Cotton Catchment Communities CRC

FINAL REPORT

Part 1 - Summary Details

Cotton CRC Project Number: **1.04.11.06**

Project Title: Irrigation Scheduling in Wheat

Project Commencement Date: 1/12/2010 **Project Completion Date:** 31/05/2012

Cotton CRC Program: **The Farm**

Part 2 – Contact Details

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Signature of Research Provider Representative: GBonnett

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Signature of Research Provider Representative: ______________________________

Part 3 – IP and In-kind

Since the November 2011 6 monthly report, please outline the additional IP and in-kind that has been generated in the project.

1. Intellectual Property developed within the project.

(What Know-How (New Ideas), Confidential Information, Copyright, Patents or Provisional Patents, Registered Design, Trade Secrets or Trademarks have come from this project to date)

Not Applicable

2. Project In-kind

(Grower Consultant Ginner or Grower Group In-Kind: Are you conducting part of your project on a cotton farm or in conjunction with an in-kind contribution from a consultant, ginner or Grower Group? Please supply group name - Number of persons involved per week and the number of hours per week involved.)

Not Applicable

Part 4 – Final Report Guide (due at end date of project or 31st May 2012)

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

Objectives

2. List the project objectives and the extent to which these have been achieved.

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

6. Please describe any:-
   a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);
   b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and
   c) required changes to the Intellectual Property register.

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken:
   (a) to further develop or to exploit the project technology.
   (b) for the future presentation and dissemination of the project outcomes.
   (c) for future research.

Publications

A. Publications relevant to this project.

Peer reviewed articles / books

Non-peered reviewed articles

Presentations (conference, field days, workshops etc)

B. All other publications by project team during this period.

Peer reviewed articles / books

Non-peered reviewed articles

(NB: Where possible, please provide a copy of any publication/s)

C. Have you developed any online resources and what is the website address?

Part 5 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

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Irrigation Scheduling in Wheat

A final report prepared for the

Cotton Catchment Communities CRC.

Allan S Peake

CSIRO Ref: WBS R-679-1-1-2 CCC-CRC Ref: 1.04.11.06

Citation

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Copyright and disclaimer

Important disclaimer

Acknowledgements

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Executive summary

On irrigation farms in northern New South Wales and Queensland, wheat has traditionally been used as a beneficial dryland rotation crop that improves the yield and profitability of subsequent cotton crops. However recent grain price fluctuations have led irrigated enterprises to grow high yielding, irrigated grain crops as a tactical response to water availability and favourable commodity prices. Therefore there is a need for improved advice to irrigated growers who have traditionally grown cotton, and have little experience in producing high yielding, irrigated grain crops. This project aimed to assist irrigated growers in the northern region by producing irrigation scheduling recommendations for irrigated wheat, in conjunction with the CCC CRC 'High Yield Grains in Cotton Farming Systems' (HYGICFS) project.

It was decided to use the APSIM (Agricultural Production Systems Simulator) model to generate irrigation scheduling recommendations for irrigated wheat growing in the northern region, as it is a more cost effective method than wide-scale, multi-year field experiments. However, this first meant that APSIM needed to be 'validated' – that is, the model had to be shown to accurately simulate irrigated wheat production.

Field trials were conducted in 2010 and 2011, to compare the effect of different irrigation strategies on wheat yield. APSIM adequately predicted crop yield and water-use, and it was therefore appropriate to use APSIM to investigate optimum irrigation strategies for irrigated wheat farming systems in the northern grains region.

APSIM simulations showed that at drier environments such as Emerald and Goondiwindi, maximum crop water use efficiency (CWUE) was attained on crops that received two in-crop irrigations, when there were high levels of soil moisture available at sowing (which may require an additional irrigation at sowing). At the wetter environment (Gunnedah), maximum CWUE was achieved with one in-crop irrigation, also assuming high levels of soil moisture available at sowing. Having less soil water at sowing (or low in-crop rainfall) will increase the amount of in-crop irrigation required to achieve maximum CWUE.

Growers wanting to maximise return on a single, 1 ML/ha irrigation, are recommended to apply that irrigation during the period between early stem-elongation through to flag leaf emergence. However, the timing of in-crop rainfall, and the amount of soil water at sowing will affect the optimum timing of this irrigation from season to season.

