FINAL REPORT

(due within 3 months on completion of project)

Part 1 - Summary Details

Cotton CRC Project Number: **1.02.05**

Project Title: Plant and soil factors optimising water use efficiency

Project Commencement Date: 1/07/2006 **Project Completion Date:** 30/06/2009

Cotton CRC Program: The Farm

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Part 3 – Final Report Guide (due within 3 months on completion of project)

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

Background

1. Outline the background to the project.

Water remains a key issue for the cotton industry, however, most of the previous research on improving water use efficiency focused on improving delivery (i.e. drip, lateral move), timing (i.e. HydroLOGIC), application (i.e. Irrimate) or quantifying losses due to drainage, seepage and evaporation. Relatively little recent research has focused on the plant and its interaction with the soil and climate, which can have significant outcomes in terms of WUE and yield. One such project was CRC79 'Water relations of the cotton plant" which investigated the effect of soil type and physiology on the plant water relations of cotton. Initial interpretation of this research has found that soil type does not influence the appearance of plant stress when normalised for soil moisture holding capacity, expressed as the fraction of transpirable soil water (FTSW). FTSW may be a valuable index to improve irrigation strategies across different soil types. A plants' response to soil moisture depends on many factors, key of which are soil type and evaporative demand (related to the saturation deficit of the air). The FTSW is a useful measure of soil moisture that may be able to be applied across soil types to understand the interaction between soil moisture, evaporative demand and plant growth. This project built on the outcomes of CRC79 by investigating the interaction between FTSW and plant stress in cotton, and the implications for WUE and profitability. The use of FTSW as a measurement of soil water availability, and therefore of plant function, may provide a benchmark for irrigation scheduling allowing development of accurate recommendations for different deficits for each soil type and evaporative demand scenario. This project continued to investigate the relationship between soil water and plant stress over a wider range of climates. We investigated plant responses to soil factors through assessment of root exploration, plant water uptake and the response of cotton to normalised soil moisture deficits (FTSW). FTSW is well suited for inclusion in modelling and the project would explore linking this measurement with HydroLOGIC. Water deficit and irrigation can influence cotton plants root systems: dryland cotton has deeper roots than fully irrigated crops and the timing of first irrigation can be used to encourage good root development. These effects are important in overall plant responses to moisture stress. Currently deficit irrigation and many different row configurations are used in the cotton industry without accurate knowledge of how these irrigation regimes affect root development. This project initiated studies to measure the rooting dynamics of cotton in response to irrigation deficit (collaboration with Steve Yeates) and plant spacing (collaboration with Mick Bange/Rose Roche). Understanding the effect that deficit irrigation and alternate row configurations have on plant root development would enable better irrigation scheduling decisions to be made. The improved scheduling is a result of knowing the effect on root development and thus subsequent plant water uptake of the moisture deficit or row configuration imposed. This would also provide an understanding of root exploration of the soil profile and therefore the potential to maximise use of available soil moisture in these systems.

This project also investigated the genetic control of root development in the cotton plant. In collaboration with the CSIRO breeding team, root development and water extraction in contrasting genotypes was measured. This was undertaken with a long term view to developing more detailed analysis of the genetic control of root development. If physiological differences in root development between varieties could be identified, microarray analysis of these varieties may be useful to develop screening procedures for use by breeders in developing varieties better adapted to stress.

Objectives

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

This research built on the results of a previous project to provide a better understanding of the way in which the cotton plants' requirement for water is affected by evaporative demand (the interaction between temperature and humidity) and soil type. This is critical in understanding how irrigation strategies should be modified to allow for the interaction of soil type, temperature and humidity – which is currently lacking.

The final project objectives were:

1. To assess factors affecting water uptake by the cotton plant to allow water management to be more precisely matched to soils, variety and climate. (80% project time). This will provide for the development of a quantitative understanding of physiological processes limiting cotton yield in relation to plant water status. The research will provide data sets to be used to increase the robustness of the Ozcot simulation model

2. Measure rooting dynamics in response to irrigation deficit and plant spacing. This will provide the ability to investigate the genetic control of root development in cotton varieties. (20% project time).

Table 1: List of objectives and Milestones achieved during the course of the project.

Obj No.	Objective	Milestone	Performance Indicator	Yr 1	Yr 2	Yr 3	Completed
1	Plant stress and yield response to soil type and climate (evaporative demand) established across cotton regions	Field experiments completed at multiple locations in the cotton regions and response established	Experiments completed with yield and plant physiological response measured, results analysed and documented	✓	✓	✓	✓
2	Determine differences in root development between contrasting cotton varieties	Field experiment screening contrasting completed	Evaluation of varied root development, Completed field and glasshouse experiments, results analysed	✓	✓		✓

			and documented				

Methods

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

Experiments in the previous project focussed on the effect of soil type on plant stress when saturation pressure deficit is constant between the different soil types (e.g. measuring plant stress on different soil types within close geographical proximity). By measuring over a range of irrigation events a data base for a range of soil types and a limited range of evaporative demands has been developed. Early analysis of this data suggested that we could account for the effects of soil type by expressing soil water content as the fraction of transpirable soil water (FTSW) and relate this to leaf water potential as an indicator of plant stress.

FTSW expresses plant available soil moisture as a percentage from 0 to 100, and theoretically soils should behave the same in terms of plant physiology with the plant requiring 1/3 FTSW to continue to have unrestricted transpiration.

Leaf water potential is the resistance to water movement within the plant, and the demands for transpiration imposed by the environment (heat load, humidity, wind, etc.).

