NORTHERN HEALTH SERVICE DELIVERY







TRADITIONAL OWNER-LED DEVELOPMENT

AGRICULTURE & FOOD





Final Report

A.2.1819105 Developing a Broadacre Cropping Sector in North Queensland

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Acknowledgements

This research is funded by the CRC for Developing Northern Australia (CRCNA) is supported by the Cooperative Research Centres Program, an Australian Government initiative. The CRCNA also acknowledges the support of its investment partners: the Western Australian, Northern Territory and Queensland Governments.

As lead for this project I want to acknowledge the significant effort by the DAF Team in undertaking project activities – Dr Lance Pendergast, Lawrie Owens, Charlie Nastasi and Melissa Joyce. In addition I wish to thank staff of the Savannah Gulf NRM who assisted the team in the 2022 season (Keerah Steele, Mandy Pickering and Taylor Smith).

The support of Ken and Brendan Fry, Forest Home Station was pivotal to the successful conduct of the on-farm replicated research trials carried over the past five years.

I'd also like to thank all participants of the Gilbert River Reference Group for their contribution to the design of project activities and feedback on research results and priorities for broadacre cropping RD&E within the Gilbert River catchment.

Finally I'd like to extend my appreciation to the funders of this project – CRCNA, Grains Research Development Corporation and the Queensland Government Department of Agriculture and Fisheries.

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The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

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- rigour
- compliance with ethical guidelines
- conclusions against results
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Australian Government
Department of Industry, Science, Energy and Resources

AusIndustry
Cooperative Research Centres Program

Queensland Government

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Department of Primary Industries and Regional Development
GOVERNMENT OF WESTERN AUSTRALIA

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Acronyms

APSIM	Agricultural Production Systems sIMulator
CRCNA	CRC for Developing Northern Australia
CSD	Cotton Seed Distributors
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAF	Department of Agriculture and Fisheries, Queensland Government
FGARA	Flinders and Gilbert Agricultural Resource Assessment
GRDC	Grains Research Development Corporation
GRRG	Gilbert River Reference Group
NQIAS	North Queensland Irrigated Agriculture Strategy
UniSQ	Unoiversity of Southern Queensland

Project Participants

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AgriVentis Technologies Pty Ltd

Equinom

Cotton Seed Distributors

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- CRCNA – Ian Biggs, Kristin Nunn, Brondwyn Maclean
- Etheridge Shire Council - Warren Devlin, Rolfe Ellem, Barry Hughes, Cameron Barnes
- Forest Home Station, Georgetown – Ken and Brendan Fry
- GRDC – Ken Young, Kaara Klepper
- Gulf Farming – Ron Greentree and Tony Harrison
- Gulf Savannah NRM – Zoe Williams, Laura Miller, John McLachlan
- Prestwood Station, Georgetown – Reg and Bev Pedraccini
- QAAFI – Dr Joseph Eyre, Dr Daniel Rodriguez
- Savannah Ag Consulting – Tony Matchett
- Strathmore Station, Georgetown - Scott and Tom Harris, Peter Anderson

Executive Summary

This report presents the results of activity within the CRCNA/GRDC funded project A.2.1819105 Developing a Broadacre Cropping Sector in North Queensland in 2020, 2021 and 2022 seasons. In addition the results from the 2018 and 2019 seasons funded through the Queensland Government Department of Agriculture and Fisheries are also included, in order to present an overall picture of the performance of four potential irrigated crops for the Gilbert River catchment of north Queensland. The crops evaluated in this research were cotton, mungbeans, soybeans and sesame. A range of seasonal conditions were experienced across the five years if research reported here. It included two above average rainfall years, two below average rainfall years and an "average" year. In season rainfall variability impacted trial results – sometimes favourably and at other times less so.

The results of research by the project team have clearly determined the potential of these four crops in an irrigated cropping system on the 20,000 ha of potential irrigated cropping lands within this region. Cotton and mungbeans are clearly well adapted. Cotton has the highest potential gross margin of the crops evaluated despite the significant freight cost associated with transport to Emerald for processing at this time. Cotton yields ranged from 7.9 to 11.2 bales/ha with excellent lint quality. The lowest yields were in 2020 when a late start to the wet season delayed planting until 20 February 2020.

Mungbeans are an excellent cropping option in the region owing to their short growing period (enabling planting later than cotton in the summer season and their lower irrigation water requirement. Yields for the best adapted varieties ranged from 1.2 to 2.6 t/ha. The lowest yields were in the dry 2020 season.

Successful establishment of soybeans remains a challenge in this environment. When establishment was successful yields more than 3.0 t/ha were achieved. Where poor establishment required replanting at a later date yields were seriously compromised. At this time, its inclusion as an irrigated cropping option in the region is not recommended.

Sesame is a relatively new crop being considered as a cropping option in Australia. It seems well adapted to the light textured soils of the Gilbert River catchment. Yields from trials in 2018 and 2019 ranged from 1.77 to 2.4 t/ha. However, there are a number of agronomic challenges which need addressing before it can be widely grown. In particular, establishment of this small-seeded crop and the lack of suitable herbicides for the management of broadleaf weeds present challenges to its wider inclusion within the cropping system.

An evaluation of the APSIM (Agricultural Production Systems sIMulator) model for cotton, mungbean and soybean clearly demonstrated that this tool does not yet adequately or consistently model the performance of these crops in this environment. This appears to limit the usefulness of this tool in the region at present.

A Gilbert River Reference Group (GRRG - comprising a range of local stakeholders) was established and met to review research results and provide guidance to subsequent research activity annually.

On-farm demonstration of broadacre cropping within the project was limited. In part this was due to seasonal conditions but there was little interest from potential croppers in planting demonstration areas. The only demonstration activity was conducted with the co-operation of Fry Bloodline Trust on Forest Home Station. Feedback from the GRRG suggested that lack of suitable infrastructure and cropping knowledge amongst the grazing sector limits the potential for their in this aspect of the project.

Several extension activities were conducted during the project. The Covid-19 pandemic impacted the delivery of face-to-face activities in 2020, necessitating on-line delivery which benefitted the wider cropping sector (but limited access to local landholders because of connectivity issues). The project team supported the Etheridge Shire in the delivery of two face-to-face forums (2021 and 2022).

Outputs from the project include four Agronomy Guides for each of the crops evaluated, and a draft set of gross margins for these crops (these will be available through the updated AgMargins website with an estimated release date of 31 October 2022).

The following are the strategic recommendations arising from this project:

1. A clear understanding of the impediments to establishing a broadacre cropping sector is needed. This requires engagement not only with existing enterprises currently undertaking broadacre cropping but also the existing livestock sector. This engagement is needed to design appropriate RD&E activities that address the impediments identified.
2. Given the cost of research activity within the region opportunities to minimise this through development of strong collaborative links with existing local organisations (e.g, Gulf Savannah) should be explored and developed.
3. Cotton and mungbeans appear well adapted to cropping within the Gilbert River catchment. Further research needs to focus on specific agronomic practices needed to maximise productivity and profitability of these crops.
4. Sesame as a crop has some way to go before it can be widely used within this region. Crop establishment and weed management are key focus areas for research to address these key constraints at this time.

5. Soybeans have limited applicability to cropping within the Gilbert Catchment given difficulties encountered with establishment. Research investment should focus on other crops at this time.

Background

In northern Australia there are large areas of soils potentially suitable for irrigated agriculture development constrained by access to sufficient water. In recognition of the challenges and opportunities facing northern communities and primary producers, the North Queensland Irrigated Agriculture Strategy (NQIAS) was initiated in January 2012 (https://www.csiro.au/en/research/natural-environment/water/Water-resource-assessment/Flinders-Gilbert/Overview) .

CSIRO led one component of the NQIAS, the Flinders and Gilbert Agricultural Resource Assessment (FGARA), with some components undertaken by the Queensland Government and TropWATER (James Cook University).

The two-year project provided a comprehensive and integrated evaluation of the feasibility, economic viability, and sustainability of agricultural development in these two catchments of North Queensland. The assessment sought to:

- identify and evaluate water capture and storage options
- identify and test the commercial viability of irrigated agricultural opportunities
- assess potential environmental, social and economic impacts and risks.

The assessment was designed to build knowledge base to inform future development decisions.

The key findings of this assessment were:

- The Flinders and Gilbert catchments differ significantly in their physical characteristics and, therefore, the extent to and methods by which agricultural development might occur.
- In the Flinders catchment, farm dams could support 10,000 to 20,000 ha of irrigation in 70 to 80% of years; irrigation may not be possible in very dry years. The precise area under irrigation will, un any year, vary depending on factors such as irrigation efficiency, water availability, crop choice and risk appetite.
- In the Gilbert catchment, large instream dams could support 20,000 to 30,000 ha of irrigation in 85% of years. Again, the precise area under irrigation will, in any year, vary depending on factors such as irrigation efficiency, water availability, crop choice and risk appetite.
- Instream dams enable more reliable irrigated production than farm dams because they can more easily carry water from one year to the next.
- Significant water use would, in the downstream environment, amplify environmental and social challenges associated with dry years and would have impacts on commercial and recreational fishing catches that were not quantified in the study.

Large-scale change of land and water use in the catchments is likely to require a wide range of regulatory, social and cultural responses, including consideration of native title implications.

A key issue limiting investment in broadacre cropping systems within Northern Australia is an understanding of the yield variability (and hence risk profile) and profitability of broadacre crops that could be grown within existing extensive grazing systems. There is also limited knowledge and experience amongst landholders and the agribusiness sector with the agronomy of these crops within the region.

These issues are replicated within the Gulf River catchments of north Queensland where there is limited experience and knowledge around the performance and profitability of potential dryland and irrigated broadacre crops that could be grown. An understanding of the variability in this performance is critical in providing local landholders and potential investors with the knowledge and assessment of risk needed to develop appropriate broadacre cropping systems for the region.

In 2018 and 2019 the Department of Agriculture and Fisheries commenced research into irrigated cropping options for the Gilbert catchment in collaboration with Fry Bloodline Trust, Forest Home Station. Funding by the CRCNA, GRDC and Queensland government enabled continuation of this initial research to progress in 2020 to 2022.

Project Aims

The project aim was to work with existing and new broadacre croppers, and the agribusiness sector, within the Gilbert River catchment to assess the performance of different broadacre crops within existing extensive grazing enterprises.

A further aim was to develop the broadacre cropping knowledge and agronomic skill of landholders and the agribusiness sector in the region.



Photo 1: Georgetown Roadshow Filed Day at original Forest Home Station research site on 30 April 2019

Project Approach

Establishment of a Gilbert River Cropping Reference Group comprising local landholders, agribusinesses, other research project leads, the CRCNA and GRDC. The reference group met each year to review results of the past year and provide input into future research and demonstration activities. The choice of crops and agronomic practices investigated was decided through consultation with reference panel members, and through consultation with other research providers operating within the region (Savannah Agriculture and University of Queensland) and commercial entities such as Equinom and Agriventis Technologies. Crops were evaluated under rainfed and irrigated scenarios.

Establishment of on-farm commercial demonstration sites with landholders in the Gilbert catchment;

Establishment of a replicated irrigated on-farm research site on the soil type most representative of the 20,000ha of potential irrigable soils in the region (based on the Department of Natural Resources, Mines and Energy 2004 report "Gulf and Mitchell Agricultural Land and Water Resources Assessment Report). Use of a replicated trial site provides greater control over the achievements of research results than is possible on commercial scale demonstration sites owing to the risks associated with vertebrate pests and other factors experienced on large-scale demonstration sites. The proposed research and demonstration sites were used to showcase the performance of crops and varieties, and the agronomic practices that should be used in this environment.

Support landholders, their workforce and agribusiness to acquire knowledge and develop the skills to maximise the profitability of their broadacre cropping activities. This included the conduct of field days at research and demonstration sites, and local presentations, to provide an opportunity for local landholders to view the crops, research results and discuss "best-practice" with collaborators, the project team and industry experts.

In addition, the project team worked closely with existing and potential growers, the Etheridge Shire Council, agribusiness and other cropping research projects (Savannah Consulting and University of Queensland), to facilitate enhanced linkages to the existing research and information networks within the grains industry. The aim was to accelerate the adoption of appropriate broadacre cropping practices within the Gilbert catchment.

The results from the replicated trials and demonstration sites will be examined using the existing APSIM crop models for the crops tested. The results of the trials and demonstration sites, together with APSIM where appropriate, will be used in the development of "best-bet" agronomic packages to support future development of a cropping sector within the region. These "best-bet" agronomic packages have been published as a series of Agronomy Guides – Gulf Rivers for each of the crops assessed by the project team – cotton, mungbean, sesame and soybean (provided in the appendices of this report).

A set of gross margins for the crops evaluated in the Gilbert catchment have been developed and are accessible on the AgMargins website (https://agmargins.net.au). The gross margins for cotton, mungbean, sesame and soybean for the Gulf Rivers are provided in the appendices to this report.



Photo 2: Irrigated mungbean trial at Forest Home Station on 16 April 2020

Gilbert River Reference Group

The following groups (individuals) were invited and participate in the Gilbert River Reference Group (GRRG) over the course of the project:

- Gulf Farming (Ron Greentree, Tony Harrison)
- Strathmore Station (Scott Harris, Tom Harris, Peter Anderson)
- Forest Home Station (Ken and Brendan Fry)
- Prestwood Station (Reg and Bev Pedracinni)
- Etheridge Shire Council (Warren Devlin, Rolfe Ellem, Barry Hughes, Cameron Barnes)
- Gulf Savannah (Zoe Williams, Laura Miller, Jon McLachlan)
- QAAFI (Daniel Rodriguez and Joe Eyre)
- Savannah Ag (Tony Matchett)
- Agforce (Nikki Hoffman)
- GRDC (Ken Young,
- CRCNA (Brondwyn Maclean, Kristin Nunn, Ian Biggs)

The inaugural meeting was held on the 18 September 2019 in Georgetown.

An overview of following three CRCNA/GRDC funded projects operating in north Queensland was presented to participants:

- De-risking broadacre cropping options for Northern Queensland
- Developing an oilseed industry in Northern Australia
- Developing a broadacre cropping sector in Northern Queensland

Following the presentations a problem census technique was used to identify and prioritise cropping system issues. Each participant was asked to individually and silently list what they saw as the key issues that exist with broadacre cropping within the Gilbert River district. These could be related directly to their own operation or more broadly within the district. These were written these down on A5 sticky note paper, one issue on each sheet. These ideas were then placed up on the wall for all to see. Ideas were then grouped together under broad headings and were then used for prioritisation.

Two rounds of prioritisation were used – one examining the key issues that should be addressed in on-farm research and the other, broader issues that need to be addressed for the future development of broadacre cropping systems in the Gilbert River. In each prioritisation round participants could allocate a total of 10 points across the issues identified. These were then summed together to identify the priorities.

Cropping Trial Issues Prioritisation

Issue (cropping trials)	Individual Priorities	Total
Soil Fertility/Nutrition/Soil Health	4,3,3,4,4,2	20
Feral/vertebrate pests, fencing	2,3,3,3,6	17
Crop choice	10,6	16
Adapted varieties for the north	2,3,4,4	13
Soil Structure	1,2,3,3	9
Skills/knowledge around chemical use	2,4	6
Residual chemicals	2,4	6
Crop protection registration, chemical use, identification)	2,3	5
Crop rotation	2,2	4
Washdown capacity	4	4
Biosecurity	2	2
Water (infrastructure, allocation, systems)	2	2
Facilities (processing, storage, handling, port)	2	2
Labour availability	2	2
Managing Crop Residues		0

It is clear that issues around soil fertility (crop nutrition) and structure, vertebrate pests (primarily pigs) and crop/variety choice are significant for participants in this meeting. There were also a number of other issues identified that need to be addressed in the longer term. The three CRCNA/GRDC funded projects have the potential to address the highest priority issues, and some of the lesser ones as well.

Whole Cropping System Issues

Issue (whole of cropping system)	Individual Priorities	Total
Water (infrastructure, allocation, systems)	3,4,5,5,5,5,5	32
Labour availability	3,5,5,5	18
Facilities (processing, storage, handling, port)	3,3,5	11
Mobile phone coverage/digital connectivity	1,4	5
Policy (vegetation, water)	5	5
Washdown capacity	3	3
Supporting industries	2	2
Critical mass of crops	2	2
Risk analysis of options	2	2
Regional branding/partnerships		0

Three issues clearly dominate the development of the whole cropping system within the Gilbert:

- Water (infrastructure, allocation, system, policy)
- Labour availability
- Facilities (processing, storage, handling and port)

This is not to say that other issues are not also important (otherwise they would not have been identified in the process used).

During general discussion the following decisions were made:

- For the Broadacre Cropping project the key crops for assessment identified were mungbeans, soybeans and cotton
- April was identified as the preferred month for holding field days to look at crop performance trials
- Social media was not considered a useful communication mechanism to reach growers locally
- There is a need for a single website portal to provide access to outputs of the projects – further discussion needed between the projects and with CRCNA to consider how to progress this
- The results of trials undertaken on farms must be provided in a timely fashion to participating landholders. It was agreed that results will be made available by 30th September each year.
- Frequency of future meetings of this Stakeholder Group to be determined in the future

On the 28 October 2020 the second annual meeting of the GRRG was held. This preceded the public meeting organised by Etheridge Shire Council held on the 29 October 2020 – the aim of this meeting was to update the community on current research and agricultural development activity within the Gilbert catchment.

At this meeting of the GRRG participants were updated on the results of the preceding season and their recommendations sought on the research to be progressed in the 2021 season. An evaluation dartboard technique was used to assess the value of the meeting. The results are presented in Figure 1.

