Building competitive banana production systems for a sustainable future

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Summary

This project began with the objective of investigating the factors influencing the maintenance of crop uniformity in bananas. A continuous ratooning system is the standard banana production system in north Queensland, the main Australian production region, and it is characterised by increasing non-uniformity with successive crop cycles. By the end of the third crop cycle bunch emergence and harvest are spread evenly throughout the year. While this contributes to a continuous fruit supply it has been shown to reduce labour input efficiency for activities target to a specific stage of plant development such bunch emergence or harvest.

A research trial was implemented at the DAFF South Johnstone Research Station to investigate the influence on maintenance of crop uniformity of planting material type, time of planting, plant density and arrangement and strategic nurse-suckering of laggard plants in a population. Assessments were also made of the influence of different times of planting and plant density and arrangement on the incidence of key pests and diseases. TC Yasi destroyed the research trial in February 2011 and it could not be recovered in an acceptable timeframe, thus preventing the achievement of many of the project objectives.

In spite of this trial results revealed that a single row arrangement at 1333 plants per hectare maintained a significantly higher crop uniformity that the traditional double row arrangement planted at 1810 plants per hectare, particularly when climatic factors were limiting plant growth and development. Plant density and arrangement also influenced the incidence and severity of yellow Sigatoka infection, with the single rows having significantly less disease than double rows across all 6 times of planting.

Time of planting influenced crop uniformity in the plant crop with lower uniformities experienced when bunch development occurred during the autumn and winter periods. Time of planting also had a significant effect on the incidence of yellow Sigatoka and Banana Scab Moth, primarily driven by the climatic suitability for pest and disease development.

Data from the original project objectives provided important information for the development of the cyclone recovery program with the banana industry in 2011.

After the destruction of the research trial by TC Yasi the project objectives were revised to focus on cyclone recovery practices, specifically the investigation of ethephon pseudostem injections for crop timing management. The project undertook three field trials, including an assessment of fruit residue status in the subsequent crop, to determine the efficacious rate and pattern of use to support a Category 21 Minor-Use Permit (MUP) application for the banana industry to the Australian Pesticides and Veterinary Medicines Authority. The MUP application was submitted to the APVMA in June 2014 for consideration.

Keywords

Bananas; labour efficiency; crop phenology; crop uniformity; ethephon; residue analysis; nurse-suckering

Introduction

Due to the impact of TC Yasi on the banana industry in north Queensland, including the project field trials, this project had a significant change in focus after February 2011. The original project objectives focused on investigating factors affecting crop uniformity and the effect of loss of uniformity over successive crop cycles on labour efficiency and other inputs. However after the impact of TC Yasi in 2011, the project refocused on cyclone recovery practices, specifically the investigation of ethephon pseudostem injections for crop timing management. The project undertook a series of field trials, including assessment of fruit residue status in the subsequent crop, to determine the efficacious rate and pattern of use to support a Category 21 Minor-Use Permit (MUP) application for the banana industry to the Australian Pesticides and Veterinary Medicines Authority.

To reflect the dual nature of the project this report is separated into two separate themes – the investigations of crop uniformity and the investigation and development of the ethephon pseudostem injection MUP.

Investigating factors influencing crop uniformity management

The Australian banana industry is valued at over $450 million dollars annually and faces significant domestic and international challenges such as potential competition from cheap imported bananas, reducing productivity and availability of labour, continuing reduction in profit margins and increasing scrutiny of environmental impacts from agricultural production.

The north Queensland production regions account for around 93% of the bananas produced in Australia. The typical production system in NQ is replanted every 6-7 years and managed as a continuous ratooning system. The flowering and harvesting patterns are largely unaltered, following a trend of increasing spread and decreasing uniformity with successive crop cycles.

While a continuous ratooning production system has the advantage of providing continuous harvest after 2 crop cycles, the non-uniform characteristic of the continuous ratooning system makes it very difficult to achieve labour and other input efficiency gains required to improve the industry's overall competitiveness. This is demonstrated by measurement of harvest times by DAFF staff in 1999 that showed harvest labour inputs increase significantly once crop uniformity drops below 5-10% i.e. less than one in 10-20 plants is harvested during each operation.

The original objective of this project was to use an established research trial at DAFF South Johnstone to quantify the impact of key factors such as type of planting material, time of planting, planting arrangement and density and sucker management strategies on banana crop uniformity over successive crop cycles. A crop uniformity management strategy was applied to treatment plots during each crop cycle and the impact of crop development monitored. At the same time assessments were made of improved input efficiency, such as pest and disease control and application of best practice nitrogen and phosphorus nutrient management, in a crop with increased uniformity.

Unfortunately the destruction of the research trial and the NQ industry by TC Yasi significantly diminished the likelihood of success in developing and implementing new production systems based on improved crop uniformity. These key reasons for this were:

- The age of the trial when TC Yasi hit meant only limited data was collected for ratoon crop cycles. While the data for the plant crops in all 6 plantings was effectively completed there is only completed first ratoon crop data for 3 plantings. Since crop uniformity declines with successive crops it means that the best data sets are for the most uniform crop stage. This limits our ability to extrapolate the results to understand economic and productivity impacts for any new production system.
- The damage wrought by TC Yasi on the research trial has made it practically impossible to return to the original staggered planting arrangement within an acceptable time period. The crop synchronization effect of the cyclone damage meant that we had effectively started again with a high uniformity crop and would need a 12 month extension to the project to achieve any meaningful uniformity measurements. This would have extended the project end date to December 2014 with significant increases in the project budget.
- The financial losses incurred by banana producers as a result of the cyclone damage meant it was unlikely a uniform cropping system could be adopted by the majority of producers in NQ. This was based on an economic assessment of the alternative cropping system using data collected from the research trial, and experiences in developing a cropping program on the producer demonstration site. While there are measured improvements in labour efficiency in a highly uniform crop, this came at a cost to implement that most cyclone-affected businesses would not have been able to absorb.

As a consequence of these issues, and discussions with the Project Reference Group, the HAL industry services manager and ABGC, a revised project proposal was developed that focused on identified high priority issues associated with cyclone recovery.

Developing ethephon pseudostem injection of bananas for crop timing management

In consultation with the HAL ISM, the project reference group and the banana IAC, the project leader proposed 3 potential options for the use of the existing trials and residual budget. The issue identified by the Project Reference Group and banana IAC as a high priority for the revised project was the development of an APVMA MUP for ethephon pseudostem injection for management of crop timing. The focus on a MUP was based on the estimates of very low volumes of product use annually (around 30L of active ingredient). The trial work focused on establishing the lowest effective product rate and residue analysis for the subsequent crop to determine the presence of any ethephon residues.

Crop timing in the north Queensland banana industry has been practiced through replanting and the “nurse-sucker” technique. “Nurse-suckering” is a system of sucker management widely used in north Queensland during the 1950’s and 1960’s to delay cropping so that fruit production occurred when prices were highest in the winter/spring months. Use of the technique has continued to varying extents by many growers, particularly for the management of continuous fruit supply and the improvement of uniformity in a treated population. Recently it has come to particular importance in the aftermath of TC Larry and Yasi with banana producers using it to overcome the industry-wide synchronisation of cropping induced by the cyclone damage.

The current methods used for nurse-suckering involve physically damaging or removing the banana plant's apical meristem which is physically demanding, labour intensive and often inconsistent in killing the apical meristem. The potential replacement of this task by ethephon pseudostem injection offers improved success rates and significant labour savings for the industry, potentially making crop scheduling and uniformity management easier to achieve in practice.

After TC Larry in 2006 the ABGC and Queensland DAFF held discussions with APVMA regarding the granting of an emergency use permit for ethephon pseudostem injection for the cyclone recovery period. However, the absence of available efficacy and residue data prevented a permit being granted. With the destruction of the BA09038 research trial by TC Yasi, and the importance of implementing a staggered return to cropping again, the banana industry identified the need for a minor-use permit. The opportunity existed to undertake research experiments to generate the product rate efficacy and residue data required by APVMA on an existing trial.

Methodology

Project structure

The original project structure was a phased approach that used the research trial at DAFF South Johnstone to develop a clear understanding of critical factors affecting crop uniformity, as well as Producer Demonstration Sites to demonstrate the management implications and practicalities associated with a uniform cropping system.

Under the revised project the original field was replaced by research trials investigating the use of ethephon pseudostem injections for management of crop timing.

1. Research trials for investigating factors influencing crop uniformity management

1.1 Crop uniformity research trial objectives

The original objectives of the research trial were:

- To understand and quantify factors affecting crop uniformity, particularly type of planting material, time of planting, plant density and arrangement and different nurse-suckering strategies.
- To understand the influence of crop uniformity on pest and disease incidence and populations, particularly yellow Sigatoka and Banana Scab Moth, and on the application of best management practices for nitrogen and phosphorus.

1.2 Crop uniformity research trial design

The pre-TC Yasi research trial was designed as a randomized complete block with 3 replicates. The treatments were:

- Control plot – 240 plants per replicate in a double row planting at 1810 plants/ha, planted with bit/sucker material. The planting date coincided with fifth planting in scheduled plots (mid-Oct 2009) and it was intended that the crop will be allowed to develop as a continuous ratooning system over successive crop cycles.
- Double row scheduled plot – 240 plants per replicate in a double row planting at 1810 plants/ha, planted with uniform plantlets (graded potted suckers). The cropping was scheduled with 6 staggered plantings over 12 months to ensure continuous fruit supply, and each planting was subject to a crop uniformity management strategy.
- Single row scheduled plot – 132 plants per replicate in a single row planting at 1333 plants/ha, planted with uniform plantlets (graded potted suckers). The cropping was scheduled with 6 staggered plantings over 12 months to ensure continuous fruit supply and each planting subject to a crop uniformity management strategy.

The crop uniformity strategy was based on nurse-suckering the last 10% of plants in a plot to bunch. This strategy targeted the laggard plants in the population and tried to accelerate the growth and development of the next crop cycle to retain an acceptable level of uniformity.

This field trial allowed the comparison of factors affecting crop uniformity such as plant density and arrangement, type of planting material and time of planting with treatment comparisons of single row (1333 plants/ha) and double row (1810 plants/ha) arrangements, uniform plantlets with bit and sucker planting material and comparison of seasonal effects on crop uniformity from the six times of planting. The trial also would allow a comparison of the ability to achieve continuous fruit supply from 6 staggered plantings managed for uniformity number with a conventional continuous ratooning system.

Data was also collected on the effect of seasonal conditions on the incidence and control requirements for Banana scab moth and yellow Sigatoka that may offer possible reductions in control costs for banana crops at certain times of the year.

1.3 Crop uniformity activities on Producer Demonstration Sites (PDS's)

Two PDS's were planned in the project to work with cooperating producers to evaluate and implement findings from the research trial. An activity plan was developed with the cooperating producer for each PDS to define the practice changes to be implemented and the assessment and monitoring requirements. Only one PDS was ultimately established because of the damage caused by TC Yasi and it was incorporated with cyclone recovery activities.

1.4 Economic comparison of crop uniformity management

A gross margin analysis tool was developed to compare the GM's of a modified, uniform cropping system with a conventional ratooning production system. The Microsoft Excel spreadsheet allowed gross margin comparisons based over 4 crop cycles for different crop uniformities. The spreadsheet uses input data on crop uniformity, total yield, price and cost of other production inputs to compare the 2 scenarios.