Plant stress response to soil type and climate

To build on previous research, in the first year of the project, experiments were established in three different cotton growing regions in collaboration with other researchers and organisations to investigate the effect of evaporative demand on cotton plant moisture stress response. Experiments with a range of irrigation treatments were established in different regions (CQLD to NSW) to provide a range of temperature x humidity combinations thereby providing a range of evaporative demand scenarios. At ACRI the research was conducted in the moisture deficit experiments of Stephen Yeates (CSIRO), in Emerald an experiment was conducted in the planting date experiment conducted by Richard Sequeria (QDPI) and at Dirranbandi the research was conducted on Cubbie Station. All experimental sites used the same variety. In order to accurately capture the relationship between soil water, climate and plant stress required intensive data collection across all sites during the crop growing period. Frequent measurements of plant functions during flowering were made including plant water status (leaf water potential and stomatal conductance). Frequent measurements of soil water were made using neutron moisture meters and capacitance probes to calculate fraction of transpirable soil water (FTSW). Climatic data was obtained from the Silo patch point data set for the weather station nearest to the experimental site (Bureau of Meteorology).

The most detailed component of this project was completed at ACRI in conjunction with Stephen Yeates deficit irrigation experiments, focusing on the plants' physiological response to soil moisture stress. Four irrigation treatments were applied with average soil moisture deficits of 37, 61, 81 and 125 mm. The varieties used were Sicot 71BR in 2006/2007 and Sicot 70BRF in 2007/2008 and 2008/09. Combining research into both agronomic and physiological responses provided an opportunity to develop a more integrated understanding of the plants' response to differing levels of soil moisture deficit, the effect of soil moisture deficit on plant growth, adjusting irrigation scheduling to avoid plant water stress and the yield response to soil moisture stress.

Root development, varieties and row spacing

Variety root development

Four cotton genotypes chosen for their known difference in shoot size were compared in two experiments to determine whether differences in shoot size conferred difference in root development under dryland conditions. The four varieties were:

- Siokra S-101B (okra leaf /early /small stature, breeding line)
- Siokra 24B (okra leaf/ full season/ large stature)
- Sicot 71B (normal leaf /full season /smaller stature)
- Fus 3B (normal leaf/ full season/ large stature, breeding line)

The experiments were planted into a full moisture profile on 1 m beds with a planting configuration of 1 row in 3 rows out to ensure there was no interference in root development from adjacent rows. The experiments were completed under very dry conditions allowing for a complete sequence of neutron probe measurements without the effect of rainfall. Plant height and node development was measured to assess above ground development. Root development using soil extraction as a non-direct measurement was tracked weekly using an array of five neutron probe tubes (one in the plant row and in two skipped rows either side of the plant row). Soil water was also monitored using theta probes and gravimetric soil cores when possible over the growing season. In addition to an intensive soil-water monitoring program, three physical measures over the season (first flower, cut-out and 60% bolls open) using the core break technique to monitor actual root growth. The core-break technique, counts the number of roots visible at a broken cross section of a soil core is used to estimate rooting. The core breaks were calibrated with root samples that were washed and length and weight of the roots measured using 2 of the 5 replicates in each experiment.

The calibration of the root samples with the core breaks were poor and did not provide any meaningful results and hence was not used in the field experiment in the second year (see results section).

A glasshouse experiment measuring early season root development in pots was conducted. The same 4 varieties as in the field were grown in 750 mm long 90mm PVC tubes with destructive harvesting at 14, 21 and 28 DAS to measure tap root length, root main branches, root and shoot weight, shoot height and leaf area.

Figure 1: 2008 Glasshouse experiment comparing the root development of four varieties at 21 days after sowing.

Vascular bundle arrangement

A separate pilot glasshouse experiment was also conducted to investigate the vascular bundle arrangement of the 4 varieties being studied. Overseas studies have shown some cotton varieties to have 5 rather than the usual number of 4 vascular bundles. Different numbers of vascular bundles in the cotton root may have an effect on the ability of the cotton plant to transport water through the root system. This difference in primarily due to the number of lateral roots produced, the lateral roots arise in distinct rows from the vascular bundles and a higher number of bundles leads to a larger number of lateral roots (McMichael et al 1985).

Results

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

Plant stress responses to soil type and climate

Soil Type Effects

In the previous project cotton plants were found to behave in the same way to moisture stress on all soil types when the soil water holding capacity of the soil was taken in to account and expressed as a percentage or fraction of transpirable soil water (FTSW). Dr Neilsen found that over the three seasons prevailing climatic conditions had a large affect on the ability of the plant to cope with a given level of soil moisture deficit. Even under low levels of soil moisture deficit, on high evaporative demand days plants often experienced stress which had an impact on yield, this was particularly high on the lighter soil type. To properly establish that the variation in the data was associated with the soil type and not other factors (climate) a number of approaches to calculate FTSW were tested. In order to take into account different growth stages of the plant in the different soil a "dynamic" soil water holding capacity was used based on the actual depth of extraction at each date of measurement instead of a "fixed" soil water holding capacity based on maximum depth of extraction. Using this approach, it became apparent that plants grown in the lighter soil type (Willawah) suffered less stress even at the same FTSW (Figure 2). The slope of the relationship remained the same, indicating that at Willawah it is likely to be some additional factor influencing the level of plant stress even at the same FTSW. Reason for this response needs to be explored in greater detail, as this difference in response may be due to other physical limitations to root growth and soil moisture extraction (such as salinity or compaction) or substantial differences in irrigation management. These reviewed results highlight the importance in not assuming plant stress has exactly the same relationship to soil water status across different soil types

