



Australian Government

**Cotton Research and
Development Corporation**

FINAL REPORT 2013

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: SIAC1301

Project Title: The Effect of Planting Density on Boll Disorders in Central Queensland Cotton Systems

Project Commencement Date: 21/09/12 **Project Completion Date:** 30/06/13

CRDC Program: 4 Farming Systems

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Part 3 – Final Report

Abstract

The Central Queensland cotton production system is a highly variable tropical climate which is heavily influenced by tropical storms and weather patterns. This provides the region with a unique set of challenges unrivalled in the Australian cotton production belt. The Central Queensland region has consistently produced higher percentage of boll disorders than any other cotton growing region in Australia. This has impacted on the overall yield and profitability of the farming system. This trial is to investigate some potential management practice changes to assist in alleviating the impact of these disorders.

Introduction

Central Queensland has been a significant cotton growing region for the Australian production system for 40 years. In that time, the Central Queensland area has faced multiple challenges, resistance to pesticides, exotic pest incursions and weather extremes (flood and drought). During these 40 years, the region has shown resilience to remain productive in spite of these issues.

The Central Queensland region differs significantly from other cotton growing regions of Australia, being in a hot and tropical climate. This climate is not unique on global standards, but the challenges that are being observed are unique to Australia's farming system. The tropical and variable climate patterns are such that attaining consistent yields is difficult for growers as tropical weather patterns (tropical lows, ex-cyclones) can impact the yield potential for the crop in multiple stages throughout the development of the crop.

The major difference between regions that has been observed over numerous seasons is the increased percentage of boll disorders (boll rots and tight locks) in the CQ system, when compared to the more southern growing regions. These have been sampled in the Cotton Seed Distributors annual Disease survey over 20 years. It is because of this information that this experiment became of interest. Discussions with researchers, grower groups and consultants suggested that a reduction in the incidence of these boll disorders would begin to bring the Central Queensland yields closer to the southern production regions.

Literature Review

Introduction

Cotton production in Central Queensland has a larger number of boll disorders than any other valley in Australia. The reasons for and practices to prevent such incidences are not well known at this stage. There is significant climate variability in the CQ system which has impacts the level of boll disorders that are present in the crop from season to season. It is therefore difficult to apply a blanket strategy to resolve this issue. The strategy will need to factor the need for sound yield and quality results in a good year, and improvements on yield and quality in a poor season.

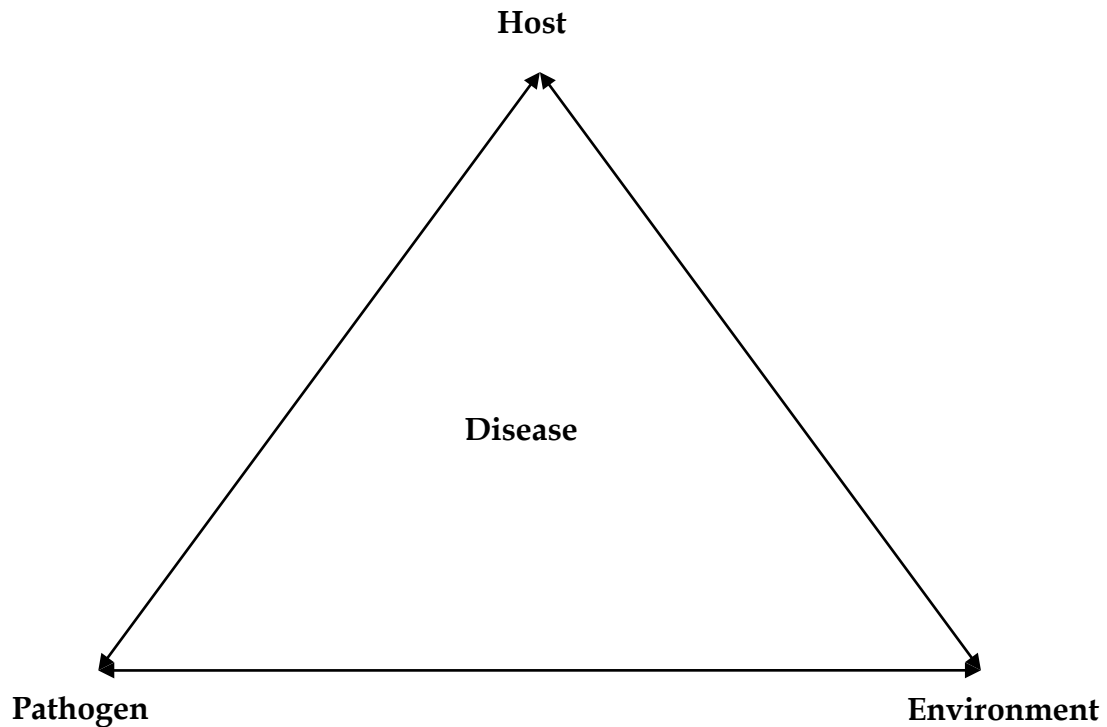
The following literature review will investigate studies on:

- Planting densities and the impact on yield
- Microclimate factors which may influence boll disorders
- Humidity and trash factors that may assist in the build-up of disorders

Where possible these articles have been sourced from local research, and have been conducted as recent as possible.