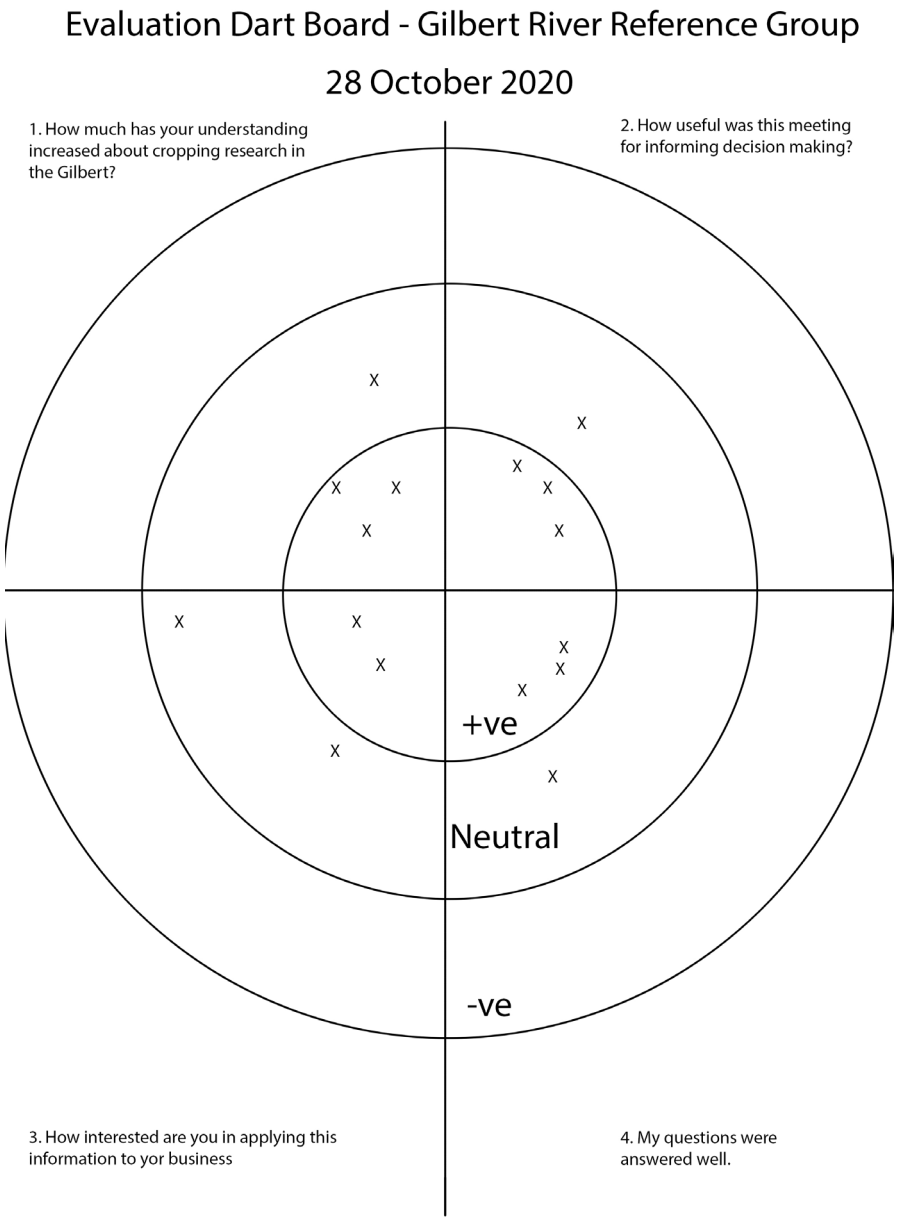


Figure 1 Evaluation dartboard results – GRRG meeting, 28 October 2020

The results clearly indicate the participants belief that the meeting had clearly informed then about the research being undertaken and assisted them in making informed decisions in relation to broadacre cropping in the district.

The third annual meeting of the GRRG was held on the 21 October 2021 in Georgetown. Participants at this meeting were updated on research results by two of the CRCNA/GRDC funded projects:

- Developing a broadacre cropping sector in Northern Queensland
- De-risking broadacre cropping options for Northern Queensland

The GRRG supported planned research activities for the 2022 season.

Difficulties in achieving interest from landholders in planting demonstration sites in the district was discussed. The project team have on several occasions offered to work with local landholders in progressing on-farm demonstration sites with little success. Only the Fry's have been forthcoming to date (with a cotton site in 2019 and a planned rice site in 2020 that did not progress because of bird damage concerns). One suggested reasons for the lack of interest from local landholders is that as graziers they are not comfortable with trialling crops – they do not have the equipment and skills to undertake this.

Replicated Cropping Research

Forest Home Research Site

In 2018 the Department of Agriculture and Fisheries (DAF) established an irrigated trial site Forest Home Station, Georgetown through collaboration with Ken and Brendan Fry, Fry Bloodline Trust. A research area of 1 hectare was fenced to exclude wallabies and wild pigs.

Trials were again planted at this site in 2019. In late 2019 a new trial area on Forest Home Station (11 ha in area) was enclosed with a substantial exclusion fence through investment by the Queensland Government (through State Development, Infrastructure, Local Government and Planning). This new trial area located on soil typical of the alluvial soils on the Gilbert and Einasleigh Rivers within Etheridge Shire.

The trials conducted at the Forest Home Station trial site in 2020, 2021 and 2022 were funded by the CRC for Developing Northern Australia, Grains Research Development Corporation, and DAF.

Table 1 Pre-trial soil analyses for 2018 and 2019 (original Forest Home Station trial site)

Date sampled	**9 November 2017 (Pre-2018 trial)**	**31 January 2019 (pre-2019 trial)**		
Depth sampled (cm)	**0 – 30**	**0 - 15**	**15 - 30**	**30 - 60**
pH (H2O)	6.50	6.1	6	6.5
Electrical conductivity (dS/m)	0.061	0.059	0.023	0.023
Chloride (mg/kg)	14			
Nitrate Nitrogen (mg/kg)	8	11	3	<1
Ammonium Nitrogen (mg/kg)	1.7	6	1	<1
Phosphorus (mg/kg)	39.3	33	19	10
Sulphur (mg/kg)	4.5	13	5.4	7.7
Potassium (meq%)	0.40	1.28	0.84	0.38
Calcium (meq%)	4.3			
Magnesium (meq%)	1.0			
Sodium (meq%)	0.1			
Zinc (mg/kg)	3.8			
CEC (meq%)	7.1			
Organic matter (%)	1.3			
Colour		GRBR	GRBR	LTBR
Texture		Loam clay	Loam clay	Loam clay

The analyses in for the original Forest Home Station trial site showed a slightly acidic profile with very low salinity levels. Nitrogen levels were low with medium levels of surface phosphorus. Medium to high levels of potassium were also reported to depth. There were no sodicity issues and organic carbon levels were low.

Table 2 Pre-trial soil analyses for 2020 trial site (sampled 6 Dec 2019)

Depth sampled (cm)	**0 – 15**	**15-30**	**30 - 60**	**60- 90**
pH (H2O)	6.8	6.8	7.0	7.1
Electrical conductivity (dS/m)	0.042	0.026	0.014	0.014
Nitrate Nitrogen (mg/kg)	6	2	1	<1
Phosphorus (mg/kg)	19	13	11	12
Sulphur (mg/kg)	2.6	1.4	0.6	0.6
Potassium (meq%)	1.42	1.08	0.61	0.54
Organic carbon (%)	0.73	0.64	0.32	0.19
Colour	GRBR	GRBR	BRGR	BRGR
Texture	Loam/clay	Loam/clay	Loam/clay	Loam/clay

Table 3 Pre-trial soil analyses for 2021 trial site (sampled 12 Jan 2021)

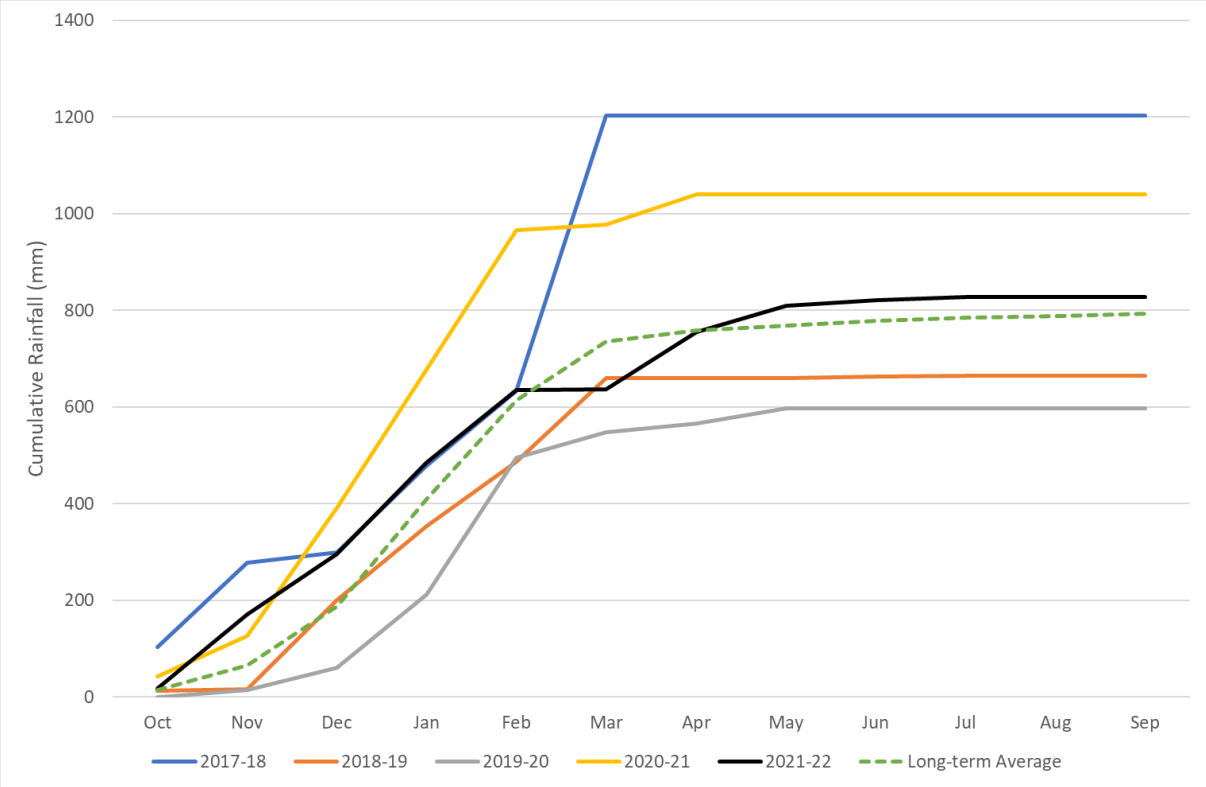
Depth sampled (cm)	**0-15**	**15-30**	**30-60**	**60-90**
pH (H2O)	6.9	7.1	7.1	7.3
Electrical conductivity (dS/m)	0.045	0.049	0.021	0.022
Nitrate Nitrogen (mg/kg)	11	9	5	4
Phosphorus (mg/kg)	46	34	35	29
Sulphur (mg/kg)	3.7	2.7	1.7	2
Potassium (meq%)	1.37	1.05	0.78	0.60
Organic carbon (%)	0.87	0.66	0.44	0.25
Colour	GR	GRBR	BRGR	LTBR
Gravel (%)	0	5	15-20	25-30

Analysis of the soil samples from the new Forest Home Station trial site in 2020 and 2021 showed a neutral pH to depth with no evidence of soil salinity. Nitrogen levels were low and phosphorus low in 2020 (but high in 2021 – due to the application of phosphorus fertiliser the previous season). Sulphur levels were very low in both years and organic carbon also low. Potassium levels were very high decreasing to high at depth.

Seasonal Conditions

The rainfall experienced at the Forest Home Research sites between 2017-18 and 2021-22 is summarised in Figure 1.

Figure 2 Cumulative rainfall in each year of the research conducted at Forest Home Station, Georgetown



The cumulative rainfall pattern shows that rainfall was above average in two years (2017-18 and 2020-21) with below average rainfall in 2018-19 and 2019-20. The 2021-22 year has been a more "average" year with respect to cumulative rainfall.

Table 4 summarises the monthly rainfall totals relative to the long-term average for Georgetown PO.

Table 4 Monthly rainfall totals at Forest Home Station research sites – 2017-18 to 2021-22

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
2017-18	103	176	20	180	155	569	0	0	0	0	0	0	1202
2018-19	13	4	185	152	133	174	0	0	3	1	0	0	664
2019-20	0	15	46	151	284	52	18	32	0	1	0	0	598
2020-21	43	83	265	288	288	12	62	0	0	0	0	1	1041
2021-22	18	153	126	190	149	2	118	54	13	6			828
Long-term Average	15	51	122	222	203	122	24	10	9	6	4	5	793

A feature of the rainfall data over the five years of research is the significant month-to-month variability at this site. In "dry" years (2018-19 and 2019-20) there were months with above average rainfall totals coupled with significant below average rainfall months. In the wetter 2017-18 and 2020-21 years there were many above average rainfall months, but there were also some below average rainfall months – in particular the dryer March 2021 month during the crop growing cycle. The "average" 2021-22 year included significant above and below average rainfall months.

2017-18

The 2017-18 year was an above average rainfall year. Figure 2 shows the daily weather data recorded (rainfall and temperature) at the trial site. Maximum temperatures were generally below the 30-year average throughout the trial period (10 January 2018 to 18 June 2018) and minimum temperatures above the 30-year average. Heavy rainfall totalling 387 mm associated with ex-tropical Cyclone Nora fell in late March 2018 (44 percent of the in crop rainfall recorded).

Figure 3 Seasonal condition (rainfall and temperature) at Forest Home Research Site 2017-18

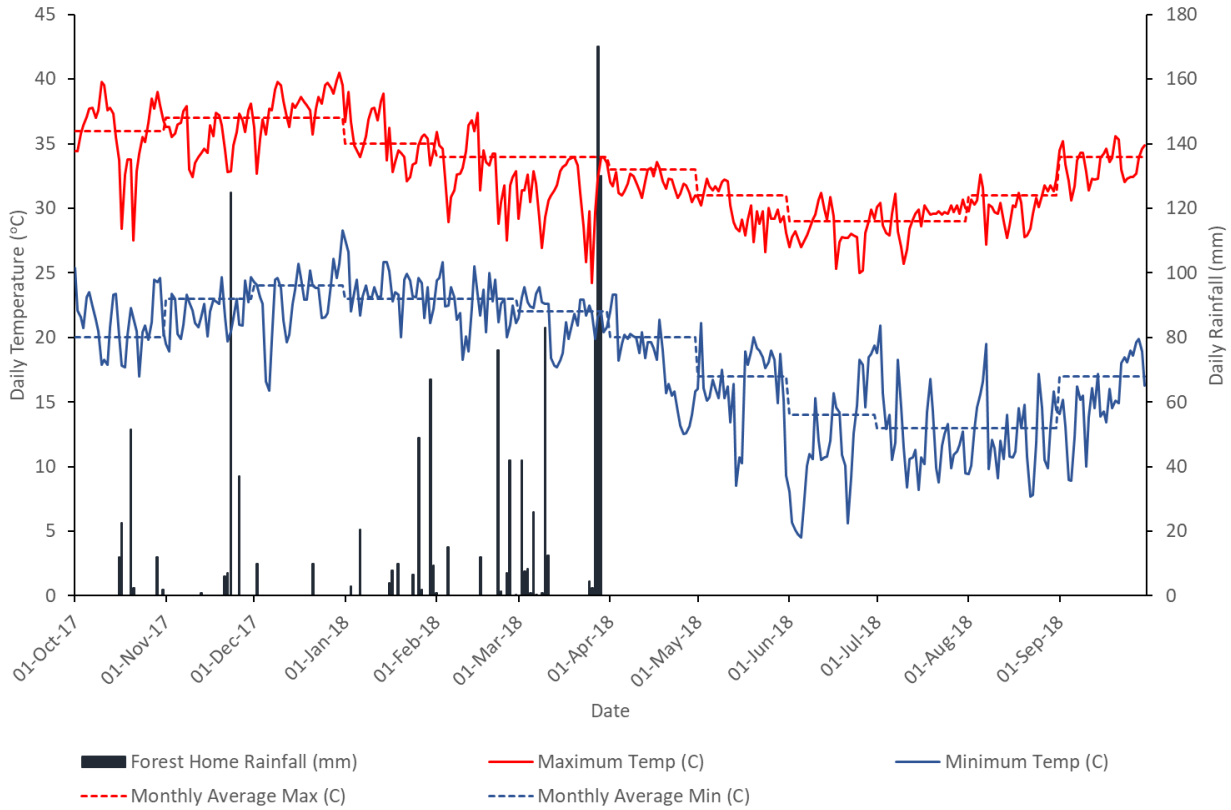




Photo 3: Irrigation being applied to cotton trial on 11 January 2018

2018-19

The 2018-19 year was a below average rainfall year. Figure 3 shows the daily weather data recorded (rainfall and temperature) at the trial site. Maximum and minimum temperatures were generally around the 30-year average throughout the trial period (22 January 2019 to 3 July 2019). A cool period at the end of January 2019 and into early February 2019 coincided with significant rainfall event (a total of 261 mm – 59 percent of the total in-crop rainfall received). This rainfall event was the result of Tropical Low 13U responsible for the long-lived monsoon event resulting in unprecedented rainfall and flooding in parts of north-western Queensland and Townsville in late January and early February 2019.