Through these improved irrigation scheduling guidelines for wheat, irrigated farming systems now have greater capacity to adapt to a variable climate, by having improved ability to grow wheat when the timing of water availability and commodity pricing means it is a profitable option.

Introduction

Wheat is nearly exclusively a dryland crop in the northern grains region of Australia (bounded in the south by Dubbo in New South Wales, and in the north by Emerald in central Queensland (GRDC 2010)). Cotton has traditionally been the favoured irrigation crop in the region, due to its higher profitability in comparison to wheat. In seasons of favourable water supply and prices, up to 400,000 ha of cotton has been produced in these irrigated areas (ANRA 2009). Wheat is commonly considered a beneficial dryland rotation crop that improves the yield and profitability of subsequent cotton crops (Hulugalle *et al.* 2006), through improved soil structure and decreased inoculum of cotton-specific diseases in the soil (Hulugalle *et al.* 1999 & 2006).

In 2007/ 2008, grain prices improved to record levels in response to socioeconomic influences in Asia, an international push for bio-energy crops, and the impact of local droughts. With wheat prices nearly 300% of those received just three years earlier (Brown *et al.* 2008) high levels of optimism were generated for future grain prices. This increase in agricultural commodity prices sparked increased investment in grain farming from the corporate sector, and initiated a paradigm shift amongst the irrigated farming community of the northern grains region. These irrigated enterprises no longer viewed themselves as cotton growers, but rather, commodity growers needing to make the greatest return on the available irrigation water. And while grain prices have since eased, demand for food grain is predicted to increase over the next 20-50 years as the world's population expands (FAO 2006; UN 2007). Demand-driven increases in grain prices are therefore likely to result in increased irrigated wheat production across the northern region.

Therefore there is a need for improved advice to irrigated crop producers that have traditionally grown cotton, but are now commodity producers who need to make tactical responses to water availability and commodity prices in order to maximise on-farm water use efficiency. This project aimed to assist irrigated growers in the northern region by producing irrigation scheduling recommendations for irrigated wheat, in conjunction with the CCC CRC 'High Yield Grains in Cotton Farming Systems' (HYGICFS) project.

Specific project objectives

The primary objectives of the research project were as follows:

(1) The farming systems simulator APSIM (Agricultural Production Systems Simulator) will be validated using on-farm data to ensure it can appropriately simulate irrigated wheat production.
(2) APSIM will be used to develop recommendations on irrigation scheduling for wheat, as well as the best way to allocate water to irrigated wheat production in water-limiting scenarios.
(3) Recommendations will be incorporated into the 'Best Practice Guide' to irrigated wheat production, prepared by the Achievable Yields for Irrigated Grains project and the HYGICFS project team.

Summary of achievements against project objectives

(1) APSIM Validated for irrigated wheat growing

The APSIM model was successfully validated on wheat yield and water use data sets developed in conjunction with the HYGICFS project, from furrow irrigated experiments at ACRI in 2010 and 2011. APSIM successfully simulated yield in both years, and successfully simulated water use in 2011. Water use data from 2010 was not used, as the growing season rainfall was very high, and little discrimination was observed between irrigation treatments.

(2) APSIM used to develop irrigation scheduling recommendations, including the best way to allocate water in water-limiting scenarios.

Irrigation scheduling recommendations were developed using APSIM for two scenarios: (1) maximising crop water use efficiency, and (2) maximising yield from a single 1.1 ML irrigation. The second scenario was developed to cater for growers wishing to maximise the area sown to wheat, to allow them to maximise the area benefiting from a cotton rotation crop. Maximum crop water use efficiency was achieved in simulation experiments where one or two in-crop irrigations of 0.9 ML/ha were applied, and the field had high levels of sowing soil moisture (whether from pre-sowing rainfall or an irrigation at or near sowing). Average maximum yields in response to a single 1.1 ML/ha irrigation were attained when the irrigation was applied during stem elongation, or flag leaf emergence.

(3) Recommendations incorporated into the 'Best Practice Guide for Irrigated Wheat Production' prepared by the HYGICFS project.

The irrigation scheduling recommendations were included in the best practice guide. An additional achievement was the provision of additional graphs to demonstrate other points made by HYGICFS team members in the irrigation scheduling chapter.