Disease Cycle

The basics of plant disease cycles are important in the complete understanding of the impact and production of boll disorders in cotton systems. The disease cycle is best represented in the figure 1 below, the disease triangle:



The above figure shows the amount of disease that becomes evident within a crop, is dependent on the amount of the pathogen that is present in the crop, the susceptibility of the host plant to that pathogen and the environment that the pathogen is exposed to. Therefore if there is a large amount of a particular pathogen presented to an extremely susceptible host and in favourable conditions, there is likely to be a high proportion of diseases develop.

There are a number of factors which may influence the efficiency of a disease infection and these will be separated into Pathogenic, Environmental and Host influences:

Pathogenic influences on disease infection

There are several pathogenic factors which may impact on the incidence of disease in field crops. Primarily the major factor is the abundance of the pathogen within the crop, the higher the incidence, the higher infection rates that is likely to occur. The aggressiveness and/or virulence of the pathogen can also impact on the severity of the disease within a crop. Other factors include the survivability and adaptability of the disease to a range of conditions and the reproductive fitness of the pathogen.

Environmental influences on disease infection

Environmental conditions are the most influential on disease infection with numerous factors which can aid or hinder the development of a pathogen in crops. Soil characteristics are a major factor in this, namely temperature, fertility and organic material. Climatic conditions, wind, irrigations, rainfall humidity and temperatures all play an extremely

important role in the severity of disease incidence. If any one of these is not conducive to pathological growth, there is likely to be a reduction in the severity of the disease. Another factor which may increase the severity of the disease is if the crop or plants are stressed (moisture, chemically or mechanically), these plants are at an increased risk of disease as the plant may not be able to fight off the pathogen.

Host influences on disease infection

The host plant is the final barrier against disease infection. Severity of disease infection is dependent on plant susceptibility primarily, but also the stage of the crop and overall plant health. A healthy crop is unlikely to be impacted by disease as severely as a crop which is stressed and a low plant-stand provided it is actively growing, and has good establishment.

Boll Disorders

Boll disorders are a term used to describe any issue with a mature cotton fruit that causes it to be deformed or un-harvestable. This is an issue in the more tropical regions of the global cotton growing areas primarily due to higher temperatures and humidity's causing a more conducive climate for pathogenic explosions. The most common forms of disorders in these climates are in the forms of "hard locks" or "boll-rots". Hard locks (or tight-locks as it is more commonly called in Australian systems) are characterized as being locks of cotton that are often fully developed, however never full open or "fluff" out and are tight in their appearance in the field, as can be seen in figure 2 below.

Due to the tight nature of the locks, commercial spindle-type picking machines are unable to effectively harvest these bolls.

Boll rots are more typically characterised by a fruit that has been totally colonized by fungal matter and usually rots, as the name suggests. These bolls rarely open and are generally black in their appearance. Typically there are several species of pathogen that can cause these rots.

Hardlock

Hardlock or tight lock as it is more commonly known in Australian systems is described as a boll that has opened up normally but at least one of the locks has not "fluffed out" and has remained in a tight state (Hillocks 1992). Hardlock or tight-locks have been studied extensively in the tropical climates of global cotton production systems extensively.

Overseas studies (Marios, Wright et al. , Mailhot, Wright et al. 2005, Marios, Wright et al. 2005, James J Marios, Mailhot; et al. 2006, Srivastava;, Mailhot; et al. 2009) suggest that the pathogen that is the cause of the Hardlock issues in their studies is *Fusarium verticillioides*. Numerous case studies investigating the severity and control options of this pathogen have been published by the University of Florida team.

The Australian system doesn't seem to replicate the northern hemisphere findings however. Stephen Allen (Cotton Seed Distributors Ltd.) has been investigating the pathological disorders in the Australian system for a number of years. In his summary journal article, he states

"In Australia tight lock symptoms are most commonly associated with Phytophthora boll rot but may occur when the crop is exposed to extended periods of wet weather as bolls are opening." (Allen 2007).

Fusarium has been sighted in the Australian systems, not in the form of tight lock, but as a species of boll rot. This has been predominately in the Queensland growing regions, and in crops that have had excessive growth and/or humid canopies (Allen 2007). Cotton Seed Distributors Ltd has been conducting annual disease surveys in conjunction with regional department of agriculture's in New South Wales and Queensland. The survey results show a

consistent presence of boll rots (inclusive of tight locks) in all cotton growing regions of Australia.

Boll Rots

Australian systems have a number of different pathogens that can cause boll rots in cotton systems. The most common (Allen 2007) is caused by *Phytophthora nicotianae*. This pathogen thrives in wet and humid conditions. *Phytophthora* produces an oospore which then germinates into a zoospore in wet soils (Allen 2007) This can then be transported onto low hanging fruit by means of rain-splash and/or irrigations.

Other forms of boll rots that are common in the Australian system are *Sclerotinia sclerotiorum*, *Fusarium spp* (Allen 2007) and *Lasiodiplodia* (Smith, Lehane et al. 2012). These rots are infrequent throughout the system, though the *lasiodiplodia* rots have been common in recent seasons in Central Queensland (Smith, Lehane et al. 2012). *Sclerotinia sclerotiorum* has been identified in a number of seasons prior to 2007, but at a relatively low frequency (Allen 2007). Identification of the pathogen is an important step in the strategy of boll rot management as each individual species develops and reproduces in slightly different circumstances.