These comparisons have been undertaken using labour input values and crop uniformities recorded from the research trial or measured on commercial properties. Where the exact data were not available previous measurements of harvest labour inputs at a range of uniformities, as well as in-field monitoring for bell injection completed in late 2010 were used to build the cropping scenarios. Crop uniformities achieved in successive crop cycles in the model have been extrapolated from the limited research trial data.

1.5 Survey of producer record-keeping systems

The survey aimed to identify the types of farm records being kept by producers and how they kept them. Crop uniformity management relied on knowledge of the bunching and harvesting statistics for individual blocks on a farm and the survey results aimed to identify the degree to which the data required for managing crop uniformity was already being collected by producers, and the ease with which the relevant information could be retrieved.

2. Research trials to develop a minor-use permit for ethephon pseudostem injection for crop timing management

2.1 Ethephon pseudostem injection research trial objectives

The objectives of the revised project were to develop and submit a minor-use permit application to the APVMA for ethephon pseudostem injection in bananas by conducting replicated field trials to determine the lowest effective ethephon rate and a suggested use pattern. Analysis of fruit for ethephon residues from a single field trial where the lowest effective rate was identified was also undertaken to provide APVMA with preliminary data about the likelihood of ethephon residues in the crop subsequent to treatment.

2.2 Ethephon pseudostem injection research trial design

The field trials were conducted as split plot factorial experiments and were designed to test the effect of ethephon pseudostem injections at 4 product rates to 3 plant height ranges on the proportion of apical meristem deaths, pseudostem integrity and sucker phytotoxicity at 3 time assessments. Each factorial combination of height and rate was replicated 3 times in a Balance Incomplete Block Design, with the plant height treatment at the main plot level and the 4 product rates applied in the split plots.

Based on initial non-replicated observational trials conducted at South Johnstone in 2000/01, the rates of 0.48%, 0.96%, 1.92% and 3.84% ethephon were selected. These early data indicated a relationship between plant size and product rate in the expression of desirable and undesirable effects. Therefore different plant heights were incorporated as an experimental treatment with 3 plant height ranges tested (1.5-2m, 2-2.5m and 2.5-3m). Each ethephon treatment consisted of a 4ml injected volume and removal of the leaf canopy after injection.

The analysis of the first trial results showed that the four rates selected all successfully killed the apical meristem. Therefore in the second trial a new range of rates (0.43%, 0.32%, 0.22% and 0.15% ethephon) were implemented. This new rate range identified rate failure was used in an additional rate trial to achieve 2 data sets.

2.3 Ethephon pseudostem injection research trial assessments

Each data plant was injected when it reached the allocated height range. Because of the variability in growth between individual plants this resulted in up to 8 consecutive rounds of injection in each subplot. Trial assessments were then conducted 3 times for individual plants at 4, 8 and 12 weeks from the date of injection. Assessments were made for:

- Apical meristem death – the objective of the pseudostem injection is to kill the apical meristem so that the secondary buds (suckers) will begin rapid growth. The 2000/01 observation trials showed that plants treated with sub-lethal rates will reshoot up to 2 months after treatment, hence the 3 assessments up to 12 weeks after injection. The assessment consisted of a 2 point rating (1-dead, 0-reshooting)
- Pseudostem integrity – in a harvested banana plant the remaining pseudostem contributes significantly to the growth and development of its suckers through nutrient recycling. Pseudostems injected with ethephon deteriorated more quickly than harvested pseudostems so treatments that successfully killed the apical meristem and maximised the integrity of the pseudostem for as long as possible maximised the subsequent sucker growth and development. Therefore an assessment was made of pseudostem integrity using a 5 point scale (0-complete shatter, 1-stem fallen over completely from ground level, 2-stem falling over/collapsing, 3-stem intact but soft/withered, 4-stem intact/turgid).
- Sucker phytotoxicity – translocation of ethephon from the injected pseudostem to the suckers can occur if the quantity of active ingredient is excessive for the plant size. Generally symptoms diminished with time so that they rarely persisted past 2

months after treatment. However, the highest rates killed all or some of the suckers. The assessment rating was made using a 5 point scale (0-suckers dead, 1-suckers significantly deformed/stem shattered, 2-suckers showing serious chlorosis/leaf edge curling, 3-suckers showing mild chlorosis/leaf edge curling, 4-suckers unaffected).

All assessment ratings were standardized using a photographic rating card which is presented in Appendix 1.

2.4 Ethephon residue analysis in fruit

The banana pseudostem treated successfully with ethephon injection does not produce fruit and the fruit to be tested for product residues comes from the subsequent suckers, harvesting 9-11 months after the actual treatment.

The APVMA was approached in early 2013 by the previous HAL Chemical Minor-Use Coordinator on behalf of the project leader regarding their residue data requirements for consideration of a minor-use permit. In response the APVMA indicated the need for preliminary residue data and suggested that the efficacy trial be used to generate the preliminary data to assist in determining the residue data requirement for approval.

As a result a sampling strategy was developed for fruit from the 2012/13 efficacy trial, incorporating the APVMA suggestions, which included:

- Sampling at 2 stages in fruit development - at mid-maturity and full commercial maturity. Analysis of the mid-maturity samples to be undertaken first to determine if analysis of the full maturity samples was required.
- Sampling from the lowest effective rate identified and the highest rate for the each of the 3 plant height treatments, and from an untreated control plot.
- Samples taken from the earliest bunching plants in each treatment combination identified to represent the shortest period from original treatment to sampling.

In consultation with the HAL Program Manager a sub-contract was developed and a successful analytical provider identified with the capability to analyse for ethephon residues and produce a report meeting the APVMA requirement.

Outputs

The outputs from the project are again separated to reflect the original project objectives and the revised objectives after TC Yasi.

1. Investigation of factors affecting crop uniformity

TC Yasi seriously damaged the trial in February 2011. While the plants were able to be recovered the trial was abandoned because it required data over successive crop cycles to determine if the concept would work. Recovery from TC Yasi would have effectively re-started the trial with inherently high uniformity and this would have extended the project timeframe excessively.

Banana crops in their first crop cycle generally have a high degree of uniformity which decreases over successive crop cycles, with crop spread throughout the year by the end of the 3rd crop cycle from planting. Only 3 of the 6 staggered plantings in the trial had completed their second crop cycle when the trial was destroyed, meaning that the most valuable data had not yet been collected. The control treatment had not finished the plant crop harvest when the trial was destroyed which significantly limited the statistical comparisons that can be made. This has limited the conclusions that can be drawn from the pre-TC Yasi data.

1.1 Assessments of productivity and uniformity

Plant growth and yield assessments were made for all sample plants, such as:

- Bunch mass (kg)
- Hand and estimated finger number per bunch
- Days to bunch emergence and harvest from planting, or from the previous crop for ratoon cycles
- Plant and sucker height at bunching
- Finger length on the 3rd hand from the top of the bunch (mm)

Assessments of uniformity were made of bunch emergence and bunch harvest for each time of planting. For each of these the measures of uniformity were:

- The proportion of the population falling into 3 different uniformity categories, <5%, 5-10% or >10%, measured weekly
- The total duration in weeks for bunch emergence and harvest and the time period taken to achieve different levels of completion of each stage – 50%, 80%, 90% and 95%
- The proportion of the weeks for each plant development stage falling into the 3 different uniformity categories. This measure is different from the first in that it takes account of the effect of weeks where no bunch emergence or harvest has occurred

1.2 Assessment of key factors influencing crop uniformity

1.2.1 The influence of the time of planting on crop uniformity

The field trial at South Johnstone consisted of 6 staggered plantings, each of single and double row arrangements, replicated 3 times in a randomised complete block design.

Plantlets in the form of potted suckers were used in all plantings, except for the Control treatment where traditional vegetative corm/sucker material was used.

The Control treatment, representing the timing and style of material used by the majority of the north Queensland industry, was planted with the 5th planting in the sequence. The planting dates were:

Treatment designation	Date of Planting
ToP 1 (Time of Planting 1)	17/12/2008
ToP 2	18/3/2009
ToP 3	27/4/2009
ToP 4	27/7/2009
ToP 5	13/10/2009
Control	13/10/2009
ToP 6	18/11/2009

Bunch emergence – plant crop (first crop cycle)

There were very few significant differences in the uniformity measures for the bunch emergence stage of the plant crop. This was anticipated because the plant crop cycle (first crop) is generally very uniform, a function of all the plants starting from an identical stage of development.

Time of planting	Mean period to achieve proportion of population bunched (weeks)			Duration of bunch emergence (weeks)	Period of bunch emergence
	80%	90%	95%		
ToP 1	7.3	11.3	12.7	15.5	May-Sept 09
ToP 2	8.7	10.4	11.5	11.8	Oct 09-Jan 10
ToP 3	7.2	7.9	8.4	9.2	Nov 09-Feb 10
ToP 4	7.4	9.5	11.2	14.0	Feb-May 10
ToP 5	13.9	18.6	22.9	25.0	Mar-Oct 10
ToP 6	11.6	17.6	21.7	27.0	Apr-Nov 10

The main results were that plants in ToP 2 and 3 had significantly shorter bunch emergence periods than all the other times of planting. This can be explained by the timing of their bunch emergence over late spring and summer when climatic conditions are less limiting to plant growth and development. Plants in ToP 5 and 6 took significantly longer to reach 80%, 90% and 95% bunch emergence than all the other times of planting. This also reflects the temperature and rainfall conditions caused by the time of year and the 2010 La Nina weather pattern limiting growth and development during that period.

Bunch harvest – plant crop (first crop cycle)

As for the bunch emergence phase there were few significant differences in the assessments of bunch harvest. This was expected because of the high level of uniformity inherent in the plant crop cycle.

Time of planting	Mean period to achieve proportion of population harvested (weeks)				Duration of bunch harvest (weeks)	Period of bunch harvest
	50%	80%	90%	95%		
ToP 1	6.5	8.9	10.8	11.9	13.3	Sept-Dec 09
ToP 2	5.9	8.9	10.3	11.8	14.0	Jan-May 10
ToP 3	6.4	8.3	9.1	10.7	11.3	Mar-July 10
ToP 4	7.2	10.3	11.8	13.7	17.0	Apr-Oct 10
ToP 5	12.9	19.9	23.2	25.6	-*	Jul 10-Feb 11*
ToP 6	8.4	11.7	15.3	19.8	-*	Aug 10-Feb 11*

** harvest not completed because of TC Yasi*

The main results were that ToP 1, 2 & 3 had significantly shorter bunch harvest periods than ToP 4, 5 & 6, reflecting the climatic conditions from September 2009 – March 2010 when ToP 1, 2 & 3 were harvesting. ToP 5 & 6 took significantly longer to achieve 80%, 90% and 95% harvest than ToP 1, 2 & 3, with ToP 5 the slowest to achieve all the harvest categories. ToP 3 which had its fruit development period during the November-March period had a significantly higher proportion of bunches harvested in weeks with >10% uniformity than ToP 2, 4, 5 & 6.

