# RRDP1730 Technical Research Report

30th July 2018

# Smarter Irrigation Grower-led Cotton Automation Integration Trial

## Gwydir Valley Irrigators Association Inc


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making every drop count

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## Contents

# Executive Summary

Over the last ten years the Gwydir Valley Irrigator Association (GVIA) in partnership with Sundown Pastoral Company have, with the support of the Cotton Research and Development Corporation (CRDC) and the Federal Department of Agriculture and Water Resources, co-ordinated the Keytah Irrigation System Comparison Trial to research alternative cotton irrigation systems including subsurface drip, lateral move, bankless channel and siphon. During the 2017-2018 season the project expanded to investigate the practical constraints of installation, management, reliability and suitability of components associated with automation of irrigation in siphon and bankless channel systems.

This is a unique project which is run by growers with the specific intention to collect relevant commercial data. This data is designed to provide cotton growers greater insight into irrigation systems and technologies giving them the ability to make more informed infrastructure investment decisions.

It is anticipated that the two flood irrigation systems; siphon and bankless channel, will continue to be widely utilised in the cotton industry. This is in part due to the lower set up costs of the systems, but also due to the good fit both systems have in the Australian cotton industry. Automation of these systems however has the potential to enhance their water use efficiency through improved scheduling and management of flow rates. In addition, there should be significant improvements in labour resourcing, which is especially important in siphon irrigation systems.

The latest season of research at Keytah (2017-2018) continued the evaluation of the different irrigation systems and expanded to evaluate flood irrigation automation concepts in a largescale grower-led trial.

The information collected over the five years of the trial provides a reference for the cotton industry, the long term data set details water use efficiency as measured using the Gross Production Water Use Index (GPWUI), a measure that enables comparison between seasons and systems. This latest set of automation information will provide growers more details of tools and techniques they can utilise to further enhance the efficiency of their irrigation systems.

The results in 2017-2018 have reaffirmed that the variability between seasons is far greater than the variability between systems when measured using the industry metrics of yield and GPWUI. The yield comparison shows an average variation of only 1.1 bales per hectare between systems while there is an average variation of 3.4 bales per hectare between seasons.

The project has demonstrated that although important, water alone is not the only driver growers must consider when making decisions on irrigation systems. They will need to continue to look for efficiency gains in labour and energy, as well as considerations of the consistency of performance and potential yield achievable under each of the systems. Growers must also look at water reliability, capital investment needed, support systems and the resources of labour and energy when looking at changing irrigation systems.

## Background

The GVIA in partnership with Sundown Pastoral Company initiated a grower led irrigation project in 2008. It was initially funded from 2008-2012 under the Raising National Water Standards Program by the National Water Commission. Additional funding from the CRDC enabled the project to continue from 2012-2015.

At the start of this project, the Keytah system comparison trial had a total of four years of data; 2009-2010, 2011-2012, 2013-2014, and 2015-2016. The addition of a fifth year of data has increased the confidence in the data and providing greater insight into possible options to automate flood irrigation systems. This will enable growers to make more well informed investment decisions.

The trial has been well received by growers and industry since its inception. This data has continually added to grower's capacity, knowledge and understanding of the alternative irrigation systems, providing growers greater understanding of the requirements and resource implications of alternative irrigation systems for cotton production.

Many growers have altered their irrigation systems following a visit to Keytah or from discussions with people involved in the project, fifty percent of growers attending the 2014 Keytah field day indicating they intended to adopt changes to their operations using information from the project. A grower survey from 2012 confirmed that growers wanted a long term dataset to utilise in their decision making with regard irrigation system choices. This desire remains relevant with 85 percent of growers surveyed at the 2014 field day wanting the project to continue. The 2017 field day survey suggested that over 70% of respondents felt that the automated smart siphon could be quite useful.

The GVIA project is a grower-led initiative, focused on commercial reality. It will complement existing data and enable extensive collaboration with industry and research partners.

## Methods

The RRDP 1730 project included two parts:

1. The continuation of the Keytah system comparison trial for sub surface drip, lateral move, furrow siphon and bankless channel, and
2. The evaluation of the practical constraints of installation, management, reliability and suitability of components associated with automation of irrigation in the siphon and bankless channel systems.

### Methodology:

- Establish a project steering committee to over-see the grower-led approach and technical aspects of the trial;
- Facilitate the installation of componentry necessary for reliable high speed internet connectivity on farm to support the integration of irrigation automation and digital agriculture;
- Facilitate the planning and installation of components for automation of the siphon and bankless channel fields;
- Assess soil moisture prior to planting and post picking using Soil cores;

- Utilise capacitance probes, head ditch and tail-water meters to collect raw water-use data;
- Utilise other forms of water-use efficiency assessments such as flow meters, Irrimate, water models, channel level sensors and IrriSat;
- Record water applied and rainfall throughout the season;
- Estimate the labour resource requirements for the systems based on commercial experience;
- Collect yield results for each system;
- Analyse yield and water use results between the systems; drip, lateral, siphon and bankless, and incorporate into previous year's results;
- Evaluate the resource requirements and management considerations for each of the systems;
- Evaluate project's ability to achieve outcomes through surveys at field days, presentations and at industry events;
- Develop a tailored communication strategy including:
    - field days, workshops and conferences;
    - opportunities to deliver results to the industry;
    - social media and internet promotion activities and
    - update promotional information packs with new results and new flyers.

# Results

## Internet Connectivity

A component of the project was to support the installation of high speed internet connectivity on farm. This is needed to support the adoption of automation of irrigation and digital agricultural componentry. The existing on farm connectivity through the primary service providers did work most of the time but had become less reliable in the last 12 months and was often too slow to enable real time monitoring of key irrigation parameters.

The progress towards automation of irrigation will require the installation of a range of sensors and monitors including; soil moisture monitors for irrigation scheduling, satellite for Irrisat and NVI images, drone images for VariWise, remote pump monitoring, remote tractor monitoring, paddock record systems, farm management systems (for example Trello the system in use on Keytah), water level and water advance sensors, canopy temperature sensors, water meters and weather stations.

The internet connectivity on farm was enhanced through the design and installation of a business internet service through the telco company Field Solutions. This process included the licensing and installation of backhaul components (intermediate links between the core network and the small subnetwork), on-farm equipment, antennas and wi-fi access points.

At completion the internet connectivity on farm was improved. Speeds were noticeably faster, and reliability significantly enhanced, which has ensured the digital agricultural systems in place on farm are able to perform at optimal levels.

## Automation

To enable automation of the flood irrigation systems the project supported the installation of pneumatic door droppers in the bankless system and smart siphons in the siphon field.

### Bankless Channel

There were seven pneumatic door droppers installed in the bankless channel field as a first step towards remote control of the field. The doors chosen cost $104/ha and were intended to streamline the transition from each bay. Unfortunately, there were issues associated with the doors chosen and some manual adjustments were still required to transition between bays.

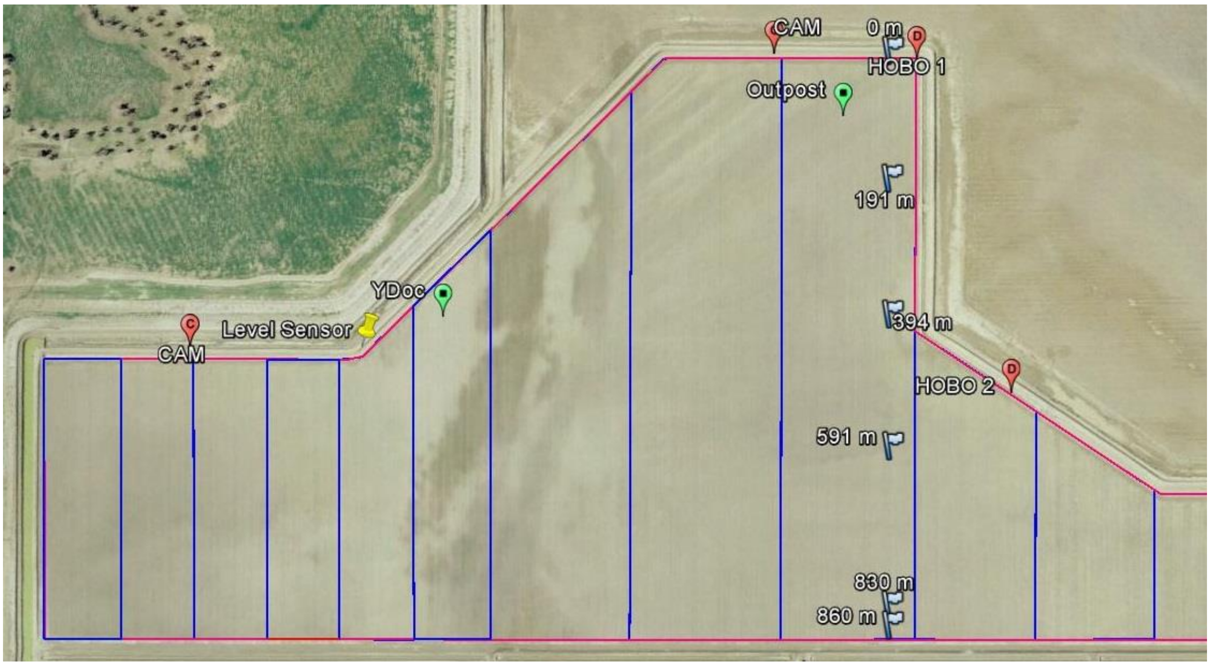
### Siphon

The siphon field was fitted with smart siphons. These are a rotating elbow fitted to a small pipe through bank. The siphons can be turned on in groups of up to 150 siphons by lowering the elbow into the water and turned off by raising the elbow out of the water. The Keytah siphon field K28 is a 75cm (30inch) configuration, fitted with 1,100 smart siphons to run water every 1.5 meters.