The initial infection of boll rots can vary from season to season and the reason for this is yet to be concluded. A study in the late 1970's by D. E. Sanders and J. P. Snow, would suggest that it might be a combination of trash components from the present crop that is contributing to the pathogen level. In this particular study, the airborne spores that had been produced from each pathogen were captured, measured and identified. Throughout the study, it became clear that the greater the abundance of the spores, the higher the infection percentage of that particular pathogen (Sanders and Snow 1978). The peak flushes of the rots and spores did not correlate, in fact, the spore production peaked significantly prior to the peak rotting period. It was then concluded that flowers, squares and bolls that had previously been aborted in the crop were a factor in increasing the spore abundance (Sanders and Snow 1978).

"The spores probably did not originate on rotted bolls because the first rotted bolls appeared after the peak spore catch at each location in both years. However it is probable that the spores were a part of an initial mass of inoculum which was produced on naturally-shed flowers, bolls squares and leaves deposited on the soil surface after the onset of flowering." (Sanders and Snow 1978).

The study also showed that the overall spore production was not influenced by the temperature or rainfall however humidity placed an integral part in the deposition of spores, as majority of the spores were deposited when the relative canopy humidity was nearing 100% (Sanders and Snow 1978). This relates closely with what the Central Queensland system can encounter during a normal season.

Control options/linkages

A study into potential fungicide protection has been investigated, with varied results. A paper that was presented to the Beltwide Cotton Conferences in 2006, concluded that despite there being a reduction in Hardlock severity, overall yield was not significantly affected (James J Marios, Mailhot; et al. 2006). The study suggested that although the fungicide application was useful in the management of the disorder, the pathogen is still present in the crop, albeit at a lesser amount.

A previous study conducted by Daniel J. Mailhot, investigated the impact insect vectors, such as thrips, had on Hardlock. This study was again inconclusive, as the *Fusarium* infected thrip numbers were significantly less than the amount of Hardlock detected in the crop. Mailhot suggests that *"If thrips transporting inoculum into the flower are a major*

component of the infection cycle, it seems likely the percentage of flowers containing Fusarium-carrying thrips should be equal to or higher than the observed hardlock frequency in the field” (Mailhot, Wright et al. 2005). In 2003, the Hardlock frequency was 25% compared to 3.9% of flowers which contained the infected thrips (Mailhot, Wright et al. 2005).

Density

Planting density trials have been conducted through various regions of the global cotton production system testing a number of different hypotheses. Research from Pakistan in 2011 was to investigate the response of cotton to both planting dates and density (Muhammad and Khan 2011). This trial was conducted with very low densities, 6.5 plants per metre being the top density, 2.2 plants per metre being the minimum treatment; 3.5 plants per metre was the final density treatment. This trial also looked at varietal performance which increases the complexity of the trial. Generally, the findings were that in an early and normally planted scenario, 3.5 plants per metre achieved the best and consistent results, however in a late planting scenario; an increase in the planting density was to provide the more consistent and higher yields (Muhammad and Khan 2011). A similar study was conducted in China in the Yellow river valley. This study had results that mirrored the results shown in the Pakistan study above. “Normal planted cotton at a plant density of 3.0-4.5 plants/metre², and late-planted cotton at 7.5 plants/ metre² produced higher lint yields than any other planting date and density (Dong, Weijiang et al. 2005). Dong et al. observed a wider range of densities, 3.0, 4.5, 6.0 and 7.5 plants per square metre and various other methods of production including films to enhance the establishment in early plantings.

Density trial work is often deemed as being unachievable on a commercial cropping system as the precision of current commercial equipment is not comparable to hand-planting/thinning. This always needs to be factored into the trial design and relevance.

Previous trials

This study is the second of these trials to be conducted in the area. In the 2011/2012 cotton season, the same trial was conducted but had issues with weather and data collection. Both trial sites were heavily damaged by hail in December 2011, followed by late rain events, which compromised yield by means of boll disorders and plant growth habits. Despite this, lessons from this trial setup and procedural changes were bought into the new trial, to enhance the quality of data that was to be collected from the site.

Yields

Whilst yields on both sites were disappointing and extremely variable, there were some trends that were promising. These trends were not significant however due mainly to the level of variability in the plots. This variability was due in part to the level of the hail damage within the crop along with soil conditions.

Boll Disorders

Similarly to the yield comparisons, there were no significant differences between boll rots and or tight locks in this trial. Variability again was an issue; however the results were reasonably consistent throughout the plots. The disorders that were observed to have most affected yields were tight lock and seed rots. These did not show any significance to density, however there did seem to be a significant difference between reps. This was due to the

environmental conditions that influenced these reps. The hail damage differed throughout the paddock and thus caused the reps to behave differently.

Methodology

This experiment was to be conducted using commercial planting, fertilizing and irrigation procedures and equipment. The reason for this was to ensure that the results that were achieved would best reflect commercial reality if the findings are implemented by local growers.

Site Selection

The site was selected in a commercial field on the Nogoia River floodplain North East of the township of Emerald. Soil type in this field was deep alluvial cracking clay which is common among the Central Queensland cotton production areas. In the previous two seasons, this field had grown cotton both years and had also been heavily affected by flooding within the last five years. This site was selected due to soil uniformity, field size and recent flood protection upgrades (levy-banked). The field was 10 ha and could be irrigated independently from most other fields, if deemed necessary.

Experiment design/Treatments

The experiment was conducted in a randomized block design, consisting of sixteen (16) plots; four (4) replications of four (4) treatments. Each of these plots was planted with commercial equipment and was eleven (11) metres wide by ten (10) metres long. The densities that were observed in the study were four (4), eight (8), twelve (12) and sixteen (16) plants per square metre.