Figure 4 Seasonal conditions (rainfall and temperature) at Forest Home Research Site 2018-19

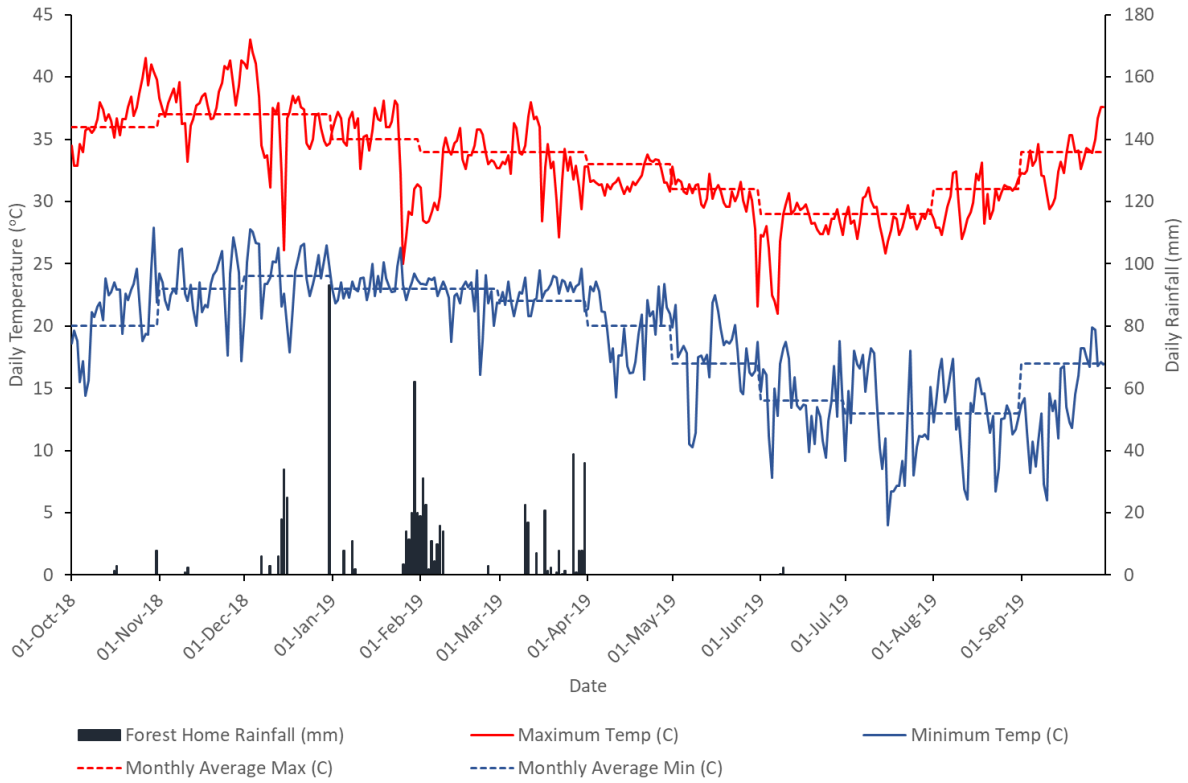




Photo 4: Sesame trial at Forest Home Station on 28 March 2019

2019-20

The 2019-20 year was another below average rainfall year. Figure 4 shows the daily weather data recorded (rainfall and temperature) at the trial site. Poor early seasonal conditions delayed site preparation and planting of the trials until the 19 February 2020 following late January - early February rainfall. Maximum and minimum temperatures were generally around the 30-year average throughout the trial period (19 February 2020 to 5 August 2020). Very cool conditions in the week starting the 23 May 2020 coincided with the last rainfall event for the 2019-20 year. Most rainfall events were infrequent and small. The most significant rainfall in crop occurred in the week following the initial planting of the soybeans and cotton (111 mm – 51 percent of in crop rainfall) and a further 44.5mm falling in the second week of March 2020 following planting of the mungbean trial and replanted soybeans.

Figure 5 Seasonal conditions (rainfall and temperature) at Forest Home Research Site 2019-20

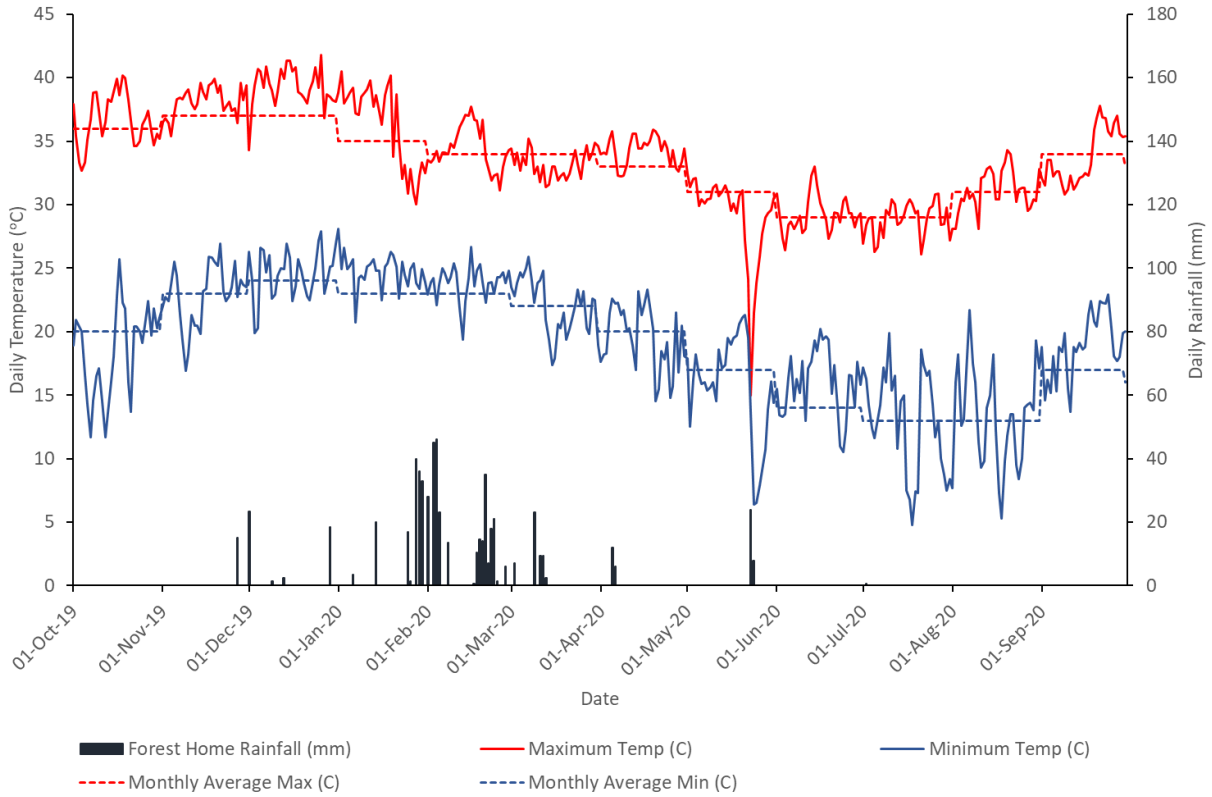




Photo 5: Furrows being installed at trial site on 19 February 2020

2020-21

The 2020-21 year was an above average rainfall year. Figure 5 shows the daily weather data recorded (rainfall and temperature) at the trial site. Good rainfall in December 2020 enabled planting of the early-sowing sesame trial. Further good rainfall in January 2021 enabled earlier planting of the cotton and soybean trials compared with the delayed planting in the 2019-20 season. It also enabled planting of the second sesame trial on the 21 January 2021. Good rainfall in February 2021 benefitted the cotton and soybean trial (it preceded the planting of the mungbean trial on the 3 March 2021).

Maximum and minimum temperatures were generally around the 30-year average throughout the trial period (16 December 2020 and 14 July 2021). Cooler maximum temperatures coincided with the three significant rainfall events during the season.

Figure 6 Seasonal conditions (rainfall and temperature) at Forest Home Research Site 2020-21

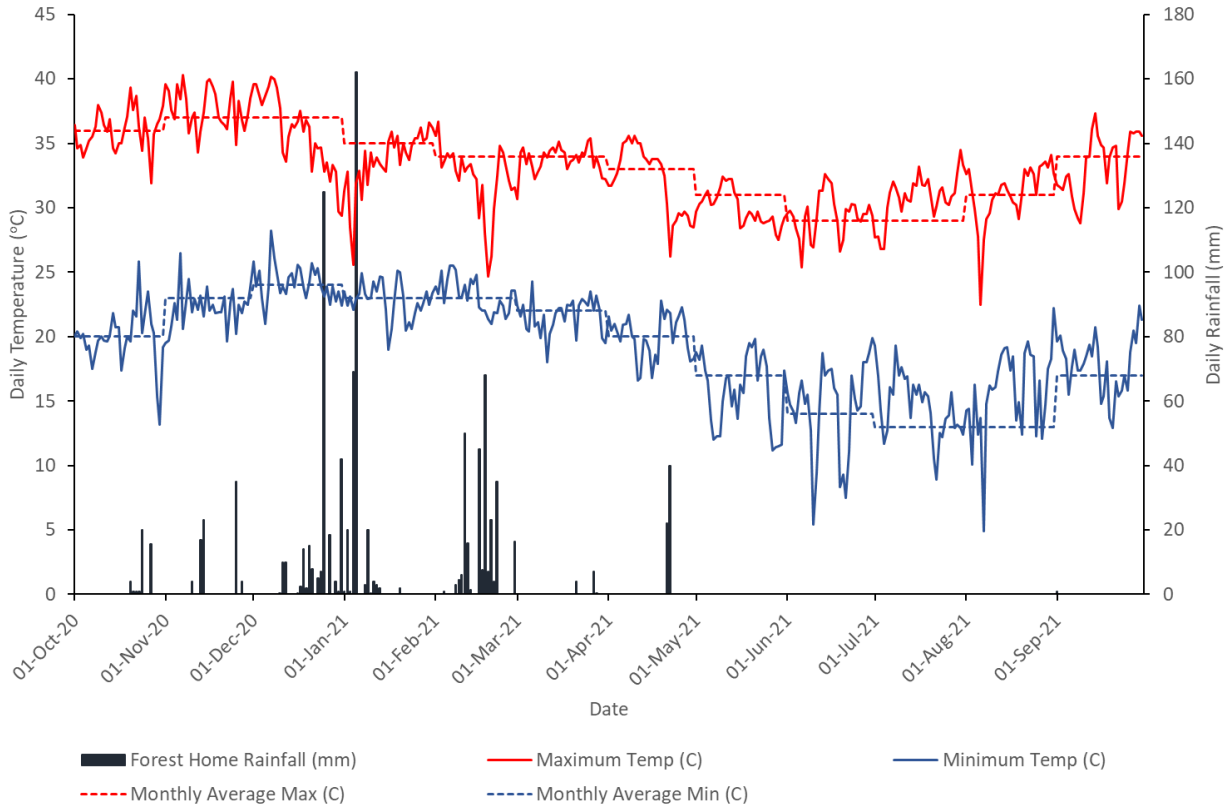




Photo 6: Forest Home Trial Site on 4 March 2021

2021-22

The 2021-22 year was an average rainfall year, with above average rainfall in the November to January period. February and March 2022 were drier than average, but good April 2022 rainfall benefited the mungbean trial.

Maximum temperatures in February 2021 were below the 30-year average coinciding with rainfall events. Higher than average maximums were recorded in April 2021.

Figure 7 Seasonal conditions (rainfall and temperature) at Forest Home Research Site 2021-22

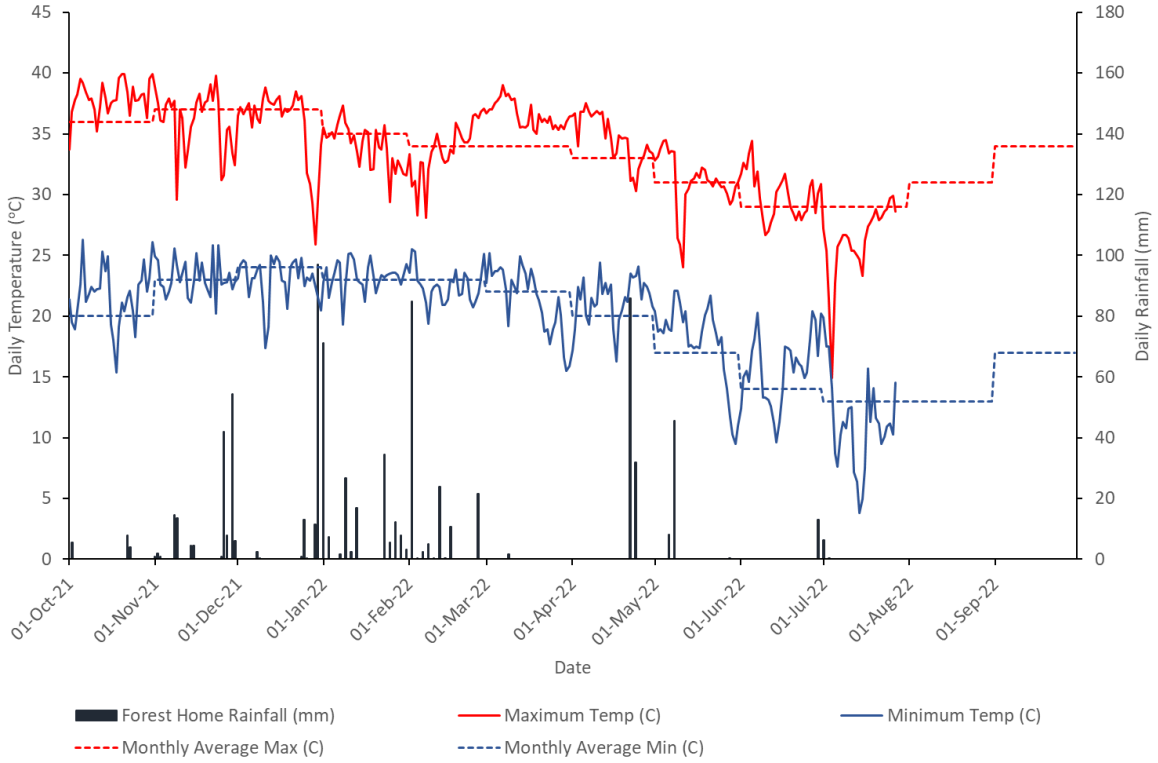




Photo 7: Forest Home replicated trial sit on 8 March 2022

Cotton Research

Research Question/s

In 2013 CSIRO completed, for the Australian Government, an investigation of opportunities for water and agricultural development within the Flinders and Gilbert catchments of north Queensland. This study identified sites within the Gilbert catchment for large instream dams capable of supporting 20,000 to 30,000 ha of irrigated cropping in 85% of years. The study reported that the precise area under irrigation would, in any one year, vary depending upon factors such as irrigation efficiency, water availability, crop choice and risk appetite. Raingrown cropping production is sensitive to the very high year-to-year variability of rainfall in the Gilbert catchment. Break-even yields of most crops can be achieved only two or three years in ten. However, it is expected that dryland cropping is likely to be a component of irrigation development within the region.

A key issue limiting investment in cropping systems within the Gilbert catchment is an understanding of the yield variability (and hence risk profile) and profitability of crops that could be grown within existing extensive grazing systems. There is limited knowledge and experience amongst landholders and the agribusiness sector with the agronomy of potential broadacre crops within the region.

Cotton is potentially a high returning crop within both irrigated and raingrown cropping systems. The project team between 2018 and 2021 assessed yield and growth characteristics of four commercial Bollgard®3 cotton varieties (chosen in consultation with Cotton Seed Distributors) under irrigated production. This assessment included fibre characteristics with the support of CSIRO. In addition, they investigated the impact of growth regulant applications on crop performance in this environment, and also compared raingrown and irrigated production.

Results

Table 5 summarises the cotton trial agronomy applied to the Forest Home trial site in the assessment years. Three varieties (Sicot 714B3F, Sicot 746B3F, Sicot 748B3F) where planted in each year in an irrigated replicated trial. In 2021 a fourth variety was included (Sicot 606B3F). In this year irrigated and raingrown treatments were applied to the trial.

Tables 6 and 7 summarise the yield and lint quality impacts on cotton varieties grown under irrigation across the four years of the trials. Cotton lint yields differed between varieties in 2018 and again in 2021. There were no differences in yields between varieties in 2019 and 2020. Yields obtained varies with seasonal conditions and irrigation applied. Yields in excess of 10 bales/ha were obtained in all but the 2020 season which had the lowest in-crop rainfall received and was the latest planted trial owing to seasonal conditions.