Methodology

Overview

Developing irrigation scheduling techniques using field experimentation alone is an expensive, long term process. Variability between seasons and soil types ensures that experiments must be conducted across a large number of sites and seasons in order to sample the full range of conditions that can be experienced by a wheat crop in the northern grains region.

Researchers around the world now realise that simulation modelling has benefits over the traditional field experimentation approach to developing irrigation scheduling recommendations. Lobell and Ortiz-Monasterio (2006) found that the modelling approach was beneficial for optimising system water use efficiecy, and allowed the user to examine irrigation management regimes for multiple environments, soil types and climatic conditions. In a review of irrigation management techniques in water scarce environments, Pereira *et al.* (2002) stated: *"More research approaches are required to relate yield responses with gross margin or revenue responses to water deficits. The development of decision support tools integrating irrigation simulation models, namely for extrapolating field trials data, economic evaluation and decision tools should be useful to base the appropriate irrigation management decisions for water scarcity conditions".* Additionally, the crop modelling approach can be used to demonstrate the level of risk associated with different strategies, by using historical weather data to generate probability distributions of production and profitability (e.g. Hammer *et al.* 1996; Hochman *et al. 2009*; Philp *et al.* 2010).

It was therefore decided to use the APSIM model to generate irrigation scheduling recommendations for irrigated wheat growing in the northern region. A key component of simulation model experiments, however, is that the model must first be 'validated' – that is, the model needs to accurately simulate the system being investigated.

Field Experiments

Field experiments were designed in conjunction with staff from NSW DPI, and conducted as part of the HYGICFS project. The field experiments consisted of irrigation scheduling experiments, where wheat plots experienced different levels of irrigation during the season. Experiments were conducted at the Australian Cotton Research Institute (ACRI) at Narrabri in 2010 and 2011. Three irrigation treatments were applied in 2010, and five irrigation treatments were applied in 2011. Irrigation treatments ranged from dryland to fully irrigated, and were conducted in furrow irrigated fields, with the wheat sown on 2m beds across three replicates.

Soil moisture was monitored using a neutron moisture meter (NMM) in each year, except for the surface layer (0-15cm) which was monitored using a Theta probe. Calibration curves for both the NMM and Theta probe were obtained using cores taken in wet and dry parts of the paddock.

Soil characterisation data (Drained Upper Limit or DUL, and Crop Lower Limit or CLL) were obtained as described in Dalgliesh and Foale (1998) for DUL, and by using the lowest soil moisture readings obtained from the NMM, for CLL.

APSIM Validation

Experimental results from the field trials were compared to APSIM simulations of each experimental treatment. Measured soil water and nitrogen at sowing, sowing dates, plant populations, meteorological data, irrigation dates and volumes for each field treatment were used to parameterise each simulation as appropriate. The APSIM 'skiprow' logic in the sowing manager was set at 0.3, to simulate the decreased light interception by the irrigation beds.

APSIM Irrigation Scheduling Experiments

APSIM was then used to conduct long term studies on different irrigation strategies using 40 years of weather data from the SILO database (Jeffrey *et al.* 2001). Irrigation scheduling recommendations were developed using APSIM for two scenarios: (1) maximising crop water use efficiency, and (2) maximising yield from a single 1 ML irrigation. The second scenario was developed to cater for growers wishing to increase the area sown to wheat, to allow them to maximise the area benefiting from a cotton rotation crop. Simulations assumed that yields are not limited by pests, diseases, frosts, nutrition or lodging. For agronomic advice to avoid lodging in a high yielding wheat crop, growers are referred to Peake *et al.* (2012).

Strategies to achieve maximum crop water use efficiency (CWUE)

CWUE is defined as the amount of grain produced per unit of water used by the crop or lost to the farm through drainage and evaporation. A series of APSIM simulations were conducted at three locations (Goondiwindi, Gunnedah and Emerald) which investigated CWUE when one, two, three, or four irrigations were applied during the season. The first irrigation occurred at sowing to raise the soil moisture to 2/3 of Plant Available Water Capacity. The remaining irrigations were 0.9 ML/ha irrigation events that occurred when the soil water deficit of the top 120cm of soil was greater than 0.9 ML/ha. The in-crop irrigations were applied at 80% application efficiency, such that 20% of each irrigation was assumed to be lost due to drainage. Representative APSIM soil types (Peake *et al.* 2010) were used for each location, with Gunnedah simulations using Typical Vertosol #3 (PAWC = 255mm), while the Emerald and Goondiwindi simulations used Typical Vertosol #7 (PAWC = 204mm). The cultivar used in these simulations was Kennedy.