Procedures

The trial is to be planted using commercial twelve row (12m) planting equipment. In order to ensure target densities are achieved, all plots are to be planted at 20 seeds/metre and each plot then hand-thinned. The thinning process is to be completed by having a 10 metre string-line marked with seedling positions on to it in accordance with the following table. If there are two seedlings near that spacing, the one that is the closest fit to the remainder of the row will be selected.

Density	cm spacing
4	25
8	12.5
12	8.3
16	6.25

Table 1: plant spacing (cm) for each density

Commercial planting operations are not precise enough to ensure the evenness of plant stands that hand-thinning will achieve. During the hand-thinning process, there will likely be occasions where the plant stand is not exactly the spacing's that have been stated above, however over a 10 metres of row, the average plants/metre will match, as closely as possible, the target density.

This experiment is going to observe the effect on yield, quality and abundance of boll disorders. Yield will be collected by means of a segmented pick and spindle picker. The segmented picking data assists in illustrating the relative fruiting behavior between treatments, where as the spindle picker brings some commercial relativity to the data. The spindle picker is a modified commercial machine which harvests an individual row into a

bag. This bag is then weighed to provide a result of one (1) row. The machine will harvest 4 rows in each density.

Segmented picking is a hand-harvesting procedure where the crop is segmented into different regions within the canopy and harvested in these regions. These are then placed into separate bags and weighed to produce a yield. This is to be conducted in each plot, and a total of two metres of hand picking is to be completed of each plot.

Local climate data is to be collected out of one replication (rep 2) for each treatment. This is to be achieved by a data logger that measures maximum and minimum temperatures and relative humidity. These will be able to assist in identifying any micro-climatic effects which may influence boll disorders. The loggers will be placed at 60 cm from the top of the bed which will allow the logger to take readings from within the crop canopy without any effect from irrigation water.

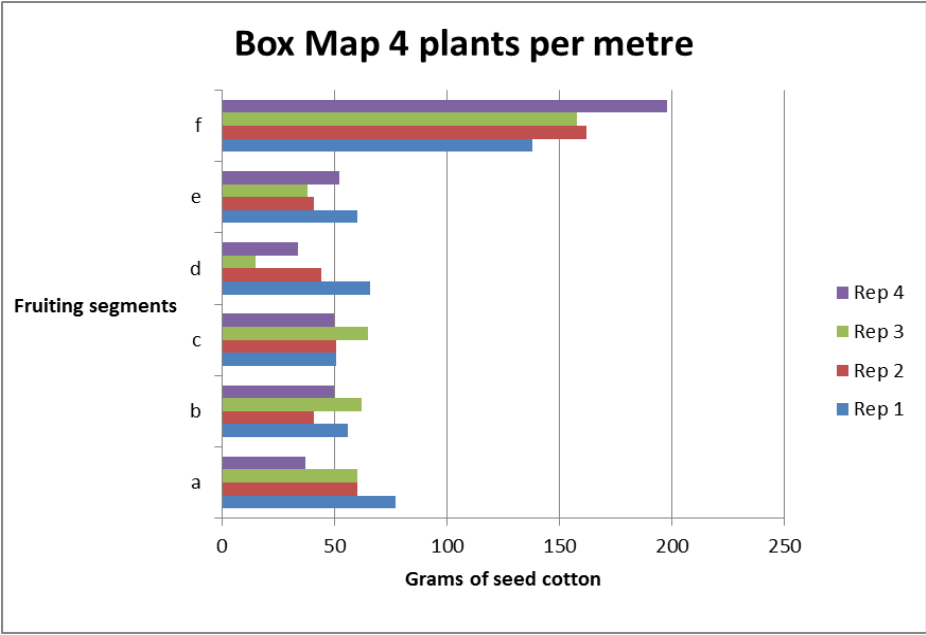
Boll disorders that are observed will be noted as a percentage of total fruit and an example of each disorder will be collected and sent to a cotton pathologist for identification. Once identified, these will then be recorded as a percentage of total disorders for further analysis at the end of the season.