The K28 field has variable row length from 418 to 868 meters and a 1,650 meter head ditch length. The field was divided into eleven groups or gangs of siphons. Five gangs had between 120 and 150 siphons, while the remaining six had between 71 and 77 siphon. The smaller gangs were necessary as they operated at a higher channel head than the other gangs. As the actuation force and tension on the cable is proportional to both the number of siphons and the channel head, it was necessary to reduce the number of siphons in these gangs, so that they could be easily turned on and off without putting too much pressure on the components. Each of the gangs was connected with a steel cable to a control box mounted on a post. The control boxes were fitted with remote terminal units, actuators and wireless modems. The remote modems were specifically designed to control the siphons via a mobile app and were not fitted until February 2018.

The field was fitted with an EnviroNode Hub, a control platform developed for customisation. Trialling during the season found that the control box and the actuators were not sturdy enough and will need to be upgraded before further testing is undertaken.

Figure 1: K28 layout and gang design




The cost of material for the smart siphons in K28 was $842/ha. This was roughly twice what it could have been in a standard 1 meter (40inch) field, watered every 2 meters, with 1,200m of head ditch and consistent 800m row length ($453/ha). The 1.5m spacing of siphons, the long head ditch length and the variable row length all contributed to the higher costs. The need to reduce siphon gang sizes down where there was a large head heights also added to the cost as there were three additional gangs each fitted with a control box, actuator and wireless modem. The unit cost for each post and actuator was $919, and each wireless modem $495, a total of $1,414 for each additional control set.

Pipes were installed following a complete renovation of the head ditch. This was chosen as the installation method as the head ditch was due for renovation in the near future, and the chain trencher was still in development. Installation cost approximately $358/ha.

Table 1: Installation and capital cost K28

| **Item** | **Number** | **Unit Cost (ex GST)** | **Unit Cost Inclusive GST** | **Total** | **Grand Totals** | **Cost per Ha** |
|---|---|---|---|---|---|---|
| Smart Siphon | 1100 | $32.63 | $35.89 | $39,482.30 | | |
| Pipes (4.5m) | 432 | $25.60 | $28.16 | $12,165.12 | | |
| Pipes (4.05) | 672 | $23.03 | $25.33 | $15,476.16 | | |
| Posts and Actuators | 11 | $919.20 | $1,011.12 | $10,111.20 | | |
| Cables (/m) | 1800 | $1.00 | $1.10 | $1,800.00 | | |
| **Total Capital** | | | | | **$79,034.78** | **$841.69** |

| Item | Number | Unit Cost (ex GST) | Unit Cost Inclusive GST | Total | Grand Totals | Cost per Ha |
|---|---|---|---|---|---|---|
| Installation of Smart Siphon | 1100 | $3.51 | $3.86 | $3,860.00 | | |
| Survey and design | | | | $4,350.00 | | |
| Installation and HD renovation | | | | $25,485.00 | | |
| **Total Design and Installation** | | | | | **$33,695.00** | **$358.84** |
| | | | | | **$112,729.78** | **$1,200.53** |

An alternative installation process could have utilised a purpose build chain trencher. The chain trencher cuts a slot in the head ditch, the pipe is fitted into the slot and backfilled. The chain trencher is only suitable for use in well established head ditches to avoid loose soil falling back into the trench. It is estimated that the chain trencher could have reduced installation costs to approximately $94/ha. However, even if the chain trencher had been utilised, it would still have been necessary to renovate the rotobuck area to ensure the slope was steeper than the field slope. Rotobuck renovations would cost between $20 and $50/ha depending on the amount of soil moved. This increases the chain trencher cost to approximately $124/ha if it had been used to install the pipes in K28.

Table 2: Comparative costs using Chain Trencher for K28

| Chain Trencher | | | Siphons | Labour/hr | Cost | cost/ha | cost/siphon |
|---|---|---|---|---|---|---|---|
| $3/pipe @ 20/hr | | **K28** | 1100 | | $3,300 | | |
| Labour $30/hr | 2 people | **Hours** | 110 | $30 | $3,300 | | |
| cover 200 pipes in 2 hours with excavator | | | 11 | $30 | $660 | | |
| Tractor and excavator running costs | | | | | $1,000 | | |
| Freight $3/km towing trailer Assumption 200km | | | | | $600.00 | | |
| | | | | | **$8,860.00** | **$94.36** | **$8.05** |
| Rotobuck renovation ($20-$50/ha estimate) | | | | | | $30.00 | |
| Total chain trencher installation with rotobuck renovation | | | | | | **$124.36** | |

Table 3: Possible scenario for similar 1m row spacing

| Item | Number | Unit Cost (ex GST) | Unit Cost (Inc GST) | Total | Assumptions | |
|---|---|---|---|---|---|---|
| Smart Siphon | 600 | $32.63 | $35.89 | $21,535.80 | **Row length** | **800** |

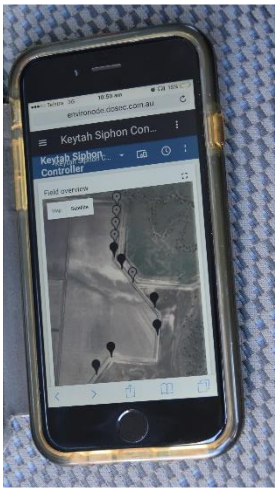
| | | | | | | |
|---|---|---|---|---|---|---|
| Pipes (4.5m) | 600 | $25.60 | $28.16 | $16,896.00 | **HD Length** | **1200** |
| Posts and Actuators | 4 | $919.20 | $1,011.12 | $3,676.80 | **Area (Ha)** | **96** |
| Cables (/m) | 1400 | $1.00 | $1.10 | $1,400.00 | | |
| **Total Capital** | | | | **$43,508.60** | | |
| **Capital Cost per Ha** | | | | **$453.21** | | |
| Installation of Smart Siphon | 600 | $4.40 | $4.84 | $2,904.00 | | |
| Survey and Design<br>(36% cost reduction) | | | | $2,784.00 | | |
| Installation and Earth works using chain trencher | 600 | $8.05 | $8.86 | $4,832.73 | | |
| Rotobuck renovation ($20-$50/ha) | | $30 | | $2,880.00 | | |
| **Total Design and Installation** | | | | **$13,400.73** | | |
| **Total Design and Installation per Ha** | | | | **$139.59** | | |
| **Total Design and Installation per m head ditch** | | | | **$11.17** | | |
| **Total capital design and installation per Ha** | | | | **$592.80** | | |

The project involved the supply of a trial telemetry and Smart Siphon management system designed by Dosec Design. This initial system was installed and commissioned following installation of the Smart Siphons and terminal units and actuators by Islex.

The telemetry and management system were managed with an EnviroNode Hub. The hub gathered data from water level sensors and enabled the control of the Smart Siphons remotely. The EnviroNode Hub is a versatile, rugged and reliable product platform developed for customisation. It is a standalone device that can simply be bolted to a mast and connected to a solar panel. It has a solar charged internal lithium ion battery and is environmentally protected to IP67. All communications, data management and control functionality are inbuilt.

The Wireless Water Level Sensors are ultrasonic with a distance measurement range of approximately 20cm to 750cm and a resolution of +/-1cm. The sensors were supplied in an IP67 protective enclosure, mounted vertically with clear space below them.

The final key component to enable the trial of remote management of the smart siphons was the Custom Mobile Device Web App. This mobile device and PC web app was provided, initially, with the following features:




- Quick display of water current water levels and graphed history over a set period.
- Quick display of Smart Siphon system status.
- Ability to download and save historical data as CSV files or similar.

Additional features such as functionality to allow syphons to raise and lower automatically in response to either water level sensor data, time and date scheduling are possible. Additionally, the App could incorporate the ability to change the water level measurement and logging schedule or to add additional sensors and set up new customers.

## Field Measurements

Malcolm Gillies from USQ supported the automation part of the project by conducting several field measurements. These measurements were utilised to determine flow rates across the field and to assess the uniformity of irrigation.

The pipes were installed through the bank with a slight uphill slope in a bid to have more uniform flow rates, (outlet higher than inlet). The pipe elevations in K28 were surveyed by Malcolm Gillies (USQ) to capture the uniformity of outlet levels and to enable the installation of level sensors to measure the water head over the pipe outlets[1]. The survey found that most of the pipes in gang six had an incline, although less than intended. The pipes in gang 5 however were not positioned with the desired incline. In addition to measuring the pipe placement, Malcolm Gillies installed a number of devices to measure head ditch water levels during the season. These complemented the water level sensor connected to the EnviroNode Hub.

In field flow meters were installed in gang 1B, 5 and 6, flow volume and rate were collected from these devices. In addition, Irrimate measures were taken from gang 6 during the season to measure water advance down the field. IrriMATE advance meters were installed in the eight consecutive furrows being supplied from pipes numbered 17 to 24 in gang 6. The fifth advance sensor coincided with the position of the flowmeter. In the advance data furrows one and three were wheeled furrows and the remaining furrows non-wheeled furrows. Advance sensors were installed at five distances along the length of these furrows. The positions of these sensors were measured using a GPS at zero meters, 191m, 394m, 591m and 830m from the start of the crop at the head ditch end of the field. The tail drain end of the field was at 860m.