Maximising yield from a single irrigation.

A series of APSIM simulations were conducted at three locations (Goondiwindi, Gunnedah and Emerald) which investigated how the timing of one in-crop irrigation affected grain yield. Simulations applied a single, 1.1 ML/ha irrigation at specific growth stages if the soil water deficit to 120cm was greater than 1.1 ML/ha. If the soil water deficit was not large enough at that specific growth stage, the irrigation was delayed until the soil water deficit was equal to (or greater than) 1.1 ML/ha. The soil types and varieties used for these simulations were the same as those used in the CWUE simulations described previously.

Results

APSIM Validation

The APSIM validation demonstrated that APSIM could accurately simulate furrow irrigated wheat production for both yield and water use. Figure 1 shows simulated vs. observed grain yield from different irrigation treatments in 2010 and 2011, where linear regression explained 71% of the variation. These results were achieved without significant incidences of lodging, due in part to specific canopy management techniques that were employed to reduce lodging risk (as described in Peake *et al.* 2012). Heavily lodged crops experience yield reductions that are unable to be predicted by APSIM (Peake, 2009) therefore it is important to note that paddocks must be managed to avoid lodging (as well as disease, pest and frost damage) in order to be able to achieve the yields predicted by APSIM.

Figure 2 demonstrates that APSIM successfully simulated crop water use in 2011. Additional data obtained from monitoring of 4 commercial paddocks in 2008 also showed that APSIM adequately predicted crop water use (Peake, 2009). It is therefore appropriate to use APSIM to estimate both yield and water use for irrigated wheat farming systems in the northern grains region.

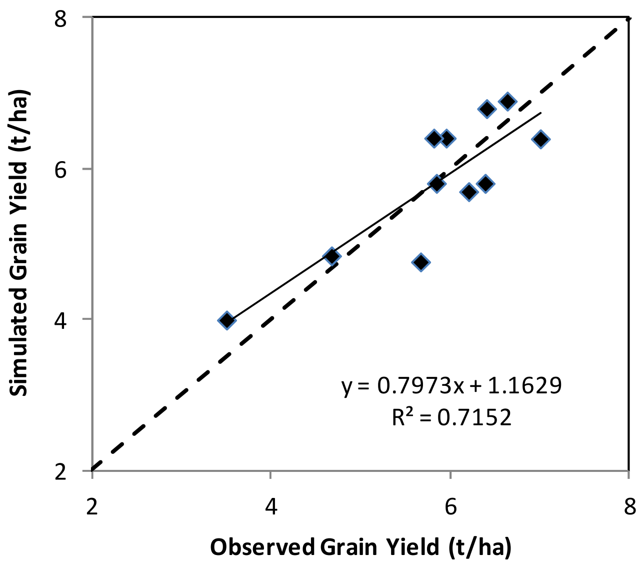

FIGURE 1: Simulated vs observed Grain Yield for a range of irrigation treatments at ACRI, 2010 and 2011.

APSIM Irrigation Scheduling Experiments

The APSIM simulation experiments found that on average across the 40 year period studied, maximum CWUE under irrigation was achieved when good soil moisture is available at sowing (or an irrigation had been applied at sowing) and then one or two supplementary spring irrigations were applied. The optimum number of irrigations was one irrigation at Gunnedah and two irrigations at Emerald and Goondiwindi (Figure 3). These results are related to the annual rainfall at these locations, with an additional irrigation required to maximise CWUE at the drier locations (Emerald and Goondiwindi).