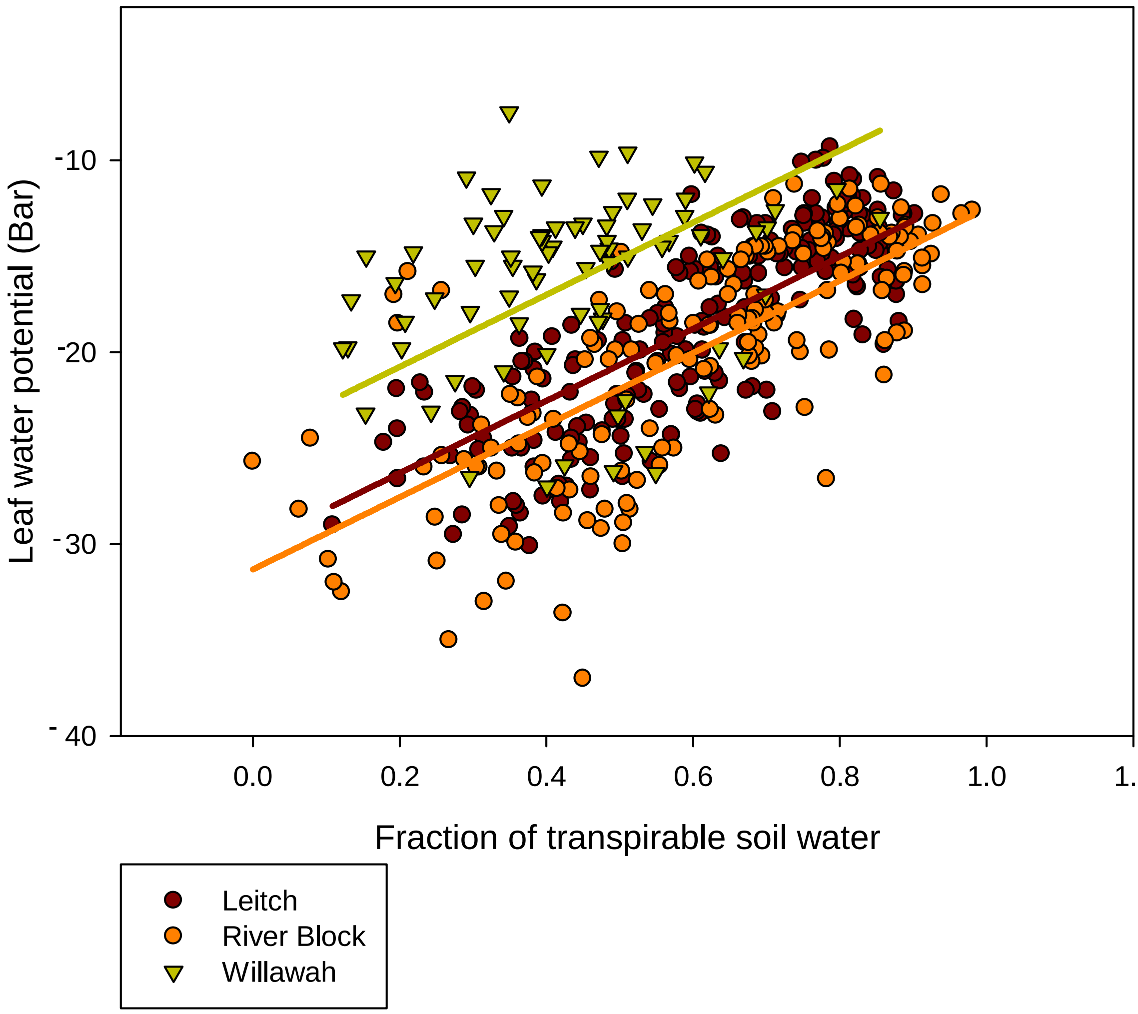


Figure 2. Soil type effect on plant stress, normalising soil water using fraction of transpirable soil water (percent water available) and leaf water potential as a measure of plant stress. Leaf water potential below -20 suggests that the crop is suffering stress. Willawah (lighter soil type) showed less stress at the same FTSW compared to the medium and heavy soil types.

Environmental Effects

The wide variability in LWP at the same FTSW across sites and years in the soil type experiments indicated that climatic conditions were likely to be having a large influence on the level of plant stress even under the same soil water conditions.

A correlation analysis of the climatic variables in these experiments showed the highest linear correlation with afternoon leaf water potential (BAR) was FTSW (0.594), other, fairly high correlations with LWP, were Vapour Pressure (0.254), Vapour Pressure Deficit (0.211), Eto (0.262), Maximum Temperature (0.306), Maximum Relative Humidity (-0.243) . Those variables were also highly correlated with each other (i.e. correlations between 0.77 and 0.99), suggesting they all accounted for the same variability in %bar and one only could/should be used in the regression model. To account for climatic influence on the data from the soil type experiment only Vapour Pressure Deficit, with FTSW, was used in the multiple regression analysis.

Vapour pressure deficit, or VPD, is the difference (deficit) between the amount of moisture in the air and how much moisture the air can hold when it is saturated. Once air becomes saturated water will condense out to form clouds, dew or films of water over leaves. Unlike relative humidity, vapour pressure deficit has a simple nearly straight-line relationship to the rate of evapotranspiration and other measures of evaporation. At a low VPD water condenses and film of water forms on a plant leaf it becomes far more susceptible to rot. On the other hand, as the VPD increases the plant needs to draw more water from its roots. As a general rule, most plants grow well at VPDs of between 0.8 to 0.95 kPa. Accounting for changes in vapour pressure deficit significantly improved the relationship between LWP and FTSW indicating that taking into account climate is important in understanding the relationship between soil water and plant stress.

In the first year of the project, experiments investigating the effect of evaporative demand on cotton response to water stress were completed at 3 sites across the industry; Narrabri, Dirranbandi and Emerald. These sites were selected as they offered a wide range of climatic variability throughout the season (Figures 3a and b). At all sites rainfall was low for the majority of the season allowing for water stress treatments to be successfully imposed. The measurement of sites at Narrabri and Dirranbandi was conducted by the principal researcher with technical assistance; the site at Emerald was more difficult to manage. Limitations in labour and funding for travel only allow for the principal researcher to visit Emerald site twice during the course of the season, however, the irrigation management of the experiment made it impractical for measurements to be taken based from Narrabri. Doug Sands (QDPI) was trained to use a spare pressure chamber that was left in Emerald for the reminder of the season to allow scheduled measurements to be undertaken. The soil moisture monitoring at the Emerald site was being conducted by the QDPI as part of their experimental protocol. This measurement was not as rigorous as planned as such soil moisture and pressure chamber measurements at this site were only from one replicate. Yield measurements were conducted at all three sites with samples kept for quality testing. The measurements at Cubbie Station were initially planned for three seasons, however lack of water prevented the experiment being repeated in the second year of the project, and the resignation of the principal researcher prevented the experiment being repeated in the third year of the project. To properly characterise and calibrate soil water measurements further data was needed to add to that collected in the first experiment, if the opportunity arises to collect this data then the soil moisture and climatic data for all three sites can be collated to compare with the plant based measurements conducted thorough the season. This assessment will give an indication of the effects of climate on cotton plant moisture stress. Establishing further experiments in Queensland proved to be difficult due to changes in personnel (Emerald) and a change in the experimental program (Kingsthorpe).