Bunch emergence – first ratoon (second crop cycle)

Only ToP 1, 2, 3 and the single rows of ToP 4 had completed bunch emergence in the first ratoon when TC Yasi destroyed the trial. There were very few differences in the bunch emergence uniformity in the first ratoon crop, with no significant differences between these 4 times of planting for the proportion of plants in the 3 different uniformity categories. The only differences identified were for ToP 2 & 3 where the bunch emergence period occurred over the colder months in the middle of the year. The seasonal effect on the crop cycle is evident in ToP 2 and 3 when comparing the duration of bunch emergence periods for their plant and first ratoon crop cycles.

Time of planting	Mean period to achieve proportion of population bunched (weeks)				Duration of bunch emergence (weeks)	Period of bunch emergence
	50%	80%	90%	95%		
ToP 1	9.2	11.9	13.9	17.0	27.0	Dec 09-June 10
ToP 2	10.3	14.3	17.5	18.8	33.0	Apr-Nov 10
ToP 3	14.6	17.5	19.2	21.2	29.0	Apr-Oct 10
ToP 4*	8.6*	12.2*	13.4*	14.7*	19.0*	Sept 10-Jan 11*

**single rows only*

Bunch harvest – first ratoon (second crop cycle)
Only ToP 1, 2 & 3 were completed before the date of TC Yasi. There was no significant effect of these times of planting on the measured uniformity characteristics.

Time of planting	Mean period to achieve proportion of population harvested (weeks)				Duration of bunch harvest (weeks)	Period of bunch harvest
	50%	80%	90%	95%		
ToP 1	11.6	16.1	18.0	19.2	33.0	Mar-Aug 10
ToP 2	11.7	14.1	16.1	18.1	26.0	Jul 10-Jan 11
ToP 3	13.9	16.4	17.7	19.1	26.0	Aug 10-Jan 11

1.2.2 The influence of plant density and arrangement on crop uniformity

For each of the 6 times of planting there were 2 plots planted at different plant density and arrangement – single row at 1333 plants per hectare, and double row at 1810 plants per hectare. These plots were designed to determine the influence of plant density and arrangement on the plant growth, yield and crop uniformity characteristics.

Bunch emergence – plant crop
There was no significant difference for most of the crop uniformity attributes between the single and double rows in the bunch emergence in the plant crop. Only in ToP 3 & 5 were there differences in the percentage of weekly bunch emergence falling in the >10% uniformity category.

Time of planting	Percentage of weekly bunch emergence in different uniformity categories					
	<5%		5-10%		>10%	
	SR	DR	SR	DR	SR	DR
ToP 1	-	9.3	23.2	17.9	77.3	73.2
ToP 2	-	9.2	27.8	19.3	60.6	71.8
ToP 3	-	7.3	9.5	11.0	90.8	82.2
ToP 4	-	7.2	28.7	21.9	71.4	71.2
ToP 5	-	29.3	38.7	54.9	61.4	15.3
ToP 6	-	12.6	34.0	41.7	66.0	45.5

Bunch harvest – plant crop
There was more difference between the planting arrangements in the harvest phase with single rows showing improved uniformity.

Time of planting		Mean period to achieve proportion of population harvested (weeks)				Duration of bunch harvest (weeks)
		50%	80%	90%	95%	
ToP 1	SR	5.8	8.3	11.4	12.3	14.0
	DR	6.5	8.9	10.8	11.9	15.0
ToP 2	SR	5.2	7.6	8.5	9.4	12.0
	DR	5.9	8.9	10.3	11.8	19.0
ToP 3	SR	5.3	6.7	7.3	7.7	9.0
	DR	6.4	8.3	9.1	10.7	19.0

ToP 4	SR	7.3	11.7	15.3	17.6	26.0
	DR	7.2	10.3	11.8	13.7	20.0
ToP 5	SR	8.8	11.8	14.8	18.7	25.0
	DR	12.9	19.9	23.3	25.6	30.0
ToP 6	SR	7.2	11.5	16.4	17.7	25.0
	DR	8.4	11.7	15.3	19.8	24.0

The single rows had a significantly higher proportion of bunches harvested in weeks with >10% uniformity, and significantly shorter bunch harvest periods than double rows. The double rows took significantly longer to achieve all stages for ToP 5 & 6 compared to all other times of planting. This seems to indicate that when the climatic conditions were limiting fruit growth and development the reduction of inter-plant competition significantly improved the plants performance.

Bunch emergence – first ratoon (second crop cycle)

Only ToP 1, 2 & 3 had completed bunch emergence for both single and double rows before the arrival of TC Yasi. As the plants in the plots became physically bigger in the second crop cycle there was the expectation that more significant differences would become apparent between the single and double rows.

There was no significant difference between single and double rows in the proportion of weekly bunch emergence falling in the different uniformity categories. The main difference measured was that the double rows in ToP 1, 2 & 3 took significantly longer to achieve 50%, 80%, 90% and 95% bunch emergence compared to the single rows.

Time of planting		Mean period to achieve proportion of population bunched (weeks)				Duration of bunch emergence (weeks)
		50%	80%	90%	95%	
ToP 1	SR	8.4	10.9	12.2	15.8	25.0
	DR	10.0	12.9	15.6	18.2	24.0
ToP 2	SR	7.4	11.5	13.9	14.7	21.0
	DR	13.3	17.2	21.0	22.9	30.0
ToP 3	SR	13.4	15.9	17.4	18.9	27.0
	DR	15.8	19.1	20.9	23.6	26.0

Bunch harvest – first ratoon

Only ToP 1, 2 & 3 had completed bunch harvest for both single and double rows before TC Yasi. Reflecting the results from the assessment of first ratoon bunch emergence, there was no difference between single and double rows in the proportion of weekly bunch harvest falling in the different uniformity categories. Again the main difference was in the time taken for single and double rows to achieve 50%, 80%, 90% and 95% bunch harvest, with double rows taking significantly longer to achieve each of these compared to the single rows.

Time of planting		Mean period to achieve proportion of population harvested (weeks)				Duration of bunch harvest (weeks)
		50%	80%	90%	95%	
ToP 1	SR	9.5	13.6	15.5	16.1	23.0
	DR	13.6	18.6	20.5	22.3	29.0
ToP 2	SR	9.3	12.1	13.6	15.0	19.0
	DR	14.2	16.2	18.7	21.2	19.0
ToP 3	SR	12.6	14.8	16.1	17.9	23.0
	DR	15.2	18.1	19.3	20.3	21.0

1.2.3 The influence of planting material type on crop uniformity

Bananas are planted using vegetative planting material. The main types used in north Queensland are corm and sucker material where plants in a field situation are dug out, washed and the parent corms are sectioned to provide pieces containing a secondary bud or "eye". The whole corms of smaller suckers are also used as planting material. Plantings made with corm and sucker material can produce populations that have low uniformity in the first crop cycle. Currently the use of this type of planting material represents about 80% of annual planting in north Queensland

An alternative is the use of plantlets which are mainly produced via tissue culture. Using corm pieces and suckers to produce potted suckers is another method of producing plantlets. Tissue-cultured plantlets, and potted suckers selected for uniform size, are known to produce very uniform populations in their first crop cycle.

To quantify the influence of planting material on crop uniformity, a comparison of potted suckers and directly sown corm and sucker material was made using ToP 5 in the sequence. The corm and sucker planting material plots, identified as the Control treatment, were planted as a double row at the same density and arrangement as the double row arrangement designated ToP 5.

Data is only available for the plant crop as the first ratoon crop was destroyed by TC Yasi.

Bunch emergence – plant crop

The use of corm and sucker planting material resulted in a significantly longer bunch emergence period of 41.3 weeks compared to 27.3 weeks for the plantlets. The control treatment also had a significantly higher proportion of weeks (84.9%) with bunch emergence at <5% uniformity compared to the plantlets (65.6%). There was no significant difference for any of the other measures of uniformity.

Treatment	Percentage of weekly bunch emergence in different uniformity categories			Duration of bunch emergence (weeks)
	>10%	5-10%	<5%	
Plantlets	4.9	29.5	65.6	27.3
Control	6.5	8.8	84.9	41.3

Bunch harvest – plant crop
The greater spread of bunch emergence in the control treatment continued to be obvious in the harvest uniformity measures. The harvest period for the control treatment (28.7 weeks) is significantly greater than the plantlets (25.0 weeks), and would have been greater because 4% of the control treatment plants were still to be harvested at the time of TC Yasi. The control treatment also had a significantly lower proportion of weeks of harvest with uniformity >10% (8.1% compared to 12.1%).

Treatment	Percentage of weekly bunch harvest in different uniformity categories			Duration of bunch harvest (weeks)
	>10%	5-10%	<5%	
Plantlets	12.1	20.0	55.4	25.0
Control	8.1*	23.3*	68.6*	28.7*

** harvest not completed because of TC Yasi*

1.3 Assessment of plant growth and productivity

1.3.1 Influence of time of planting on plant growth and productivity

Plant crop cycle
The time of planting had a significant effect on some of the plant growth and yield characteristics, especially in the plant crop. The key findings for the plant crop were that ToP 1, 6 and Control treatments produced significantly shorter plants at bunching and significantly lighter bunches than the other times of planting. ToP 2 produced the tallest trees at bunching compared to all other times of planting and ToP 2 & 3 produced the heaviest bunches compared to all other times of planting.

Time of planting		Bunch wt (kg)	Hand 3 finger length (mm)*	Plant height (cm)	Days to bunch emergence	Days to bunch harvest
ToP 1	SR	24.3	245.0	209.5	176	302
	DR	24.6	248.4	212.0	180	306
ToP 2	SR	33.3	262.8	238.7	245	334
	DR	35.1	262.9	249.0	249	342
ToP 3	SR	33.6	267.9	253.8	242	329
	DR	34.0	268.8	253.6	245	339
ToP 4	SR	31.4	275.8	261.0	215	322
	DR	30.4	273.8	258.0	211	320
ToP 5	SR	28.0	274.6	247.9	193	313
	DR	28.7	277.4	251.1	224	341
Control	SR	-	-	-	-	-
	DR	23.3	259.5	218.8	215	329
ToP 6	SR	24.5	266.1	227.7	197	315
	DR	22.2	265.8	213.9	195	317

**measured from flower scar to end of pedicle*

First ratoon crop cycle
There were fewer differences in the ratoon crop cycle than the plant crop, mainly due to the limited data set. The main differences in the first ratoon crop were that ToP 1 had taller plants and suckers at bunching, produced bunches with more hands, and had shorter fruit length on Hand 3 than ToP 2 & 3.

Time of planting		Bunch wt (kg)	Hand 3 finger length (mm)*	Plant height (cm)	Days to bunch emergence	Days to bunch harvest
ToP 1	SR	47.1	276.8	347.0	114	212
	DR	44.3	274.8	338.1	110	224
ToP 2	SR	42.3	279.9	322.3	111	229
	DR	42.3	286.5	330.4	141	248
ToP 3	SR	42.5	288.1	311.4	99	209
	DR	45.0	289.2	321.8	100	210

**measured from flower scar to end of pedicle*

1.3.2 Influence of plant density and arrangement on plant growth and productivity

The type of planting material had a significant effect on some aspects of plant growth and productivity in the first crop cycle. The main effects were that the Control treatment produced significantly lighter bunches with shorter fruit on Hand 3 compared to the plantlets. The Control treatment also produced shorter plants at bunching, with a lower total leaf count compared to plantlets.