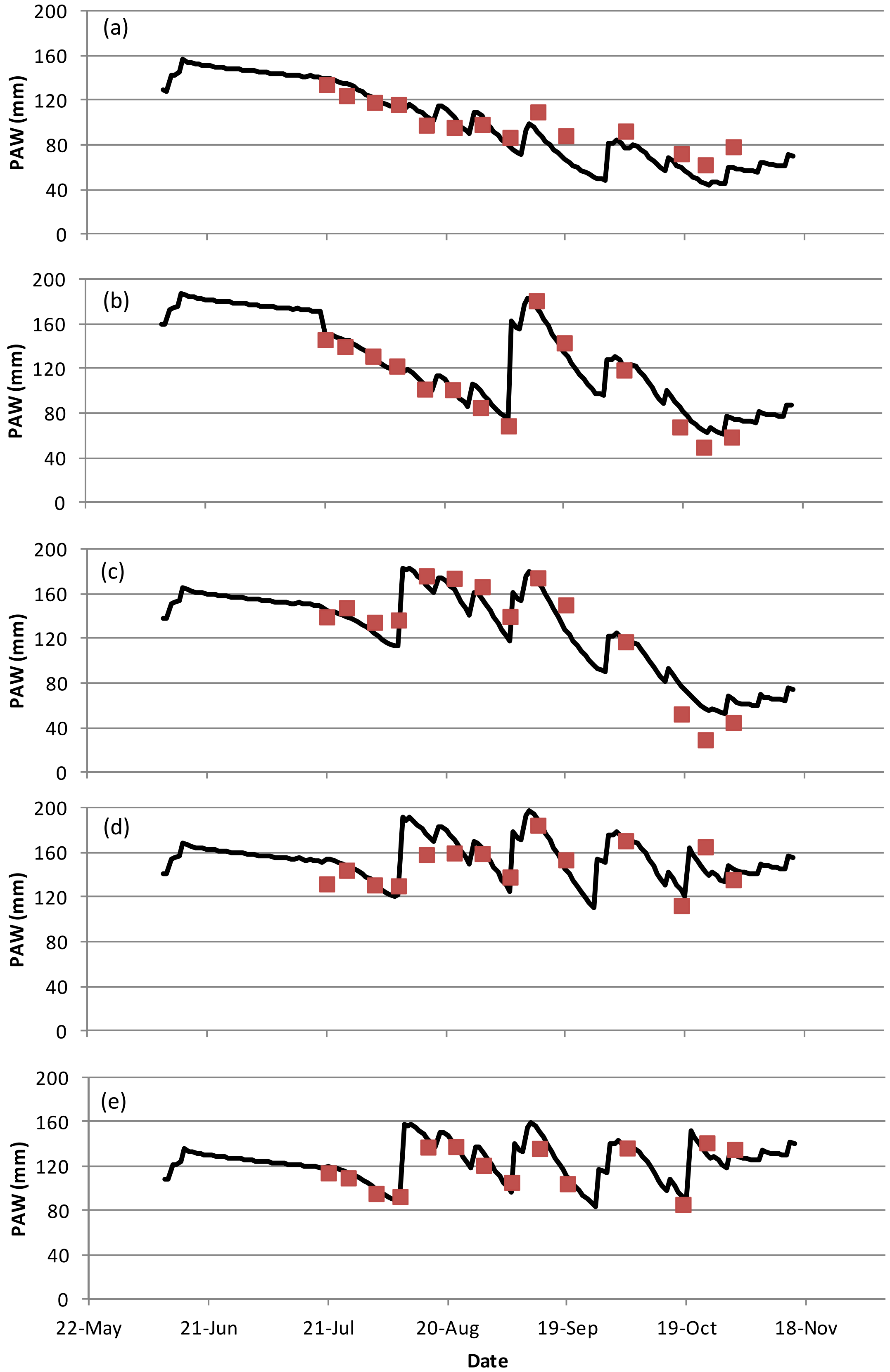

FIGURE 2: APSIM simulated Plant Available Water (PAW – solid line) and measured PAW (red squares) for a range of irrigation wheat treatments at ACRI 2011 (a) irrigation at sowing (b) irrigation at sowing + 1 in-crop irrigation (c) irrigation at sowing + 2 in-crop irrigations (d)) irrigation at sowing + 4 in-crop irrigations (e) sown into stored soil-water at sowing + 4 in-crop irrigations.