[1] Summary of field measurements

During the irrigation event on the 22nd December 2017 the flow rates recorded were; 5.198 L/s (flowmeter) or 5.322 L/s (water level over mean pipe RL). There was no significant change in flow rate over time, so a constant flowrate was used in SISCO. For the following irrigation on the 5th of January the flow meter failed mid irrigation, using the water level over the mean pipe RL the flow rate was measure at 4.95L/s. During this irrigation the channel water level increased with time resulting in a variable flowrate. SISCO was used to analyse the data which is available in the Summary of field measurements[1].

## System Comparison

The trial was completed in May 2018, with ginning in late May and early June 2018.

### Soil Moisture

Soil cores were taken to assess the starting and finishing soil moisture levels. The soil cores were collected as per guidelines from QDPI.

Table 4: Soil Moisture 2017-2018

| Soil Water Deficits 2017-18 soil core data (0-100cm) | | | | | |
|---|---|---|---|---|---|
| **Profile Water Content (0-100cm)** | | **Starting** | **Finishing** | **Used soil reserve** | |
| **Drip** | **D1** | 344.63 | 280.87 | 64 | |
| | **D2** | 287.63 | 252.70 | 35 | |
| | **D3** | 349.78 | 260.89 | 89 | 63 |
| **Bankless** | **B1** | 325.77 | 270.28 | 55 | |
| | **B2** | 328.84 | 360.80 | -32 | |
| | **B3** | 373.15 | 334.45 | 39 | 21 |
| **Siphon** | **S1** | 332.65 | 252.53 | 80 | |
| | **S2** | 276.57 | 231.00 | 46 | |
| | **S3** | 365.78 | 299.01 | 67 | 64 |
| **Lateral** | **L1** | 322.43 | 275.30 | 47 | |
| | **L2** | 318.50 | 193.20 | 125 | |
| | **L3** | 251.16 | 145.38 | 106 | 93 |

### Crop Management

Table 5: Crop Management activities 2017-2018

| **Activity** | **Siphon Furrow** | **Lateral Move** | **Subsurface Drip** | **Bankless Channel** |
|---|---|---|---|---|
| **Soil core** | 10th October 2017 | 10th October 2017 | 10th October 2017 | 10th October 2017 |
| **Pre-Irrigation** | Planted on following rain | | | |
| **Variety** | Sicot 746B3F | | | |
| **Planting** | 31st Oct 2018 | 31st Oct 2018 | 31st Oct 2018 | 31st Oct 2018 |
| **Watered-up** | 8th Nov 2017 | 2nd Nov 2017 | 3rd Nov 2017 | 6th Nov 2017 |
| **First Defoliation** | 30th March 2018 | 30th March 2018 | 30th March 2018 | 30th March 2018 |
| **Picking** | 5th May 2018 | 3rd May 2018 | 5th May 2018 | 6th May 2018 |
| **Soil core** | 15th May 2018 | 15th May 2018 | 15th May 2018 | 15th May 2018 |

## Irrigation Water

There was no pre-irrigation this season following rain in October. All systems were watered up between the 2nd and 8th of November 2017.

The last irrigation for all systems was in March 2018. Irrigation water was tight as there was limited in-crop rainfall during the season.

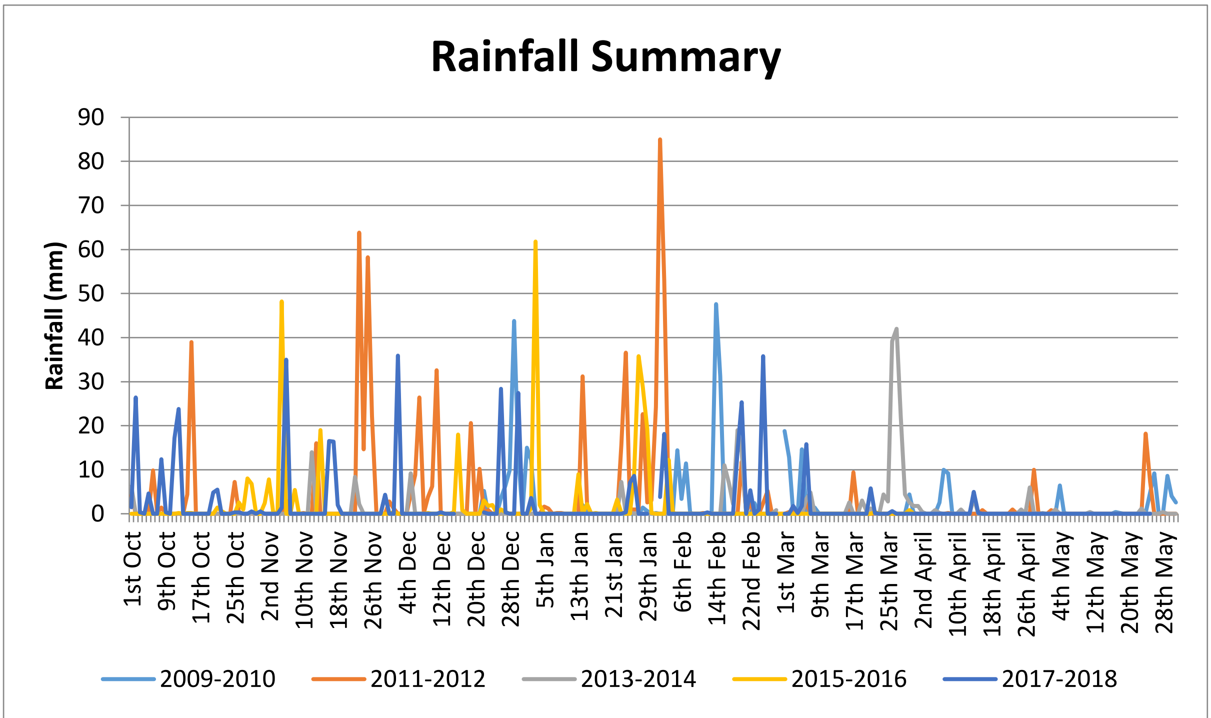
Table 6: Irrigation Water Applied 2017-2018

| System | Date of Last Irrigation | Number of Irrigation | ML/ha |
|---|---|---|---|
| **Siphon Furrow** | 22nd March 2018 | 9 | 7.07 |
| **Lateral Move** | 11th March 2018 | 15 | 6 |
| **Subsurface Drip** | 9th March 2018 | 14 | 6.06 |
| **Bankless Channel** | 21st March 2018 | 8 | 7.53 |

## Climatic Data

The system comparison trial has been run over five seasons which has enabled the collection of data under a number of different climatic scenarios. The 2009-2010 was a typical season, 2011-2012 was wet and overcast with two flood events, 2013-2014 was hot and dry with very little in crop rainfall, 2015-2016 the season was again quite typical, but there was limited irrigation water, and 2017-2018 was initially very mild, then quite warm with limited in crop rainfall and restricted water during peak boll fill.

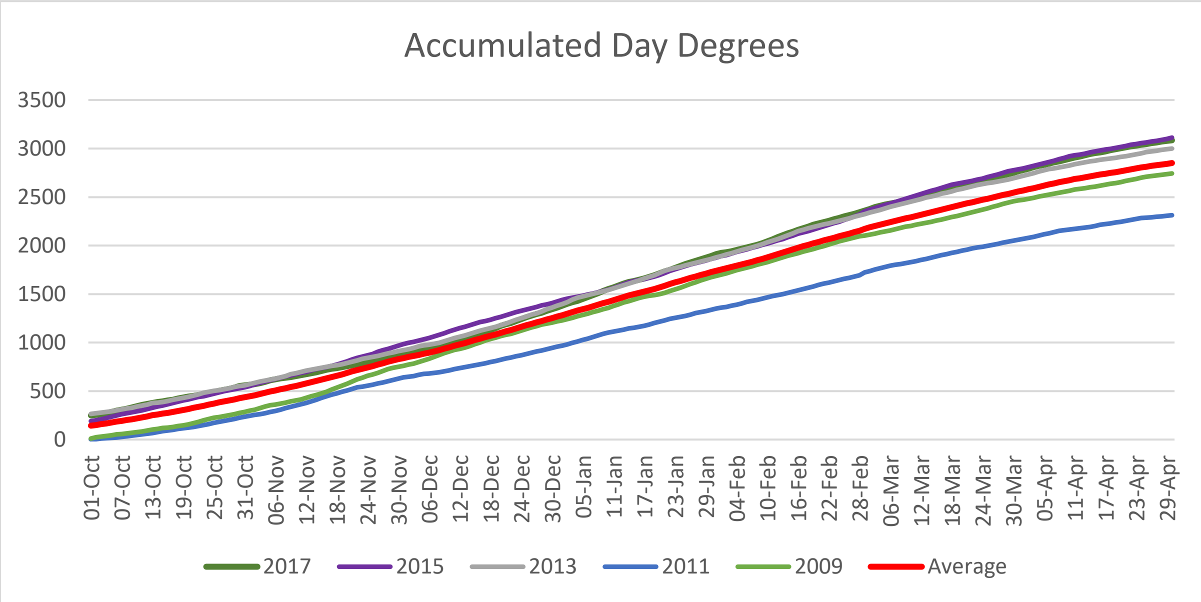
Figure 2: Rainfall



The trial site received a total of 421mm of rainfall from October 2017 to May 2018. The daily rainfall data (figure 2), indicates that there were 12 effective rainfall events during the season where more than 10mm of rain was received (88% effective rainfall).

The accumulated day degree which was slightly above the long-term average as shown in figure 3.