Treatment	Bunch wt (kg)	Hand 3 finger length (mm)*	Plant height (cm)	Days to bunch emergence	Days to bunch harvest
Plantlets	28.7	277.4	251.1	224	341
Control	23.3**	259.5**	218.8	215	329**

**measured from flower scar to end of pedicle*
*** harvest not completed because of TC Yasi*

1.4. Assessment of pest and disease incidence

1.4.1 Influence of time of planting and plant arrangement and density on Yellow Sigatoka infection

The key principle behind the project design was that of crop uniformity management over successive crop cycles with a view to achieving maximum efficiency of key production inputs. To ensure a consistent fruit supply, a series of relatively uniform production units with overlapping harvest periods was implemented. Since the various plantings have been initiated at different times through the year, the climate has had different effects on growth and disease.

Yellow Sigatoka is the most important fungal leaf disease affecting banana production in north Queensland. A regular deleafing program when combined with chemical controls is generally very effective at controlling yellow Sigatoka. Due to the nature of banana biology and the need to balance disease control with effective plant function, deleafing once the bunch emerges is usually stopped as reduction in leaf surface area affects bunch quality.

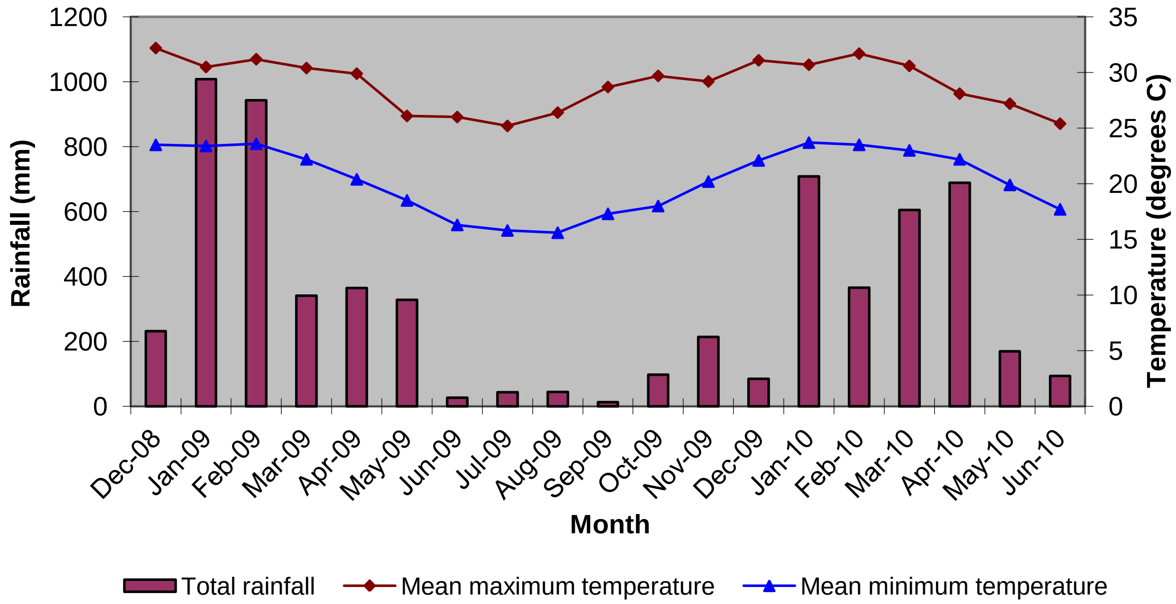
Climatic conditions in the period leading up to bunch emergence and immediately after can have a serious impact on disease levels on individual plants and in the field in general. Similarly, microclimates created by planting density and arrangement in combination with the time of year can also impact disease incidence and development. This study aimed to assess the influence of time of planting and plant arrangement on yellow Sigatoka disease levels.

Assessments of the plant crop for total leaves (TL), youngest leaf spotted (YLS), disease index (DI) were conducted at the 18 leaf stage and at 50% bell emergence, and TL, YLS the average leaf rating (ALR) and the disease severity index (DSI) were made 8 weeks after the 2nd disease assessment.

	1st Assessment	2nd Assessment	3rd Assessment
ToP 1	25th March 2009	10th Jun 2009	5th Aug 2009
ToP 2	1st July 2009	16th Nov 2009	12th January 2010
ToP 3	12th August 2009	4th January 2010	1st March 2010
ToP 4	28th October 2009	24th February 2010	21st April 2010
ToP 5	6th January 2010	21st April 2010	16th June 2010
ToP 6	5th February 2010	19th May 2010	13th July 2010
Control	5th February 2010	21st April 2010	16th June 2010

Total monthly rainfall and the mean maximum and minimum temperatures for South Johnstone Research Station for the plant crop at each of the planting times are shown below. In the first disease assessment plants in the July 2009 planting had significantly fewer leaves (P<0.05) than those at other planting times. The YLS and DI showed a higher incidence of disease (P<0.05) in the December 2008 planting compared to all other planting times and a higher incidence of disease in the December 2008 and March 2009 plantings compared to all other planting times except July 2009. There was no significant difference (P>0.05) between single and double rows for TL, the DI and the YLS.

Total monthly rainfall and mean monthly maximum and minimum temperatures for South Johnstone Research Station for the period December 2008-June 2010.



Assessment 1 – Effect of planting time on yellow Sigatoka disease levels in a banana plant crop at the 18 leaf stage

Time of Planting	Total Leaves[A]	Youngest Leaf Spotted[A]	Disease Index[AB]
Control (13th Oct 2009)	11.31 a	12.16 a	1.076 a
1 (17th Dec 2008)	11.25 a	9.68 c	0.864 c
2 (18th Mar 2009)	11.29 a	11.02 b	0.976 b
3 (27th Apr 2009)	11.09 a	12.08 a	1.090 a
4 (27th Jul 2009)	10.47 b	11.45 ab	1.094 a
5 (13th Oct 2009)	11.23 a	12.19 a	1.087 a
6 (18th Nov 2009)	11.21 a	12.10 a	1.080 a

[A]Means in the same column followed by the same letter are not significantly different (P>0.05).

[A]Where individual plants had no disease symptoms the youngest leaf spotted was calculated as one more leaf than the total leaves on the plant.

[B] Disease index was calculated as Total Leaves/Youngest Leaf Spotted. Values greater than 1 indicate little or no disease.

In the second disease assessment plants in the March 2009 planting had significantly more leaves (*P*<0.05) than all other planting times and there were fewer leaves (*P*<0.05) in the December 2008, October and November 2009 plantings than all other planting times except the control (October 2009) and the April 2009 planting time. In the assessment for the YLS, the lowest incidence of disease (*P*<0.05) occurred in the March 2009 planting and the highest incidence of disease (*P*<0.05) occurred in the December 2008 planting when compared to all other planting times. The assessment for the DI showed a very low disease incidence in the March, April, July and October 2009 plantings and the control (October 2009) planting. There was also a significant difference (*P*<0.05) between single and double rows for TL with single rows having more leaves than double rows (14.78, 14.30). The assessment for YLS and the DI showed a higher incidence of disease in double rows compared to single rows (13.70, 14.81) and (1.00, 0.96).

Assessment 2 – Effect of planting time on yellow sigatoka disease levels in a banana plant crop at 50% bell emergence

Time of Planting	Total Leaves[A]	Youngest Leaf Spotted[AB]	Disease Index[AC]
Control (13th Oct 2009)	14.03 bc	14.34 bc	1.024 a
1 (17th Dec 2008)	13.83 c	11.23 d	0.813 c
2 (18th Mar 2009)	16.74 a	17.41 a	1.039 a
3 (27th Apr 2009)	14.19 bc	14.84 b	1.047 a
4 (27th Jul 2009)	14.77 b	14.78 b	1.004 a
5 (13th Oct 2009)	13.76 c	14.52 b	1.057 a
6 (18th Nov 2009)	13.96 c	12.75 c	0.915 b

[A]Means in the same column followed by the same letter are not significantly different (P>0.05)

[B]Where individual trees had no disease symptoms the youngest leaf spotted was calculated as one more leaf than the total leaves on the plant.

[C]Disease index was calculated as total leaves/youngest leaf spotted. Values greater than 1 indicate little or no disease.

In the final disease assessment conducted on bunched plants, there were significantly fewer leaves ($P<0.05$) in the December 2008 planting compared to all other planting times. April 2009 and November 2009 planting times had more leaves ($P<0.05$) than December 2008 and March 2009 plantings. The assessment of the YLS showed a lower incidence of disease ($P<0.05$), in the March, April and July 2009 plantings than at all other planting times. The assessments for the ALR and DSI showed a lower disease severity ($P<0.05$) in the April and July plantings compared to plantings in October and November 2009, and the December 2008 planting. There was also a significant difference ($P<0.05$) between single and double rows with the YLS, ALR and DSI assessments showing that yellow Sigatoka was less severe in plants growing in single rows compared to those growing in double rows (YLS, 7.68, 6.45), (ALR, 0.26, 0.40) and (DSI, 4.35, 6.72). There was no interaction between time of planting and row spacing.

Assessment – Effect of planting time on yellow sigatoka disease levels in a bunched banana plant crop

Time of Planting	Total leaves[A]	Youngest Leaf Spotted[A]	Average Leaf rating[AB]	Disease Severity Index[AC]
Control (13th Oct 2009)	10.36 abc	5.71 b	0.44 bc	7.33 bc
1 (17th Dec 2008)	8.71 d	5.33 b	0.44 c	7.31 c
2 (18th Mar 2009)	9.89 bc	8.19 a	0.22 ab	3.64 ab
3 (27th Apr 2009)	10.66 a	8.19 a	0.19 a	3.12 a
4 (27th Jul 2009)	9.73 c	8.46 a	0.17 a	2.88 a
5 (13th Oct 2009)	10.51 ab	6.07 b	0.43 c	7.18 c
6 (18th Nov 2009)	11.22 a	6.15 b	0.55 c	9.08 c

[A]*Means in the same column followed by the same letter are not significantly different (P>0.05).*

[B]*Average leaf rating is calculated as the sum of individual leaf disease ratings per plant (0-6 score of increasing disease severity)/total leaves. Two l.s.d. values created due to the unequal replication of the split block design.*

[C]*Disease severity index= [(Sum nb)(N-1) x T] x100 where n = number of leaves in each grade used (7), and T=total of leaves graded on each plant.*

1.4.2 Influence of time of planting on Banana Scab Moth incidence

Banana Scab Moth (BSM) is a major bunch pest in north Queensland and the current bell injection method of control has a high labour cost component. Because bell injection must be applied at a specific stage of plant development, lack of uniformity significantly affects the efficiency of the labour component, so seasonal reductions in BSM populations offer the possibility of safely reducing control inputs. Assessments were made of the presence of BSM larvae in datum plant bunches at bract fall. The presence of BSM damage, the number of hands damaged and the number of larvae present were recorded for each bunch.

Banana Scab Moth activity in the first crop cycle was generally low in all the times of planting, with the greatest incidence of bunch infestation in ToP 3 with 6.4%. The lowest incidence of bunch damage generally correlated well with bunch emergence periods between May 2009 and January 2010 when rainfall, humidity and temperatures are lower.