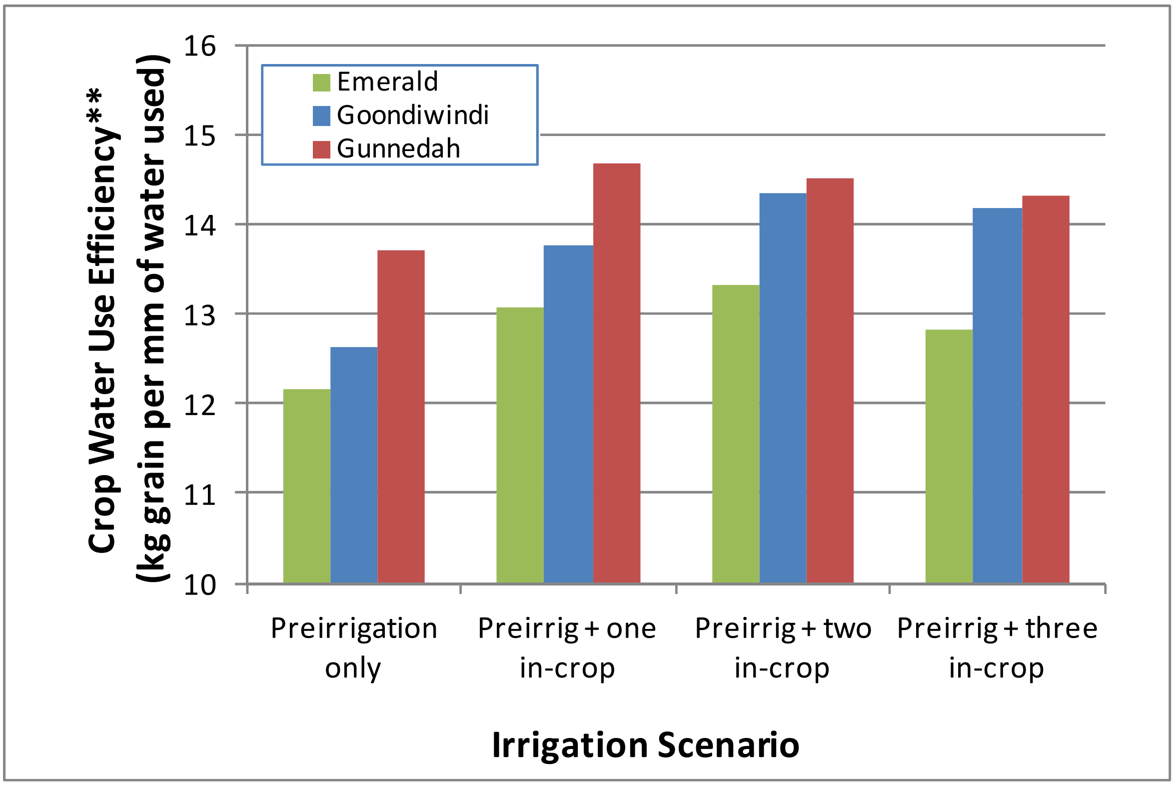

Figure 3: APSIM-simulated crop water use efficiency of various irrigation scenarios (using 0.9ML/ha irrigation events at 80% application efficiency) for Emerald, Goondiwindi and Gunnedah.

However, consultants and growers should consider that additional irrigations could still return more than 1 tonne of grain per ML of irrigation water use once the maximum CWUE is achieved (Figure 3). Therefore, growers may achieve maximum profitability by applying additional spring-irrigations. The key consideration for growers is whether the yield gain from extra irrigation of the irrigated cropping area is more valuable than the cost of preparing, sowing and managing the additional paddocks, on which they could use the water as an alternative.

The APSIM simulations also found that the best timing for a single in-crop irrigation of around 1 ML/ha is from early stem-elongation, through to flag leaf emergence (Figure 4). While head emergence is the most sensitive growth stage to a short, severe water stress, the APSIM simulations suggest that the best timing for a single irrigation occurs earlier in the life-cycle of the crop, to spread the water across a number of growth stages and avoid a severe stress at any one growth stage. It should be remembered that these results have been obtained on average, from 40 years of weather data. The best timing of a single irrigation within individual seasons will vary depending on the timing of in-crop rainfall, and stored soil water at sowing.