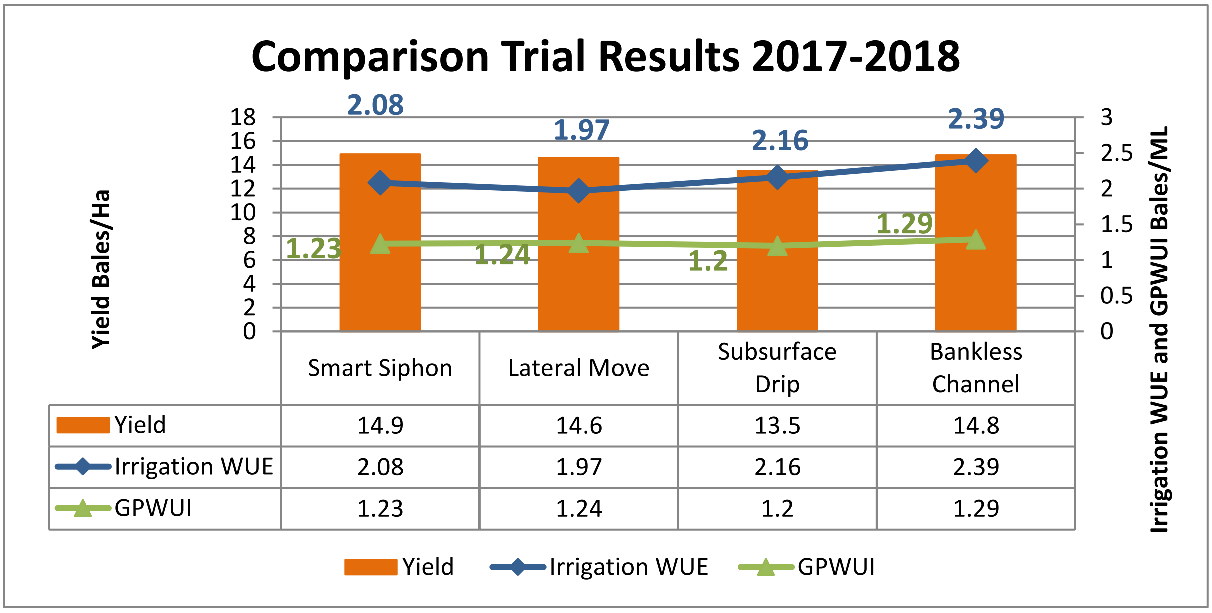
Figure 3: Accumulative Day Degrees




## Yield

The performance of all four systems was better from a yield perspective in the 2017-2018 season than in the previous seasons. A summary of the yield, irrigation water use index and Gross Production Water Use Index (GPWUI) is shown in figure 4.

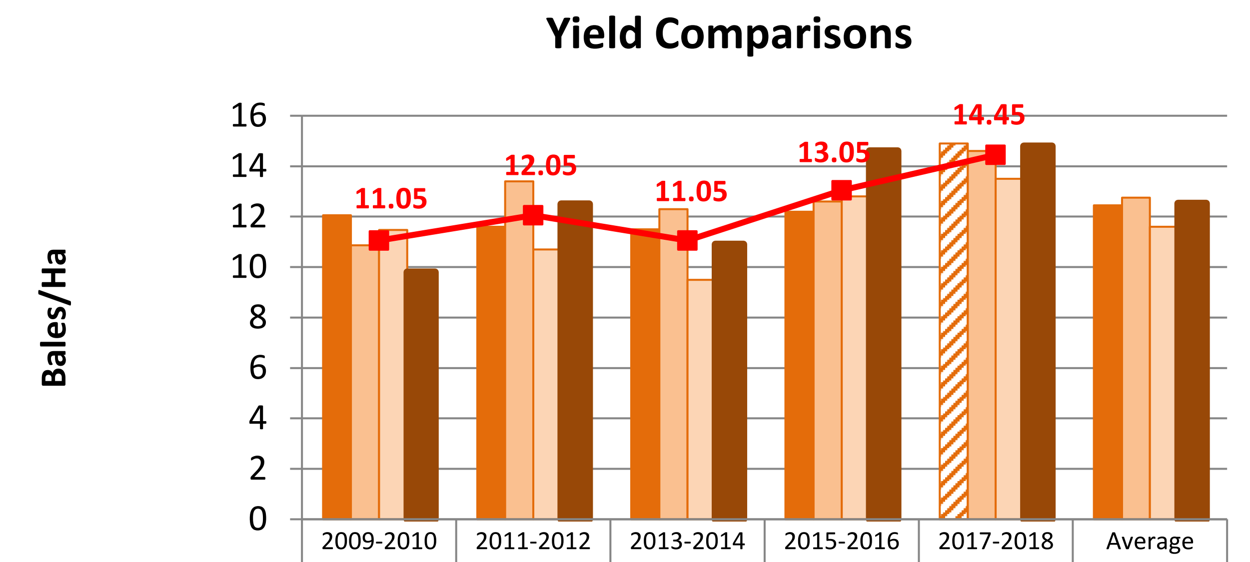
Figure 4: Yield (module estimates) and Water Use Efficiency 2017-2018




| | Smart Siphon | Lateral Move | Subsurface Drip | Bankless Channel |
|---|---|---|---|---|
| Yield | 14.9 | 14.6 | 13.5 | 14.8 |
| Irrigation WUE | 2.08 | 1.97 | 2.16 | 2.39 |
| GPWUI | 1.23 | 1.24 | 1.2 | 1.29 |

The irrigation water use index is calculated using area grown, bales produced, and total irrigation water applied. The GPWUI is however a more realistic index to make comparisons between systems and between seasons as in additional to area, yield and irrigation water, it considers the used soil reserves and the in season rainfall. The higher the GPWUI the more efficiency the performance.

Figure 5: Yield Comparison over five seasons




| | 2009-2010 | 2011-2012 | 2013-2014 | 2015-2016 | 2017-2018 | Average |
|---|---|---|---|---|---|---|
| Siphon | 12.06 | 11.6 | 11.5 | 12.20 | 14.90 | 12.45 |
| Lateral Move | 10.86 | 13.4 | 12.3 | 12.60 | 14.60 | 12.75 |
| Subsurface Drip | 11.47 | 10.7 | 9.5 | 12.80 | 13.50 | 11.59 |
| Bankless Channel | 9.8 | 12.5 | 10.9 | 14.60 | 14.80 | 12.52 |
| Average | 11.05 | 12.05 | 11.05 | 13.05 | 14.45 | |

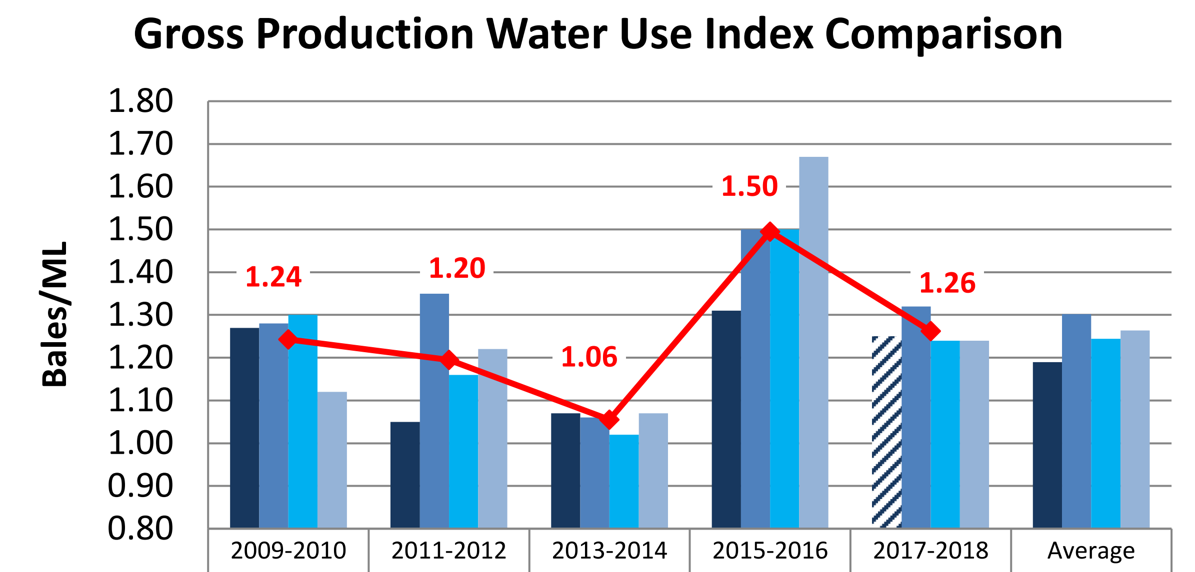
Figure 5 combines the yield data for the five years of the trial. The graph shows that the highest yields for each of the systems were achieved in 2017-2018. There was an average 10% increase in yield in 2017-2018 compared to 2015-2016, which highlights that the 2017-2018 was a good season.

The 2017-2018 season is the first set of data for the Smart Siphon, the four previous seasons were irrigated with traditional siphons.

Throughout the project, Keytah have struggled to get comparable yields from the subsurface drip system. The average yield over five seasons with the drip is 11.59 bales per hectare compared to 12.45 for the siphon, 12.52 for the bankless and 12.75 for the lateral move. It is important to note that the yield average of the bankless channel field may have been impacted by the results in 2009-2010 when there were significant establishment issues with the bankless channel. In addition, there was flooding, and water logging experienced in the siphon field in the 2011-2012 season.

The graph shows that there is more yield variation between seasons than there is between systems. This however is less than the variation seen in water use efficiency and GPWUI between seasons (figure 6).