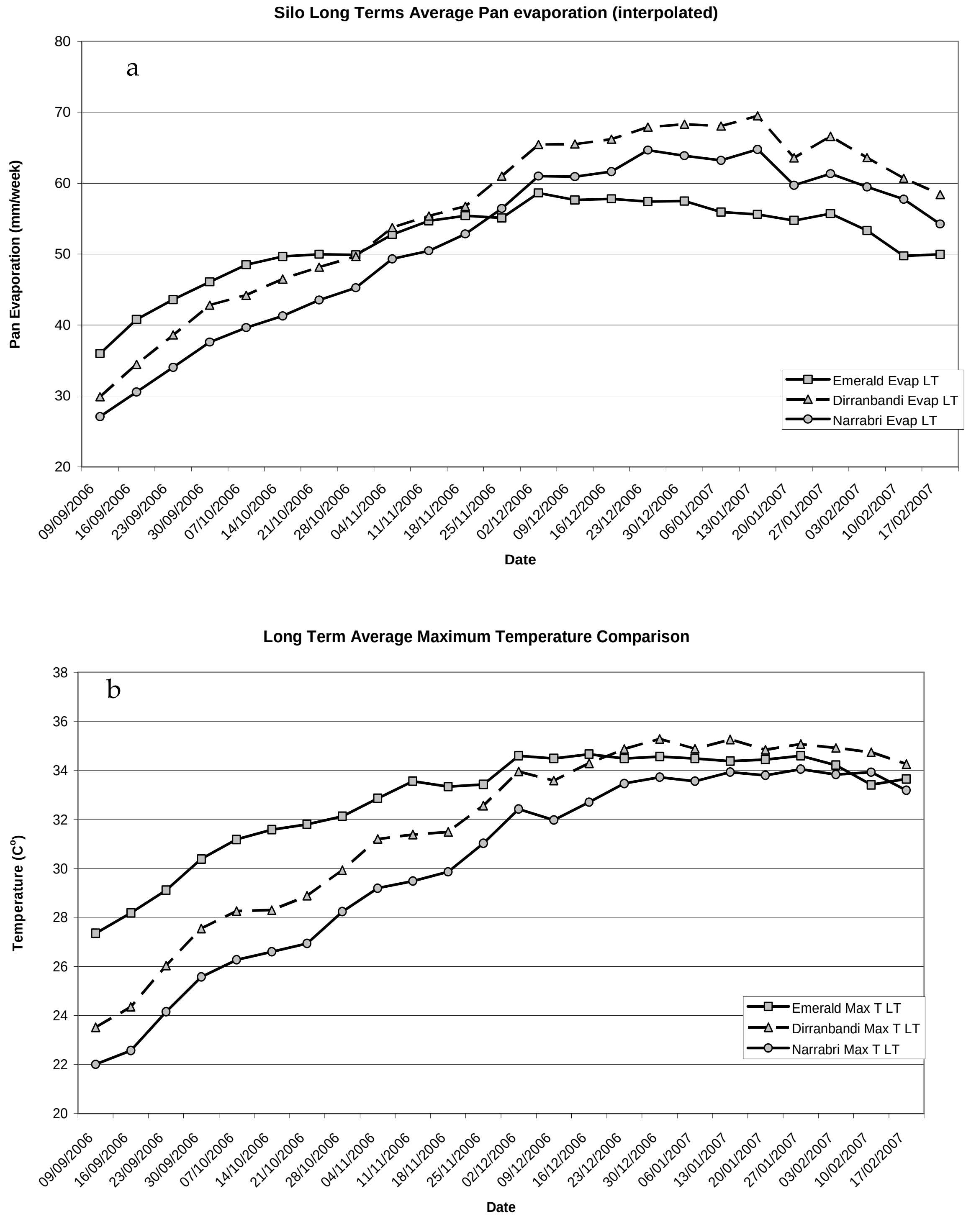


Figure 3. Long term average pan evaporation (a) and temperature (b) for experimental sites in the cotton growing season (data from Silo). Note that both Narrabri and Dirranbandi have much higher evaporation rates than the more humid climate at Emerald at similar maximum temperatures.

Measurement of stomatal conductance (opening and closure of stomata is one of the main mechanisms a plant can control water loss – closure indicates the plant is suffering water stress) as an indicator of plant stress was curtailed as a result of equipment failure. Though measurements were collected through the early season, later in the season, both porometers experienced problems with their battery capacity preventing us making reliable field measurements. The porometers were modified to accept a more robust battery configuration for the second season, however the results were highly variable and it was determined that leaf water potential using the pressure bomb provided a much more realistic indicator of plant stress.

Analysis of the Narrabri Experiments.

This study showed that changes in vapour pressure affected the level of stress a plant regardless of the level of soil moisture, highlighting the need for irrigation scheduling to reflect both factors. The combination of the four irrigation treatments (from Steve Yeates deficit experiments) and a large difference in climatic conditions between two growing seasons (2006/2007 and 2007/2008) produced a wide range of leaf water potential data. The average atmospheric vapour pressure during flowering was 20.8 hPa in 2006/2007 compared to 18.2 hPa in 2007/2008. This indicates a hotter drier atmosphere experienced during the season in 2006/2007. These differences in vapour pressure significantly affected the leaf water potential of the crop. Generally, when crops experienced high vapour pressure (greater than 20 hPa) during flowering in both seasons crops were more stressed compared when they experience low vapour pressure (lower than 20 hPa) during flowering (Figure 4). The results also showed that only when soil moisture levels were near to field capacity there was little affect of vapour pressure. The responses found here have important implications for irrigation management as differences in evaporative demand, including those associated with climate change, may necessitate changes in irrigation scheduling. Irrigation frequency may need to increase and soil moisture deficits reduced to maintain plant growth and yield under adverse climatic conditions.