Photo 8: Irrigated cotton trial on 16 April 2020

Table 5 Cotton trial agronomy at Forest Home Station – 2018, 2019, 2020 and 2021

Year	2018	2019	2020	2021
Varieties	Sicot 714B3F Sicot 746B3F Sicot 748B3F	Sicot 714B3F Sicot 746B3F Sicot 748B3F	Sicot 714B3F Sicot 746B3F Sicot 748B3F	Sicot 714B3F Sicot 746B3F Sicot 748B3F Sicot 606B3F
Nutrients Applied	104 kg N/ha 26 kg P/ha 83 kg K/ha	95 kg N/ha 9 kg P/ha 62 kg K/ha	162 kg N/ha 98 kg P/ha 35 kg K/ha	105 kg N/ha 80kg P/ha
Planting Date	10 January 2018	22 January 2019	20 February 2020	27 January 2021
Harvest Date	18 June 2018	3 July 2019	5 August 2020	14 July 2021
Season length (days)	159	162	152	168
In-crop Rainfall (mm)	301	243	205	362
Irrigation Applied (mm)	135	257	476	343
Herbicide	2 x glyphosate	2 x glyphosate	1 x glyphosate	4 x glyphosate
Insecticide	1 x methomyl 1 x dimethoate	3 x dimethoate	3 x dimethoate	
Growth Regulant (mepiquat chloride)		0.50L/ha (58 das) 0.70L/ha (79 das)	0.25L/ha (34 das) 0.50L/ha (56 das) 0.70L/ha (69 das)	0.25L/ha (21 das) 0.25L/ha (42 das) 0.25L/ha (63 das)



Photo 9: Irrigated cotton trial on 16 April 2020

Table 6 Crop development, yield and lint quality characteristics for irrigated cotton varieties– 2018 and 2019

Year	2018			2019		
Variety	714B3F	746B3F	748B3F	714B3F	746B3F	748B3F
Plants/m	8.4 a	8.8 a	9.4 a	10.3 a	9.4 ab	8.3 b
Height (cm)	126 a	131 a	134 a	139 a	121 b	129 ab
Nodes (no.)	21.2 a	20.9 ab	22.9 b	23 a	22.3 ab	21.9 b
Yield (b/ha)	11.1a	10.4 ab	8.7 b	10.0 a	11.2 a	10.7 a
Lint %	45.5 a	47.5 b	44.7 a	40.9	41.6	43.6
Micronaire	4.6 a	4.4 b	4.3 b	4.3 a	3.8 b	4.0 b
Fibre length (in)	1.18 a	1.21 ab	1.26 b	1.23 a	1.28 a	1.28 a
Short fibre index	6.2 a	6.1 a	5.9 a	5.6 a	5.2 a	5.2 a
Strength (g/tex)	29.5 a	31.4 b	31.9 b	30.5 a	32.2 b	31.7 b

Means followed by the same letter in each row in each year are not significantly different at P ≤ 0.05

Table 7 Crop development, yield and lint quality characteristics for irrigated cotton varieties – 2020 and 2021

Year	2020			2021			
Variety	714B3F	746B3F	748B3F	714B3F	746B3F	748B3F	606B3F
Plants/m	12.4 a	13.1 a	12.6 a	7.2a	6.7a	8.3a	8.2a
Height (cm)	109 a	92 b	105 ab	90 ab	80 b	95 ab	99 a
Nodes (no.)	16.0 a	14.6 b	16.0 a	16.1a	17.0 a	17.4 a	16.1 a
Yield (b/ha)	7.9 a	9.0 a	8.5 a	10.9	9.2	9.5	11.1
Lint %	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Micronaire	4.4 a	4.0 b	4.3 a	n/a	n/a	n/a	n/a
Fibre length (in)	1.23 a	1.28 a	1.25 a	n/a	n/a	n/a	n/a
Short fibre index	5.4 a	5.2 a	6.1 a	n/a	n/a	n/a	n/a
Strength (g/tex)	30.4 a	30.2 a	29.3 a	n/a	n/a	n/a	n/a

Means followed by the same letter in each row in each year are not significantly different at P ≤ 0.05

In 2019 and 2020 treatments compared nil application of growth regulant were compared with growth regulant use, across the three varieties ((Sicot 714B3F, Sicot 746B3F, Sicot 748B3F). The purpose of this was to investigate the impact of growth regulant use in cotton in this environment. Tables 8 and 9 summarise the results of growth regulant use in 2019 and 2020.

Table 8 Crop development, yield and lint quality for growth regulant use on irrigated cotton varieties– 2019

Regulant	With			Without		
Variety	714B3F	746B3F	748B3F	714B3F	746B3F	748B3F
Plants/m	10.3	9.4	8.3	11.7	8.8	9.5
Height (cm)	139	121	129	155	154	170
Nodes (no.)	23.0	22.3	21.9	23.3	24.8	25.1
Yield (b/ha)	10.0	11.2	10.7	9.5	10.7	10.1
Lint %	40.9	41.6	43.6	43.4	44.9	42.0
Micronaire	4.3	3.8	4.0	4.1	4.1	4.3
Fibre length (in)	1.20	1.22	1.26	1.23	1.28	1.25
Short fibre index	6.5	6.6	5.8	5.6	5.2	5.2
Strength (g/tex)	30.8	30.5	31.0	30.5	32.2	31.7

Table 9 Crop development, yield and lint quality for growth regulant use on irrigated cotton varieties – 2020

Regulant	With			Without		
Variety	714B3F	746B3F	748B3F	714B3F	746B3F	748B3F
Plants/m	13.2	12.7	13.2	12.2	15.3	11.8
Height (cm)	122	89	101	107	95	108
Nodes (no.)	15.8	14.3	15.5	16.3	14.9	16.5
Yield (b/ha)	7.9	9.0	8.5	8.1	7.6	8.5
Lint %	na	na	na	na	na	na
Micronaire	4.4	4.0	4.3	4.1	4.0	4.1
Fibre length (in)	1.23	1.28	1.25	1.25	1.23	1.28
Short fibre index	5.4	5.2	6.1	4.6	6.5	5.0
Strength (g/tex)	30.4	30.2	29.3	30.0	29.4	30.4

In 2019 the use of growth regulant reduced the height of cotton but there was little apparent yield benefit and no impact on fibre quality. It is possible that the regulant treatments were applied too late to produce significant differences. In 2020 the regulant treatments produced no obvious benefits over non-regulant cotton. This was a difficult year with the cotton planted later than desired. Clearly further research is needed to develop an appropriate strategy for the use of growth regulant in this environment.

In 2021 a comparison of raingrown cotton with irrigated cotton was implemented – the aim was to assess the likely impact of irrigation on both yield and quality. The results of this one-year comparison are presented in Table 10.

Table 10 Crop development, yield and lint quality of cotton under irrigated and raingrown conditions - 2021

	Irrigated				Raingrown			
Variety	714 B3F	746 B3F	748 B3F	606 B3F	714 B3F	746 B3F	748 B3F	606 B3F
Plants/m	7.2	6.7	8.3	8.2	6.7	6.7	10.4	8.3
Height (cm)	90.4	80.4	95.1	98.5	83.7	72.7	84.7	82.7
Nodes (no.)	16.1	17	17.4	16.1	17.0	15.6	15.9	14.5
Yield (b/ha)	10.9	9.2	9.5	11.1	9.0	8.2	10.1	11.3

As 2021 was a wetter than average year the yield differences between irrigated and non-irrigated crops was fairly small – in fact the yields for two of the varieties (746B3F and 606B3F) were similar for both irrigated and raingrown treatments. Clearly in wetter years raingrown cotton could be a profitable cropping option in this environment.

The APSIM (Agricultural Production Systems sIMulator) model was used to compare research results obtained over the four years of cotton trials with those generated by the model. The aim was to check its potential use for modelling crops within this region with cropping systems. The results of the APSIM analysis for cotton are presented in Table 11.

Table 11 APSIM output comparison for irrigated cotton research site results – 2018 to 2021

	2018		2019		2020		2021	
Attribute	Trial	APSIM	Trial	APSIM	Trial	APSIM	Trial	APSIM
Yield (b/ha)	8.7 to 11.1	7.2	10 to 11.2	7.4	7.9 to 9.0	8.9	10.9 to 11.1	10.2
Crop Ht (cm)	126 to 134	117	121 to 139	94	89 to 122	118	80 to 99	117
Plants/m	8 to 9	9	8 to 10	9.3	13	13	7 to 8	8

The data in Table 11 suggests the APSIM cotton model produced inconsistent yield estimates compared with the actual yields from trials over the 2018 to 2021 years. In 2018 and 2019 APSIM under-estimated the yields obtained from actual trials grown. In 2020 APSIM over-estimated cotton yields. The 2021 APSIM yield was slightly less than that from trials grown. At this time, it appears that the APSIM 7.10 cotton model cannot be used to examine cotton performance in this northern environment with any confidence.

Discussion

Crop establishment in all years and for all varieties met or exceeded the desirable established plant population considered for optimal yields of 8-12 plants per metre for fully irrigated conditions (Quinn and Petty, 2019).

There were no significant differences in crop height between varieties in any one year. Growth regulant was applied in the second and third season to manage crop growth. Although more and earlier growth regulant was applied in 2020 its impact on crop growth may be confounded by the delayed planting (due to the late wet season break) and the poorer seasonal rainfall conditions that year. This is reflected in the lower node counts in 2020 and the subsequent lower yields achieved.

The yields achieved in 2018 (8.7 to 11.1 bales/ha), 2019 (10 to 11.2 bales/ha) and 2021 (9.2 to 11.1 bales/ha) are respectable. The varieties 714B3F and 746B3F produced the highest yields in 2018 where there was significant rainfall from planting until the end of March 2018 (when 387mm of rain associated with ex-tropical cyclone Nora fell) and little irrigation was applied. In 2019 yields were similar across varieties (ranging from 10 to 11.2 bales/ha). In this year there was 438mm of in-crop rainfall falling from after planting through to the end of March 2019 – all in falls of less than 40mm. In that year 250mm of irrigation was applied. The 2021 yields were also similar across varieties (ranging from 9.2 to 11.1 bales/ha). In this year there was 362mm of in-crop rainfall and 243mm of irrigation applied.

The yields achieved in 2020 were lower than those of the previous two years and in 2021. In 2020 the wet season break did not eventuate until mid-January 2020. This delayed ground preparation at a new trial site and limited pre-plant management of weeds. This delayed planting until the 20 February 2020. This planting delay and the dry seasonal conditions (a total of 205mm of in-crop rain) is most likely responsible for the poorer yields that year (ranging from 7.9 to 9.0 bales/ha).

The fibre characteristics of varieties were assessed in 2018, 2019 and 2020. Results for the quality assessments for 2021 season have not yet been supplied by CSIRO. The assessments indicated:

- Gin turnouts were similar to or exceeded the relative gin turnouts expected for these varieties (Sicot 714B3F of 42%, Sicot 746B3F of 45% and Sicot 748B3F of 44%) in 2018 and 2019 (data not available for 2020)
- Micronaire values were within the optimal range between 3.8 and 4.5 for all varieties and in all years.
- Fibre length exceeded the desired upper half mean length of 1.125 inch or 36/32nds for all varieties and years
- Short fibre index measures the proportion by weight of fibre shorter than 0.5 inch or 12.7 mm. Ideally this should be below 8 %. All varieties and years produced less than this quantity of short fibre.
- The fibre strength is defined as the breaking force required for a bundle of fibres of a given weight and fineness. Ideally this should exceed 29 grams/tex. Fibre strength exceeded this level in all varieties in all years.

Mungbean Research

Research Question/s

In 2013 CSIRO completed, for the Australian Government, an investigation of opportunities for water and agricultural development within the Flinders and Gilbert catchments of north Queensland. This study identified sites within the Gilbert catchment for large instream dams capable of supporting 20,000 to 30,000 ha of irrigated cropping in 85% of years. The study reported that the precise area under irrigation would, in any one year, vary depending upon factors such as irrigation efficiency, water availability, crop choice and risk appetite. Raingrown cropping production is sensitive to the very high year-to-year variability of rainfall in the Gilbert catchment. Break-even yields of most crops can be achieved only two or three years in ten. However, it is expected that dryland cropping is likely to be a component of irrigation development within the region.

A key issue limiting investment in cropping systems within the Gilbert catchment is an understanding of the yield variability (and hence risk profile) and profitability of crops that could be grown within existing extensive grazing systems. There is limited knowledge and experience amongst landholders and the agribusiness sector with the agronomy of potential broadacre crops within the region.

A sustainable cropping system cannot rely upon a single crop. Reliance on a single crop places the profitability of a farming enterprise at risk owing to biotic impacts and market vagaries. There are a range of possible crop choices that could be included within an irrigated and raingrown cropping system within the Gilbert catchment. One of these crops includes mungbeans which are a short-season pulse crop with potentially high returns. The project team between 2018 and 2022 assessed yield and growth characteristics of several commercially available mungbean varieties under irrigated production. In 2019 the performance of several advanced mungbean lines (provided by DAF and AgriVentis Technologies) were also assessed under irrigation. In 2021 and 2022 the project team also evaluated the performance of commercially available mungbean varieties under irrigated and raingrown systems.

Results

Table 12 summarises the mungbean trial agronomy applied to the Forest Home trial site in the assessment years. Commercially available mungbean varieties were planted in 2018, 2020, 2021 and 2022 seasons. The varieties planted were:

- Crystal (2018 and 2020)
- CeleraII-AU (2021 and 2022)
- Jade-AU (2018, 2020, 2021 and 2022)
- Opal -AU (2021 and 2022)

In 2021 and 2022 the black gram variety Onyx-AU was also included in the trials.

In 2019 six mungbean lines were evaluated in an irrigated replicated trial – DAF lines M11236 and M12036, and the Agriventis lines AVYMB1, AVYMB2, AVYMB3 and AVYMB4.

The trials in 2021 and 2022 included irrigated and raingrown treatments.



Photo 10: Irrigated mungbean trial at original trial site on 28 March 2019

Table 12 Mungbean trial agronomy – 2018, 2019, 2020, 2021 and 2022

Year	2018	2019	2020	2021	2022
Varieties	Crystal Jade	M11236 M12036 AVYMB1 AVYMB2 AVYMB3 AVYMB4	Crystal Jade	Celera Jade Opal Onyx	Celera Jade Opal Onyx
Nutrients Applied	104 kg N/ha 26 kg P/ha 83 kg K/ha 71 kg S/ha 78 kg Ca/ha	9 kg P/ha 62 kg K/ha 38 kg S/ha 97 kg Ca/ha	9 kg P/ha 11 kg S/ha 19 kg Ca/ha	9 kg P/ha 11 kg S/ha 19 kg Ca/ha	18 kg N/ha 20 kg P/ha 41 kg K/ha 33 kg S/ha 17 kg Ca/ha
Planting Date	13 Mar 2018	26 Feb 2019	4 Mar 2020	3 Mar 2021	8 Feb 2022
Harvest Date	30 May 2018	23 May 2019	2 Jun 2020	13 May 2021	20 Apr 2022
Season length (days)	78	86	90	71	71
In-crop Rainfall (mm)	387	174	95	74	63
Irrigation Applied (mm)	50	218	220	131	297
Herbicide	2 x glyphosate 1 x Vezir 3 x Blazer 2 x Verdict	1 x glyphosate 1 x Vezir 1 x Blazer 1 x Verdict	1 x glyphosate 1 x Vezir 1 x Verdict	4 x glyphosate 1 x trifluralin 1 x Verdict	4 x glyphosate 1 x trifluralin 2 x Verdict
Insecticide	3 x methomyl 3 x dimethoate 1 x Altacor	1 x methomyl 3 x dimethoate 2 x Altacor	3 x dimethoate 1 x Altacor	1 x methomyl 3 x dimethoate 3 x Altacor	1 x dimethoate 2 x Altacor
Defoliation			1 x glyphosate	2 x glyphosate	

Tables 13 and 14 summarise the yield and plant physiology for the mungbean and black gram lines and varieties grown under irrigation across the five years of the trials. Yields obtained varies with seasonal conditions and irrigation applied.

Table 13 Crop development and yield for irrigated mungbean varieties/lines – 2018 and 2019

Year	2018		2019					
Variety	Crystal	Jade	M11236	M12036	AVYMB1	AVYMB2	AVYMB3	AVYMB4
Plants/m^2	27	28.5	34	28	20	25	26	27
Height (cm)	63a	59a	90	90	79	86	85	85
Nodes (no.)	10.1a	9.9a	na	na	na	na	na	na
Yield (t/ha)	2.6a	2.6a	1.7	1.4	1.8	2.1	2.4	2.4

Means followed by the same letter in each row in each year are not significantly different at P ≤ 0.05

Table 14 Crop development and yield for irrigated mungbean varieties/lines – 2018 to 2022

Year	2020		2021				2022			
Variety	Crystal	Jade	Celera	Jade	Opal	Onyx	Celera	Jade	Opal	Onyx
Plants/m^2	20a	21a	45a	17c	29b	31b	na	na	na	na
Height (cm)	60a	54b	93a	88a	89a	69b	64	64	61	58
Nodes (no.)	9.4a	8.5b	na	na	na	na	na	na	na	na
Yield (t/ha)	1.3a	1.2a	1.2a	1.9a	1.1b	1.7ab	1.4	1.8	0.9	0.4

Means followed by the same letter in each row in each year are not significantly different at P ≤ 0.05

Table 15 Crop development and yield of mungbeans/black gram under irrigated and raingrown conditions - 2021

	Irrigated				Raingrown			
Variety	Celera	Jade	Opal	Onyx	Celera	Jade	Opal	Onyx
Plants/m^2	45.4a	17.4c	29.1b	30.7b	49a	26b	26b	32b
Height (cm)	93a	88a	89a	69b	55ab	60a	62a	42b
Yield (t/ha)	1.16a	1.87b	1.11a	1.71ab	0.53a	1.01a	0.67a	0.83a

Table 16 Crop development and yield of mungbeans/black gram under irrigated and raingrown conditions - 2022

	Irrigated				Raingrown			
Variety	Celera	Jade	Opal	Onyx	Celera	Jade	Opal	Onyx
Plants/m^2	na	na	na	na	na	na	na	na
Height (cm)	648	64	61	58	48	41	50	40
Yield (t/ha)	1.44	1.83	0.87	0.4	0.75	0.45	0.38	0.29

Mungbeans appear well adapted to this district with irrigated yields up to 2.6 t/ha achieved in the best seasons (2018). Even in the drier 2019 year yields up to 2.4 t/ha were achieved – note the rainfall in March 2019 particularly benefitted the mungbean trial in that year. Less favourable conditions in 2020 and 2021 resulted in lower mungbean yields – in order of 1.9 t/ha and 1.8 t/ha for Jade in those years respectively.

Across the years of these trials the variety Jade-AU performed well compared with all other varieties trialled. It performed similarly to Crystal in 2018 and 2019, and significantly out-performed Celera in 2021 and 2022. The variety Opal-AU performed poorly relative to Jade-AU. This is not surprising given it is best adapted to the Eastern Darling Downs and NSW when compared with Jade-AU (where it has a yield advantage over Jade-AU). It was generally shorter in height than Jade-AU.

Insect pressure was a significant feature of the trials across all years. This necessitated between 3 and 7 applications of insecticides annually across the 5 years of trials. The major insect pests were cluster caterpillar and sucking bugs. In 2022 a significant amount of legume little leaf (caused by a phytoplasma spread by brown leaf hoppers) occurred in the mungbean trial and prevented late flowers developing into pods.

The black gram variety Onyx performed best in 2021. It is a shorter plant than the mungbean varieties – making it less competitive with weed competition and more difficult to harvest. It yielded like Jade in 2021 but much less in 2022.