Figure 6: Gross Production Water Use Index




| | 2009-2010 | 2011-2012 | 2013-2014 | 2015-2016 | 2017-2018 | Average |
|---|---|---|---|---|---|---|
| Siphon | 1.27 | 1.05 | 1.07 | 1.31 | 1.25 | 1.19 |
| Lateral | 1.28 | 1.35 | 1.06 | 1.50 | 1.32 | 1.30 |
| Drip | 1.30 | 1.16 | 1.02 | 1.50 | 1.24 | 1.24 |
| Bankless | 1.12 | 1.22 | 1.07 | 1.67 | 1.24 | 1.26 |
| Average | 1.24 | 1.20 | 1.06 | 1.50 | 1.26 | |

The Average GPWUI for 2017-2018 was 1.26 bales per megalitre. The average GPWUI over the five seasons studies varied from 1.06 bales per megalitre in 2013-2014, a warm to hot season with almost no rainfall, to 1.50 bales per megalitre in 2015-2016, a more typical season. There were similar trends in the individual systems over each of the seasons. Variation between seasons have been found to be greater than the variation between systems. It is important to note that in 2011-2012 the siphon field was more dramatically impacted by the two flood events which caused water logging as the flood water could not be drained from the siphon field as quickly as necessary. This may have caused the low GPWUI for the siphon field in that season. The poor establishment of the bankless channel field in 2009-2010 may also have impacted the GPWUI for that year.

## *Individual system results*

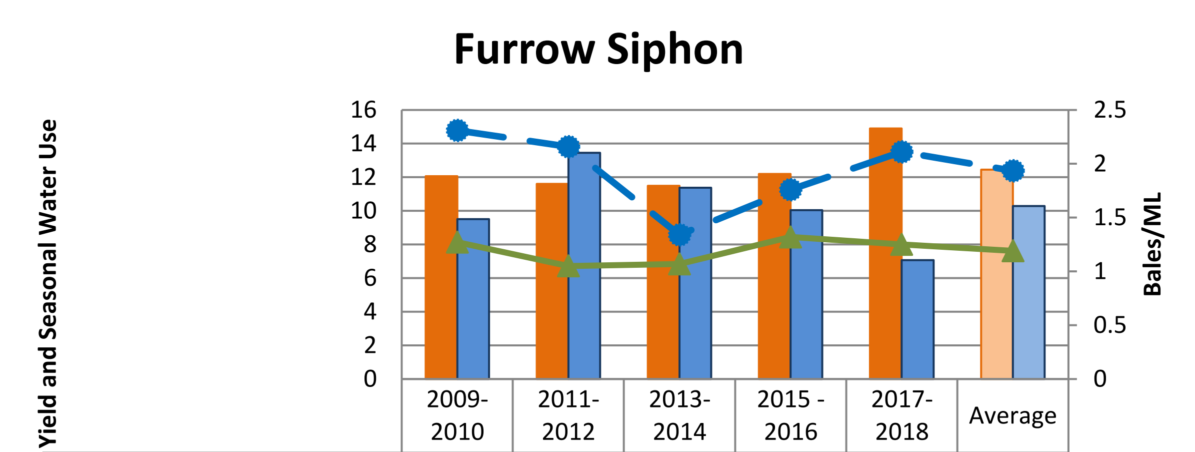
The individual data combines Gross Production Water Use Index (GPWUI), seasonal water (rainfall and irrigation water received during the season), expressed as mega litres per hectare and the Irrigation water use index, expressed as bales produced per megalitre of irrigation water applied.

### Furrow Siphon

The system comparison trial has confirmed that the furrow siphon system does produce consistent yield, a reasonable irrigation water use index and a Gross Production Water Use Index (GPWUI) which is comparable to the other systems. The average yield was 12.41 bales per hectare, an irrigation water use efficiency of 1.94 bales per mega litre and a GPWUI of 1.19 bales per megalitre.

The high seasonal water use figure of 13.46 ML/ha in 2011-2012 was in part due to flooding as a result of a very heavy rainfall events soon after an irrigation. This potentially impacted the yield and the water use efficency of the system in that season. In contrast it produced the strongest GPWUI (along with the bankless system) in the hot dry 2013-2014 season. In the 2017-2018 season the GPWUI was very similar to the bankless channel and the drip systems. This season produced the highest yield and lowest seasonal water use of the five seasons. The yield was noticably more than in previous seasons.

Figure 7: Furrow Siphon System

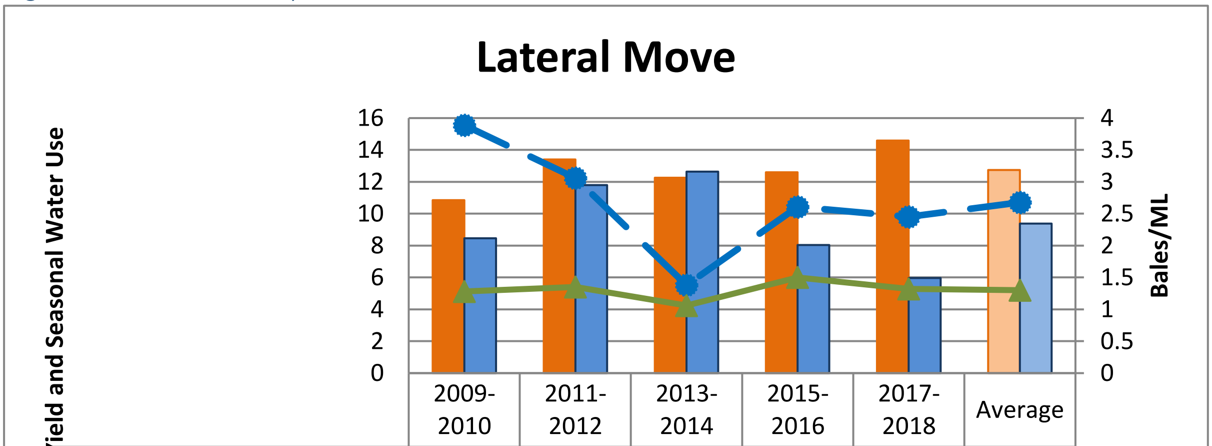



| | 2009-2010 | 2011-2012 | 2013-2014 | 2015 -2016 | 2017-2018 | Average |
|---|---|---|---|---|---|---|
| Yield (Bales/Ha) | 12.06 | 11.6 | 11.5 | 12.2 | 14.9 | 12.45 |
| Seasonal Water (ML/Ha) | 9.5 | 13.46 | 11.37 | 10.04 | 7.07 | 10.29 |
| Irrigation WUE Bales/ML | 2.31 | 2.16 | 1.34 | 1.76 | 2.11 | 1.94 |
| GPWUI (Bales/ML) | 1.27 | 1.05 | 1.07 | 1.32 | 1.25 | 1.19 |

## Lateral Move

The lateral move results shown in figure 8 below demonstrate that this system has the potential to produce the highest average yield, irrigation water use efficiency and GPWUI. The lateral produced the highest average yield of 12.74 bales per hectare, an irrigation water use efficiency of 2.68 bales per mega litre and a GPWUI of 1.30 bales per mega litre. Better than the other three systems.

Figure 8: Lateral Move System



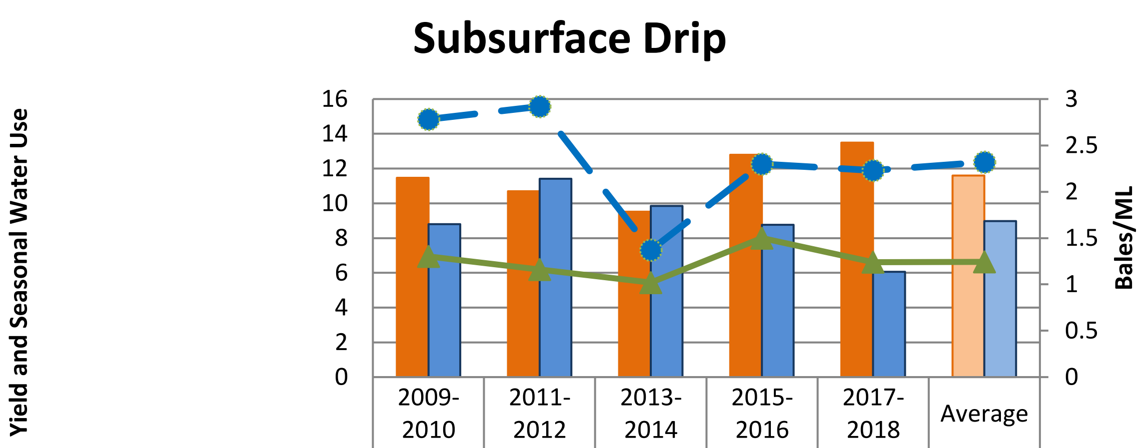

| | 2009-2010 | 2011-2012 | 2013-2014 | 2015-2016 | 2017-2018 | Average |
|---|---|---|---|---|---|---|
| Yield (Bales/Ha) | 10.86 | 13.4 | 12.26 | 12.6 | 14.6 | 12.74 |
| Seasonal Water (ML/Ha) | 8.46 | 11.79 | 12.65 | 8.04 | 5.97 | 9.38 |
| Irrigation WUE Bales/ML | 3.89 | 3.06 | 1.38 | 2.61 | 2.45 | 2.68 |
| GPWUI (Bales/ML) | 1.28 | 1.35 | 1.06 | 1.5 | 1.32 | 1.30 |

The results do however show quite an amount of seasonal variation. Figure 8 suggest that in a hot dry season as seen in 2013-2014 that the GPWUI for the lateral system has the potential to be compromised, as irrigators strived to maintain sufficient water to the crop. In contrast the lateral system is well suited to wet seasons (2011-2012) where there were two flood events and a large number of cloudy days. It is easier to manage irrigation volumes with this system under these conditions, minimising the potential for water logging despite the flooding. Whilst in the hot seasons there is constant pressure to maintain irrigation, any breakdown in such conditions could have very dramatic consequences.