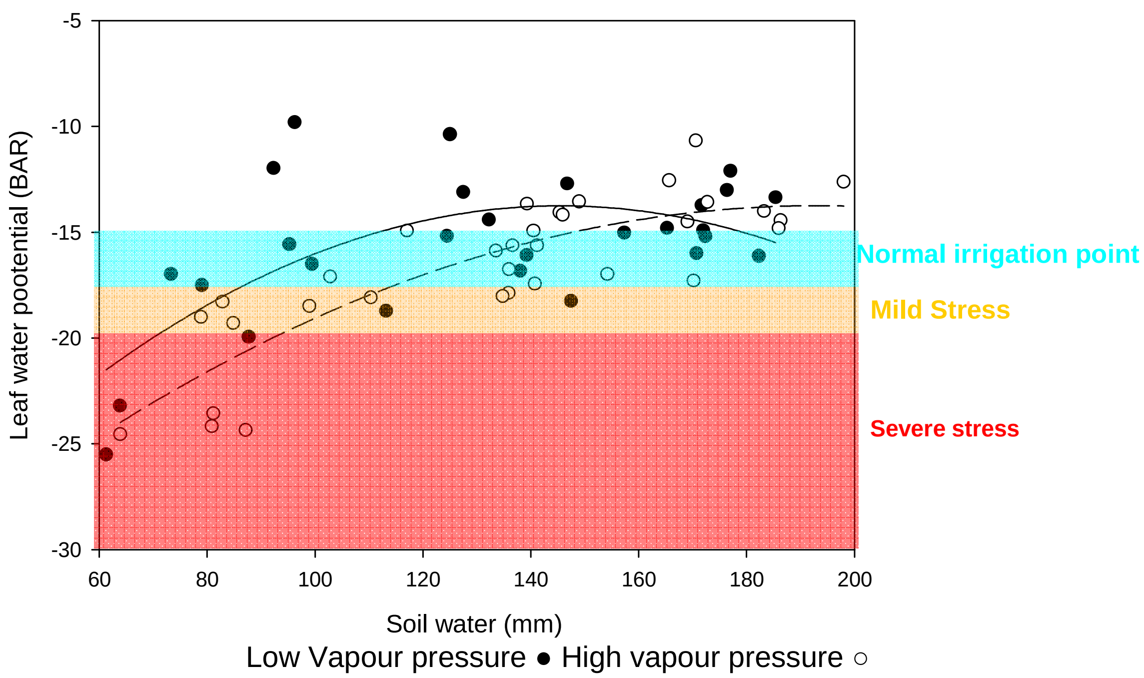


Figure 1. Effect of vapour pressure on leaf water potential, high vapour pressure (○,dashed line) and low vapour pressure (●, solid line). Note that at the same level of soil moisture depending on the atmospheric vapour pressure plants will more or less stressed.

Steve Yeates is further refining calibrations for the soil water in these experiments and once complete this data needs to be further analysed in addition to that from the other sites and the analysis from the soil type experiments to further refine the relationship between soil water, plant stress and vapour pressure.

Root development, varieties and row spacing

Variety root development

After the first year, this part of the project was then supported by the Cotton Breeding Australia joint venture (CSIRO/CSD). Field techniques identifying differences between genotypes proved difficult. A large data set on the development of roots of 4 cotton varieties was collected over the two years of field experiments. The experimental protocol was adjusted in the second year to ensure that effort was put in to the measurements with the highest possible chance of measuring root development differences.

Initial analysis of the root core sampling conducted at three times during the experiment (1st flower, 60% open and cut-out) showed no significant difference between varieties in terms of root proliferation (Figure 5). The core-break technique, counts the number of roots visible at a broken cross section of a soil core is used to estimate rooting. However, when compared to actual root length and weight from washed soil samples the calibration was very poor (Figure 6). Due to this poor correlation the core break method was not used in the following year's field experiment.

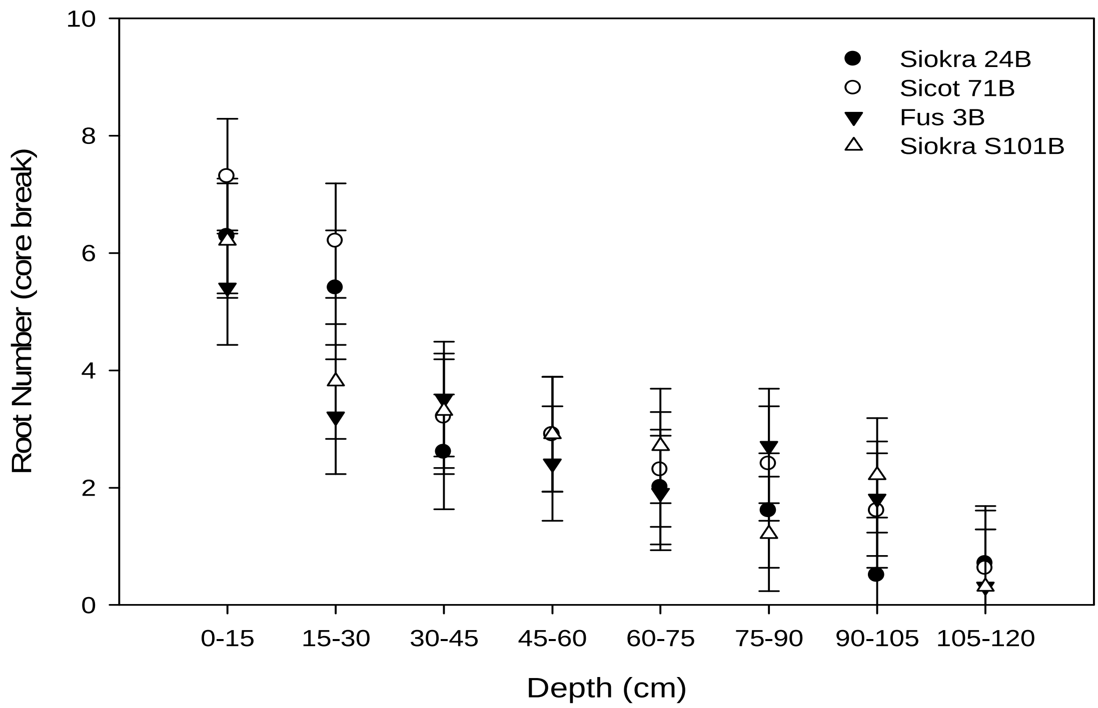


Figure 2. Root counts (from core break) at first core sampling date (1st flower) at different soil depths in 2006-07 field experiment.

