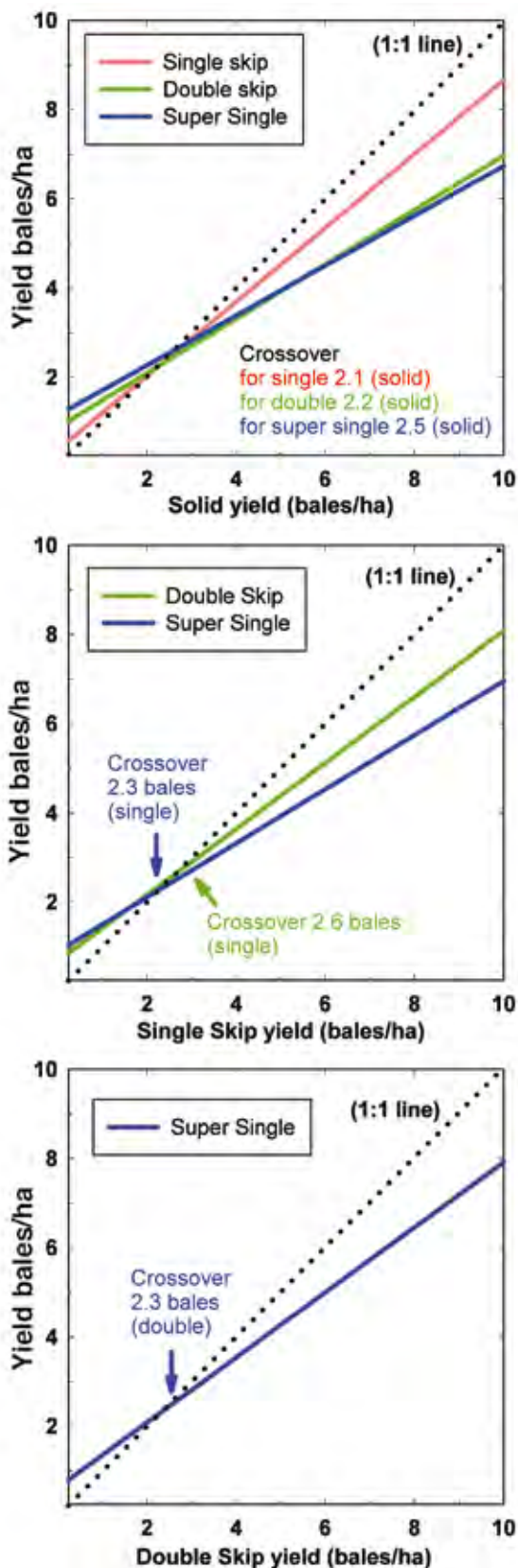
- Whether they would benefit from using skip row configurations; and,
- Which skip row configuration they would use ...should consider the following points.

The yield/cost/fibre quality mix of each configuration

Extensive research has shown that while skip row cotton does limit yield potential (Figure 2), the combination of reduced fibre length discounts and variable cost savings in growing skip row cotton often lead to a better risk/return proposition.

FIGURE 2:

Comparison of average yields of various combinations of row configurations. Responses are generated from controlled comparisons undertaken over many seasons. Crossover refers to the average yield potential at which there is no further improvement in the yield of a particular configuration compared to the configuration stated on the bottom of each graph. For example in the middle graph, when comparing double skip to single skip, the average yield potential at which single skip outperforms double skip is 2.6 bales/ha. Compiled by M. Bange (CSIRO 2012).



Semi-irrigated single skip (3 irrigations) left and solid plant (fully irrigated) on the right. (Photo: CSIRO)

To use these graphs, growers need to consider their yield potential, based on all the factors discussed later in this chapter.

Single Skip has the lowest risk of losing yield when conditions are favourable. It will however also use its moisture profile the quickest. Having a plant row 50cm one side and a one metre skip row to the other, this configuration will enjoy some benefits of ‘partial root zone drying.’ It is best suited to situations on heavier soil types with high PAWC and more irrigation water availability.