Banana Scab Moth incidence, plant crop cycle

Planting	Row	Incidence of BSM (% bunches)	Period of bunch emergence
ToP 1	Single	0	May-Sept 09
	Double	0	May-Sept 09
ToP 2	Single	0	Oct 09-Jan 10
	Double	0.9	Oct 09-Jan 10
ToP 3	Single	1.6	Nov 09-Feb 10
	Double	6.4	Nov 09-Feb 10
ToP 4	Single	3.3	Feb-May 10
	Double	1.9	Feb-May 10
ToP 5	Single	5.0	Mar-Oct 10
	Double	3.0	Mar-Oct 10
Control	Double	3.4	Mar-Dec 10
ToP 6	Single	5.5	Apr-Nov 10
	Double	0.9	Apr-Nov 10

In the first ratoon crop cycle the highest incidence of BSM was in ToP 3 single row with 8.5%, and all but 1 of the plots recorded 3% or more bunch incidence. The incidence of BSM in ToP 2 & 3 during the months when activity is expected to reduce is probably a function of the unseasonal rainfall in 2010 caused by the La Nina climate pattern.

Banana Scab Moth incidence, first ratoon crop cycle

Planting	Row	Incidence of BSM (% bunches)	Period of bunch emergence
ToP 1	Single	5.4%	Dec 09-June 10
	Double	3.0%	Dec 09-June 10
ToP 2	Single	0%	Apr-Nov 10
	Double	3.3%	Apr-Nov 10
ToP 3	Single	8.5%	Apr-Oct 10
	Double	5.6%	Apr-Oct 10

1.5 Economic comparison of continuous ratooning and managed uniformity banana production systems

A comparison of modelled gross margins for conventional and uniform cropping system scenarios was undertaken us a Microsoft Excel spreadsheet developed to allows gross margin comparisons based over 4 crop cycles for different crop uniformities. The spreadsheet used input data on crop uniformity, total yield, price and cost of other production inputs to compare the 2 scenarios.

The comparisons were undertaken using labour input values and crop uniformities recorded from the research trial or measured on commercial properties. Where the exact data was not available previous measurements of harvest labour inputs at a range of uniformities, as well as in-field monitoring for bell injection completed in late 2010 were used to build the cropping scenarios. Crop uniformities achieved in successive crop cycles in the model have been extrapolated from the limited research trial data.

The spreadsheet model used the following underlying assumptions:

- Planting density of 1800 plants per hectare.
- The conventional system is planted using corm and sucker material and the uniform cropping system is planted with tissue-cultured plantlets
- There are different pack-out ratios for the plant crop cycle – 1.2 cartons per bunch in the conventional and 1.5 cartons per bunch in the uniform cropping system to reflect the greater productivity of tissue-cultured plantlets.
- The price received is weighted in each crop cycle to reflect different proportions of fruit >220 mm and <220 mm in length. The proportions in each crop cycle and price are applied equally to the 2 systems
- Labour costs for key tasks – bell injection, bunch covering and harvesting – are based on field assessments of labour efficiency at differing levels of crop uniformity
- All other input costs are applied consistently to both systems

The key inputs in the model that influence the gross margin comparison are the cost of maintaining the crop uniformity, expressed as a percentage of the plant population that is sacrificed due to nurse-suckering, and the price received.

A sensitivity table is presented below to demonstrate the relative influence of price received and percentage of population nurse-suckered. The dollar value represents the difference in gross margin value per hectare of the uniform cropping system from the conventional cropping system.

% nurse sucker	Price per carton								
	$14	**$16**	**$18**	**$20**	**$22**	**$24**	**$26**	**$28**	**$30**
2%	2,650	1,860	1,070	280	-520	-1,310	-2,100	-2,890	-3,680
5%	3,020	2,230	1,430	640	-150	-940	-1,730	-2,530	-3,320
8%	3,380	2,590	1,800	1,010	220	-580	-1,370	-2,160	-2,950
10%	3,630	2,830	2,040	1,250	460	-330	-1,120	-1,920	-2,710
15%	4,160	3,370	2,570	1,780	990	200	-600	-1,390	-2,180

The model indicates that a uniform cropping system, based on the assumptions used in the spreadsheet, can reduce costs per hectare in the third crop cycle onwards but the gross margins are heavily influenced by the price received and the proportion of the population subject to intervention. As the price received falls the uniform cropping systems offers better returns than the continuous ratooning system.

1.6 Establishment and monitoring of Producer Demonstration Sites (PDS)

Only a single PDS was established due to the impact on production by TC Yasi, and this PDS finished in 2011 when the project objectives were altered. A cooperating producer in the Innisfail district proposed implementing the uniformity management system of staggered crops and then managing the laggard plants in each crop as a part of his cyclone recovery program. As a result the proposition from the cooperating producer was to develop a scheduled cropping strategy for the whole farm of 28 ha, with subsequent interventions to maintain the relative uniformity in each scheduled production block. However, after planning and implementing the staggered cropping program the financial impact of TC Yasi and change in project objectives resulted in the abandonment of the uniformity management program.

1.7 Survey of producer record-keeping systems

A single page checklist was developed and provided to a stratified sample of producers in hard copy and via email. Unfortunately only 14 businesses out of 50 responded to the survey and follow up visits and phone call reminders did not increase the response rate. Based on the limited sample responses the key points from the survey data were:

- Records of bunch emergence – 93% keep a record of bunch emergence, all on a weekly time scale with most (92%) kept for individual blocks; 62% of respondents keep these records as paper copy only (diary/record sheets), 38% as computer records
- Records of bagging – only 46% of respondents keep records of bagging with all kept weekly by individual block; 80% of respondents keep these records as paper copy only
- Number of bunches harvested – 54% of respondents keep records, all on a weekly time scale; 63% keep them for individual blocks, 37% for the farm as a whole; 86% keep these records as paper copy only
- Fertilisers/chemical applications – 100% keep records of fertiliser and chemical applications, with 60/40 split for weekly and monthly timescales and an 80/20 split for paper copy and computer records
- Farm size – 86% of respondents indicated their farm size as either 50-100 or 100-200 acres

An important consideration from the response data is the high level of record-keeping for bunch emergence which would be important in identifying key interventions for managing crop uniformity. However, most of the key records were recorded as paper copies which would make retrieval of the information for effective management decisions tedious and difficult.

2. Developing a minor-use permit for ethephon pseudostem injection for crop timing management

The revised project objectives aimed to develop and submit a minor-use permit for ethephon pseudostem injection by establishing the lowest effective rate with regard to death of the apical meristem, maintenance of pseudostem integrity and sucker phytotoxicity. It also investigated the likelihood of ethephon residues being present in the subsequent crop.

2.1 Apical Meristem Death

Experiment 1 (2011/12)
The ethephon injection treatments were applied on 4 different occasions from mid-January to mid-February 2012. Assessments began in mid-February 2012 and were completed by early May 2012. There was no significant effect of rate or height on the percentage of plants recorded with apical meristem death at each of the 3 assessment times. This result meant the lowest effective rate had not been defined by this rate range and that a new rate range was needed in the subsequent experiments.

Ethephon rate	Percentage of plants recorded with meristem death	
	4 weeks after treatment	12 weeks after treatment
3.8%	100	100
1.9%	100	100
0.96%	98.41	95.44
0.48%	96.83	96.83
	n.s.	**n.s.**

Experiment 2 (2012/13)

The ethephon injection treatments were applied on 10 different occasions from late December 2012 to late February 2013. The much bigger time period compared to experiment 1 reflected a greater variability in the plant size and growth rates in the plots over this period. Assessments began in mid-January 2013 and were completed by late May 2013. The rate range applied was altered in response to the lack of a rate failure in experiment 1. The rates applied were reduced and a there was a significant effect of rate on the percentage of plants recorded with apical meristem death at all 3 assessment times. There was however no significant effect of height at any assessment time.

Rate	Percentage of plants recorded with meristem death	
	4 weeks after treatment	12 weeks after treatment
0.43%	97.31 a	99.98 *
0.32%	95.20 a	94.74 a
0.22%	93.98 a	99.93 *
0.11%	68.15 b	70.19 b
	P<0.001	**P<0.001**

** over-inflated standard error*

Because 100% of plants in Height 1 recorded meristem death the statistical model calculates an over-inflated standard error at assessment time 3 for Rates 1 & 3. Therefore these proportions are excluded from the pairwise comparison. Given that the proportions for Rates 1 & 3 are higher than Rate 2, we can intuitively conclude they had a significantly higher proportion of meristem death compared to Rate 4.

Experiment 3 (2013/14)

The ethephon injection treatments were applied on 7 different occasions from late November 2013 to early February 2014. Assessments began in late December 2013 and were completed by early May 2013. The same rate range was applied as experiment 2. There was a significant effect of rate on the percentage of plants recorded with apical meristem death at all 3 assessment times and there was a significant effect of height at the 3rd assessment time.

Rate	Percentage of plants recorded with meristem death	
	4 weeks after treatment	12 weeks after treatment
0.43%	87.36 a	86.10 a
0.32%	80.93 a	78.10 a
0.22%	65.27 b	64.27 b
0.11%	43.90 c	45.61 c
	P<0.001	**P<0.001**

Height	Percentage of plants recorded with meristem death	
	4 weeks after treatment	12 weeks after treatment
2.5-3 m	78.04	77.26 a
2-2.5 m	55.36	55.89 b
1.5-2 m	79.24	76.30 a
	n.s.	**P=0.005**

Additional field experiment – Influence of canopy removal on primary meristem death

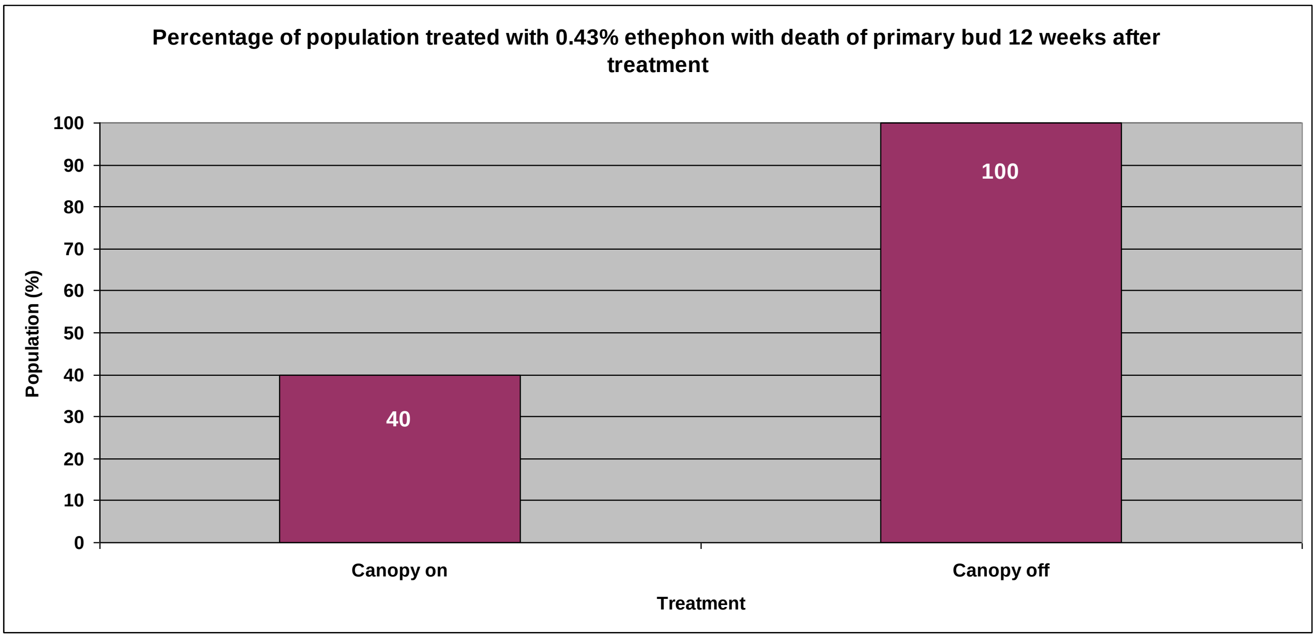
The success of the lowest rate in experiment 1 (0.48% ai) confounded that trial. Previously this rate had shown significant regrowth in observation trials conducted at SJRS in 2000/01 and its success in killing the apical meristem was completely unexpected.