### Subsurface Drip

Figure 9 following shows the five years of results for the subsurface drip system. During the five years of the trial it has struggled to produce consistency in yield but has achieved good irrigation water use efficiency results. The average yield of 11.6 bales per hectare is 0.86 of a bale behind the other systems. The performance of the drip was expected to be stronger in the wet 2011-2012 season, but there was some difficulty in removing runoff following several heavy rain events. This caused some waterlogging which may have affected the result. The hot conditions in 2013-2014 impacted the efficiency of the drip system. It was difficult to maintain sufficient irrigation water to the crop during the hot weather.

Figure 9: Subsurface Drip System




| | 2009-2010 | 2011-2012 | 2013-2014 | 2015-2016 | 2017-2018 | Average |
|---|---|---|---|---|---|---|
| Yield (Bales/Ha) | 11.47 | 10.7 | 9.52 | 12.8 | 13.5 | 11.60 |
| Seasonal Water (ML/Ha) | 8.8 | 11.42 | 9.84 | 8.77 | 6.06 | 8.98 |
| Irrigation WUE Bales/ML | 2.78 | 2.92 | 1.37 | 2.3 | 2.23 | 2.32 |
| GPWUI (Bales/ML) | 1.3 | 1.16 | 1.02 | 1.5 | 1.24 | 1.24 |

The system has received a major overhaul by Netafim during the 2017-2018 season to improve the capacity of the system and help address some of the limitations being experienced. Unfortunately, this was not completed until late in the season. In future seasons the performance of the drip system is expected to be improved as a result of the changes to the system and through the agronomic support of Netafim.

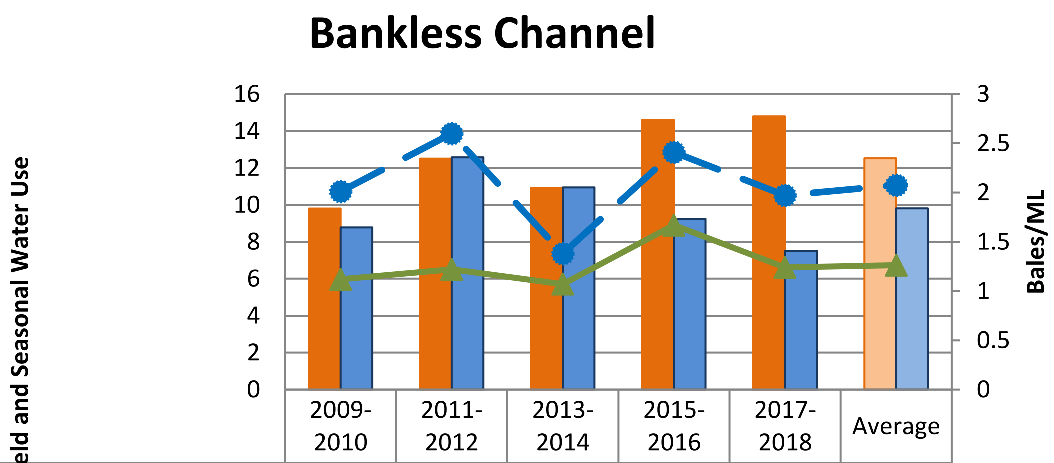
### Bankless Channel

There are many variations of the bankless channel system, the Keytah site has a rooftop variation where water is pushed "up" from each end of the field. The is only a minimal 50mm incline to the centre of the field. Each subsequent bay is 7 to 10cm (3-4 inches) lower enabling the previous bay to drain completely.

The bankless channel system results over five seasons (figure 10) demonstrates that this system shows considerable promise. The bankless channel has produced the highest yield in the last two seasons 2015-2016 and 2017-2018, and the highest GPWUI in both 2013-2014 and 2015-2016. Unlike the siphon and drip fields the bankless system does not seem to have been impacted by any water logging in the wet 2011-2012 season, possibly as the water could be drained quickly from the field. The bankless channel design appears to be suited to the hotter conditions as demonstrated by the GPWUI of 1.07 bales per megalitre in the hot dry 2013-2014 season.

It is important to note that the 2009-2010 season saw some significant establishment issues due to late field development. The yield is believed to be impacted because of establishment issues. The reduced yield would have influenced both the irrigation WUE and the GPWUI in 2009-2010 and the average performance of the system over the five years of the trial.

Figure 10: Bankless Channel System




| | 2009-2010 | 2011-2012 | 2013-2014 | 2015-2016 | 2017-2018 | Average |
|---|---|---|---|---|---|---|
| Yield (Bales/Ha) | 9.8 | 12.5 | 10.93 | 14.6 | 14.8 | 12.53 |
| Seasonal Water (ML/Ha) | 8.78 | 12.57 | 10.95 | 9.25 | 7.52 | 9.81 |
| Irrigation WUE Bales/ML | 2.01 | 2.6 | 1.38 | 2.41 | 1.97 | 2.07 |
| GPWUI (Bales/ML) | 1.12 | 1.22 | 1.07 | 1.67 | 1.24 | 1.26 |

## *Operational Data*

Over the five years of the trial, data associated with the operation of each of the systems has been compiled. This is displayed in table 7 below. It includes labour, energy, capital and depreciation costs of each of the systems.

There are a number of assumptions associated with operation data presented in table 7.

- The figures for the smart siphon K28 are the actual cost incurred in the 2017-2018 season.
- The $1,000 capital set up cost for levelling a siphon field has been added to the cost of set up for each of the smart siphon scenarios. It is likely that this $1,000 figure is conservative.
- The capital setup costs for the bankless channel, lateral move and subsurface drip systems are based on historical data and are likely to be conservative.

- There has been no change in the operating cost of extras between the standard siphon and the smart siphon scenarios.
- The Labour requirements for each of the smart siphon scenarios is assumed to reduce from 3.36 hours per annum for a typical siphon field to an estimate of 0.5 hours.
- There has been no predicted reduction in fuel usage in Litres of fuel per megalitre per hectare.
- The average yield of the first four seasons of the trial has been used as the standard siphon yield.
- The average yield over five seasons from the siphon field (12.45 bales/hectare) has been used for the three smart siphon operational scenarios.

Table 7: System Operational Costs

| | **Siphon** | **Smart Siphon K28** | **Smart Siphon K28 (Chain Trencher)** | **Smart Siphon (standard)** | **Lateral Move** | **Subsurface Drip** | **Bankless Channel** |
|---|---|---|---|---|---|---|---|
| **Operating Labour Cost @$40/hr ($/ha/yr)** | $134 | $20 | $20 | $20 | $22 | $8 | $11 |
| **Operating Energy Cost (fuel in L/ML/ha)** | $2.82 | $2.82 | $2.82 | $2.82 | $35.40 | $37.50 | $0.72 |
| **Operating Extras (rotobucks, siphon placement etc.)** | $18 | $18 | $18 | $18 | | | |
| **Total Operating Cost ($/ha/yr.)** | $175 | $62 | $62 | $62 | $255 | $246 | $17 |
| **Ongoing Maintenance Cost ($/ha/yr.)** | $20 | $22 | $22 | $22 | $110 | $25 | $15 |
| **Field Maintenance Cost ($/ha/yr.)** | $80 | $80 | $80 | $80 | $50 | $40 | $140 |
| **Capital Setup Costs ($/ha)** | $1,000 | $2,200 | $1966 | $1,592 | $3,880 | $8,500 | $2,000 |
| **Total Operational, Maintenance, Ownership Cost ($/ha/yr.)** | $295 | $252 | $242 | $227 | $609 | $651 | $212 |

NB: Yield and GPWUI used for smart siphon were average of K28 over five years.

Smart siphon estimates of labour and capital setup costs do not include the automation with the envirohub modems.

## Discussion

The 2017-2018 season was a transitional phase of the project where progression towards automation was assessed. Options for the commercial installation of the smart siphon pipes were still being determined at the start of the project and the telemetry and siphon management system were custom build during the season. There were several challenges during the season, as such these findings should be considered as an indication until further investigation is possible. A selection of the steering committee met in July to discuss the findings and the assumptions used in the operational assessments. Further analysis in this area is needed to increase the confidence in the assumptions.

## Internet Connectivity and Automation

The decision to install a business internet service on farm through a microwave link into the fibre optic cable in Moree has provided enhanced connectivity to the farm. The telco, Field Solutions, was engaged to install backhaul and on farm componentry, radio pairs, antennas and licences. The installation process took approximately six months and cost in excess of $60,000.

The internet connectivity on farm is now significantly quicker and notably more reliable. The setup has also ensured that Keytah can have unlimited data and Wi-Fi coverage over most of the farm. As a result, Keytah has been able to more readily access crop and management systems on farm.

Keytah monitor soil moisture, water pumped, storage levels and weather which is complemented by satellite and drone imagery. The information is utilised to improve the understanding of soil variability, improve the placement of moisture probes and irrigation scheduling. The management team are able to ensure water is pumped on time and at the rate required. They have been able to trial remote monitoring of channel water levels, manage head heights and make more well informed assessments of flow rates during irrigation. Additionally, the irrigation team can monitor storage water levels, which gives them additional information on evaporation and seepage and enables the calculation of real time water balances. Better connectivity has enhanced the efficiency of information exchange, improved the ability to transfer data and images, and capture better more timely data across the whole farm.