Results

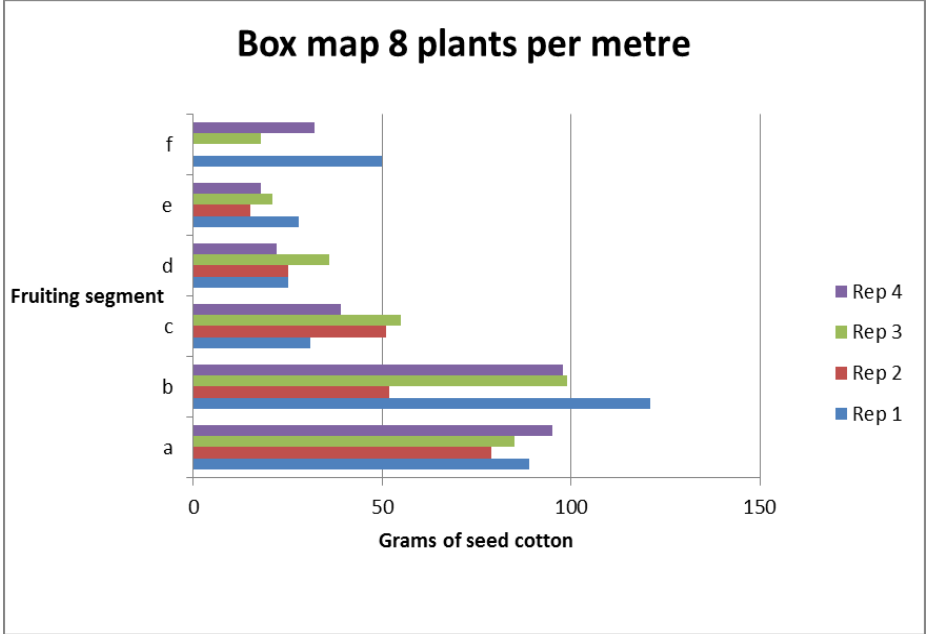
The summer of 2012/2013 was a very warm and dry season, not conducive to boll disorders. Within the trial there were minimal signs of any disorders, which were also reflected in the commercial planting of the region. This impacted on the ability to correlate density and boll disorder linkages in this particular season. Despite this, the trial produced some very good data on the overall yields of each density and can be analyzed as a proof of concept of how densities can manipulate plant architecture and thus affect the timing of fruit development. All treatments progressed through the season rapidly due to the high heat units that the crop was exposed to. This caused some pressures with the timings of irrigations toward the latter part of the season, which may have impacted on the final yields by means of earlier “cut-out”. Some of the lower densities lacked the ability to compensate enough to compete with the dense stands with outer position fruit. This can be seen diagrammatically in graphs 1-4 below. The segments are harvested into 6 sections; table 2 explains these sections.

Section	A	B	C	D	E	F
Plant segment	Fruiting nodes 1 to 4 1 st position fruit	Fruiting nodes 5 to 9 1 st position fruit	Fruiting nodes 10 to 13 1 st position fruit	Fruiting nodes 1 to 4 2 nd and 3 rd position fruit	Fruiting nodes 5 to 9 2 nd and 3 rd position fruit	Vegetative node fruit