While **one-in-one-out (1.5m or 2m)** cotton has not been included in these comparisons, grower experience and some trial work has shown its yield potential to be similar to or slightly higher than double skip but possibly more prone to fibre quality discounts because it does not have the advantage of mild early stress. Detailed research is currently being undertaken to investigate this issue. A more uniform growth habit in one-in-one-out cotton can reduce lodging; allow better spray penetration and defoliation processes when compared to double skip.

Double Skip provides more insurance against lower yields when compared to single skip especially when conditions are less favourable. Having a plant row 50cm one side and a 1.5m skip row to the other, this configuration provides the benefits of ‘partial root zone drying’ which toughens the plant up. Plants can be prone to lodging, especially vegetative branch fruit which takes advantage of the extra light available in the skip area. It is best suited to drier profiles and hotter environments.

Some growers have tried **Super Single** (one-in-two-out) in semi-irrigated situations. The widely spaced plant rows 3 metres apart means the yield potential and potential upside in a good season is severely limited. However, this configuration may be an option with a full soil moisture profile at planting and minimal irrigation water resources where there is a high chance of severe water limitations during flowering and boll fill. This configuration allows growers to minimise growing costs as well as limit the likelihood of fibre quality discounts.

Non uniform configurations have been tried in some circumstances but can lead to variability in maturity, and subsequent difficulties in management.

Skip row configurations function by increasing the volume of soil that plants have to explore thereby providing a bigger reservoir of available moisture and thus allowing the plants to hold on for longer during dry periods.

Skip row cotton provides an 'in between' option for increasing the area of cotton which can be grown, allowing some upside in production if conditions improve and far less downside in potential fibre quality discounts if the season deteriorates.

In some cases, inherent growing characteristics such as soil type and location may mean there is minimal advantage in adopting skip row practices.

Planting row configuration effects on cotton gross margin

The vigorous tap root of the cotton plant allows for wider exploration of the soil profile for moisture and nutrients, particularly when compared with fibrous root type crops. This characteristic has led to the use of wide row configurations that increase the total amount of soil moisture available to the plants. This extends the time before in-crop rainfall is required and therefore makes the crop less reliant on in-crop rainfall particularly in the first 2-3 months of its life. Narrower row configurations such as single skip are more popular in higher rainfall areas while the wider row configurations such as super single are used in the lower rainfall western areas.

The wide row spacings provide greater surety in yield and maintenance of base grade fibre quality. There is a strong relationship between row configuration and fibre quality, especially for fibre length. In row configuration trials, fibre quality improved with wider row configurations. Therefore the row configuration chosen in combination with the seasonal conditions experienced will have an influence on the likelihood of quality discounts being incurred on delivery of the cotton.

Savings in variable costs of inputs such as planting seed, insecticides, defoliant and the picking operation are likely with wider row configurations. Taking this into account, a lower yielding wider row configuration crop can at times give a better gross margin than a higher yielding crop on a closer configuration. In many ways growing skip row cotton really emphasises that gross margin is not just a function of the yield produced, but very much a combination of yield and costs associated with the row configuration chosen.

How does the planting row configuration affect variable costs?

Cotton has a couple of big ticket items which make up the majority of the growing costs, these being picking and technology licencing fees. In wide row configurations, efficiencies in picking can be made through not trafficking every pass, with some contractors altering machinery or charging on a green hectare basis.

The biotechnology licence fee can either be based on a green hectare rate, or end point royalty scheme where the licence fee paid is related to the yield achieved. This not only works as a risk management tool but also in wider planting row configuration where the green hectare rate and yield potential is lower, it is also a cost management tool because the grower pays less.

For more information on using wider row configurations in irrigated cotton, see the publication 'Getting the most out of skip row irrigated cotton', available from Cotton Seed Distributors.