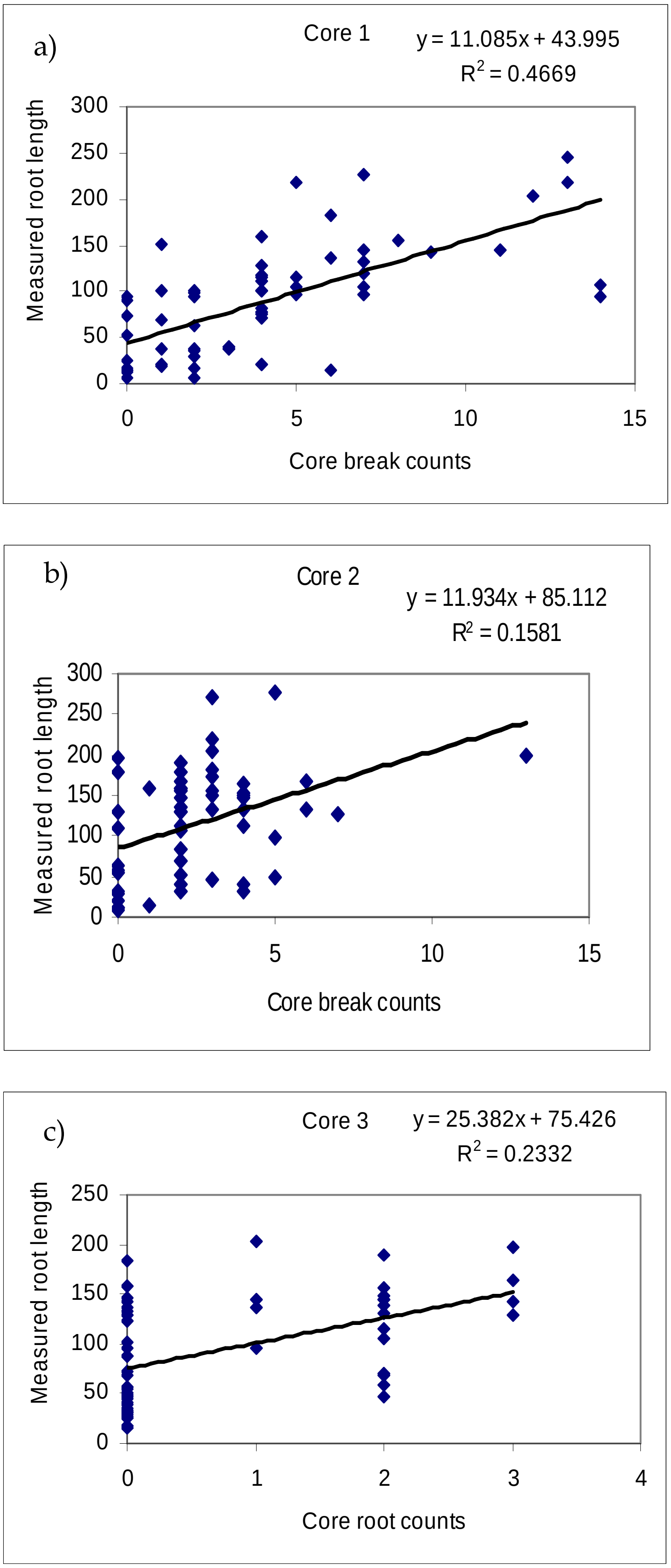
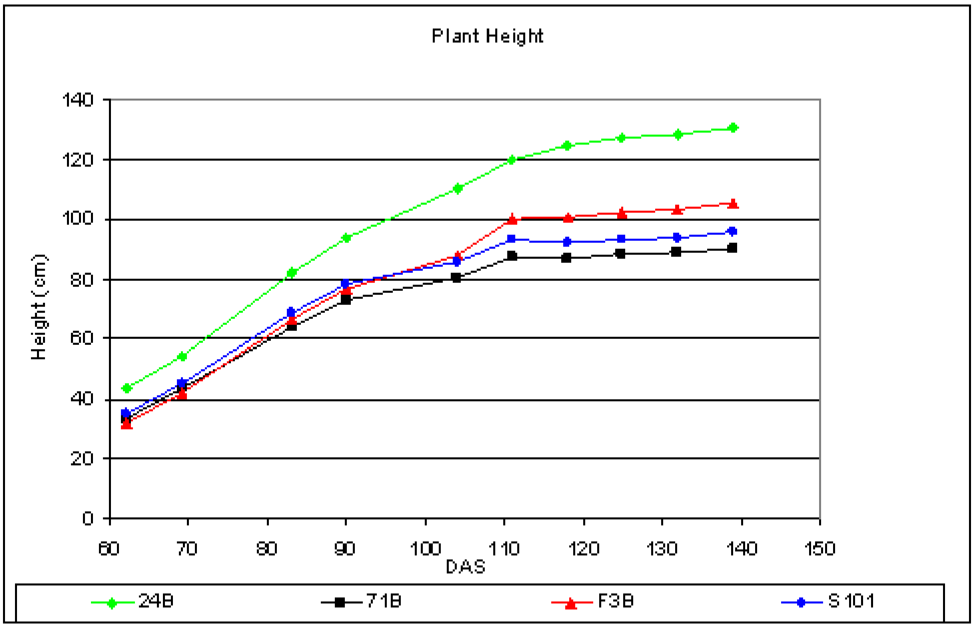


Figure 3. Calibration curves of core breaks compared to measured root length from washed root sample for the three coring times; a)1st flower, b) cut-out, and c) 60% open bolls in 2006/07 field experiment.