The irrigated and raingrown comparisons in 2021 and 2022 clearly demonstrated the value of irrigation in this district – resulting in improved yields in both the above average rainfall 2021 and average rainfall 2022 year.

The APSIM (Agricultural Production Systems sIMulator) model was used to compare research results obtained over the five years of mungbean trials with those generated by the model. The aim was to check its potential use for modelling crops within this region with cropping systems. The results of the APSIM analysis for mungbean are presented in Tables 17 and 18.

Table 17 APSIM output comparison for irrigated mungbean with research site results – 2018 to 2021

	2018		2019		2020		2021		2022	
Attribute	Trial	APSIM	Trial	APSIM	Trial	APSIM	Trial	APSIM	Trial	APSIM
Yield (t/ha)	2.55	0.8	2.39	0.5	1.18	0.59	1.87	0.45	1.83	1.06
Crop Ht (cm)	59	38	83	24	54	38	88	35	64	76
Plants/m2	28.5	28.5	27	27	21.3	21.3	17.4	17.4	na	20

Results for Jade used in all years except 2019 – it that year results for AVYMB4 used

Table 18 APSIM output comparison for raingrown mungbean at research site – 2021 and 2022

	2021		2022	
Attribute	Trial	APSIM	Trial	APSIM
Yield (t/ha)	1.01	0.6	0.45	0.87
Crop Ht (cm)	60	31	41	87
Plants/m2	26	26	na	20

Results for Jade used in both years

Discussion

Crop establishment in all years and for all varieties were generally in the optimal range of 20 to 30 plants/m2 for raingrown crops. This did not seem to impact crop performance under irrigation. Where higher populations were achieved the crop was more prone to lodging issues. The later planting of mungbeans compared with soybeans (owing to the short crop length) seemed to benefit crop establishment.

There were no significant differences in crop height between mungbean varieties in any one year. Where better rainfall occurred the mungbean crops tended to grow taller and were more prone to lodging. The black gram Onyx was significantly shorter than the mungbean varieties – this and its lower yield potential suggests this crop is not as well suited to this region as mungbean.

The yields achieved by the best mungbean varieties suggest this crop is well adapted to the region. Yields ranged from 1.3 to 2.6 t/ha for the best varieties, with the best yields in the wetter years and poorer yields in the drier seasons. The benefits of irrigation were clearly evident in 2021 and 2022 where irrigated yields of Jade-AU exceeded raingrown yields by 46 percent in 2021, and there was a threefold yield improvement in 2022.

The data in Table 17 suggests the APSIM mungbean model under-estimates actual irrigated mungbean yields across all years. It tends to under-estimate crop height except in 2022. The data for raingrown mungbeans shows APSIM under-estimated yields in 2021 but over-estimated these in 2022 (Table 18). At this time it appears that the APSIM 7.10 mungbean model cannot be used to examine mungbean performance in this northern environment with any confidence.



Photo 11: Irrigated mungbeans on replicated trial site on 16 April 2020

Sesame Research

Research Question/s

In 2013 CSIRO completed, for the Australian Government, an investigation of opportunities for water and agricultural development within the Flinders and Gilbert catchments of north Queensland. This study identified sites within the Gilbert catchment for large instream dams capable of supporting 20,000 to 30,000 ha of irrigated cropping in 85% of years. The study reported that the precise area under irrigation would, in any one year, vary depending upon factors such as irrigation efficiency, water availability, crop choice and risk appetite. Raingrown cropping production is sensitive to the very high year-to-year variability of rainfall in the Gilbert catchment. Break-even yields of most crops can be achieved only two or three years in ten. However, it is expected that dryland cropping is likely to be a component of irrigation development within the region.

A key issue limiting investment in cropping systems within the Gilbert catchment is an understanding of the yield variability (and hence risk profile) and profitability of crops that could be grown within existing extensive grazing systems. There is limited knowledge and experience amongst landholders and the agribusiness sector with the agronomy of potential broadacre crops within the region.

A sustainable cropping system cannot rely upon a single crop. Reliance on a single crop places the profitability of a farming enterprise at risk owing to biotic impacts and market vagaries. There are a range of possible crop choices that could be included within an irrigated and raingrown cropping system within the Gilbert catchment. One such crop currently under consideration more broadly within northern Australia is sesame. Sesame is a small-seeded oilseed crop well adapted to the semi-arid tropics. It is high value (around $1,200/t for white seeded varieties and up to $1,800/t for black-seeded lines).



Photo 12: Sesame trial at original Forest Home trial site on 28 March 2019

Results

Table 19 summarises the agronomy of sesame trials conducted at the Forest Home Research Site from 2018 until 2022. In 2018 four white-seeded lines supplied by Equinom were planted in a replicated trial to assess the performance of sesame. In 2019 and 2020 four sesame lines (two white seeded supplied by Equinom and two black-seeded varieties supplied by Agriventis) were planted in replicated trials. In 2020 two sowing dates were used to assess impact on crop performance.

Having identified early weed competition as a significant agronomic issue for successful crop performance, the 2021 and 2022 seasons were used to assess the field performance of potential herbicide options to manage weed competition. In 2021 three herbicide combinations and a control were assessed using two planting dates with four sesame lines (two white seeded and two black seeded). In 2022 three herbicide options, together with a control and a hand-weeded treatment were evaluated in a replicated trial with a white and black sesame line.

Table 19 Sesame trial agronomy – 2018, 2019, 2020, 2021 and 2022

Year	2018	2019	2020	2021	2022
Varieties	6821	6855	6825	6855	Equinom White
	6824	6858	6855	6859	Equinom Black
	6825	Black Patch	Black Patch	Equinom Black	
	6835	Moriah Black	Moriah Black	Moriah Black	
Nutrients Applied	104 kg N/ha	95 kg N/ha	145 kg N/ha	145 kg N/ha	125 kg N/ha
	26 kg P/ha	9 kg P/ha	35 kg P/ha	35 kg P/ha	40 kg P/ha
	83 kg K/ha	62 kg K/ha			41 kg K/ha
	71 kg S/ha	86 kg S/ha	80 kg S/ha	80 kg S/ha	45 kg S/ha
	78 kg Ca/ha	97 kg Ca/ha	76 kg Ca/ha	76 kg Ca/ha	
Planting Date	10 Jan 2018	23 Jan 2019	13 Feb 2020	16 Dec 2020	8 Feb 2022
			3 Mar 2020	21 Jan 2021	
Harvest Date	3 May 2018	6 Jun 2019	8 Jun 2020	na	n.a.
			24 Jun 2020		
Season length (days)	113	134	116	na	n.a
			113		
In-crop Rainfall (mm)	880	438	230	na	n.a
			95		
Irrigation Applied (mm)	82	100	243	na	0
Herbicide	2 x glyphosate	1 x glyphosate	1 x diuron	4 x glyphosate	4 x glyphosate
	1 x Diuron	1 x Verdict	2 x Verdict		1 x trifluralin
	1 x Verdict	1 x Diuron			2 x Verdict
Insecticide	4 x methomyl	2 x dimethoate	2 x dimethoate	2 x methomyl	1 x dimethoate
	2 x Altacor	2 x Altacor	2 x Altacor	3 x dimethoate	2 x Altacor
				4 x Altacor	

Table 20 summarises the crop development and yield performance of the sesame lines evaluated in 2018 and 2019. The optimal plant population for high yields and effective weed competition is 30 plants/m^2. This was achieved in 2018 for all lines but was sub-optimal for three of the four lines planted in 2019. The black seeded lines tended to be taller than white seeded types. There were no statistical yield differences (all hand-harvested) between lines in either year – with yields averaging 1.87 t/ha in the wet 2018 and 2.38 t/ha in the drier 2019 season.

Table 20 Crop development and yield for irrigated sesame lines – 2018 and 2019

Year	2018						2019	
Line	6821	6824	6825	6835	6855	6858	Black Patch	Moriah Black
Plants/m^2	35a	40a	37a	41a	26	18	22	58
First pod height (cm)	49a	48a	52a	57a	40	29	64	76
Height (cm)	130a	129a	122a	110b	103	106	153	161
Yield (t/ha)	2.01a	1.87a	1.83a	1.77a	2.3a	2.6a	2.2a	2.4a

Means followed by the same letter in each row in each year are not significantly different at P ≤ 0.05

Table 21 summarises the crop development of four sesame lines planted at different planting dates in the 2020 season. Originally the plan was to plant at three planting times but the failure of early wet season rainfall delayed site preparation and weed control. Both sesame plantings - 13 February 2020 (TOS2) and 3 March 2020 (TOS03) were outside the optimal planting period (mid-December to January). There were issues with crop establishment also (indicated by the sub=optimal plant population). This exacerbated weed control issues due to poor crop competition. Again, the black seeded lines grew taller and set their first pods higher than the white seeded lines. No useful yield was produced by these crops.

Table 21 Crop development for irrigated sesame lines at two planting dates - 2020

Year	2020 (TOS2)				2020 (TOS3)			
Line	6825	6855	Black Patch	Moriah Black	6855	6858	Black Patch	Moriah Black
Plants/m2	5.5	5.8	5	5.5	9	9	14	10
First pod height (cm)	42	44	61	56	na	na	53	57
Height (cm)	70	70	104	95	47	65	108	105
Nodes/plant (no.)	17	11	17	17	7	6	7	7
Yield (t/ha)	na	na	na	na	na	na	na	na

Crop establishment and poor early weed competition have been identified as significant issues for this crop. In 2021 and 2022 it was decided to focus on early weed competition through the assessment of potential herbicide control options. Herbicides were chosen for assessment based on current glasshouse studies being conducted by the DAF Weed Research Team at Leslie Research Facility, Toowoomba.

The weeds present at this site included - nutgrass (*Cyperus rotundus*), black pigweed (*Trianthema portulasastrum*), caltrop (*Tribulus terrestris*), Cavalcade (*Centrosema pascuorum* cv Cavalcade) and several summer growing grass species.

Herbicides assessed in the 2020 trials were:

- Lontrel Advanced Herbicide – registered to control a range of volunteer legume species and broadleaf weeds
- Basagran – a broadleaf weed herbicide registered for use in a range of pulse crops
- Verdict 520 – a grass weed herbicide registered in a range of broadleaf crops

Table 22 White sesame herbicide trial 2021 – planted 16 December 2020

Line	6855				6859			
Treatment	Control	Lontrel Adv	Basagran	Basagran + Verdict	Control	Lontrel Adv	Basagran	Basagran + Verdict
Plant Height (cm)	55	61	57	60	64	72	58	67
Number of Plants/m	15a	18a	14b	6b	23a	16a	9b	11b
Plant stand rating[1]	3.8	3.3	2.8	1.5	3.5	3.3	2.0	2.0
Weed Competition Rating[2]	2.8	2.3	3.0	3.3	2.5	3.0	2.8	3.3
Chemical Damage Rating[3]	1.0	1.3	3.3	3.0	1.0	1.0	4.0	4.3
Clean Seed Wt (g/m)	43.8	56.0	56.0	25.7	62.0	42.3	24.0	52.3

[1] 1 = bare ground; 2 = patches of plants and poor row fill; 3 = gaps, ½ plants and poor row fill; 4 = small gaps and mid row present; 5 = full establishment

[2] 1 = small weed volume and mostly bare ground between sesame; 2 = some bare ground; 3 = weeds covering ground, starting to climb sesame and affect growth; 5 = covering sesame and pulling plants down, seriously impacting sesame

[3] 1 = Nil damage; 5 = whole leaves damaged in target zone of sesame

Table 23 Black sesame herbicide trial 2021 – planted 16 December 2020

	Equinom Black				Moriah Black			
	Control	Lontrel	Basagran	Basagran + Verdict	Control	Lontrel	Basagran	Basagran + Verdict
Plant Height (cm)	71	80	72	76	50	55	56	64
Number of Plants/m	18a	17a	12b	13b	17a	13a	10b	6b
Plant stand rating[1]	4.8	3.0	3.0	3.5	4.0	4.0	2.8	2.0
Weed Competition Rating[2]	1.5	2.0	2.5	2.5	2.0	2.0	1.5	2.8
Chemical Damage Rating[3]	1.5	1.3	3.8	4.8	1.0	1.7	3.0	4.0
Clean Seed Wt (g/m)	50.3	70.7	79.8	78.8	50.8	33.8	48.5	37.7

[1] 1 = bare ground; 2 = patches of plants and poor row fill; 3 = gaps, ½ plants and poor row fill; 4 = small gaps and mid row present; 5 = full establishment

[2] 1 = small weed volume and mostly bare ground between sesame; 2 = some bare ground; 3 = weeds covering ground, starting to climb sesame and affect growth; 5 = covering sesame and pulling plants down, seriously impacting sesame

[3] 1 = Nil damage; 5 = whole leaves damaged in target zone of sesame

Table 24 White sesame herbicide trial 2021 – planted 21 January 2021

Line	6855				6859			
Treatment	Control	Lontrel	Basagran	Basagran + Verdict	Control	Lontrel	Basagran	Basagran + Verdict
Plant Height (cm)	86	81	67	54	79	81	46	43
Chemical Damage Rating[1]	1	1.25	3.25	3	1	4	4	4.25
Clean Seed Wt (g/m)	43.8	56	56	25.6	62	42.3	24	52.3

[1] 1 = Nil damage; 5 = whole leaves damaged in target zone of sesame

Table 25 Black sesame herbicide trial 2021 – planted 21 January 2021

	Equinom Black				Moriah Black			
	Control	Lontrel	Basagran	Basagran + Verdict	Control	Lontrel	Basagran	Basagran + Verdict
Plant Height (cm)	98	69	80	48	88	81	76	50
Chemical Damage Rating[1]	1.5	1.25	3	4.75	1	1.7	3	4
Clean Seed Wt (g/m)	50.3	70.7	79.8	78.8	50.8	33.8	48.5	37.7

[1] 1 = Nil damage; 5 = whole leaves damaged in target zone of sesame

In the 2021 trials a control and three herbicide options (Lontrel. Basagran, Basagran + Verdict) were applied to four sesame lines – the white seeded 6855 and 6859, and the black seeded Equinom Black and Moriah Black. This trial was replicated by two sowing dates (16 December 2020 and 21 January 2021). The results for the 2021 trials are provided in Tables 24 to 25.

In the December 2020 trial the sesame crop established poorly, exacerbating the weed issue by providing little competition with establishing weeds, reflected in the weed competition ratings for this trial. It appears that Basagran severely damages the sesame plants – this was observed in both white seeded and black seeded lines. Lontrel Advanced did not seem to damage the sesame significantly but it's effectiveness on the weed spectrum at this site was limited.

The results for the herbicide trial planted in January 2021 mirrored those from the December 2020 planted trial. The Basagran once again damaged all sesame lines. Lontrel Advanced again did not damage sesame lines but weed control was limited.

In 2022 a further sesame herbicide trial was carried out. Based on the results of the 2021 trials it was decided to evaluate the following herbicides:

- Lontrel Advanced Herbicide – registered to control a range of volunteer legume species and broadleaf weeds
- Verdict 520 – a grass weed herbicide registered in a range of broadleaf crops
- Diuron – registered in a range of crops for both grass and some broadleaf weed control

A control without weed management and one with hand weeding were included in the trial. The trial was planted on the 8 February 2022 with a single white seeded and black seeded varieties planted. Herbiicide treatments were applied to the established sesame on the 9 March 2022. The results of the weed competition and chemical damage assessments are provided in Table 26.

In this trial the herbicides used did not appear to damage either of the sesame varieties. At the same time they did not appear to provide significant weed control for the weed spectrum at this site.

Table 26 Herbicide sesame trial evaluation - 2022

	Equinom White					Equinom Black				
	Control	Hand weeded	Diuron	Lontrel Adv	Lontrel Adv + Verdict	Control	Hand weeded	Diuron	Lontrel Adv	Lontrel Adv + Verdict
Weed Competition Rating[1]	1.75	1.75	1.33	2.25	1.25	1.5	1.25	1.25	1.5	1.5
Chemical Damage Rating[2]	1	1	1	1	1	1	1	1	1	1

[1] 1 = Bare ground under sesame plants; 3 = no visual effects on sesame plants, maybe some competition for water and nutrients; 5 = weeds smothering or pulling down sesame plants

[2] 1 = Nil damage; 5 = whole leaves damaged on target zone of sesame plants

As there is no crop model for sesame within APSIM it was not possible to undertake a similar analysis of the sesame trials to that conducted for the other crops over the five years of trialling. At this time the University of Southern Queensland (UniSQ) is working on development of a sesame model within APSIM. We have shared the results of the five years of sesame trialling with UniSQ to enable validation of the model they are developing.

Discussion

Sesame is a relatively new crop for Australian agriculture. Based on overseas experience and market signals there may well be an opportunity for the development a sesame industry in Northern Australia. The research undertaken at Forest Home Station has clearly identified agronomic issues that need addressing if this development is to be successful. Sesame appears well adapted to the light soils in the Gilbert River catchment. Successful crop establishment remains a challenge as does the poor early competitiveness of the crop with weeds. Experience has shown that sesame is a very poor competitor in its first 35 days after planting so weed management options to assist the crop during this period are needed.



Photo 13: Forest Home sesame trial on 16 April 2020

Soybean Research

Research Question/s

In 2013 CSIRO completed, for the Australian Government, an investigation of opportunities for water and agricultural development within the Flinders and Gilbert catchments of north Queensland. This study identified sites within the Gilbert catchment for large instream dams capable of supporting 20,000 to 30,000 ha of irrigated cropping in 85% of years. The study reported that the precise area under irrigation would, in any one year, vary depending upon factors such as irrigation efficiency, water availability, crop choice and risk appetite. Raingrown cropping production is sensitive to the very high year-to-year variability of rainfall in the Gilbert catchment. Break-even yields of most crops can be achieved only two or three years in ten. However, it is expected that dryland cropping is likely to be a component of irrigation development within the region.