For more information the following resources and tools are available at https://www.mybmp.com.au/auth_user/grower_tools_and_resources.aspx

• WATERpak

Alternative Irrigation Systems

By **LANCE PENDERGAST** (Qld DAFF)

Over the bank siphons / furrow irrigation is, and will remain in the foreseeable future, the dominant mode of irrigation used by the Australian cotton industry. As a result of extensive efforts the industry has achieved significant improvements in the performance of siphon / furrow irrigation. When optimised under appropriate conditions this method can produce high levels of performance. There are however a range of factors inherent in siphon irrigation that have driven efforts to develop alternative options. Competition for labour and water resources, and increased yields, are principal drivers. Increased automation, the ability to deliver precise amounts to meet crop demand in a timely

BEST PRACTICE

- Evaluate full potential performance of existing system (e.g. furrow) when considering change to alternative system (e.g. to overhead, drip etc).
- When assessing the viability of an alternative investments the following need to be considered: Yield & prices risk, the extent of water savings and risk of water availability, likely impact of changing energy costs, and availability of labour. Note that pipes through the bank system still subject to issues associated with furrow irrigation e.g. relationship between run- time, flow rate, field length and their impact on distribution uniformity etc Design to meet site specific conditions. Identify site specific constraints of existing infrastructure and design accordingly (see pipe through bank case study)
- Cost of professional advice is invariably returned manifold
- Successful operation requires ability to change mindset from furrow irrigation techniques. Full potential of systems such as overhead and drip are achieved via ability for greater control (which requires more refined scheduling)
- Inquiries to cotton D & D team will assist access to growing body of knowledge regarding optimising system / crop performance.



manner, and energy efficiencies underlie most ongoing efforts to develop alternatives.

Centre Pivots/Lateral Moves (CPLM)

Centre pivot and lateral moves (CPLMs), have been around since the 1950s. Early experiences with CPLMs were often poor.

Typically early Australian system designs were incapable of delivering the application rates required by cotton growing under Australia conditions, a problem exacerbated by the relative lack of knowledge regarding peak crop water use. They operated at high pressure using overhead knocker sprinklers and were prone to poor hydraulic design. Operating costs were high, water use efficiencies low and a great deal of time was spent just keeping the systems going.

Much has changed since those early days. Pressure on water availability and environmental sustainability, as well as economic and political factors, have contributed to increasing attention to the viability of CPLMs.

Design and operating protocols have come a long way in the past decade. Systems capable of operating efficiently over a wide range of soil types and environmental conditions now efficiently irrigate an increasing area of cotton.

Before replacing a current surface irrigation system with a CPLM system you should assess the performance of the existing system. This will ascertain potential improvements before considering the alternative irrigation systems. Optimisation of an existing furrow system could significantly reduce potential gains expected from investment in an alternative system.

It is not possible to make a 'rule-of-thumb' statement that the investment in CPLMs is or is not profitable – every farm business differs and so do the water savings and yield benefits for the many crops that can be grown with these machines.

- A 'with' and 'without' scenario analysis approach with support from a suitably qualified agri-business financial advisor is a robust method to assess the economic and financial performance of investment in CPLMs. This approach involves the following steps.
- Prepare a steady state profit analysis at the whole farm scale for the current farming system (the 'without' scenario) and the one with the CPLM investment (the 'with' scenario).
- Undertake a financial analysis over the life of the investment for the 'with' and 'without' scenarios.
- Complete an economic analysis to calculate and compare the Internal Rate of Return and the Net Present Values for the 'with' and 'without' scenarios.
- Perform a marginal analysis to calculate the marginal return and payback period for the CPLM investment.

Growers considering purchasing CPLMs should look, listen and learn from those with experience with these machines. One of the most consistent messages is the importance of obtaining a 'site specific' system

design – CPLM designs must be tailored to match the environment (e.g. soil characteristics) in which it will be operating. Field by field considerations often result in system design varying considerably between machines operating in close proximity to each other.

A well designed CPLM should:

- Maximize the amount of water placed into the crop root zone from water pumped;
- Distribute the water uniformly across the field;
- Be capable of meeting peak crop water use; and,
- Have minimal energy and labour inputs.

Fortunately the industry has matured since its early days when disappointment could often be traced back to inappropriate designs sold and built by overly 'optimistic' providers. Growers can now access providers with a proven track record of delivering machines that perform as promised. A range of tools has been developed to assist grower's initial decision making process, to verify system performance, and to plan ongoing machine operation.