In addition to differences in above ground development (Figure 7), analysis of the data suggested some significant difference between varieties in terms of soil water extraction, although further interpretation will be required to see if this is of any practical significance.

There were differences between genotypes measured in terms of the production of root dry matter in the glasshouse experiment which shows some promise as a means to improve early water extraction. The results showed no significant difference in the main taproot length and number of main branches between the four varieties (Figures 8 and 9). Siokra 24B and Siokra S-101B had significantly higher root dry weight than Sicot 71B and Fus 3B. Siokra 24B and Fus 3B were significantly taller in plant height than the other varieties and 24B had a significantly higher shoot weight then the other varieties. The difference in root weight despite no difference in tap root length and the number of root main branches suggests that Siokra 24B and Sicot 71B may have thicker roots or may be producing longer lateral roots both of which may be potentially beneficial for early season water uptake.



LSD (5%) 4.7

Figure 7. Height development of the different varieties in 2007/08

Figure 8. Washed plants for comparing root Development of the four varieties compared in 2008 glasshouse experiment. From left - Siokra S-101B, Siokra 24B, Sicot 71B and Fus 3B

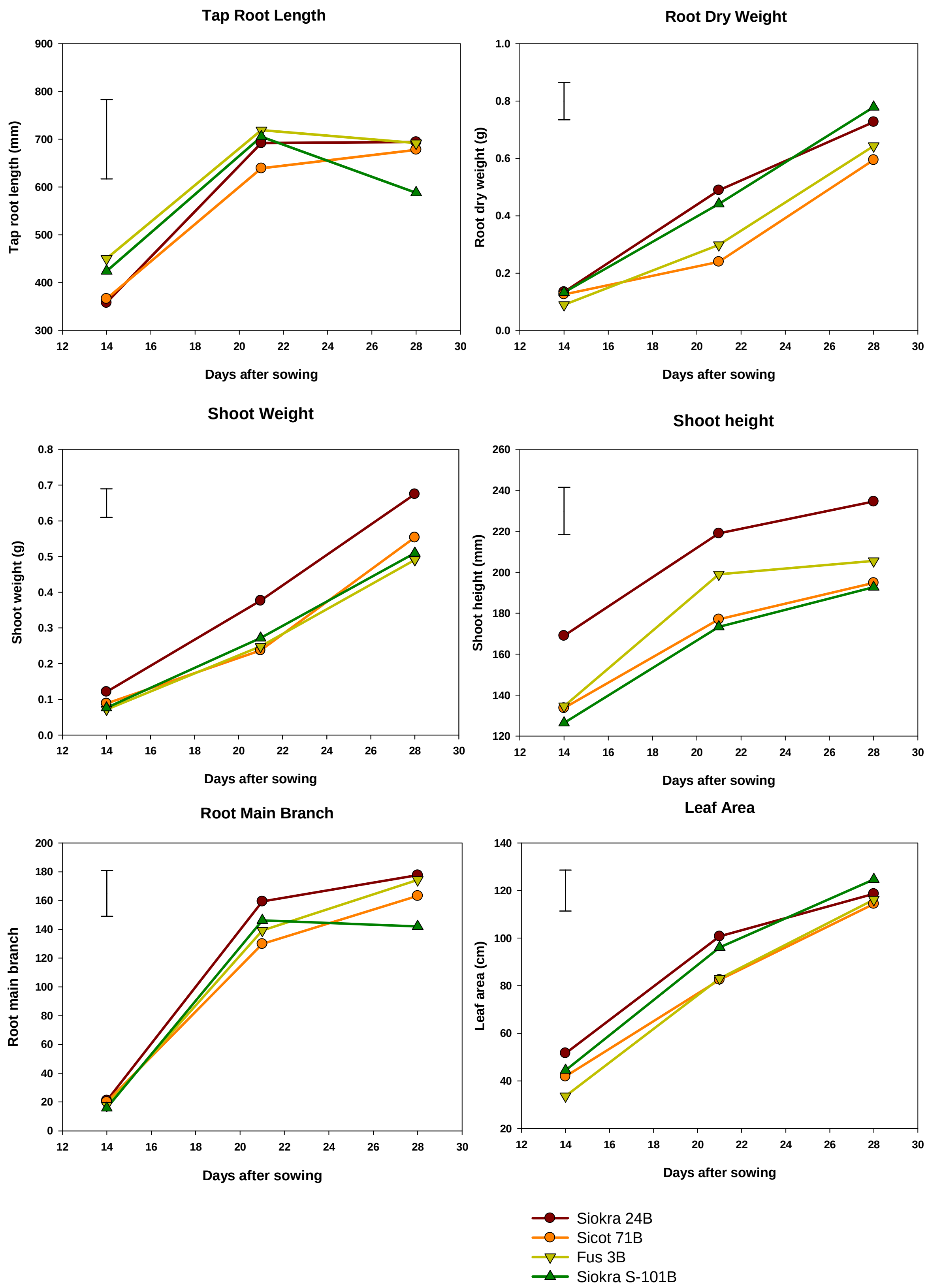


Figure 9. Tap root length, root dry weight, shoot weight, shoot height, number of root main branches and leaf area of the four varieties in glasshouse experiment. Siokra 24B and Fus3B. Error bars are the LSD of the interaction term.

Vascular bundle arrangement

In addition to field experiments a glasshouse experiment in controlled conditions measuring early season root development on the same genotypes was completed. A complementary study was investigating potential differences in the size of vascular bundles was also conducted, and found there were no differences between the genotypes used in the field and glasshouse studies. Each of the varieties had four vascular bundles.

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.