A key issue limiting investment in cropping systems within the Gilbert catchment is an understanding of the yield variability (and hence risk profile) and profitability of crops that could be grown within existing extensive grazing systems. There is limited knowledge and experience amongst landholders and the agribusiness sector with the agronomy of potential broadacre crops within the region.

A sustainable cropping system cannot rely upon a single crop. Reliance on a single crop places the profitability of a farming enterprise at risk owing to biotic impacts and market vagaries. There are a range of possible crop choices that could be included within an irrigated cropping system within the Gilbert catchment.

One of these crops includes soybeans which is a longer season, potentially high yielding pulse crop well adapted to irrigated cropping. The project team between 2018 and 2021 assessed yield and growth characteristics of several commercially available soybean varieties under irrigated production. In 2019 and 2021 the project team compared soybean performance under raingrown and irrigated systems.



Photo 14: Irrigated soybean trial at original trial site on 28 March 2019

Results

Table 27 summarises the agronomy of soybean trials conducted at the Forest Home Research Site from 2018 until 2021. In 2018 two soybean varieties commonly grown in north Queensland (A6785 and Stuart) were planted in a replicated trial to assess soybean performance. Following advice from the Dr Andrew James, CSIRO two different varieties (Kuranda and Mossman) were selected for assessment in 2019. These varieties, together with Mossman, were planted in replicated trials in 2020 and 2021.

Table 27 Soybean trial agronomy – 2018, 2019, 2020 and 2021

Year	2018	2019	2020	2021
Varieties	A6785 Stuart	Kuranda Mossman	Kuranda Mossman Hayman	Kuranda Mossman Hayman
Nutrients Applied	104 kg N/ha 26 kg P/ha 83 kg K/ha 71 kg S/ha 78 kg Ca/ha	9 kg P/ha 62 kg K/ha 38 kg S/ha 97 kg Ca/ha	17.6 kg P/ha 22 kg S/ha 38 kg Ca/ha	17.6 kg P/ha 22 kg S/ha 38 kg Ca/ha
Planting Date/s	10 Jan 2018	23 Jan 2019	19 Feb 2020 13 Mar 2020	15 Jan 2021 2 Feb 2021
Harvest Date	18 Jun 2018	6 Jun 2019	Abandoned	9 Jun 2021
Season length (days)	159	134	na	120
In-crop Rainfall (mm)	880	438	na	358
Irrigation Applied (mm)	117	200	na	173
Herbicide	2 x glyphosate 3 x Verdict 1 x Vezir 1 x Blazer	1 x glyphosate 3 x Verdict 1 x Vezir 1 x Blazer	1 x glyphosate 3 x Verdict 1 x Vezir 1 x Blazer	4 x glyphosate 1 x trifluralin 1 x Verdict 1 x Vezir
Insecticide	2 x methomyl 2 x Altacor	2 x dimethoate 2 x Altacor	2 x dimethoate 2 x Altacor	3 x dimethoate 3 x Altacor
Defoliation				2 x glyphosate

The characteristics of the varieties planted are summarised below:

- A6785 - a medium-maturity variety resistant to phytophthora root rot. It has a brown hilum, small seed size and moderate to high weathering tolerance. In coastal environments it has a tendency to lodge.
- Stuart – a long-duration variety adapted to the tropics (released in 2006). A light-coloured hilum variety with resistance to rust races that cause problems in cool, wet years on the Atherton Tableland.

- Kuranda – a medium to long duration variety with good adaptation to Queensland Coastal environments to the Wet Tropics. It has a clear hilum and high potential to access price premiums in the human consumption market. Resistant to all current strains of foliar diseases.
- Mossman – a light hilum dual-purpose variety which is late flowering – long duration. It can be grown as a green manure crop in rotation with sugarcane in Central to North Queensland
- Hayman - A clear hilum high-yield potential variety suited to higher value culinary markets. It is a medium to long duration variety.

In 2018 the two soybean varieties produced similar yields – averaging 3.5 t/ha despite achieving sub-optimal plant populations below the desirable 20 to 25 plants/m^2 (see Table 28).

Table 28 Crop development and yields for irrigated soybean trials - 2018

Year	2018	
Variety	A6785	Stuart
Plants/m^2	16.8a	12.5b
Height (cm)	83.5a	91.5a
Nodes (no.)	13.1a	13.9a
Yield (t/ha)	3.09a	3.90a

Means followed by the same letter in each row in each year are not significantly different at P ≤ 0.05

The results of the irrigated soybean trials in 2019, 2020 and 2021 are provided in Table 29. An optimal plant population achieved in 2019 contributed to an average soybean yield of 3.65 t/ha.

Table 29 Crop development and yields for irrigated soybean trials for 2019, 2020 and 2021

Year	2019		2020			2021		
Variety	Kuranda	Mossman	Kuranda	Mossman	Hayman	Kuranda	Mossman	Hayman
Plants/m^2	21.9	25.3				14.2a	19a	17.7a
Height (cm)	55.9	66.3	41.3	54.4	34.3	67.5a	73.5a	80.0a
Nodes (no.)	na	na				10.7a	11.5a	11.7a
Yield (t/ha)	3.74	3.55	0.00	0.00	0.00	1.37a	2.03a	1.05a

Means followed by the same letter in each row in each year are not significantly different at P ≤ 0.05

Table 30 Soybean yields (t/ha) for irrigated and raingrown soybeans at Forest Home Station in 2019 and 2021

Year	2019		2021		
Variety	Kuranda	Mossman	Kuranda	Mossman	Hayman
Irrigated	3.74	3.55	1.37a	2.03a	1.05a
Raingrown	2.10	1.84	0.12	0.08	0.15

Means followed by the same letter in each row in each year are not significantly different at P ≤ 0.05

Soybean establishment proved difficult in 2020 and in 2021. In 2020 the late start to the wet season delayed ground preparation and weed control, leading to a late planting on the 19 February 2020. High rainfall after planting coupled with high temperatures 'cooked' soybean seedlings as they tried to emerge. This necessitated a replant on the 3 March 2020 during showerer weather. Once again, the soybeans failed to establish properly and grew poorly because of the late planting (reflected in the short crop height. The trial was abandoned for 2020.

In 2021 the soybeans were planted on the 15 January 2021 following good early January rainfall. High temperatures more than 34^0C again 'cooked' soybean seedlings requiring a re-plant on the 2 February 2021. Good rain after this planting and cooler temperatures resulted in a better crop establishment – although it was still sub-optimal with populations below 20 to 25 plants/m^2. Much lower yields were recorded in the 2021 season compared with those in 2019 and 2018.

The opportunity was taken in 2019 and in 2021 to compare irrigated and raingrown production of soybeans. The results of this trialling are presented in Table 31. These results clearly demonstrate the value of irrigation in achieving higher soybean yields in this environment.

The APSIM (Agricultural Production Systems sIMulator) model was used to compare research results obtained over the four years of soybean trials with those generated by the model. The aim was to check its potential use for modelling crops within this region with cropping systems. The results of the APSIM analysis for soybean are presented in Table 31.

Table 31 APSIM output comparison for irrigated soybean with research site results – 2018, 2019 and 2021

	2018		2019		2021	
Attribute	Trial	APSIM	Trial	APSIM	Trial	APSIM
Yield (t/ha)	3.09 to 3.90	1.88	3.55 to 3.74	2.16	1.05 to 2.03	1.36
Crop Ht (cm)	84 to 92	120	56 to 66	120	68 to 80	120
Plants/m2	13 to 17	17	22 to 25	25	14 to 19	19

The data in Table 31 suggests that the APSIM soybean model is tending to under-estimate soybean yields and over-estimate crop heights compared with the results of the field trials conducted at Forest Home Station in this environment.

Discussion

Crop establishment appears to be a significant issue for soybean production within the Gilbert River catchment. Optimal populations were only achieved in one out of the four years of trialling. In two of those years a replant was needed due to poor crop establishment. Poor crop establishment seems to be related to the combination of high soil temperature and high soil moisture following planting. This is particularly of concern for soybeans which need to be planted earlier than the shorter season mungbean crop – at a time of highest ambient temperatures.

Planting in February and March were largely unsuccessful. Yields more than 3 t/ha are achievable in this environment when there is a reasonable establishment.

The data in Table 31 suggests the APSIM soybean model under-estimated actual irrigated soybean yields in 2018 and 2019. In 2021 when the crop was replanted in February, the APSIM model more closely matched actual soybean yields. The model tends to over-estimate crop height in all years. At this time, it appears that the APSIM soybean model cannot be used to examine soybean performance in this northern environment with any confidence.

On-farm Demonstrations

One of the aims of the project was the establishment of on-farm demonstrations of broadacre cropping. The only on-farm demonstrations established during the project were on Forest Home Station through the excellent collaboration of Ken and Brendan Fry.

2020 - Irrigated vs Raingrown Cotton, Forest Home Station

In the 2018 and 2019 cotton had been planted on the field adjacent to the Forest Home Station Replicated Trial site. Although this field is partially covered by a centre pivot it had not been used to irrigate these crops.

In the 2020 season after discussion with the property owners, it was determined that:

- the additional yield potential of irrigated cotton justified the required effort to bring the pivot up to operational condition
- the site provided an ideal opportunity to compare irrigated vs rainfed cotton in this environment

The entire field was uniformly planted out (15th February 2020) on a full soil moisture profile following 110mm in late January 2020. A subsequent rainfall event of 119mm was received across the latter half of February. Inconsequential rainfall following this triggered two irrigation passes on that area serviced by the centre pivot.

Two 2 linear metre plant stands were randomly selected in both the irrigated and the rain-fed areas of the crop. Within each of these areas three representative individual plants were tagged and progressively followed through to harvest.

Table 32 Comparison of pivot irrigated v rainfed cotton

Date	Observation	Irrigated	Rainfed
12 May 2020	Plants/m	9.0	7.5
	Plant Height (cm)	122	112
	Nodes (number/plant)	18.3	17.7
	NAWF	4.8	4.8
10 June 2020	Nodes (number/plant)	18.5	19.5
	NAWF	12.6	17.1
21 July 2020	Bolls picked	133.5	152
	Unopened bolls/plant	0	0
	Yield (bales/ha)	5.49	5.31

Visual inspections early in the season found the rainfed cotton was showing symptoms of inadequate soil moisture owing to inadequate in-crop rainfall. At the same time the irrigated cotton appeared to be progressing towards yields of about 10 bales/ha.

Sampling on 12th May 2020 indicated no significant differences between the irrigated and rain-fed cotton other than number of plants per metre (irrigated with 9 plants/m compared to the rainfed population of 7.5 [plants/m). The only significant difference detected by subsequent sampling conducted on the 10 June 2020 was nodes above white flower (NAWF) - an index used to predict time to crop maturity. These results (rain-fed at 17.1 NAWF compared to the irrigated at 12.6 NAWF suggested that the irrigated crop was closer to reaching cut-out than the rainfed cotton.

Harvest yield analysis (21 July 2020) revealed no significant difference between the irrigated and the rain-fed plant stands (5.5 vs 5.3 bales/ha respectively). The irrigated produced more bolls (152 compared to 133) however the difference was not regarded as significant.

Results of the demonstration did not reflect the visual impression of the field (wherein the area under irrigation appeared to be appreciably more productive than the rainfed) or the yields recorded by the picker monitor. It is possible that the sampling methodology employed failed to adequately address the in-field variability that was evident at harvest (as indicated by the pickers yield monitor results). Any future investigations would benefit from a more comprehensive sampling protocol.

Despite the relatively inconclusive results subsequent discussions with the property owner did provide valuable outcomes:

- Increased appreciation by the grower of the additional yield potential of irrigated cropping
- Justification to invest in capital investment to bring existing pivots up to their potential performance
- Increased ability to consider further investment in overhead irrigation systems on existing cropping area ideally suited to this form of irrigation
- Pivots typically reduce reliance on labour inputs (a challenge continually present on properties in the region)
- Enhanced ability to improve herbicide & pesticide management.
- Enhanced risk management

2021 - Irrigated Rice Demonstration – Forest Home Station

The planned commercial demonstration of upland rice by Fry Bloodline Trust during the 2021 season did not progress. The collaborators felt the risk from bird damage would be too great to plant upland rice and opted for cotton instead.

2022 - Cropping Soil Variability Assessment – Forest Home Station

In January 2022 EM38 surveys and soil core sampling (using equipment borrowed from Gulf Savanna NRM) was conducted on the research trial site and two commercial fields (Field 2 and Field 3) on Forest Home Station. The aim was to investigate the apparent field variability at these sites observed by the property owners.

The results of this assessment are presented in Figure 7 and Tables 33-35.

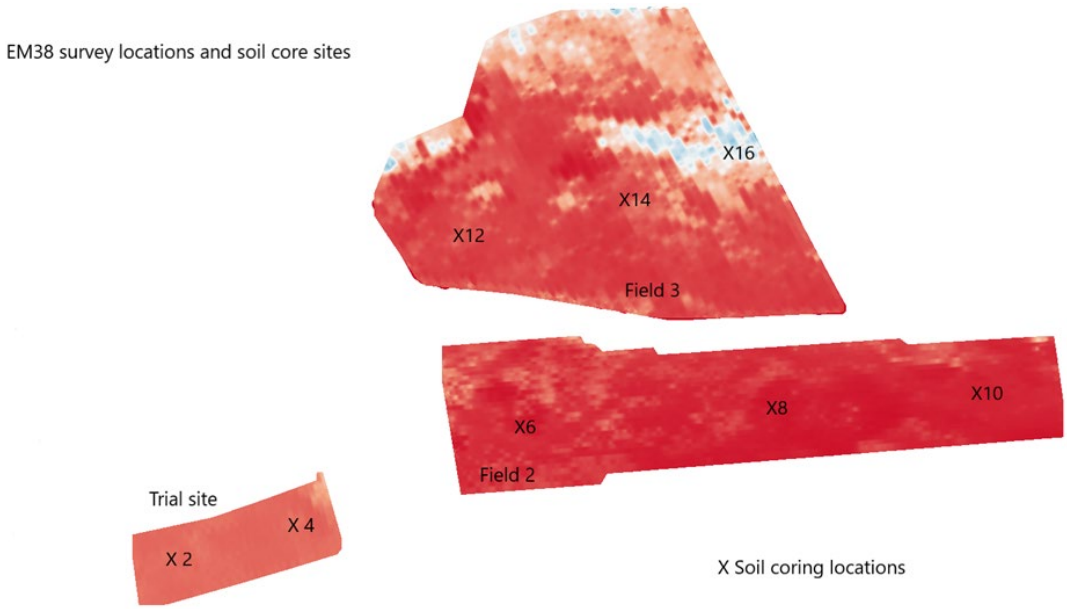


Figure 8 EM38 survey map and soil sampling sites for Forest Home Station sites (January 2022)

Results of the analyses suggest no significant in-field soil type variation apart from the low lying area at the eastern edge of Field 3 (at core site X16). Difficulties in extracting cores due to the high sand content of these soils prevented gravimetric moisture analysis. The analyses indicate a slightly acid to neutral pH profile, with low nitrogen and organic carbon levels. There was some variability in levels of phosphorus, potassium and sulphur across the samples. There were no significant levels of salinity identified in the profiles sampled.

Table 33 Soil core analysis – Forest Home Research Trial Site

Sample	Units	2a	2b	2c	4a	4b	4c
Depth (cm)	(cm)	0-30	30-90	90-150	0-30	30-90	90-150
Colour		LTBR	LTBR	LTBR	LTBR	GRBR	BR
Gravel	(%)	0	0	5	5	5	5
Texture		2	2	2.5	2.5	2.5	2.5
Ammonium Nitrogen	(mg/kg)	5	3	3	2	>1	2
Nitrate Nitrogen	(mg/kg)	4	3	3	2	>1	>1
Phosphorus Colwell	(mg/kg)	31	25	20	33	22	13
Potassium Colwell	(mg/kg)	440	300	225	312	206	141
Sulphur	(mg/kg)	8.3	7.5	9	1.4	0.6	0.8
Organic Carbon (%)	(%)	0.65	0.51	0.32	0.41	0.2	0.15
Conductivity (ms/cm)	(mS/cm)	0.062	0.05	0.062	0.052	0.047	0.015
pH Level (CaCl2)		5.3	6.1	5.6	5.8	5.7	5.9
pH Level (H20)		6.3	7.1	6.7	6.7	6.7	7.2

Table 34 Soil core analysis – Forest Home Field 2

Sample	Units	6a	6b	6c	8a	8b	8c	10a	10b	10c
Depth	(cm)	0-30	30-90	90-150	0-30	30-90	90-150	0-31	60-90	90-150
Colour		LTBR	LTBR	LTBR	YWBR	BR	BR	LTBR	LTBR	LTBR
Gravel	(%)	5	0	0	15-20	0	15-20	5-10	5-10	5-10
Texture		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Ammonium N	(mg/kg)	3	1	1	11	22	7	4	2	5
Nitrate N	(mg/kg)	3	1	>1	21	7	17	3	3	2
P Colwell	(mg/kg)	35	24	19	43	60	22	12	4	18
K Colwell	(mg/kg)	357	226	149	135	155	116	197	141	223
S	(mg/kg)	3.5	2.8	1.2	22.7	35	120	2.9	1.7	6.0
OC (%)	(%)	0.42	0.25	0.15	0.41	0.360	0.300	0.530	0.300	0.680
Conductivity	(mS/cm)	0.031	0.019	0.013	0.195	0.207	0.567	0.025	0.015	0.034
pH (CaCl2)		5.2	5.7	5.4	4.7	5.6	5.5	5.3	5.3	4.9
pH (H20)		6.4	6.9	6.8	6.3	7.5	7.4	5.9	7.0	6.1

Table 35 Soil core analysis – Forest Home Field 3

Sample	Units	12a	12b	12c	14a	14b	14c	16a	16b	16c
Depth (cm)	(cm)	0-30	30-90	90-150	0-30	30-90	90-150	0-31	60-90	90-150
Colour		BR	BR	BR	DKBR	BRRD	BRRD	GRBR	BRRD	BRRD
Gravel	(%)	0	0	0	0	5-10	5-10	5-10	0	0
Texture		2.5	2.5	2.5	2.00	2.00	2.5	2.0	2.5	2.5
Ammonium N	(mg/kg)	6	3	3	2	1	3	4	2	2
Nitrate N	(mg/kg)	2	2	4	7	4	3	12	14	3
P Colwell	(mg/kg)	13	9	6	10	8	8	20	4	4
K Colwell	(mg/kg)	115	116	105	80	88	92	142	160	158
S	(mg/kg)	1.6	1.2	0.9	1.4	0.9	0.9	2.2	2.4	1.0
OC (%)	(%)	0.240	0.210	0.300	0.470	0.280	0.470	1.530	1.570	1.110
Conductivity	(mS/cm)	0.014	0.014	0.019	0.040	0.056	0.021	0.042	0.020	0.018
pH (CaCl2)		5.3	5.1	5.4	5.9	6.4	6.0	5.9	5.9	5.8
pH (H20)		6.6	6.3	6.5	7.0	7.8	7.3	7.0	7.2	7.0

Discussion

One of the difficulties encountered in this project was encouraging landholders to undertake on-farm cropping demonstrations. This issue was raised with the Gilbert River Reference Group who suggested that the greatest impediment amongst graziers was the availability of appropriate equipment to undertake such demonstrations and their limited cropping skills.