Reflections on the earlier trials and experiment 1 identified the main difference as the management of the foliage/canopy on treated trees. In 2000/01 the canopy was retained as it was thought to improve subsequent sucker growth rates. In experiment 1 the canopy was removed at the time of injection to reduce the leaf disease inoculum and to facilitate easier assessment of the success in killing the primary bud.

A small replicated trial was therefore undertaken at SJRS to determine if the removal of the canopy at the time of injection improved the efficacy of the 0.43% rate treatment. The trial was designed as a randomised complete block design with ten plant plots replicate 3 times. Plants were injected with the 0.43% rate treatment and their canopies either retained or removed as the treatment variation. Plants were then assessed for death of the primary bud at 4, 8 and 12 weeks after injection.

The results shown below demonstrate that retaining the canopy after injecting with 0.43% ethephon resulted in the primary meristem dying in only 40% of the population compared to 100% where the canopy had been removed. Therefore the unexpected success of the lowest rate (0.43%) in experiment 1 can be explained by the changed canopy management implemented in this trial.

Influence of canopy removal on primary bud death (99.8% LSD = 7.05)



2.2 Maintenance of pseudostem integrity

Experiment 1 (2011/12)

Data for pseudostem integrity at 12 weeks after treatment application is presented with data presented as percentage of plants in each rating category (Rating 0-4; 0-complete shatter, 1-stem fallen over completely from ground level, 2-stem falling over/collapsing, 3-stem intact but soft/withered, 4-stem intact/turgid)

Rate	Plant height range		
	2.5-3m	2-2.5m	1.5-2m
3.8%	0 - 4.8% ab 1 - 38.1% cd 2 - 28.6% 3 - 28.6% 4 - 0%	0 - 78.0% e 1 - 17.9% abc 2 - 4.2% 3 - 0% 4 - 0%	0 - 100% g 1 - 0% a 2 - 0% 3 - 0% 4 - 0%
1.9%	0 - 0% a 1 - 22.2% abc 2 - 22.8% 3 - 55.0% 4 - 0%	0 - 50.0% d 1 - 34.9% bcd 2 - 9.5% 3 - 5.6% 4 - 0%	0 - 90.5% fg 1 - 9.5% ab 2 - 0% 3 - 0% 4 - 0%
0.96%	0 - 0% a 1 - 4.8% a 2 - 30.4% 3 - 64.9% 4 - 0%	0 - 17.9% c 1 - 51.8% d 2 - 21.4% 3 - 4.8% 4 - 4.2%	0 - 90.5% fg 1 - 4.8% a 2 - 0% 3 - 0% 4 - 4.8%
0.48%	0 - 0% a 1 - 4.8% a 2 - 34.1% 3 - 61.1% 4 - 0%	0 - 13.1% bc 1 - 48.8% d 2 - 33.9% 3 - 4.2% 4 - 0%	0 – 81.0% ef 1 - 9.5% a 2 - 0% 3 - 0% 4 - 9.5%

There was a significant rate by height treatment interaction at 12 weeks after treatment (P=<0.001) for plants scoring 0 and 1. For plants scoring 2 and 3 there was a significant effect of height (P=<0.001) but no significant effect of rate or interaction between height and rate. There was no significant effect of height or rate on plants scoring 4.

The smallest plant height range (1.5-2 m) had a significantly higher percentage of plants scoring 0 at all ethephon rates than 2-2.5 m range, which was significantly more than the 2.5-3 m height range. At all rates the smallest plants had a greater than 80% of plants with a 0 rating (complete shatter) which has significant implications on growth and development of the subsequent crop cycle.

A simplified analysis was also conducted looking only at the proportion of plants with a rating score of 3 or higher, indicating the most desirable outcome in terms of maintaining pseudostem integrity for as long as possible. This pseudostem integrity data for 12 weeks after treatment application is presented as percentage of plants with a rating score of 3 or greater

Rate	Plant height range		
	2.5-3m	**2-2.5m**	**1.5-2m**
3.8%	28.5	0.0	0.0
1.9%	55.0	5.6	0.0
0.96%	64.9	8.9	4.8
0.48%	61.1	4.2	9.5
P=(<0.001)	**b**	**a**	**a**

This data clearly shows the significant effect of height range on the percentage of plants with a rating of 3 or greater.

Experiment 2 (2012/13)

Data for pseudostem integrity at 12 weeks after treatment application is presented with data presented as percentage of plants in each rating category (Rating 0-4; 0-complete shatter, 1-stem fallen over completely from ground level, 2-stem falling over/collapsing, 3-stem intact but soft/withered, 4-stem intact/turgid). Plants where the meristem was not killed were excluded from this analysis to avoid skewing the percentage of plants with a rating of 4.

Rate	Plant height range		
	2.5-3m	**2-2.5m**	**1.5-2m**
0.43%	0 - 0% 1 - 52.3% 2 - 33.4% 3 - 14.1% 4 - 0%	0 - 7.7% 1 - 76.6% 2 - 5.3% 3 - 5.6% 4 - 0%	0 - 91.8% 1 - 9.0% 2 - 0% 3 - 0% 4 - 0%
0.32%	0 - 0% 1 - 34.4% 2 - 31.6% 3 - 34.1% 4 - 0%	0 - 11.8% 1 - 73.2% 2 - 9.7% 3 - 2.0% 4 - 0%	0 - 89.6% 1 -10.5% 2 - 0% 3 - 0% 4 - 0%
0.22%	0 - 0% 1 - 27.6% 2 - 45.0% 3 - 27.2% 4 - 0%	0 - 14.7% 1 - 68.6% 2 - 6.2% 3 - 6.1% 4 - 0%	0 - 90.7% 1 - 7.4% 2 - 2.5% 3 - 0% 4 - 0%
0.11%	0 - 0% 1 - 8.4% 2 - 37.2% 3 - 42.9% 4 - 0%	0 - 5.3% 1 - 74.6% 2 - 10.5% 3 - 3.9% 4 - 0%	0 - 86.8% 1 - 13.6% 2 - 0% 3 - 0% 4 - 0%

For the 3rd assessment time data analysis was not possible on a number of rating categories because of zero or very few plants in some categories. No 2.5-3 m plants scored a 0 rating and no 1.5-2 m plants scored a 3 and therefore these groups have been excluded from the analyses for these rating scores. Also there were only 4 plants that scored a 4 rating in the 2.5-3 m height range and none in the other height ranges, hence this rating group has also not been analysed. The analyses suggest that there is a significant effect (P=<0.001) due to height for plants scoring 0, 1 or 2. A significantly higher proportion of 1.5-2 m plants scored a 0 rating compared to 2-2.5 m plants, and given that no 2.5-3 m plants scored a 0 rating, then we can infer that it was a significantly higher proportion than in the tallest plant height range as well. There was no significant effect of height in the percentages of plants from each height range scoring a 3 or 4 rating.

A simplified analysis was also conducted looking only at the proportion of plants with a rating score of 3 or higher, indicating the most desirable outcome in terms of maintaining pseudostem integrity for as long as possible. This pseudostem integrity data for 12 weeks after treatment application is presented as percentage of plants with a rating score of 3 or greater

Rate	Proportion of plants scoring 3 or 4 at 12 weeks after treatment		
	2.5-3 m	**2-2.5 m**	**1.5-2 m**
0.43%	14.1 ab	5.7 abc	0
0.32%	34.0 c	2.0 a	0
0.22%	27.1 bc	6.2 abc	0
0.11%	54.4 d	4.0 ab	0
	P=0.016	**P=0.016**	*

** no plants scored 3 or greater creating an over-inflated standard error and preventing a pair-wise comparison*

There was no significant effect of rate for rating scores of 0, 1, 2 or 3, but there was a significant main effect of rate for the combined scores of 3 and 4.

Experiment 3 (2013/14)

Data for pseudostem integrity at 12 weeks after treatment application is presented with data presented as percentage of plants in each rating category (Rating 0-4; 0-complete shatter, 1-stem fallen over completely from ground level, 2-stem falling over/collapsing, 3-stem intact but soft/withered, 4-stem intact/turgid). Plants where the meristem was not killed were excluded from this analysis to avoid skewing the percentage of plants with a rating of 4.

Rate	Plant height range		
	2.5-3m	**2-2.5m**	**1.5-2m**
0.43%	0 - 0% 1 - 31.6% 2 - 37.0% 3 - 25.8% 4 - 0%	0 - 9.4% 1 - 68.8% 2 - 15.4% 3 - 4.6% 4 - 0%	0 - 94.4% 1 -5.6% 2 - 0% 3 - 0% 4 - 0%
0.32%	0 - 0% 1 - 28.6% 2 - 33.4% 3 - 34.9% 4 - 0%	0 - 9.5% 1 - 71.4% 2 - 9.6% 3 - 6.2% 4 - 0%	0 - 95.2% 1 - 4.8% 2 - 0% 3 - 0% 4 - 0%
0.22%	0 - 0% 1 - 26.5% 2 - 43.9% 3 - 29.4% 4 - 0%	0 - 0% 1 - 47.1% 2 - 47.5% 3 - 4.1% 4 - 0%	0 - 97.4% 1 - 2.6% 2 - 0% 3 - 0% 4 - 0%

0.11%	0 - 0% 1 - 28.6% 2 - 24.3% 3 - 47.1% 4 - 0%	0 - 28.6% 1 - 14.3% 2 - 28.2% 3 - 25.4% 4 - 0%	0 - 85.7% 1 -14.3% 2 - 0% 3 - 0% 4 - 0%

For the 3rd assessment time data analysis was not possible on a number of rating categories because of zero or very few plants in some categories. No 2.5-3 m plants scored a 0 rating and no 1.5-2 m plants scored more than a 1 rating and therefore these groups have been excluded from the analyses for these rating scores. Also there were only 3 plants that scored a 4 rating at the 3rd assessment, hence this rating group has also not been analysed.

The analyses suggest that there is a significant effect (P=<0.001) due to height for plants scoring 0 and1. A significantly higher proportion of 1.5-2 m plants scored a 0 rating compared to 2-2.5 m plants, and given that no 2.5-3 m plants scored a 0 rating, then we can infer that it was a significantly higher proportion than in the tallest plant height range as well.