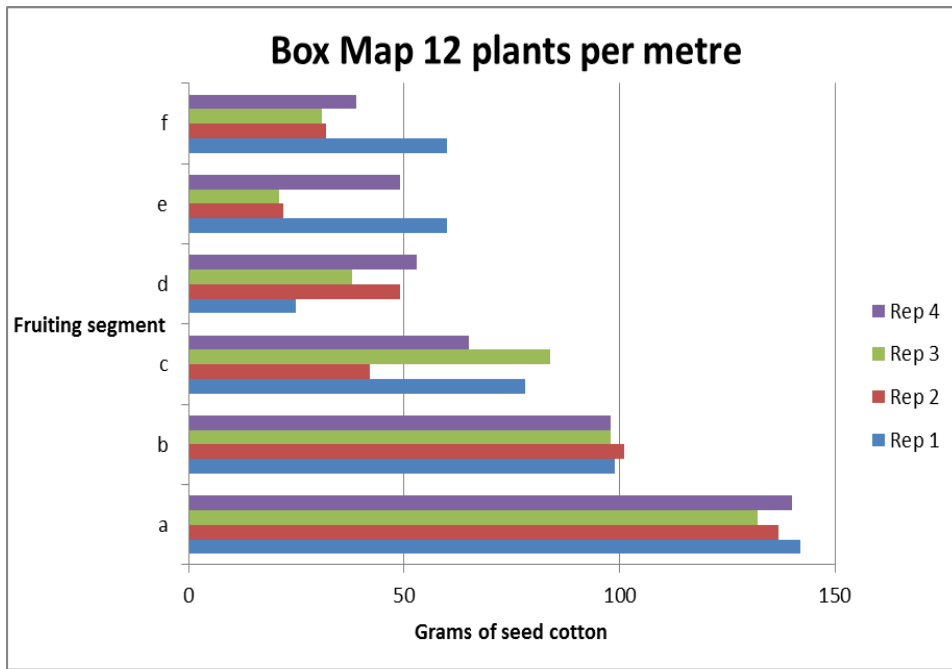
Table 2: Fruiting segment descriptions



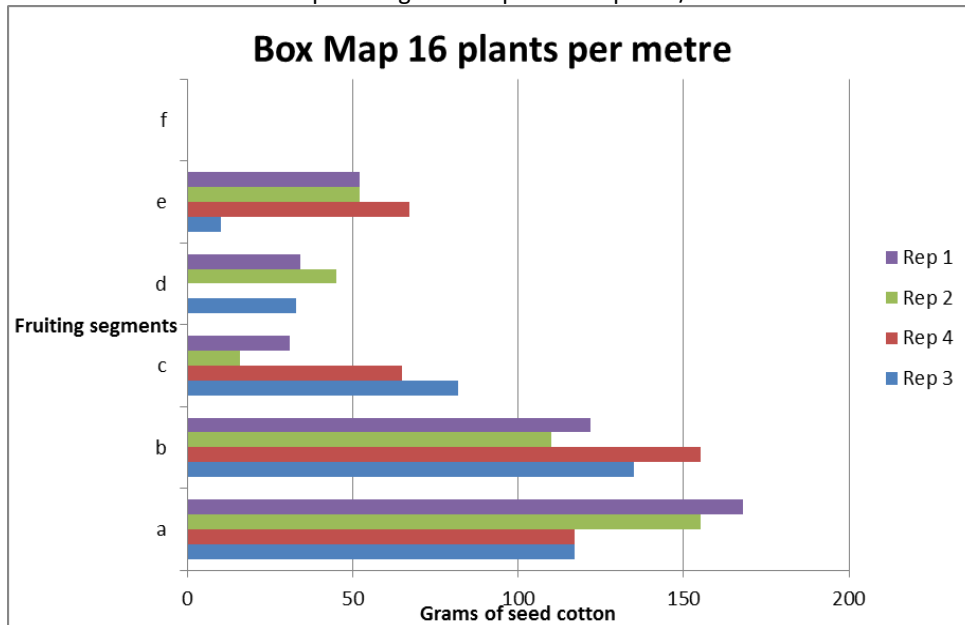
Graph 1: Segmented pick 4 plants/m



Graph 2: Segmented pick of 8 plants/m



Graph 3: Segmented pick of 12 plants/m



Graph 4: Segmented pick of 16 plants/m

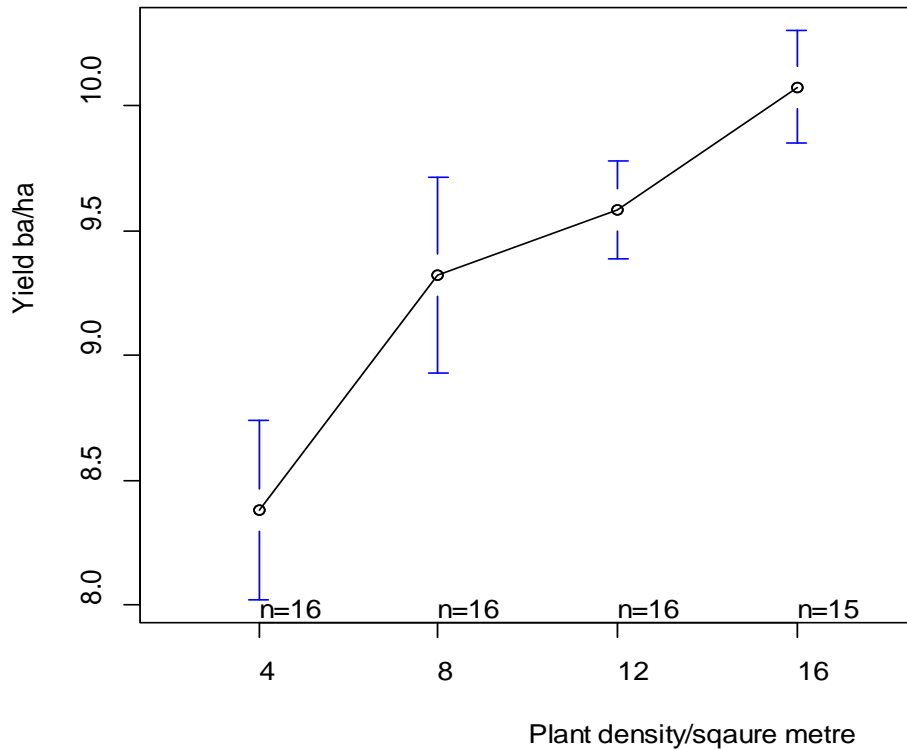
These segmented picking highlight that by reducing or increasing planting densities, a change in plant architecture can be achieved. This trial shows that by means of increasing the planting density, the fruiting behavior of the plant is very compact to the centre stem (an increase in weights in sections A,B&C), with very few second, third and vegetative position fruit being produced. In comparison, the lower planting density showed that the fruiting behavior changed to enhance the second, third and vegetative fruiting positions (Particularly segment F but also D&E), but in this case, this wasn't enough to compensate for the lack of yield, due to the climatic conditions.

To develop an understanding of whether this trial provided any statistical differences, an ANOVA statistical analysis and LSD test comparing yield and treatments has been conducted. This was analyzed with a 95% confidence interval.

LSD table for the Effect of Plant Density on Cotton Yields		
Plant Density (plants/m ²)	Yield (bales/ha)	Statistical Group
16	10.07	A
12	9.584	B
8	9.322	B
4	8.382	C

Table 3: LSD Table shown at a 95% confidence interval

Effect of Plant Density on Cc



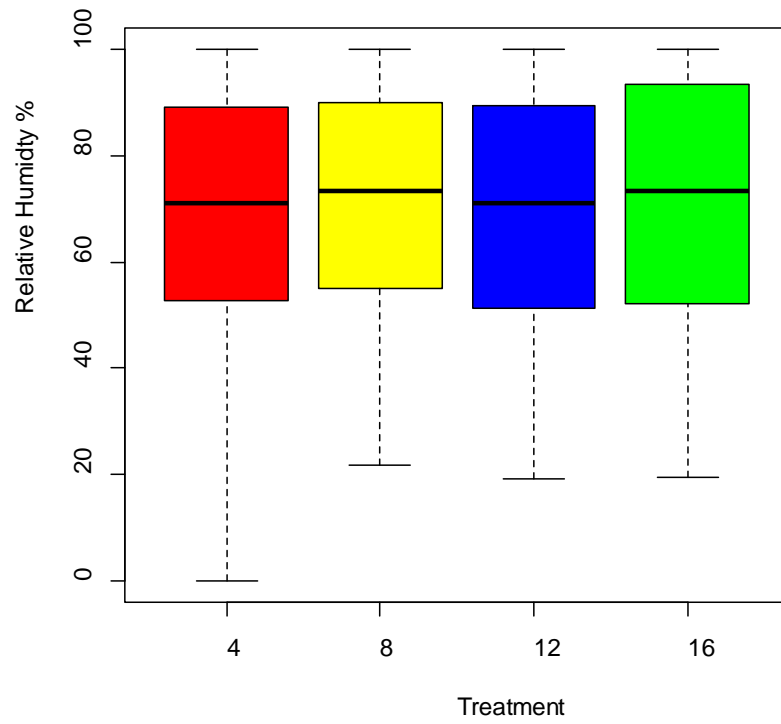
Graph 5: Means plot with error bars (note: n=16 number represents the number of samples within the treatment)