Ken and Brendan Fry provided excellent support to this project and were the only collaborators willing to undertake on-farm demonstration work with the project team.

Extension Activities

Communication

The communication and engagement objectives of the project included:

- The detail of DAF on-farm cropping research within the Gilbert River catchment is regularly reported to Primary Target Audiences
- The results of the on-farm cropping research are reported directly to collaborators in a timely fashion (by 30 September each year)
- The results of the on-farm cropping research are reported more broadly to landholders within the Gilbert River catchment

The target audiences for communication were identified as:

Primary

- Gilbert River Stakeholder Reference Group
- Collaborating local growers
- Collaborating researchers (Daniel Rodriguez and Joe Eyre, Tony Matchett)
- Etheridge Shire Council
- Mark Hickman (C&FS Director)
- C&FS General Manager

Secondary

- Investors (Brondwen Maclean, Kristin Nunn, Dena Lillico, Carla Keith, Ian Biggs – CRCNA; Ken Young – GRDC)
- Agribusiness suppliers
- Non-collaborating landholders
- Northern Gulf RMG (Zoe Williams, Laura Miller)
- AgForce (Nikki Hoffman)

Tertiary

- Wayne Hall (ASQ)
- DAF BOM
- Other Queensland landholders

The communication activities by the project team are detailed below:

- DAF SitRep – Gilbert River Reference Group inaugural meeting – 4 Oct 2019
- DAF SitRep - On-farm cropping research gets underway at Forest Home Station, Georgetown – 28 Feb 2020
- Webinar – Broadacre Cropping in northern Queensland – 6 May 2020 (replacing field day due to Covid-19 restrictions)
- DAF SitRep – Georgetown Virtual Field Day a Success – 15 May 2020
- Newsletter - Broadacre Cropping in Northern Queensland, Issue 1 – May 2020
- Crop Options Trial – 2020 Report – Georgetown – 21 October 2020
- DAF SitRep – Good response to face-to-face cropping meetings in North Queensland – 11 Dec 2020
- Newsletter - Broadacre Cropping in Northern Queensland, Issue 2 – February 2021
- Webinar – Broadacre Cropping in Northern Australia – 30 Apr 2021
- DAF SitRep - DAF Showcases Cropping Activities conducted in the Far North – 21 May 2021
- DAF SitRep – DAF Presents at Northern Australia Food Futures Conference – 18 Jun 2021
- LRF Seminar – Developing a Broadacre Cropping Sector in North Queensland – 29 Sep 2021

- Summer 2021 Trial Report – Georgetown – 11 Oct 2021
- DAF SitRep – Big Turnout to the North-West Cropping Forum – 25 Nov 2021
- DAF SitRep – Gilbert River Stakeholder Engagement a Success – 3 Dec 2021
- DAF SitRep – Broadacre Cropping Tials Established in Gulf River Catchments – 25 Feb 2022

Field Days/Forums

The following field days and forums were conducted in the five years of the research in the Gilbert River reported here:

- 2020 season field days – unable to be held because of delayed start to wet season and COVID-19 pandemic restrictions in force. A virtual field day webinar held to overcome this issue – 6 May 2020
- 2021 season field days – held in conjunction with Gilbert River Agricultural Forum – 7,8 April 2021 (initiated by Etheridge Shire Council)
- Cropping in the Northwest Information Day, Julia Creek – 20 October 2021. Results of research in Gilbert River catchment presented.
- Etheridge Agricultural Forum, 29 March 2022 – Lance Pendergast presented the results of cropping research to date to attendees. No field visit to site scheduled by organisers (Etheridge Shire Council)
- 2022 season field day – a pre-harvest field day at the Forest Home Research site was held on the 28 April 2022. Although attendance was low it provided an excellent opportunity for the project team to discuss overall results of the five years of trialling and for participants to inspect the final project trials.

Best Practice Guides

Four agronomy guides for the crops trialled in this project have been produced:

- Agronomy Guide – Cotton (Gulf Rivers)
- Agronomy Guide – Mungbean (Gulf Rivers)
- Agronomy Guide – Sesame (Gulf Rivers)
- Agronomy Guide – Soybean (Gulf Rivers)

These were developed based on the experience in growing these crops in the region and in collaboration with the GRRG. Copies of these are provided in the appendices of this report.

Conference Presentations

Northern Australia Food Futures Conference 2018, Darwin – 2-4 July 2018

- Gulf Rivers Grain RDE (Graham Harris)
- Collaborative development of profitable cropping systems (Graham Harris)

Northern Australia Food Futures Conference 2021, Darwin – 17-20 May 2021

- Developing a broadacre cropping sector in North Queensland (Lance Pendergast)

Australian Agronomy Conference 2022, Toowoomba

- Irrigated Bollgard®3 cotton performance in the Gilbert catchment of north Queensland

AgMargins

Gross margins for irrigated production of the four crops assessed in this project are in the process of development. The delay in finalisation of these is the result of updating of the web-based AgMargins tool where these gross margins will be hosted. Current drafts of these are provided in the appendices to this report.

Table 36 summarises these draft gross margins.

Table 36 Draft gross margins ($/ha) for irrigated cotton, mungbean, sesame and soybeans in the Gulf Rivers

Detail	Cotton	Mungbean	Sesame	Soybean
INCOME				
Yield				
Lint (bales/ha)	10.0			
Seed (t/ha)	3.0	1.7	2.0	3.0
Price				
Lint - $/bale	$550			
Seed - $/t	$190	$941	$1200	$475
TOTAL INCOME	**$6,070**	**$1,600**	**$2400**	**$1425**
Variable Costs				
Fallow management	$127	$87	$107	$84
Planting	$488	$74	$25	$107
Nutrition	$231	$45	$165	$45
Crop Protection	$114	$53	$48	$171
Growth Regulant	$6			
Irrigation	$267	$133	$133	$267
Harvesting	$258	$78	$78	$45
Other	$178	$96	$65	$94
Post-harvest	$1534	$207	$57	$85
TOTAL COSTS	**$3,203**	**$773**	**$678**	**$898**
GROSS MARGIN ($/ha)	**$2,867**	**$827**	**$1722**	**$527**
GROSS MARGIN ($/ML)	**$573**	**$331**	**$689**	**$105**

The gross margins in table 36 are based on achievable crop yields and inputs gleaned from the on-farm research trials conducted in this project. The variability in gross margins associated with yield and price changes are detailed in the draft AgMargins reports for each crop included in Appendix 2. Further refinement of these gross margins is planned by the 31 October 2022.

The gross margins above clearly indicate the importance of cotton in developing broadacre cropping within the region. The returns from other crops are lower but will be important inclusions within a cropping system where crop rotation provides significant benefits to the farm operation. Care needs to be exercised in interpreting the returns of sesame and soybeans. The above gross margins assume good crop establishment which has proven difficult for sesame and soybeans to date. For sesame it also assumes good weed management – weed control options for this crop are limited at this time.

Discussion

This report has presented the results and experiences of on-farm research and extension activities conducted in 2018 and 2019, and the three years of research funded under the CRCNA/GRDC Project A.2.1819105 Developing a broadacre cropping sector in Northern Queensland (2020, 2021 and 2022).

Research

Investment in the exclusion fencing used at Forest Home Station was essential to the success of trials conducted there. This excluded the impact of wild pigs and wallabies on the trial site.

The replicated research conducted at Forest Home Station has clearly identified the yield potential of irrigated cropping for four crops – cotton, mungbeans, sesame and soybeans – within this region on the alluvial soils of the Gilbert River catchment. The variability in seasonal conditions encountered over the five years of trialling has provided a valuable insight into the cropping potential on the soil type representative of the 20,000 ha of potential irrigable soils in the region.

The range of irrigated yields obtained for each crop and available varieties were:

- Cotton – 7.9 to 11.2 bales/ha
- Mungbeans – 0.9 to 2.6 t/ha
- Sesame – 1.77 to 2.6 t/ha
- Soybean – 0.00 to 3.90 t/ha

The highest yields were obtained when seasonal conditions enabled optimal timing of planting for all crops. It was clear from the research that cotton and mungbeans are particularly well adapted to this environment. Soybean establishment was a significant issue in some years owing to the need to plant them in January when soil moisture and high temperatures could make emergence difficult. Sesame is a relatively new crop which requires further research around establishment and weed management in order to maximise yield performance.

Evaluation of the APSIM model using the results of the five years of research clearly demonstrated its limitations in modelling the performance of cotton, mungbeans and soybeans in this environment (at present there is no sesame model available in APSIM – UniSQ are currently developing such a model using their own research and the results collected for sesame at Forest Home Station). Further modification of APSIM is needed before it can be reliably used as a modelling tool for broadacre cropping of the crops assessed in this environment.

Agronomic research conducted at these sites included:

- Evaluation of growth regulant treatments in cotton (2019 and 2020)
- Time of sowing of sesame (2020)
- Evaluation of potential post-herbicide options in sesame (2021 and 2022)
- Irrigation vs raingrown performance of cotton (2021), mungbean (2021 and 2022) and soybean (2019 and 2021)

The results from these agronomic trials suggest:

- Further research is needed on the most appropriate use of cotton growth regulants in this environment
- Further research needed into the optimal timing for sesame planting and establishment
- Basagran causes significant damage to sesame and is not recommended for broadleaf weed control
- Lontrel Advanced, Verdict and Diuron do not visually affect sesame – further research needed to confirm crop safety and weed control effectiveness
- Irrigation important to optimising crop performance in this environment except in highly favourable rainfall seasons

The conduct of remote research is expensive given associated travel and accommodation costs. The support of locally based personal (such as that provided by Gulf Savannah in 2022) is of great assistance in minimising these costs. The value of good collaborators such as Ken and Brendan Fry cannot be overstated.

Extension

The Gilbert River Reference Group was particularly valuable in gaining feedback on the results of research in each year and planning subsequent activities in the following season. More frequent meetings (even remotely) would have been beneficial but there needs to be a balance in time commitments that members of the GRRG could give and the difficulties of connectivity in the region (which limited the possibility of remote meetings).

It was particularly difficult to undertake on-farm demonstrations in the region. Feedback from the GRRG suggested this was due to lack of equipment and knowledge amongst existing graziers. The support of Ken and Brendan Fry in the conduct of some of the on-farm demonstration activities is highly valued.

In 2020 the Covid-19 Pandemic produced its own set of challenges for the project. Some face-to-face field day events were curtailed because of it and replaced with two on-line webinars. Although this was useful to reach a wider audience in relation to work being undertaken it attracted limited number of local participants owing to the connectivity issues in this region.

Working with the local Etheridge Shire Council enabled successful conduct of some on-site extension activities in 2021. In 2022 however, the timing of the Etheridge Agricultural Forum on the 29 March 2022 probably negatively impacted attendance at the field day held on the 28 April 2022 (delayed because of the earlier event).

A series of Agronomy Guides for the four crops trialled at Forest Home Station (cotton, mungbean, sesame and soybeans) have been prepared and are available for distribution. These are provided in Appendix 1

In addition, a set of gross margins for cotton, mungbean, sesame and soybean for the Gulf Rivers Region have been created in the DAF Agricultural Gross Margin Calculator tool (AgMargins). Copies of these are provided in Appendix 2. This tool is currently being upgraded and the new version upgraded (with an intended release date of the 31 October 2022).

Strategic recommendations

Recommendation 1

A clear understanding of the impediments to establishing a broadacre cropping sector is needed. This requires engagement not only with existing enterprises currently undertaking broadacre cropping but also the existing livestock sector. This engagement is needed to design appropriate RD&E activities that address the impediments identified.

Recommendation 2

Given the cost of research activity within the region opportunities to minimise this through development of strong collaborative links with existing local organisations (e.g, Gulf Savannah) should be explored and developed.

Recommendation 3

Cotton and mungbeans appear well adapted to cropping within the Gilbert River catchment. Further research needs to focus on specific agronomic practices needed to maximise productivity and profitability of these crops.

Recommendation 4

Sesame as a crop has some way to go before it can be widely used within this region. Crop establishment and weed management are key focus areas for research to address these key constraints at this time.

Recommendation 5

Soybeans have limited applicability to cropping within the Gilbert Catchment given difficulties encountered with establishment. Research investment should focus on other crops at this time.

Appendix 1 Best Practice Guides

Agronomy Guide - Cotton (Gulf Rivers)



Figure 1 – Irrigated cotton trial on Forest Home Station, Georgetown 2020

This Agronomy Guide summarises information relevant to cotton production within the Gulf River catchments of north Queensland. More detailed information related to cotton agronomy is found in:

- Australian Cotton Production Manual 2021 (2021 Australian Cotton Production Manual | CottonInfo
- Tropical Cotton Production (Tropical cotton production | CottonInfo

Planning

In its native habitat cotton is a perennial shrub which enables it to survive year after year. In situations with inadequate resources (moisture, solar radiation, nutrients) it will shed some flowers and small bolls (the fruit where the seed and fibre form). This is a way to guarantee survival by using limited resources available to support its leaves, branches, roots and remaining bolls.

The cotton plant has an indeterminant growth habit. The plant develops fruit over an extended period of time, so in many cases it can compensate for stress events by continuing to grow and produce new fruit if time permits.

The development of the cotton plant is strongly influenced by temperature. Cotton is grown as an annual crop by balancing vegetative and reproductive growth. Maintaining vigorous vegetative growth before flowering is important as it is these leaves, branches and roots that will support/supply the future boll load. As a cotton plant develops, new leaves grow and expand,

producing carbohydrates to allow new growth of leaves and the developing roots. Once reproductive structures begin to develop, vegetative and root growth will slow down as the plant begins to supply resources to the developing fruit. Good crop management aims to keep the reproductive and vegetative growth in balance for as long as the season allows,

The Australian cotton industry operates in a cohesive and cooperative environment, where a number of industry organisations exist specifically to support growers. Cotton growers are prepared to willingly share their experiences and offer advice to new growers.

Among the critical factors in growing cotton are:

- Fitting cotton into your crop rotation program
- Sound weed management
- Good soil management
- Integrated pest management strategies
- Effective stubble management after harvest

You should also consider the following questions:

- Who will harvest your crop?
- Will you grow raingrown or irrigated cotton?
- Do you have a water budget?
- How do you feel about complying with GM cotton regulations?
- Have you talked to your neighbours?
- Have you engaged a consultant?
- Do you have the necessary machinery to successfully grow cotton?
- Have you contacted a spraying contractor?
- Have you contacted a farm inputs supplier?

More detail in relation to these questions can be found in the Australian Cotton Production Manual 2021.

Pre-planting

Like most crops cotton performs best when grown in well structured soils. Good structure enables good root growth and water infiltration, and adequate internal drainage throughout the season. Good internal drainage re-establishes aeration after irrigation and rainfall events. Soil structure also affects the Plant Available Water Capacity (PAWC) of the soil, which needs to be sufficiently large enough to meet the water requirements of the crop. Cotton responds well to a range of irrigation systems which should be matched with the soils on which they are grown. Alluvial soils and better structured clay soils provide favourable conditions for vigorous root growth. Soils with hard setting surfaces, or with dense, sodic subsoils have poor permeability and limit root development.

When growing cotton in rotation with other crops beware of residual herbicides which may impact cotton and subsequent crops. Keep good records and always check the label for plant-back periods for your soil type and environment.

Varieties

Choose varieties on the basis of yield, quality and disease resistance characteristics. Seed is purchased from Cotton Seed Distributors. Information on the varieties - Sicot 714B3F, Sicot 746B3F and Sicot 748B3F – trialled in the 2018, 2019, 2020 and 2021 season are summarised in Table 1. In the 2021 season Sicot 606B3F was trialled for the first time.

Seed quality

- Each seed lot has a batch number on the butt sticker of each bag. This number can be used to access actual seed quality at www.csd.net.au/auslot
- The seed quality data includes warm and cool germination percentage, physical purity and seeds per kilogram
- Always re-test carry-over seed purchased in previous seasons by using the CSD free carry-over seed testing service

Planting

- Even establishment means even maturity and a crop that is easier to harvest.

Marginal soil moisture at planting will result in poor emergence and crop growth

Planting time

Soil temperature is important in the germination and rate of development of the cotton seedling. Below 12^{o}C, the growth of the cotton plant is severely retarded. Proper growth requires a soil temperature above 15^{o}C. This is usually not an issue in the Gulf Rivers because of the high ambient temperatures there.