A simplified analysis was also conducted looking only at the proportion of plants with a rating score of 3 or higher, indicating the most desirable outcome in terms of maintaining pseudostem integrity for as long as possible. This pseudostem integrity data for 12 weeks after treatment application is presented as percentage of plants with a rating score of 3 or greater

Rate	Proportion of plants scoring 3 or 4 at 12 weeks after treatment		
	2.5-3 m	**2-2.5 m**	**1.5-2 m**
0.43%	31.2	4.9	0*
0.32%	37.4	6.6	0*
0.22%	29.4	4.4	0*
0.11%	47.2	25.9	0*

** no plants scored 3 or greater creating an over-inflated standard error and preventing a pair-wise comparison*

There was no definitive significant effect of rate (P=0.052) for the combined rating scores of 3 and 4.

2.3 Sucker phytotoxicity

Experiment 1 (2011/12)

Data for sucker phytotoxicity at 12 weeks after treatment application is presented as percentage of plants in each rating category (Rating 0-4; 0-suckers dead, 1-suckers significantly deformed/stem shattered, 2-suckers showing serious chlorosis/leaf edge curling/leaf edge necrosis, 3-suckers showing mild chlorosis/leaf edge curling/leaf edge necrosis, 4-suckers unaffected)

Rate	Plant height range		
	2.5-3m	2-2.5m	1.5-2m
3.8%	0 - 0% 1 - 0% 2 - 0% 3 - 0% 4 - 100%	0 - 17.3% 1 - 0% 2 - 0% 3 - 8.9% 4 - 64.9%	0 - 71.4% 1 - 0% 2 - 0% 3 - 0% 4 - 28.6%
1.9%	0 - 0% 1 - 0% 2 - 0% 3 - 0% 4 - 100%	0 - 4.8% 1 - 0% 2 - 0% 3 - 4.8% 4 - 90.5%	0 - 28.6% 1 - 0% 2 - 0% 3 - 23.8% 4 - 47.6%
0.96%	0 - 0% 1 - 0% 2 - 0% 3 - 0% 4 - 100%	0 - 0% 1 - 0% 2 - 0% 3 - 0% 4 - 100%	0 - 4.8% 1 - 0% 2 - 0% 3 - 9.5% 4 - 85.7%
0.48%	0 - 0% 1 - 0% 2 - 0% 3 - 0% 4 - 100%	0 - 0% 1 - 0% 2 - 0% 3 - 0% 4 - 100%	0 - 0% 1 - 0% 2 - 0% 3 - 0% 4 - 100%

At the 3rd assessment time the general trend is that rate had no significant effect on the percentages of plants in the 2.5-3m height range. All plants in this height range scored 3 or 4 at all 3 assessment times. At the 2-2.5 m and 1.5-2 m height ranges there was a significant effect of rate, with decreasing rate treatments having higher proportions of plants scoring 3 and 4 and lower proportions scoring 0. Only 2 plants scored a 1 or 2 at the 3rd assessment and hence have not been analysed.

A simplified analysis was also conducted looking only at the proportion of plants with a rating score of 3 or higher, indicating the most desirable outcome. This sucker phytotoxicity data for 12 weeks after treatment application is presented as proportion of plants with a rating score of 3 or greater.

Rate	**Plant height range**		
	2.5-3m	**2-2.5m**	**1.5-2m**
3.8%	100% c	73.8% b	28.6% a
1.9%	100% c	95.2% c	71.4% b
0.96%	100% c	100% c	95.2% c
0.48%	100% c	100% c	100% c
	P=<0.001	**P=<0.001**	**P=<0.001**

Experiment 2 (2012/13)

The ethephon rates used in experiments 2 and 3 were reduced to try and define the lowest effective rate. A result of the lower rates was that sucker phytotoxicity symptoms did not persist beyond the first assessment time of 4 weeks after treatment. Therefore the data for sucker phytotoxicity presented here is for 4 weeks after treatment application. It is presented as percentage of plants in each rating category (Rating 0-4; 0-suckers dead, 1-suckers significantly deformed/stem shattered, 2-suckers showing serious chlorosis/leaf edge curling/leaf edge necrosis, 3-suckers showing mild chlorosis/leaf edge curling/leaf edge necrosis, 4-suckers unaffected)

Rate	**Plant height range**		
	2.5-3m	**2-2.5m**	**1.5-2m**
0.43%	0 - 0% 1 - 0% 2 - 0% 3 -19.1% 4 - 81.0%	0 - 0% 1 - 0% 2 - 1.5% 3 - 48.7% 4 - 46.3%	0 - 0% 1 - 0% 2 - 4.6% 3 - 75.6% 4 - 13.2%
0.32%	0 - 0% 1 - 0% 2 - 0% 3 - 20.5% 4 - 79.5%	0 - 0% 1 - 0% 2 - 3.0% 3 - 48.8% 4 - 39.6%	0 - 0% 1 - 0% 2 - 2.9% 3 - 52.4% 4 - 40.1%
0.22%	0 - 0% 1 - 0% 2 - 0% 3 - 30.0% 4 - 69.9%	0 - 0% 1 - 0% 2 - 0.7% 3 - 28.6% 4 - 69.1%	0 - 0% 1 - 0% 2 - 4.4% 3 - 63.4% 4 - 24.8%
0.11%	0 - 0% 1 - 0% 2 - 0% 3 - 4.8% 4 - 95.3%	0 - 0% 1 - 0% 2 - 2.1% 3 - 30.3% 4 - 62.9%	0 - 0% 1 - 0% 2 - 0.9% 3 - 39.5% 4 - 58.3%

Only 1 plant had a 0 rating at any of the assessment times and no plants had a 1 rating so these two ratings have not been analysed. No plants in the 2.5-3 m height range scored a rating of less than 3, indicating that the largest plants generally showed very low or no phytotoxicity symptoms in their suckers. Apart from the single plant with a 0 rating (suckers dead) all other plants scored a 4 rating at the 2nd and 3rd assessment times, indicating that these ethephon rates do not result in significant sucker phytotoxicity.

Experiment 3 (2013/14)

A result of the lower rates was that sucker phytotoxicity symptoms did not persist beyond the first assessment time of 4 weeks after treatment. Therefore the data for sucker phytotoxicity presented here is for 4 weeks after treatment application. It is presented as percentage of plants in each rating category (Rating 0-4; 0-suckers dead, 1-suckers significantly deformed/stem shattered, 2-suckers showing serious chlorosis/leaf edge curling/leaf edge necrosis, 3-suckers showing mild chlorosis/leaf edge curling/leaf edge necrosis, 4-suckers unaffected)

Rate	**Plant height range**		
	2.5-3m	**2-2.5m**	**1.5-2m**
0.43%	0 - 0% 1 - 0% 2 - 0% 3 - 26.8% 4 - 73.2%	0 - 0% 1 - 0% 2 - 0% 3 - 62.8% 4 - 37.2%	0 - 0% 1 - 0% 2 - 0% 3 - 79.0% 4 - 18.4%
0.32%	0 - 0% 1 - 0% 2 - 0% 3 - 17.0% 4 - 83.0%	0 - 0% 1 - 0% 2 - 0% 3 - 57.5% 4 - 37.5%	0 - 0% 1 - 0% 2 - 0% 3 - 75.6% 4 - 22.2%
0.22%	0 - 0% 1 - 0% 2 - 0% 3 - 29.0% 4 - 65.8%	0 - 0% 1 - 0% 2 - 0% 3 - 41.5% 4 - 53.7%	0 - 0% 1 - 0% 2 - 0% 3 - 63.8% 4 - 36.2%
0.11%	0 - 0% 1 - 0% 2 - 0% 3 - 18.6% 4 - 81.4%	0 - 0% 1 - 0% 2 - 0% 3 - 20.5% 4 - 76.9%	0 - 0% 1 - 0% 2 - 0% 3 - 32.3% 4 - 67.7%

Once again almost all plants scored a 4 rating at the 2nd and 3rd assessment times with only 1 plant scoring a 0 rating at the 2nd and 3rd assessment times and 5 plants scored a 3 rating at the 2nd assessment time. Therefore only assessment data for the 1st assessment (4 weeks after treatment) are presented.

At the 1st assessment only single plants scored a 0 rating or 1 rating and therefore these scores have not been analysed. Only 7 plants scored a 2 rating and this was insufficient to allow the algorithm to converge so analysis was not able to be undertaken on this rating. Significant differences were found between the mean percentages of plant populations scoring 3 and 4 ratings for both height (P=<0.001) and rate (P=0.003). Generally bigger plant sizes had greater proportions of the plant population rating 4 (suckers unaffected) and the proportion of plants scoring a 3 rating was significantly lower for the lowest rate compared to all other rates.

2.4 Fruit residue data investigation

From a single trial undertaken in north Queensland no detectable residues of ethephon (< 0.05 mg/kg) were found in bananas harvested from the subsequent crop, approximately 32-41 weeks after injection into the parent plant. Assessments were made for 0.22 g ai/L (0.22%) or 0.43 g ai/L (0.43%) of ethephon applied were at all of the three evaluated height range treatments.

Table 1 Ethephon residues in bananas harvested from plants a single ethephon injection to the nurse-sucker

<table>
<tr><th rowspan="2">Location, (Variety) Year</th><th colspan="3">Application</th><th rowspan="2">Time since treatment (days)</th><th rowspan="2">Treatment height (m)</th><th rowspan="2">Matrix</th><th rowspan="2">Residue, (mg/kg)</th></tr>
<tr><th>Form</th><th>g ai/L</th><th>No</th></tr>
<tr><td rowspan="6">South Johnstone Qld, (Williams), 2013</td><td rowspan="6">EC</td><td rowspan="3">0.43 (0.43%)</td><td rowspan="3">1</td><td>240-270</td><td>2.5-3.0</td><td rowspan="6">Whole fruit</td><td>< 0.05</td></tr>
<tr><td>228-293</td><td>2.0-2.5</td><td>< 0.05</td></tr>
<tr><td>239-268</td><td>1.5-2.0</td><td>< 0.05</td></tr>
<tr><td rowspan="3">0.22 (0.22%)</td><td rowspan="3">1</td><td>241-242</td><td>2.5-3.0</td><td>< 0.05</td></tr>
<tr><td>239-257</td><td>2.0-2.5</td><td>< 0.05</td></tr>
<tr><td>239-248</td><td>1.5-2.0</td><td>< 0.05</td></tr>
</table>

Outcomes

The impact of TC Yasi in February 2011 general resulted in the original project objectives not being achieved. The development of non-uniformity in the Control treatment did not occur because of the destruction of the trial. This prevented any direct assessment of the crop uniformity management strategy impact over successive crop cycles and significantly limited the assessment of the other factors being investigated. As a result direct outcomes on crop uniformity management for the banana industry have been limited. However, the data recorded on plant growth and development was successfully applied in the development of crop recovery activities after TC Yasi. The trial outputs allowed the development of a crop staggering program with data to support the proposed scheduling of nurse-suckering and the estimation of the subsequent cropping patterns.

The development of the minor-use permit for ethephon pseudostem injection for management of crop timing has been successfully undertaken with the NUP submitted in June 2014. The field research identified an effective rate and pattern of use and undertook limited chemical residue analysis to check for ethephon residues in the subsequent crop. The impact for the banana industry will be limited until the APVMA finishes its review of the MUP application and makes a decision on the granting of the permit.

1. Crop uniformity management

1.1 Crop uniformity and productivity

In spite of the trial destruction some useful comparisons were available regarding the influence of time of planting, planting material type and planting arrangement and density on crop uniformity. Some times of planting led to a greater degree of non-uniformity in the plant crop, particularly for the harvest period. These ToP’s generally had their bunch development coinciding with lower temperatures experienced in the period from April – August, and would have required intervention in the plant crop phase to prevent the development of a high degree of non-uniformity in the second crop cycle.