Due to this trial being small plot with a smaller number of treatments and replications, any variability within the trial significantly affects the result. In the above graphic, for there to be a statistical difference, the error bars cannot overlap between treatments. Therefore in this analysis, there is no significant difference between the 8 and 12 plants per square metre treatments; however there is a significant difference between 4 plants per square metre and every other treatment, and 16 plants per square metre and every other treatment. In this particular trial, there was a lost piece of data due to the picking operation. This is why Graph 5 shows 16 data points for each treatment except for 16 plants per square metre treatment which has 15 due to the lost data.

This trial also provided some in-crop climate data by means of a series of data-loggers. This data was collected in the second replication of the trial by means of a humidity/temperature data-logger. These were set up 60cm from the top of the bed to measure if there was any impact on the canopy climate between treatments.

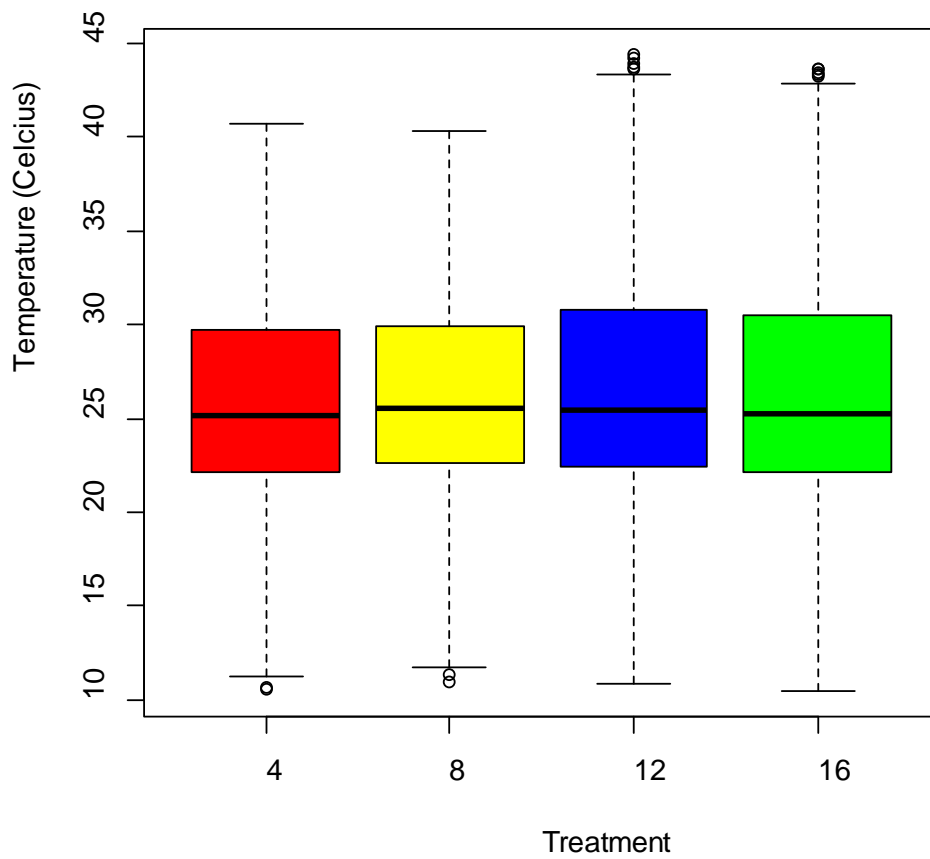
Measurements were taken every 15 minutes from the 2nd of December up until 19th of March. The graphs below (graphs 7 and 8) show that very minimal affect is recorded by these data-loggers between the treatments. This is likely to have been caused by the crop not reaching the required height to have a significant impact on the data-logger climate. The benefit of this data is that it shows the temperature and humidity ranges that this trial was exposed to and what ultimately assisted in the final cut-out of the trial.

Box and Whisker Plot Relativ



Graph 6: Box and Whisker Plot of Relative Humidity vs Treatment

Box and Whisker Plot Temp



Graph 7: Box and Whisker Plot of Temperature vs Treatment

As shown in each of these graphs, the analysis concludes that no statistical difference between relative humidity and temperature between the treatments. These analyses have been completed with a 95% confidence interval.

Discussion

Effect of planting density on yield

The results that were achieved this season was markedly different to the expectations, in that yield was not going to be significantly impacted by a reduction in density. Upon accounting for the lost data point, this dataset is highly significant. As previously stated in the results; the treatments 4 and 16 plants per m² are statistically different from each other and the other two treatments, being 8 and 12 plants per m² respectively. The yields achieved this season were very dependent on the climatic conditions that the crop was exposed to. The 16 plants per m² plots were consistently higher yielding than the remainder of the treatments which was most likely caused by those particular plots setting more fruit quickly due to the inter-row competition in the plot. The hot and dry weather pattern then caused the three other plots to suffer a premature cut-out and limited the yield potential of these treatments.