While irrigation efficiency for CPLM is often higher (85–90%) than for furrow (about 75–85%), there is still the potential for losses due to evaporation and increased foliar diseases. Improved designs of both machines and sprinklers, and innovations such as the use of low energy precision applications have led to some operations increasing water use efficiency to exceed 90% (with associated improvements in application uniformity). Successful operation of CPLM requires a different mindset to furrow irrigation. Existing equipment can be audited to help improve this understanding and identify opportunities for modifications that can improve uniformity of application.

Useful resources:

The cotton industry publication **WATERpak** provides a useful discussion of alternative irrigation systems, including CPLMs.

A comprehensive CPLM training package, developed and delivered by the National Centre for Engineering in Agriculture (NCEA) with funding from CRCDC and the CRC-IF.

A Centre Pivot and Lateral Move one day workshop available through Growcom.

OVERSched – an on-line CPLM management tool for visualising soil moisture deficits and irrigation scheduling options.

Subsurface Drip Irrigation (SDI)

SDI is an alternative irrigation system for improving water use efficiency. SDI is the application of water below the soil surface through emitters with a discharge equivalent to crop water requirements – to meet the crop evapo-transpiration demand. It is a low pressure, low volume irrigation system that uses buried drip tubes. SDI tape is laid permanently and has been documented lasting for 10-15 years. Recent developments in SDI technologies and materials have increased system affordability and reliability with systems now capable of achieving irrigation efficiencies as high as 90-100%.

Capital investment and labour costs are, therefore, low compared to surface drip where tape needs to be placed,

TABLE 1:

Impact of drip irrigation on Water Use Efficiency Indices (bales/ML) on three Darling Downs drip irrigation demonstration sites.

	Gross Production Water Use Index (GPWUI)		Irrigation Water Use Index (IWUI)	
	Furrow	Drip	Furrow	Drip
Site 1 (1m drip)	0.84	1.11	1.58	2.60
(2m drip)	0.84	1.04	1.58	2.41
Site 2 (solid)	1.22	1.30	2.20	2.80
(skip)	1.32	1.50	2.19	2.66
Site 3 (60')	1.13	1.82	1.66	2.69
(skip)	0.92	1.15	2.24	3.17

removed and then replaced after each crop. It has a number of potential benefits over furrow irrigation:

- Water savings, control of runoff and deep drainage, increased rainfall capture, and reduced soil surface evaporation.
- Reduced incidence of disease and weeds.
- Enhanced fertiliser efficiency.
- Reduced labor demands.
- Field operations possible even when the irrigation is turned on.

As was the case with CPLM historically SDI irrigated cotton systems provided disappointing results. Their failure to produce the anticipated improvements in yield and water use efficiencies (which had been critical components in the initial decision to outlay the considerable required installation capital) may be attributed to a range of factors. Again, as with early CPLM installations, poor design or adherence to design at installation, and insufficient operator expertise, so often associated with application of any new technology, did little to produce expected outcomes. Just as a high performance engine behaves atrociously when out of tune, SDI systems perform poorly if not operated correctly, even if their design is excellent.

Trials conducted by the Cotton Catchments Communities CRC, in collaboration with a tape manufacturer and three irrigators on three sites, (see Table 1) showed a range of yield impacts of drip irrigation on cotton. The average yield decreased with the use of drip at one site (although here drip out-yielded furrow irrigated cotton in the first year of installation), and increased at the second (a 10% yield increase on average over furrow irrigation with 1m drip) and third sites (where yield increases ranging from 20 to 34% for drip over furrow irrigation were recorded). The average reduction in applied irrigation for drip irrigation over furrow irrigation ranged from 15 to 31% across the three demonstration sites.

The impacts of the yield increases and reduction in water use, as captured in the Water Use Efficiency Indices (IWUI– bales/ML), showed significant improvements in water use efficiency from the investment in drip irrigation. However, for an increase in profitability from the installation of drip the water savings must be

significant enough to enable an expansion in cotton area and an increase in yield sufficient to increase profits over the existing furrow irrigation system.