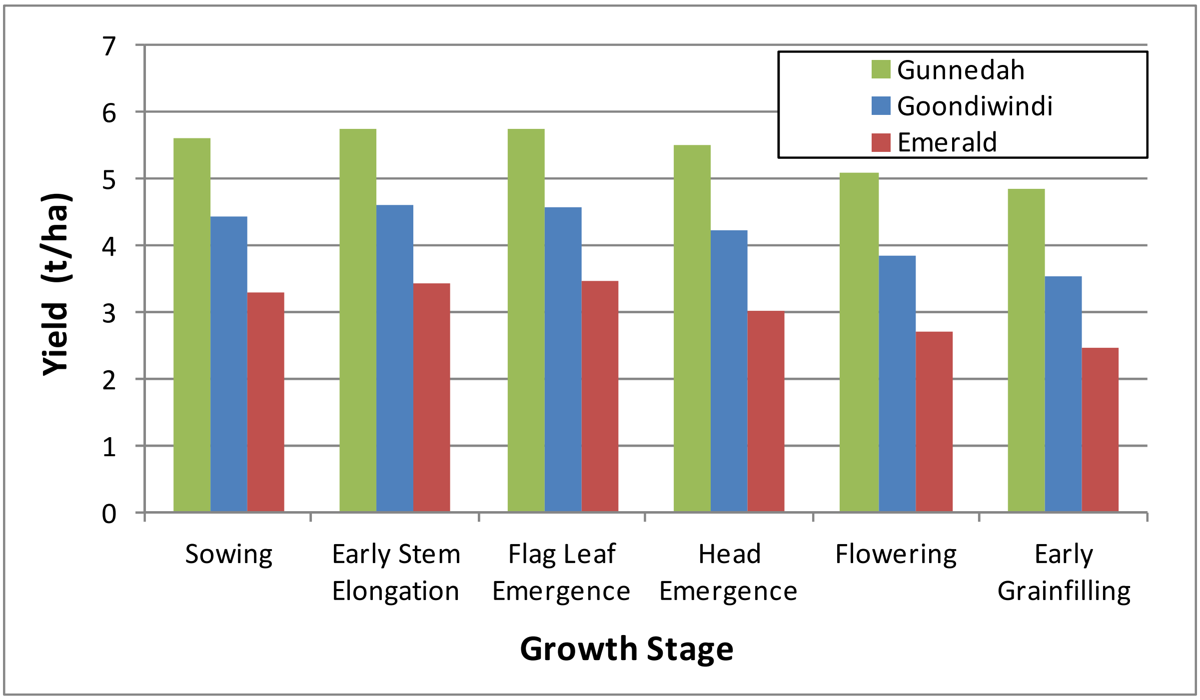

Figure 4: Average yield after application of a 1 ML/ha irrigation at different growth stages, from a 40 year APSIM irrigated wheat simulation at Goondiwindi, Gunnedah and Emerald.

Conclusions & Outcomes

The APSIM farming systems model was shown to accurately predict wheat yield and water use, when the crops were managed to avoid lodging. The APSIM model was used successfully to generate irrigation scheduling recommendations for irrigated wheat growers across the northern grains region.

For growers wanting to maximise crop water use efficiency (CWUE), APSIM simulations showed that at in drier environments such as Emerald and Goondiwindi, maximum CWUE was attained on crops that received two in-crop irrigations, when there were high levels of soil moisture available at sowing (which may require an additional irrigation at or near sowing). At the wetter environment (Gunnedah), maximum CWUE was achieved with just a single in-crop irrigation, also assuming high levels of soil moisture available at sowing. Having less soil water at sowing (or low in-crop rainfall) will increase the amount of in-crop irrigation required to achieve maximum CWUE.

Growers wanting to maximise return on a single, 1 ML/ha irrigation, are recommended to apply that irrigation during the period between early stem-elongation through to flag leaf emergence. However, the timing of in-crop rainfall, and the amount of soil water at sowing will affect the optimum timing of this irrigation from season to season.

The adoption of these irrigation scheduling techniques will (in the long term) help northern region irrigators improve on-farm economic and environmental sustainability through increased profitability and irrigation WUE, and improve the viability of cotton farming systems.

Through these improved irrigation scheduling guidelines for wheat, irrigated farming systems now have greater capacity to adapt to a variable climate, by being able to make tactical decisions to grow wheat (successfully) when the timing of water availability and commodity pricing means it is a profitable option.

Publications

These irrigation scheduling guidelines have been disseminated to growers as part of the following publication, prepared by the CCC-CRC funded 'High Yielding Grains in Cotton Farming Systems' project:

Jackson R, Harris G, Peake AS (2012) Irrigation. *In* Sykes J (Ed), Irrigated Wheat: Best Practice Guidelines in Cotton Farming Systems. Cotton Catchment Communities CRC, Narrabri, NSW

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