Effect of planting density on boll disorders

The 2012/2013 summer was significantly different to the previous seasons and was not conducive to boll disease or disorders. Therefore this trial doesn't however show the impact of the planting density on boll disorders as the season was not conducive to the production of these. Upon studying the segmented picking graphics (graph 3/4) the original theory behind the trial has still been proven, albeit in the reverse situation to the aim. The higher populations produced large amounts of fruit tight in on the main stem of the plant, in a short time-frame. This increased the risk of more fruit within the crop being affected from a single boll rot/disorder event. It was this rapid production of fruit that allowed the crop to out-yield the other treatments in this particular season. The climatic conditions, being hot/dry weather and inability to irrigate timely, due to capacity issues, caused a premature cut-out of the trial.

The lower densities performed just as expected also, with more lateral and compensatory fruit production on each plant. This again was shown in the segmented picking graphs (graphs 1/2); less fruit per metre was produced tighter to the stem, due to the smaller number of plants in that metre, but the plant had begun to compensate with vegetative and outer position fruit. This fruiting sequence is the reason for the theory to suggest these densities would be better suited in a boll rot event as less fruit/metre were at risk of a boll infection in a single event. This statement cannot be proven as yet, though it seems to still be a possibility that this could be the case.

Management issues with implementation of densities

There are some inherent difficulties with implementing the higher and lower planting densities on a commercial scale. The higher densities are more likely to have higher nutrient and or water demands during peak growth periods. These densities are also more likely to force the canopy to grow taller for the leaves to obtain adequate sunlight. This may cause "rank" growth which could influence the crop canopy climate, making it more conducive to fruit and leaf diseases. Rank crops can also be difficult to manage at the time of harvest. Lower planting densities are much more of a risk in the commercial planting system as the precision required to evenly place seeds is not currently available to the farmer. However if

the environment and planting conditions are optimal, these lower densities can be achieved. Once planted, these densities also run the risk of seedling mortality causing a much more significant impact on the overall yield than that of the higher densities. A greater percentage of plants per square metre have died if 1 or 2 plants per metre die in low densities compared with high densities. Harvesting may also be an issue with these plants as the architecture of the crop in low densities is such that these plants become a lot more vegetative and “hedge-like” due to the plants compensatory behavior to get leaf exposure to sunlight. These “hedge-like” plants are often difficult to feed into a commercial spindle picker.

Conclusions

In summary, the 2012/2013 cotton season was not conducive to boll rots and as such provided limited data for analysis. In this particular season, it became clear that there was a significant difference between lower densities and higher densities per square metre. The results achieved are not likely to cause any significant practice change to the area as the data is only from a small trial in one particular season. This trial could be repeated for several years and likely achieve different results each time.

Despite the yield results differing from the initial beliefs, the data has begun to prove the concept of utilizing plant architecture by means of plant density, to reduce the risk of boll disorders in Central Queensland cotton systems. This trial shows conclusively that by changing planting density, the plant architecture can be manipulated to a degree whereby fruiting patterns are altered.

Extension Opportunities

There is the potential for further research to be completed on this topic, however with the variability between seasons and regions, on any given trial year the results will vary. If there was more work to continue, the focus should be on gaining knowledge about how, when and why boll disorders occur. Although this trial was aimed at delivering some data on this topic, due to the seasonal influences this returned with just a comparison on the yield and plant density analytes.

This trial does however highlight the influence of seasons in the Central Queensland system and research into how best manage cotton generally in this variable climate would be worthwhile.

Appendix



Trial site overview



Datalogger setup, in-crop prior to cut-out



8 Plants per metre



4 Plants per metre



12 Plants per metre



16 Plants per metre

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Part 4 – Final Report Executive Summary

The Central Queensland cotton production system is a highly variable tropical climate which is heavily influenced by tropical storms and weather patterns. This provides the region with a unique set of challenges unrivalled in the Australian cotton production belt. The Central Queensland region has consistently produced higher percentage of boll disorders than any other cotton growing region in Australia. This has impacted on the overall yield and profitability of the farming system. This trial is to investigate some potential management practice changes to assist in alleviating the impact of these disorders.

The project was designed to prove the concept that plant architecture can be manipulated by varying the planting density and investigate how that was going to impact on boll disorders. The theory was that a reduction in the planting densities was going to limit the number and percentage of susceptible fruit to a boll disorder event. Increasing the density was going to increase the percentage of fruit that was exposed and susceptible to a boll disorder event and thus increases the incidence of boll disorder.

The 2012/2013 cotton season in Central Queensland was such that boll disorders were not the major yield limiting factor; it was more influenced by irrigation capacity and high temperatures. This density trial was no different and in fact these weather conditions were detrimental to the result achieved in certain treatments. The lower densities were reliant on compensatory growth to achieve similar yields to higher densities; it was at the time this initiated that the high temperatures and delays in irrigation eventuated. This resulted in a shorter plant, with less vegetative development on which compensatory fruit development would have occurred and this caused a significant 2 bales/ha reduction in yield in comparison to the highest yielding treatment, 16 plants/metre². Despite this differing from the initial belief that plant density would not impact on crop yield, this result still proved the concept of how reducing and/or increasing planting density can impact on plant growth habits. This concept can then be extrapolated to add strength to the concept that a reduction in planting density could be used as a risk management tool against boll disorders in the Central Queensland production system.

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