It is also important that there is reliability in water supply from year to year to justify the significant capital investment. It is critical that best management practices in design, installation, management and maintenance of drip irrigation systems are followed – if not, then profitable investment in these systems is unattainable.

Useful resources:

CRDC funded, NCEA produced publication: Alternative Irrigation Systems for the Australian Cotton Industry by Raine, Foley and Henkel remains a very informative reference for both SDI and CPLM. Ask your local cotton or water use efficiency extension officer for access to a copy.

More Profit Per Drop (<http://moreprofitperdrop.wordpress.com>) website has a range of articles discussing SDI.

Articles discussing SDI can also be accessed at <http://www.cottonandgrains.irrigationfutures.org.au> including WATERpak provides a useful discussion of alternative irrigation systems, including SDI.

Bankless Irrigation Systems

By **LANCE PENDERGAST & NIKKI PILCHER**

Bankless channel systems are designed to remove the need for siphons, with the field split into bays. The field is designed to be watered at a high flow rate with all furrows in a bay irrigated at once.

There are several types of bankless channel systems in use in Queensland and NSW. The original bankless channel system is the 'roof-top' system. In the roof-top system the bay is graded from both ends on a reverse slope forming a peak in the centre of each bay. Innovations in design are being made with this design with the most recent version in the St George area eliminating the roof top configuration.

Bankless irrigation systems are being used by broad acre irrigators seeking to improve farm efficiencies. The main motivation is the labour savings that can be made with such a system.

Pros

- Reduced labour requirements through removal of siphons.
- Improved machinery efficiency – no need for traditional management operations such as rotobuckling and drive through ditches for spraying and harvesting operations.
- Ability to better manage crop water use in response to hot, dry weather and pending rainfall events.
- Limited maintenance – tail drains are graded every 2–3 years but no need to do head ditches.

Cons

- Not suitable for paddocks with varying soil types.
- Current efficiency and uniformity evaluation methods not suitable to assess bankless systems.
- Need suitable slopes.



- Installation costs – suited to properties in the developmental phase as opposed to converting old siphon fields to bankless systems.

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Pipes Through The Bank

Efforts over the last decade to optimise the efficiency of siphon irrigation have resulted in significant improvements. In some situations fully optimized siphon irrigation systems now achieve performance levels (e.g. distribution uniformity, application efficiency and requirement efficiency) approaching those more typically associated with overhead and drip systems. There remain however a range of factors fueling considerable interest in options that provide alternatives to the traditional methodology of siphon irrigation. Innovative implementation conducted over the last five years by one grower and his consultant in the St George area has produced very encouraging results with the pipe through the bank system.

Although the potential for water savings were originally regarded as the main goal it is now recognized that labour savings was in fact the principal motivator. Labour savings of 50%, increased yields and a 25% water saving achieved by this grower attest to the potential of pipes through the bank systems as a viable alternative option to some fields currently irrigated via traditional over the bank siphons. These results have been attributed to the ability to adjust the inflow rate which, when used



Cotton being irrigated with pipe through the bank system.

FIGURE 1:
Cross-section view of PTB irrigation system

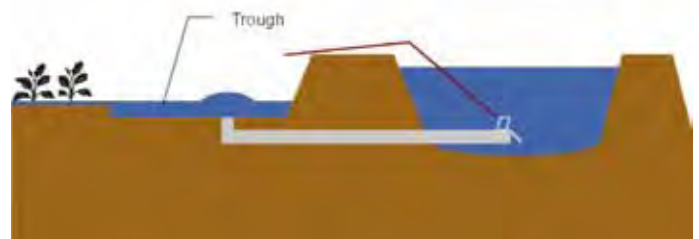


FIGURE 2:
erial view of PTB irrigation demonstrating pipe outlet situated in Guess row away from wheel tracks



in conjunction with optimization programs available, allows for delivery of irrigations adjusted to meet crop specific requirements.

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