The effect of planting material type was obvious in the plant crop with traditional bit/sucker vegetative material producing a very high degree of non-uniformity. Cyclone damage prevented any assessment beyond the plant crop but it is likely that the control treatment would have achieved a level of non-uniformity in it second crop equivalent to the third crop cycle of the uniform plantlets. Any cropping system seeking to improve crop uniformity should therefore be based on the use of uniform plantlets to establish the block. This should reduce the level of intervention required which would improve the cost/benefit of the uniformity management.

The influence of plant density and arrangement had a significant effect on the development of non-uniformity in the trial populations, even in the plant crop cycle. The trial showed that the intra-plant competition occurring at 1810 plants per hectare was slowing down plant and bunch development compared to the single rows at 1333 plants per hectare. This was particularly the case during the autumn and winter period when climatic conditions were limiting to plant growth and development. In the second and third crop cycles for ToP 1, 2 and 3 the single row plots were beginning to show significantly faster cycle times than the double row plots and would probably have been as much as half a crop cycle ahead by the end of the third crop cycle. Thus any cropping system seeking to improve crop uniformity should carefully consider reducing the planting density to reduce intra-plant competition to improve the ease of maintenance of crop uniformity. The productivity reduction associated with lower plant numbers would likely be compensated by the faster crop cycling based on the available trial data.

1.2 Influence of time of planting and plant arrangement and density on yellow Sigatoka infection and Banana Scab Moth incidence

Yellow Sigatoka

Significant differences in yellow Sigatoka disease incidence and severity were evident across the various planting times. In the first disease assessment, plantings established in December 2008 and assessed in March 2009 which grew through the high temperature, high rainfall summer months developed more disease than at all other planting times. In the second disease assessment, plantings established December 2008 and November 2009 and assessed for disease in June 2009 and May 2010 respectively, had more disease that those plantings established at other times. These planting times had the greatest period of exposure to high rainfall and high temperatures which favoured the development of disease.

In the final disease assessment for the plant crop planting times, plantings established in April 2009 and July 2009 and assessed in March and April 2010 respectively developed less disease (YLS, ALR, and DSI) than those planted at most other times of the year. Climatic conditions in the months which followed these plantings which were cool and dry would not have favoured the development of yellow Sigatoka. Conversely, the highest level of disease was recorded in the control (October 2009, double row only), the December 2008, October 2009 and the November 2009 plantings. All these plantings were assessed after having grown through periods when climatic conditions would have favoured the development of yellow Sigatoka.

The other key result from the assessments was the influence of planting density and arrangement on disease. Double row spacing consistently produced higher levels of disease across all planting times. This can be most likely attributed to disease enhancing microclimatic conditions and reduced spray penetration and coverage within the plant canopy of the double row plantings.

Banana Scab Moth (BSM)

The BSM activity in the first crop cycle was generally low in all the times of planting. The lowest incidence of bunch damage generally correlated well with bunch emergence periods between May 2009 and January 2010 when rainfall, humidity and temperatures were lower.

Results in the ratoon crop cycles were limited due to cyclone damage. In the first ratoon crop cycle the highest incidence of BSM was in ToP 3 and all but 1 of the plots recorded a bunch incidence of 3% or more. The incidence of BSM in ToP 2 & 3 during the months when activity is expected to reduce is probably a function of the unseasonal rainfall in 2010 caused by the La Nina climate pattern. The results point to potential in reducing management inputs at time of the year when the weather conditions do not favour BSM populations provided those conditions can be more critically defined.

1.3 Economic comparison of continuous ratooning and managed uniformity banana production systems

The modelling of gross margins from the continuous ratooning and uniform cropping systems show that there could be a positive impact on gross margins by managing crop uniformity. The key factors influencing the gross margin were the price received, the efficiencies gained from increased uniformity and the size of the intervention required. Because the management intervention used in the trial required a percentage of the population to be killed to improve the uniformity of the next crop cycle, this negatively influenced the gross margin as the price received increased. An alternative management intervention that preserves the productivity levels (such as nurse-suckering the following suckers on the earliest 10% of plants undergoing bunch emergence) could fundamentally increase the benefits from a uniform cropping system.

Overall, the economic assessment indicates that a uniform cropping system offers a potential improvement over the conventional ratooning system when the returns are consistently close to the cost of production. The uniform cropping system could be even more cost effective if the level of crop uniformity can be kept high while maintaining productivity.

2. Developing a minor-use permit for ethephon pseudostem injection for crop timing management

Three field experiments were ultimately conducted to determine the most effective ethephon rate for pseudostem injection to kill the primary meristem in banana plants. Experiment 1 failed to identify a rate that would constitute a failure of control but did identify the relationship between higher rates, smaller plant sizes and the expression of phytotoxicity symptoms in the subsequent suckers. There was also an effect of plant size and rate on the early decomposition and disintegration of the treated pseudostem. Generally the biggest plants (2.5-3 m) exhibited fewer phytotoxicity symptoms in their suckers and the treated pseudostem remained intact for longer.

For experiments 2 and 3 the rate range was reduced from 3.8%, 1.9%, 0.96% and 0.48% to 0.43%, 0.32%, 0.22% and 0.11%. This rate range identified a significant effect of rate on the percentage of primary meristem deaths. In experiment 2 significant control failure occurred at 0.15% while experiment 3 demonstrated control failure at 0.22%. In both experiments only the 0.43% and 0.32% rates achieved similar levels of control. Based on the consistency of the results for the 0.43% rate in the experiments, and the absence of residues in fruit samples analysed from this rate in experiment 2, 0.43% ai ethephon was recommended as the most effective rate.

The lower rate range used in experiments 2 and 3 also produced much less persistent phytotoxicity symptoms in the subsequent suckers, with virtually all plants free of symptoms beyond 4 weeks after treatment. The severity of the symptoms was also significantly reduced. Small plant size was a major contributor to increasing symptom severity. Plants in the 1.5-2 m range consistently suffered more severe phytotoxicity symptoms in their suckers than the other height ranges. The persistence of the treated pseudostem was also significantly affected by plant size with significantly less plants in 1.5-2 m height range recording the most desirable ratings.

From this data it was suggested that only plants at least 2 m high (measured from ground level to the axil of the newly emerged leaf) are considered suitable for ethephon pseudostem injection at the 0.43% ai rate.

Removal of the leaf canopy at or soon after pseudostem injection has been shown to significantly improve the percentage of plants experiencing meristem death. Retention of the canopy resulted in levels of reshooting by treated plants that would be considered unacceptable in commercial production conditions. Removal of the canopy has a number of other practical benefits in a commercial scenario including reduction in leaf disease inoculum and ease of identifying plants that have begun reshooting.

Evaluation and Discussion

The project objectives relating to crop uniformity management were only partially achieved because of the destruction of the trial and the north Queensland industry by TC Yasi. The lack of significant trial data meant that communication and extension activities regarding crop uniformity management were largely limited to their use during the cyclone recovery program. The available trial results were a significant advantage in the development, communication and implementation of the cyclone recovery program developed with the banana industry. The proposed timing of scheduled cropping, forecasting of the return to cropping and its productivity were all developed using the data set collected during the initial stages of the project. Some of the collected data has also been used in the proposition of potential mechanisation/robotics R&D in bananas.

The significant loss of income at the time from the cyclone damage also attenuated the interest of many producers in the development of a uniform cropping system. However, discussions with some producers about the data collected and its application has occurred in 2013/14. Mostly the project results are being used to refine uniform cropping systems that have already been implemented.

Project results were also provided to the broader industry through written communication in the Australian Bananas magazine and via a poster display at the 2011 National Banana Industry Congress.

The revised project objectives after February 2011 focused on conducting research activities to support the development and submission of a MUP for ethephon pseudostem injection for crop timing management. This was identified as major priority for the banana industry, particularly as it applied to cyclone recovery by the project reference group and the banana IAC.

Previous severe, industry-wide tropical cyclone damage caused regional synchronisation of cropping that resulted distinct periods of undersupply and oversupply for 2 years until the crop cycle returns to an asynchronous situation. To overcome this synchronised cropping cycle a staggered cropping program was developed in consultation with the Australian Banana Growers' Council (ABGC) which proposed a scheduled application of the nurse-suckering technique or replanting to provide a more consistent distribution of harvest once production returned.

The current methods used for nurse-suckering involve physically damaging or removing the banana plant's apical meristem which is labour intensive and physically demanding. The potential replacement of this difficult and physically demanding task by ethephon pseudostem injection offers significant labour savings for the industry, potentially making crop scheduling and uniformity management easier and more cost effective to implement.

The submission of the MUP application to the APVMA has the potential to assist the banana industry in north Queensland to reduce costs and improve profitability if it is approved. The data generated could also support any emergency MUP application should cyclone damage occur before any formal decision is made by the APVMA.

Throughout both phases of the project a project reference group was important in providing feedback and guidance on project progress. The group members were regularly updated on activities and results, mainly via email rather than regular meetings due to the members' time commitments on their farms.

Recommendations

The main recommendations from the project are:

- The further investigation of labour input efficiency in banana production activities has the potential to reduce the cost of production. Results from the industry benchmarking project show that labour is the largest cost component in the cost of production. Therefore practices that can improve labour input efficiency without compromising productivity will have a significant impact on the cost of production. Investment in this area is also a recommendation of the recently completed industry benchmarking project.
- Any potential requests for additional data to support the ethephon pseudostem injection MUP are referred to the banana IAC for consideration. The major industry status accorded to bananas by APVMA may require additional residue data than the project could undertake for a longer-term permit.
- The extension and communication of the ethephon pseudostem injection technique for nurse-suckering be undertaken by BA13004 National Banana Development and Extension Project if the APVMA approves the MUP application.

Scientific Refereed Publications

None to report

IP/Commercialisation

None to report

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- The project reference group members – Mr Doug Phillips, Mr Cameron Mackay, Mr Mark Nucifora and Mrs Naomi Brownrigg – for the contribution of their time and experience in guiding the project activities through both phases of the project.
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- The DAFF staff who assisted in the project field measurement and recording – Miss Naomi King, Mr Luigi De Marchi (deceased), Mr Jacob Vecchio, Mr Lynton Vawdrey, Dr Tony Pattison and Miss Tegan Kukulies.
- Dr Carole Wright, DAFF Biometrician, for her detailed analyses of the many data sets generated in this project

Appendices

Appendix 1 – Ethephon pseudostem injection assessment rating scales

Meristem death rating	
0 - Reshoot	**1- Dead**
	

Pseudostem integrity rating		
0 – Complete shatter	**1 – Stem fallen over completely**	**2 – Stem fallen over/collapsing**
		
3 – Stem upright but soft/withered	**4 – Stem upright/turgid**	
		

<table>
<tr><td colspan="3">Sucker phytotoxicity rating</td></tr>
<tr><td>0 – Suckers dead</td><td>1 – Suckers significantly deformed/shattered</td><td>2 – Suckers showing serious chlorosis/leaf edge curling/leaf edge necrosis</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">3 – Suckers showing mild chlorosis/leaf edge curling/leaf edge necrosis</td><td>4 – Suckers unaffected</td></tr>
<tr><td colspan="2"></td><td></td></tr>
</table>