An important component of the project was to evaluate the practical constraints of installation, management, reliability and suitability of components associated with automation of irrigation in the siphon and bankless channel systems.

There were seven pneumatic door droppers installed in the bankless channel field as a first step towards remote control of the field. The doors chosen were intended to streamline the transition from each bay, when the water level reached a set height at the door. Unfortunately, there were issues associated with the type of doors chosen. As the pneumatic doors are triggered by water level, if one side of the bay triggers a release before the second side of the bay, water levels on the second side are not reached in a timely manner, as water drains preferentially through the first door that opens. Manual adjustments were required to efficiently transition between bays. Alterations to the doors will be necessary prior to the next irrigation season to improve the suitability of the pneumatic doors.

Automation of the siphon field K28 was facilitated through the installation of smart siphons. A smart siphon was fitted to a small pipe through bank every 1.5m along the head ditch. There were several possible approaches which could have been used to install these pipes.

The approach taken on Keytah was to fully renovate the head ditch and install the siphons. This decision was made as the head ditch on K28 would have needed to be renovated in the next few years regardless of the installation of the smart siphons. Renovating the head ditch and installing the smart siphon pipes through the bank was intended to ensure the head ditch would not need significant works for a minimum of ten years. The head ditch renovation included the renovation of the rotobuck area. This was re-levelled to ensure that the rotobuck slope was steeper than the field slope. The head ditch renovation was significantly more expensive that the alternative having cost $358 per hectare (table1).

The alternative installation process would have utilised the chain trencher specifically designed for the installation of the smart siphon pipes. At the time when the decision to renovate the head ditch was made the chain trencher was still being developed. The development and construction of the chain trencher was completed in Autumn 2017. It was tested on an alternative site. The site chosen had a recently developed head ditch which had not stabilised sufficiently for the chain trencher to be used effectively. Further testing on a stabilised head ditch proved that the chain trencher was an efficient and effective means of installing the smart siphon pipes. Assessments of the use of the chain trencher, with the required rotobuck renovation were found to be $234.48 less than the full head ditch renovation installation (table 2).

An additional consideration is that K28 has a 0.75 meter row spacing. This means that there needs to be a siphon ever 1.5 meters as opposed to one every two meters with one meter row spacing. Moreover, K28 was a difficult shape with a range of short and long row lengths and a very long head ditch. These issues have significantly increased the cost of componentry for the field.

An analysis was conducted to demonstrate the potential costs for a more uniform field. The installation of smart siphons into a one meter row spacing field, with 800 meter row lengths and a 1,200 meter long head ditch indicates that componentry and installation costs could be reduced. Component costs would decrease to approximately $453 per hectare (table 3) compared to $842 per hectare for K28 (table 1). Installation using the chain trencher is estimate at $110 per hectare compared to $124 per hectare with the chain trencher on K28 (table 2), or $359 per hectare with full head ditch renovation (table 1).

The field measurements conducted by USQ showed that placement of the pipes can vary. The variation in placement will mean that the flow rates will vary as the flow rates in each of the pipes is impacted by the height between the pipe outlet and the channel water level. The more uniform the pipe positioning the more uniform the flow rates which will be achieved during irrigations. Despite this recorded variation, the fixed nature of the smart siphon pipes through the bank means that there will be consistency of flow at any specified head height out of each individual pipe every time an irrigation takes place. In contract, when siphons are manually thrown over the head ditch every single placement is likely to vary making it very difficult to uniformly manage flow rates. It is possible that the more uniform flow rates may have enhanced the yield performance of the field.

The other component designed and installed during the season was the Smart Siphon management system. The telemetry and management system were managed with an EnviroNode Hub which collected data from water level sensors and enabled the control of the Smart Siphons remotely. There were some issues identified in the management system which stemmed primarily from the actuators in the Smart Siphon control boxes. The capacity of the initial actuators was not sufficient to give the reliability and hence confidence to turn siphon gangs on or off remotely. Trials continued with alternate actuators in the final irrigations, changes in actuator selection will be necessary in any smart siphon management systems implemented commercially. Given experience this season it may be necessary to consider a check in the system so that have confidence actuation (on or off) is correct.

An important component of the progress towards automation of the siphon field involved the investment in channel level sensors. The ultrasonic equipment was installed in the head ditch of K28. This equipment measures the water level in the head ditch. Information from the sensor was readily available on the customised mobile device web app developed for the project. The irrigation team at Keytah found that this worked extremely well providing real time information enabling more accurate monitoring of head height and hence flow rates. The critical nature of this information and the importance of real time access reaffirms the need for effective telecommunications on farm.

The customised mobile device web app provided a display of current water levels and graphed history over a set period from the channel level sensors. The app also provided a display of Smart Siphon system status and gives the user the capacity to download and save historical data in various formats. Unfortunately, the issue with the actuators in the siphon control boxes caused some problems with the display of the siphon system status. Further fine tuning is taking place to rectify this issue and it is expected that this app will be widely utilised in the management of smart siphons going forward.

## System Comparison

### 2017-2018 season

The 2017-2018 results increase the level of confidence in the data and will give growers a better understanding of which system will deliver the yield and water efficiencies best suited to their needs.

The 2017-2018 data has produced the highest yield (14.9 bales per hectare) for the siphon field over the five years of the trial. The bankless channel system, 14.8 bales per hectare, and the lateral, 14.65 bales per hectare also produced good yields. The lateral move was once again the strongest performer from a gross production water use index perspective (GPWUI). However, the subsurface drip continued to struggle to achieve comparable yield results; it produced 13.51 bales per hectare, 1.43 bales behind the smart siphon field.

The operational data presented in table 7 shows that all three smart siphon installation scenarios have similar capital set up costs to the bankless channel system, all of which are significantly less than for the two pressurised systems the lateral move and the drip. When considered on a total operational, maintenance and ownership bases it suggests that the four siphon scenarios and the bankless channel system are similar, varying from $227 per hectare per year for a standard smart siphon installation with a chain trencher to $295 per hectare per year for a typical manual siphon system.

The further development and implementation of the telemetry and adjustments in the control actuators to remotely manage smart siphon gangs will alter the cost breakdown by further reducing the labour resourcing and increasing the capital set up. Importantly the project has demonstrated that automation of siphon irrigation can be achieved cost effectively and can be easily retrofitted into existing siphon fields. The various scenarios presented show that irrigators can choose the installation approach which best suits them and stage the implementation of automation so that the capital costs are spread over numerous years if required.

### Five-year comparison

To enhance the value of the system comparison data it is important to look at the results over the five years of the trial. This information is presented in figures 5 to 10.

The results show that there is less variation between systems than there is between seasons. The yield comparison presented in figure 5 shows an average variation of only 1.16 bales per hectare between systems while there is an average variation of 3.4 bales per hectare between seasons. The highest average yield was for the lateral move (12.75 bales per hectare), while the lowest average yield was for the subsurface drip (11.59 bales per hectare). The highest yielding season was 2017-2018 with an average yield of 14.45 bales per hectare and the lowest average yield occurred in 2009-2010 and again in 2013-2014.

As with the yield comparisons, over the five trial seasons it is possible to see trends in GPWUI which are most probably due to the climatic conditions. The average GPWUI across all systems for 2009-2010, 1.24 bales per mega litre, and 2017-2018, 1.26 bales per mega litre, both were reasonably typical seasons with similar day degree and rainfall profiles. The average of 1.20 bales per mega litre in the wet 2011-2012 was better than expected given that there was flooding and some water logging, especially in the siphon field. In 2011 – 2012 the lateral performed strongly as it was possible to more precisely manage the applied water thus avoiding any water logging. It was expected that the result from the drip should have been similar to the lateral, however as with the siphon and to a lesser degree the bankless channel field, there was difficulty in removing excess rainfall from this field, and some water logging was experienced.

The average GPWUI drops significantly to 1.06 bales per mega litre, in the hot dry 2013 – 2014 season which is not surprising given the temperatures and the lack of rainfall, all systems were pushed to their limits. The much higher GPWUI in 2015 – 2016 (1.50 bales per mega litre) when irrigation water was tight is less easily explained but may be a result of the crop using more of the soil moisture reserves than in the other years of the trial.

## Conclusions

### Internet Connectivity and Automation

There is no doubt that the installation of the on farm business internet service has been beneficial, streamlining the existing digital systems in use on farm. With the ever increasing integration of digital systems into agriculture and the need for high speed real time data in irrigation management, the role of a reliable internet connection will increase in importance.

Automation of irrigation presents a real solution to the labour resourcing challenge being faced by industry. The installation of automated doors in a bankless channel system or smart siphons in a siphon system are effective alternative to manual irrigation. Both approaches can be easily retrofitted to existing flood irrigation systems cost effectively. In addition to addressing the labour resourcing challenge, automation of irrigation has a real potential to improve the efficiency of water management. Improved uniformity of irrigation is more easily achieved with systems such as the smart siphon. The use of additional channel level sensors, soil monitors and water advance meters will all become increasingly important in streamlining the irrigation process and in monitoring the irrigation performance, a necessary process in enhancing irrigation efficiency

### System Comparison

The average yield in the 2017-2018 season is estimated at over a bale more than the average in any other season, with all systems producing their highest yield (figure 5). With each of the systems producing a GPWUI of 1.24 or above the average GPWUI of 1.26 bales per megalitre was a good result (figure 6).