Objective 1: **Plant stress response to soil type and climate**

Due to the loss of the principal researcher during the project, data analysis and the preparation of papers for publication is ongoing, the results of the parent project "water relations of the cotton plant" are being complied in two papers, one focusing on the soil type effects and the other on the root development and water extraction of high and low retention cotton. Interpretation of results will assist in analysis of this project and support the development of guidelines that will relate the effect of soil type, temperature and climate (humidity/evaporative demand/vapour pressure deficit) on cotton plant stress. The experiments in this project showed that changes in vapour pressure affected the level of stress a plant regardless of the level of soil moisture, highlighting the need for irrigation scheduling to reflect both factors. Establishing these guidelines is important as although Denmead and Shaw (1962) and Shaw and Laing (1974) showed that the impact of a given water deficit on plant function is greater when the evaporative demand is high, there is no quantified data available showing cotton plant response under these conditions. A review on cotton plant response to soil water status by Sadras and Milroy (1996) found some data on cotton plant response to soil type, however, this had not been related to the prevailing evaporative demand. To optimise the irrigation strategy for a given location it is necessary to know the response of the plant to the prevailing humidity and soil type. Currently, little information of this type has been developed for cotton grown in the various production areas of Australia.

Objective 2: **Root development, varieties and row spacing**

Field techniques identifying differences between genotypes have proved difficult. There were differences between genotypes measured in terms of the production of root dry matter in glasshouse studies which shows some promise as a means to improve early water extraction. A complementary study investigating potential differences in the size of vascular bundles was also conducted, and found there were no differences between the genotypes used in the field and glasshouse studies.

6. Please describe any:-
   a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);

None

b) other information developed from research (eg discoveries in methodology, equipment design, etc.);

Assessment and calibration of the core break technique for determining root development was found to be highly inaccurate and labour intensive.

A simple technique for assessing vascular bundle number in different varieties was developed and may be used to assess differences with a greater range of genetic variation.

c) required changes to the Intellectual Property register.

None

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?

This project contributed to knowledge of the effects of soil type, temperature and climate (humidity/evaporative demand/vapour pressure deficit) on cotton plant stress. Current irrigation strategies rely strongly on assessment of soil moisture content by probes. However, as growers strive for and obtain higher yields and improved WUE, the interaction between irrigation timing and plant stress becomes more critical. Results from this project, Steve Yeates' and Dirk Richards's research have indicated an exciting opportunity to refine irrigation scheduling to help reduce the effects of stress during periods of high evaporative demand and particularly save irrigation during periods of low evaporative demand. The new 'Dynamic Deficits' project evolved out of the research conducted in this project.

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken:

New knowledge from this project will be used to update WATERpak and to refine the OZCOT crop simulation model.

Publications

8. A. List the publications arising from the research project and/or a publication plan.

Yeates S., Roberts J., Neilsen J. and Richards D., 2009. Toward better water management of Bollgard II cotton. The Australian Cottongrower, Jun-July 2009: 22-27.

Yeates, S., Neilsen, J., Conaty, W. and Roberts, J.
Irrigation scheduling and cotton productivity during the drought
In: Cotton in a Climate of Change, proceedings 14th Australian Cotton Conference (Broadbeach, 12-14 August, 2008) 10pp (www.australiancottonconference.com.au)

Neilsen, J. Evaporative effects on cotton water stress. In: Cotton in a Climate of Change, proceedings 14th Australian Cotton Conference (Broadbeach, 12-14 August, 2008) 12pp (www.australiancottonconference.com.au)

Neilsen, J. Effect of Soil Water Holding Capacity on Cotton Plant Water Stress. In: Beltwide Cotton Conferences, Jan. 8-11 2008 Nashville. TN.

A publication plan has been developed with two papers from the parent project "Water relations of the cotton plant" in preparation. One focusing on the calibration of AM vs. PM Leaf Water Potential measurements and the second focussing on the relationship between FTSW and leaf water potential across different soil types. A third paper which discusses the effect of climatic variables on this relationship is anticipated once collation and data analysis from this project is finalised.

Part 4 – Final Report Executive Summary

Principal Researchers J. E. Neilsen, R. Brodrick

Supervisor L.J. Wilson

Water remains a key issue for the cotton industry, with improving water use efficiency a priority. Relatively water research has focussed on the plant and its interaction with the soil and climate. Currently deficit irrigation and many different row configurations are used in the cotton industry without accurate knowledge of how these irrigation regimes affect root development. Water deficit and irrigation can influence cotton plants root systems: dryland cotton has deeper roots than fully irrigated crops and the timing of first irrigation can be used to encourage good root development. These affects are important in overall plant responses to moisture stress.

This project built on the outcomes of the research project CRC 79 "Water relations of the cotton plant", continuing to investigate the relationship between soil water and plant stress over a wider range of climates. We investigated plant responses to soil factors through assessment of root exploration between cotton varieties, plant water uptake and the response of cotton to normalised soil moisture deficits (FTSW). This project contributed to knowledge of the effects of soil type, temperature and climate (humidity/evaporative demand/vapour pressure deficit) on cotton plant stress.

To accurately detect differences in water use efficiency in cotton varieties, new techniques for measuring differences in root development are required; especially for larger scale screening of breeding lines. Field assessment to detect differences in varietal root development was not successful however glasshouse studies found differences. There is also potential for collaboration in developing molecular techniques / microarray and improving in-situ field root measurement to identify cultivar differences. Future work on this subject will be supported by the CBA JV water use efficiency and stress tolerance initiative.

Studies into environmental influences showed that changes in vapour pressure affected the level of stress a plant regardless of the level of soil moisture, highlighting the need for irrigation scheduling to reflect both factors. Current irrigation strategies rely strongly on assessment of soil moisture content by probes or using strategies that have relied on monitoring soil water. However, as growers strive for and obtain higher yields and improved WUE, the interaction between irrigation timing and plant stress becomes more critical. Results from this project, Steve Yeates' and Dirk Richards's research have indicated an exciting opportunity to refine irrigation scheduling to help reduce the effects of stress during periods of high evaporative demand and particularly save irrigation during periods of low evaporative demand.

The new 'Dynamic Deficits' project will focus on irrigation strategies to maximise water use efficiency. It will investigate approaches to irrigation scheduling that take into account plant stress, soil water and climate utilising the knowledge gained in this project about the importance of the impact of vapour pressure on plant stress and water use.