The results from the five years of the grower-led irrigation system comparison trial shows that there is no single system which will deliver perfectly to the requirements of the industry. Irrigation needs will differ by farm, by region and importantly by season.

The results in 2017-2018 have reaffirmed that the variability between seasons is far greater than the variability between systems when measured using the industry metrics of yield and GPWUI. The yield comparison presented in figure 5 shows an average variation of only 1.16 bales per hectare between systems while there is an average variation of 3.4 bales per hectare between seasons.

The lateral move produced the highest average yield and the highest average GPWUI over the five years of the trial. The difficulty however with the lateral move and the other pressurised system subsurface drip is that there is a high capital setup cost and a high operating energy requirement. As a result, the data suggests that growers would be carrying a loss relative to the siphon system if they were to invest in either of these systems. An additional consideration is water reliability; in regions where there is low reliability it may be necessary to carry the capital costs in a season where the system is not utilised, as irrigation water is not available.

In contrast the two flood irrigation systems, siphon and bankless, have significantly lower capital setup costs and minimal energy requirements. All three smart siphon system scenarios and the bankless channel system produce a profit relative to the standard manual siphon system. The smart siphon system effectively addresses the high labour requirement commonly associated with manual siphons. As the monitoring and management systems are enhanced it is anticipated that the labour requirements will reduce further with the smart siphon system.

The more consistent flow that can be achieved with permanent placement of small pipes through bank has the potential to enable optimisation of siphon irrigation still further, especially when used in combination with other irrigation management tools such as channel level sensors or water advance meters.

The results suggest that the bankless channel system is the preferred option, but the topography of the farm will impact on the suitability of this system. The bankless system works most effectively when the slope is developed correctly. In many cases this will require the removal of large volumes of top soil. The removal of 0.5 – 1m of top soil has the potential to have significant yield impacts and is not seen by many growers as a preferred course of action. Where there are existing siphon fields, it may not be practical to change to bankless channel, this analysis of the smart siphon system provides growers with a greater understanding of an alternative for those who are looking to reduce labour and avoid too much soil disturbance. It has also provided proof that the progression to automation can be a staged process which growers can manage within the constraints of their own management systems.

The findings highlight that growers looking to make investment in irrigation upgrades need to consider a range of factors including; soil, topography or existing land use, water reliability, crop type and financial capital. In addition, growers need to consider the availability of labour and the energy requirements of each of the systems and their commitment to make progress in improving their irrigation efficiency through adoption of automation tools. Access to reliable high speed internet connection is becoming increasingly important. Tools that can enhance irrigation efficiency need to be able to be reliably accessed in real time by irrigation managers in automated systems. Reliable access to Wi-Fi, phone connectively or systems such as Lora-Wan or Taggle  are options growers will also need to consider.

The GVIA grower-led irrigation system comparison has demonstrated that although Improvements in Water Use Efficiency (WUE) and Gross Production Water Use is important, changes to irrigation systems focused solely on WUE may not be practical. To remain profitable and productive, growers need to conduct an analysis of all the components that contribute to the efficiency of an irrigation operation.

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making every drop count

# Appendix

## 2017-2018 Yield Results

| System | Field | Ha's | Variety | Total Modules | Estimated Module Yield by number | | Estimated Module Yield by weight | | Average Turnout | Total lint weight | Actual Yield | | Irrigation Water Applied | WUE of Applied Water |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | B/ha | B/ac | B/ha | B/ac | | | B/Ha | B/ac | ML/Ha | B/ML |
| Siphon | K28 | 93.9 | Sicot 746B3F | 325 | 15 | 6.1 | 14.7 | 6 | 43.90% | 1403 | 14.9 | 6.05 | 7.07 | 2.11 |
| Bankless | K29 | 32.7 | Sicot 746B3F | 114 | 15.1 | 6.1 | 14.8 | 6 | 43.40% | 484 | 14.8 | 5.99 | 7.53 | 1.96 |
| Drip | K30 | 11.4 | Sicot 746B3F | 37 | 14.1 | 5.7 | 13.1 | 5.3 | 44.40% | 153 | 13.4 | 5.43 | 6.06 | 2.22 |
| Lateral | L1 | 124.4 | Sicot 746B3F | 410 | 14.3 | 5.8 | 14.3 | 5.8 | 44.30% | 1822 | 14.6 | 5.93 | 6 | 2.44 |

## Irrigation Schedule

| Fields | Ha's | Variety | Date Planted | Total Water Used (mm/ha) | Total Water Used (megs) | Pre Irrigation | | Waterup Irrigation | | Days from Establishment to 1st Irrigation | 1st Irrigation | | Days between Irrigations | 2nd Irrigation | | Days between Irrigations | 3rd Irrigation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Date | Water Applied (mm) | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) |
| L1 | 124.4 | Sicot 746B3F | 31-Oct | 600 | 746 | | | 2-Nov | 50 | 40 | 12-Dec | 30 | 7 | 19-Dec | 40 | 8 | 27-Dec | 40 |
| L3 | 123.8 | Sicot 746B3F | 31-Oct | 600 | 743 | | | 2-Nov | 50 | 40 | 12-Dec | 30 | 7 | 19-Dec | 40 | 8 | 27-Dec | 40 |
| K30 | 11.4 | Sicot 746B3F | 31-Oct | 606 | 69 | | | 3-Nov | 139 | 46 | 19-Dec | 30 | 8 | 27-Dec | 30 | 4 | 31-Dec | 35 |
| K28 | 93.9 | Sicot 746B3F | 1-Nov | 707 | 664 | | | 8-Nov | 106 | 44 | 22-Dec | 75 | 14 | 5-Jan | 68 | 9 | 14-Jan | 62 |
| K29 | 32.7 | Sicot 746B3F | 31-Oct | 753 | 246 | | | 6-Nov | 106 | 45 | 21-Dec | 99 | 14 | 4-Jan | 80 | 12 | 16-Jan | 119 |

| | Days between Irrigations | 4th Irrigation | | Days between Irrigations | 5th Irrigation | | Days between Irrigations | 6th Irrigation | | Days between Irrigations | 7th Irrigation | | Days between Irrigations | 8th Irrigation | | Days between Irrigations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) | |
| L1 | 4 | 31-Dec | 40 | 6 | 6-Jan | 40 | 5 | 11-Jan | 40 | 5 | 16-Jan | 40 | 5 | 21-Jan | 40 | 3 |
| L3 | 4 | 31-Dec | 40 | 6 | 6-Jan | 40 | 5 | 11-Jan | 40 | 5 | 16-Jan | 40 | 5 | 21-Jan | 40 | 3 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K30 | 4 | 4-Jan | 40 | 7 | 11-Jan | 33 | 5 | 16-Jan | 40 | 5 | 21-Jan | 72 | 7 | 28-Jan | 55 | 3 |
| K28 | 9 | 23-Jan | 71 | 13 | 5-Feb | 75 | 8 | 13-Feb | 78 | 10 | 23-Feb | 56 | 17 | 12-Mar | 61 | 10 |
| K29 | 9 | 25-Jan | 65 | 12 | 6-Feb | 68 | 8 | 14-Feb | 87 | 23 | 9-Mar | 65 | 12 | 21-Mar | 64 | |

| | 9th Irrigation | | Days between Irrigations | 10th Irrigation | | Days between Irrigations | 11th Irrigation | | Days between Irrigations | 12th Irrigation | | Days between Irrigations | 13th Irrigation | | Days between Irrigations | 14th Irrigation | | Days between Irrigations | 15th Irrigation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) | | Date | Water Applied (mm) |
| L1 | 24-Jan | 40 | 7 | 31-Jan | 40 | 8 | 8-Feb | 40 | 5 | 13-Feb | 40 | 5 | 18-Feb | 40 | 12 | 2-Mar | 20 | 9 | 11-Mar | 20 |
| L3 | 24-Jan | 40 | 7 | 31-Jan | 40 | 8 | 8-Feb | 40 | 5 | 13-Feb | 40 | 5 | 18-Feb | 40 | 12 | 2-Mar | 20 | 9 | 11-Mar | 20 |
| K30 | 31-Jan | 12 | 7 | 7-Feb | 35 | 6 | 13-Feb | 45 | 7 | 20-Feb | 40 | 10 | 2-Mar | 20 | 7 | 9-Mar | 20 | | | |
| K28 | 22-Mar | 55 | -43181 | | | | | | | | | | | | | | | | | |
| K29 | | | 0 | | | 0 | | | | | | | | | | | | | | |

## In-crop Nitrogen Applications (75cm row spacing)

| **Fields** | **Ha's** | **UREA APPLICATIONS ( kgs per hectare )** | | | | | | **Urea By Plane** | | **Total N Applied in-crop** | **N Applied Up Front** | **Total Crop N** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1st irrigation** | **2nd irrigation** | **3rd irrigation** | **4th irrigation** | **5th irrigation** | **6th irrigation** | kg/ha | Total (t) | | | |
| L1 | 124.4 | 56 | 60 | 60 | 100 | 100 | 80 | 27.4 | 3.4 | **222** | 74 | **296** |
| L3 | 123.8 | 56 | 60 | 60 | 100 | 100 | 80 | 43.5 | 5.4 | **230** | 74 | **304** |
| K30 | 11.4 | 53 | 53 | 53 | 80 | | | | 0.0 | **110** | 200 | **310** |
| K28 | 93.9 | 0 | 110 | 80 | 110 | | | 54.7 | 5.1 | **163** | 200 | **363** |
| K29 | 32.7 | 80 | 110 | 80 | 120 | | | | 0.0 | **179** | 200 | **379** |