Table 1 Bollgard 3 cotton varieties trialled in the Gulf Rivers

	Sicot 714B3F	Sicot 746B3F	Sicot 748B3F	Sicot 606B3F
Climate suitability	Cool/Central	Central /hot	Central/hot	Cool/Central
Production	Irrigated/dryland	Irrigated	Irrigated/dryland	Irrigated
Maturity	Full	Full	Full	Med/full
Growth Habit	Compact	Compact	Moderate	Compact
Relative gin turnout	42.0	45.0	44.0	42.6
Relative length	1.20	1.21	1.23	1.19
Relative strength	30.0	30.0	31.0	31.9
Relative micronaire	4.4	4.5	4.5	4.0

There is also an upper limit to temperatures suitable for cotton germination. Temperatures above 35-40^{o}C may negatively affect germination. At higher temperatures establishment may be impacted but this has not been a major issue in trial or commercial plantings to date in the region.

Experience to date suggests January planting is preferred in the Gulf River region. Planting earlier than this increases the risk that the early flowering period of the crop may affected by cloudy, wet weather. This may result in the shedding of many early flowers and squares, requiring management to growing later compensatory flowers and bolls during sunnier weather in March.

Planting later than January increases the risk that cooler-than-average seasons will lead to increased bale price discounts from poorer fibre quality.

The recommended sowing window carries the risk of wet weather interrupting planting. This risk is greatest in the northern Gulf Rivers catchments like the Gilbert and lower Flinders, but less likely in the Upper Flinders catchment. Management strategies to minimise the likelihood of wet weather delaying planting or emergence include:

- Prepare fields 1 to 2 months ahead of planting
- Design field tail-drains to shed water quickly
- Have ready access to a planter
- Do not plant too deeply

Row spacing

Choose a row spacing that fits your existing farming system and other crop types. Cotton is traditionally grown on 102cm (40 inch) rows. Avoid rows narrower than 71cm (28 inches) due to an inability to harvest the crop with a conventional spindle head picker below this row spacing. Wider row spacings are used in dryland cotton (skip row configurations) but in a fully irrigated system where solar radiation limitations might occur, wider spacings may decrease yield potential; and/or delay crop maturity.

Planting depth

Plant at 20 to 35mm depth and cover with soil settled with a press wheel, taking care not to use too much pressure. Seedlings should emerge with 4 days of sowing into a moist seedbed.

Planting rate

- Aim for 10 to 12 plants per metre established
- Aim for the lower end of the range when planting in dryland or marginal conditions. It also suits wetter and warmer climates and better soil types, where a larger plant size usually grows that can compensate for gaps in the plant stand
- Aim for the higher end of the range in tighter soils that limit plant size that cannot compensate for plant stand gaps.

- Use the cotton planting rate calculator available at the CSD website (www.csd.net.au/planting-rate-calculator) to work out the planting rate for your desired population
- Ensure the planting depth across the width of the sowing machinery is even to aid the timing and consistency of crop emergence

Irrigation

Irrigation can be used to regulate vegetative and reproductive growth to maximise yield and fibre quality. Appropriate irrigation scheduling improves water use efficiency, reduces waterlogging, controls crop canopy development and improves the effectiveness of rainfall.

Cotton has an indeterminate growth habit – under favourable conditions it will produce leaves, new nodes, fruiting branches and squares unlimited by a phenological time frame and nutrition. During pre-flowering stages of growth the plant will produce carbohydrates in ex cess of demand, resulting in vigorous vegetative growth. As plant growth continues, the demand for carbohydrates by the bolls increases, and production becomes limited by environmental conditions as the season progresses. Boll growth exerts large demands for carbohydrates. The balance between this demand and leaf production restricts vegetative growth.

Water stress can restrict both vegetative and boll growth. Cotton is most sensitive to water stress during peak flowering. Stress during peak flowering is likely to double the yield loss compared to stress during squaring and late boll maturation.

Too much water can result in waterlogging. This reduces the transfer of oxygen between the roots and soil atmosphere. Root growth is restricted and nutrient uptake decreased leading to less overall plant growth. A reduction in node numbers leads to a reduction in the number of fruiting sites and a reduction in the number of bolls produced. Cotton is most susceptible to waterlogging during the early stages of flowering as this is when the plant is setting the fruit load that will determine final yield.

Plants exposed to rainfall-induced waterlogging may also suffer from reduced sunlight availability associated with overcast conditions. Under these conditions the plant may shed fruit. Waterlogging may also affect the availability and uptake of nutrients, further limiting yield.

Cotton is suited to a range of irrigation systems. Surface irrigation is best suited to medium to heavy clay soils. Field layout and management can minimise the effect of waterlogging on cotton:

- Select fields with reasonably steep grades
- Fields should have no low spots (ideally they should be laser levelled)
- Form up high-volume hills or beds, which drain quickly after rain
- Select fields with short runs – preferably 200 to 400m
- An efficient tail-water system that will rapidly drain water away from the paddock is essential
- Irrigate down every alternate furrow
- Apply water quickly, preferably in 4-8 hours (use multiple siphons per furrow)
- Apply the first irrigation before soil cracks open up

Overhead irrigation systems can be used on all soil types. Their advantage is the ability to apply smaller amongst of water more frequently than surface irrigation. This reduces the waterlogging risk. Avoid heavy overhead applications to young plants because the caked-on dirt from mud-splash can reduce growth and thus plant stands.

Irrigation scheduling is the decision of when and how much water to apply to an irrigated crop to maximise productivity. Good scheduling should provide plants with water within the desired soil water range and should limit over or under irrigation for balanced growth. For some Bollgard 3 varieties, insufficient available water prior to and during flowering will reduce plant size and lead to early cut-out while too much water can result in rank growth and waterlogging.

The timing of last irrigation is also important. Plan the last irrigation to allow the crop sufficient time to begin natural senescence and the soil to dry without affecting yield and quality. If the soil is not adequately dried there is a risk the crop will re-shoot before picking and require an additional defoliation.

Refer to more detailed information on cotton irrigation in:

- Australian Cotton Production Manual 2021 (2021 Australian Cotton Production Manual | CottonInfo
- Tropical Cotton Production (Tropical cotton production | CottonInfo
- WATERpak (WATERpak | CottonInfo)

Nutrition

Fertiliser recommendations need to be based on soil test results, fallow length, yield potential and paddock history.

Table 2 presents the quantity of nutrients required to produce 10 bales/ha of cotton and the amount of nutrients at picking. Cotton removes significant amounts of nitrogen (N), phosphorus (P) and potassium (K). Adequate supply of these nutrients is needed for best yields.

The cotton plant uses nitrogen throughout the entire growing season, with greatest demand during the flowering stage. Insufficient supply during this period will reduce yield. However, excessive supply can lead to rank vegetative growth, boll shedding, delayed full boll load and crop maturity, small fruit, increased disease problems, difficulties in defoliating, harvesting problems and reduced fibre quality.

On clay soils apply between a third and half the total required nitrogen at sowing. In seasons receiving average or above average rainfall in January and February the efficiency of uptake of nitrogen fertiliser applied at sowing is generally low (20–40%).

On sandy or loam soils the amount of nitrogen applied at sowing is determined by the risk of fertiliser burn to seedlings. Apply up to one third of the total required nitrogen in a band separate from the seed.

Due to the risk of nitrogen loss early in the season, at least half the seasonal nitrogen requirement should be applied after sowing. Apply in-crop nitrogen fertiliser 25-50 days after planting. Application should be prior to flowering.

Phosphorus is important for early plant growth, as P deficiency causes reduced seedling vigour, poor plant establishment and root development, and delayed fruiting and maturity. P is immobile in soil – staying where it is applied. Cotton roots do not congregate in areas of high P concentration like the fibrous roots of cereal crops and are not good at finding bands of P in the soil. The aim of fertiliser P application should be to treat the largest volume of soil as possible and to be available throughout the soil profile where plant roots are active. Only about 2—30 per cent of the P applied as fertiliser is used by the crop in the year of application. Low rates of P can be applied with the seed (up to 9 kg P/ha or 40 kg MAP/ha in 1m row spacings) where there is good seedbed moisture.

Table 2 Cotton nutrient removal for a crop yield of 10 bales/ha

Nutrient	Removed at harvest (kg/ha)	Total crop uptake (kg/ha)
Nitrogen	100	200
Phosphorus	20	30
Potassium	50	200
Sulfur	10	40
Calcium	10	220
Magnesium	12	30

Potassium is a mobile nutrient within the plant. Adequate K is linked to reducing the incidence or severity of diseases and improving yield and fibre quality. Premature senescence is a potassium-related disorder that can occur in cotton when there is an imbalance between plant nutrient demand due to a high boll load and the ability of the plant to meet this demand. Premature senescence can be compounded by stresses such as waterlogging, cool, cloudy weather or soil compaction. Treatment with K related to early senescence is rarely effective after the appearance of symptoms.

Weed management

Integrated weed management (IWM) should be used to not only manage existing herbicide resistance and prolong the useful life if each herbicide, but also to reduce the rate of species shift, manage the cost of future weed control by depleting the number of weed seeds in the soil, and improve crop productivity through effective weed management.

A short term approach to weed management may reduce costs in the short term but is unlikely to be cost effective over a five to 10 year cropping plan.

The five principles to developing a long term approach to weed management are:

- Know your weeds and monitor changes
- Use cultural, in-crop and fallow management tactics to reduce the seed bank and prevent weeds from surviving to seed set
- Rotate herbicide modes of action
- Monitor and follow up to ensure weeds that survive a herbicide are controlled by another tactic before they sed seed
- Come Clean Go Clean to prevent movement of weed seeds onto, off, or around the farm.

Detailed advice on developing an integrated weed management strategy for your farm is contained in the Cotton Pest management Guide 2020-21 (https://www.cottoninfo.com.au/publications/cotton-pest-management-guide).

Roundup Ready Flex® technology in cotton varieties provides the opportunity to better manage weeds in cotton crops but its use should be considered as part of an IWM system, not as an answer to all weed management scenarios.

The reliance on glyphosate herbicide alone to manage weeds poses the greatest risk to glyphosate resistance developing. You should plan fallow weed management, pre- and post-plant control, and post-harvest management to minimise the impact of weeds in your farming system now and into the future.

You should also take every precaution to minimise the risk of causing or suffering spray drift damage from herbicide application.

Insect management

Integrated Pest Management (IPM) aims to use our knowledge and understanding of the pest, the crop, and the environment to minimise the likelihood of pest outbreak and reduce our reliance on insecticides. Some pest populations (such as mites, mealy bugs and whitefly) have limited chemical options for control and populations can quickly increase if IPM is not practiced.

The outcome of an effective IPM system is long term management of pests and beneficials, reducing the risk of resistance, so that economic losses of crop yield and quality and threats to human health and the environment can be minimised.

An IPM system should:

- Seek to prevent pest outbreaks through good farm hygiene, complimentary crop rotation and conserving beneficial populations
- Regularly monitor pest species, beneficials, crop stage, crop growth and the weather
- Bring it all together with effective action that is mindful of pest thresholds, resistance risks and potential impacts on natural enemies, bees and the environment.

The availability of Bollgard cotton has significantly reduced the impact of Helicoverpa larvae in cotton and reduced the reliance on insecticide

applications for their control. Maintenance of the effectiveness of this technology relies on adherence to all aspects of the Insecticide Resistance Management Strategy used across the industry.

There are other potential pests which need to be managed using an IPM approach. Details on implementing this approach and the management of specific insect pests is provided in the Cotton Pest management Guide 2020-21 (https://www.cottoninfo.com.au/publications/cotton-pest-management-guide).

Diseases

No diseases have been identified in cotton crops grown within the Gulf River catchments to date. Note that the absence of disease symptoms does not necessarily indicate an absence of disease.

An Integrated Disease Management (IDM) strategy should be implemented on your farm to minimise the likelihood of disease outbreaks. The components of this strategy include:

- Monitor your crop for disease symptoms. Get unusual symptoms identified, noting where they occur and monitoring extent over time.
- Select disease resistant varieties where possible
- Practice good integrated disease management at planting, in-crop and post-harvest
- Ensure all farm personnel are made aware of diseases on farm and unusual symptoms reported
- Awareness of insect vector diseases and if required, control these insects according to industry thresholds
- Follow good farm hygiene and biosecurity practices.

Detail on these components of an IDM strategy is provided in the Cotton Pest management Guide 2020-21 (https://www.cottoninfo.com.au/publications/cotton-pest-management-guide).

Managing crop growth

Vigorous vegetative growth before flowering produces the leaves, fruiting branches and roots that will support the future boll load. After flowering this vegetative growth will normally slow down as the plant prioritizes its resources to boll growth. When there is an excess of resources to the needs of fruit growth, vegetative and reproductive growth continue. Eventually, when all the resources are allocated and there is no excess, further growth ceases and the crop will cut-out.

The growth regulator Mepiquat Chloride (MC) is used to manage excess vegetative growth. This can occur when fruit is lost due to shedding during prolonged cloudy weather, very high temperatures or insect attack. It can also occur where there is abundant moisture, humidity, heat, or nutrients, and there is excess resources above the needs of the developing bolls.

Control of this excessive growth can increase canopy light penetration and air circulation reducing physiological shedding, and increasing fruit retention, and possibly increasing yield.

The aim is to grow and retain as many bolls per metre of crop row as possible within the normal season timeframe. In northern Queensland this is the period beginning when sunny conditions return after the monsoon and ends with the onset of cool late autumn/early winter night temperatures .

The principles in managing crop growth in this region can be based on the experience detailed in NORpak. The Burdekin Growth Model detailed here provides a guideline for the use of MC to manage excessive growth in the crop.

Defoliation

The cotton is treated with a combination of harvest aid chemicals that remove the leaves and hasten the opening of bolls in preparation for machine picking. Defoliants (Drop®, Reveal®) increase the ethylene concentration in leaves which causes the cells at the base of the leaf stem to die. If used correctly the leaf will drop from the plant before it dies.

Prep® may be used with the first defoliation pass to improve boll opening and leaf drop under cool

conditions. Defoliation can generally be completed within 10 to 20 days depending on temperature.

Key issues for defoliating northern crops include:

- Aim to have soil moisture as close to refill by defoliation.
- If boll openers/conditioners are applied before the crop is mature, a number of top bolls might be lost due to shedding
- To avoid quality issues only use boll openers and defoliants when the bolls are mature
- Follow the product label and check the 7 day temperature outlook
- Before defoliating check that the cotton can be picked within 2-3 weeks

Picking

Picking can start when the last top bolls have opened and at least 95% of the crop leaves have fallen.

Secure the services of a picking contractor who will be able to pick and form the cotton into either the modern round modules or older large rectangular modules. It is important that the picker is fully serviced before starting, is setup correctly and that a daily service schedule is followed.

Modules should be built and/or placed at locations readily accessible to road transport, and unlikely to interfere with adjacent field operations. Avoid locations where field water runoff from irrigation or rainfall occurs. While modules can withstand rainfall, they will absorb standing water which will result in significant downgrading or total loss.

Do not commence picking until morning dew has completely evaporated. Picking cotton that is excessively moist can cause self-combustion of modules, additional ginning costs if lint drying is required, and can also affect the lint quality post-picking.

Picking should also stop before evening dew forms. Thus there may only be a picking window of 7 to 9 hours/day.

Yields

Research and commercial experience in the Gulf River catchments suggest an irrigated yield range of 8 to 12 bales/ha. Raingrown yields of 3 to 6 bales/ha are likely.

Ginning

Cotton modules produced at picking are delivered to a cotton gin for processing. Cotton quality after ginning is a function of the initial quality of the seed cotton delivered to the gin, and the degree of cleaning and drying it receives during ginning. The aim of the ginner is to balance the amount of cotton produced (turn-out), production speed and the effects of cleaning and ginning components on fibre quality. To maximise turn-out and ginning quality growers need to:

- Ensure defoliation and picking practices minimise trash
- Minimise contamination
- Ensure moisture content during picking is equal to or less than 12%
- Control silverleaf whitefly and cotton aphid to minimise the incidence of sticky cotton.

The grower should communicate with the ginner prior to the start of ginning. An understanding of the issues experienced in the field may give the ginner insights on how best to handle the cotton to optimise turn-out and quality.

At present the closest location for ginning of cotton is Emerald in Central Queensland. The cost of freight for cotton produced in the Gulf Rivers is a significant cost with rates varying depending on the type of modules used, the availability of southern bound transport and the type of semi-trailer decks available.

End of Season Crop Destruction

Successful crop destruction following picking is the first step towards preparing the field for the next crop and is required as part of the Bollgard 3 Resistance Management Plan.

Ratoon (cotton regrowing from left over root stock) and volunteer cotton plants (from seed cotton) need to be removed as soon as possible from all fields. These plants provide a 'green bridge' for pests and diseases to carry over between seasons, as well as providing additional Heliocoverpa spp resistance risk.

More detail on post harvest crop residue management is provided in the publications listed in the Further Reading Section of this guide.

Marketing

The ability to 'lock in' a price for some or all of a crop before picking is a key feature of the Australian cotton marketing system. This can be a major advantage for cotton growers. However, fixing prices before harvest can be risky due to uncertain production levels.

Growers should seek advice from reputable merchants about the alternative marketing arrangements suitable to their specific situation. The primary areas of risk in cotton profitability is production risk (quantity and quality of cotton produced) and price risk (adverse price changes in input costs or decrease in commodity prices).

There are a number of cotton merchants who buy cotton from growers to sell in the international market. These merchants will offer a range of marketing options which allows growers the opportunity to create a marketing strategy that best suits their production plan, business needs and hopefully maximise profits.

The value of cotton seed can be a significant component of the income from a cotton crop. Traditionally the price of cotton seed has been strongly correlated with feed grains and fluctuates with supply and demand. The yield of cotton seed is around 240 to 260 kg seed for each bale of lint produced.

Further reading

Australian Cotton Production Manual 2021 (2021 Australian Cotton Production Manual | CottonInfo

Cotton Pest management Guide 2020-21 (https://www.cottoninfo.com.au/publications/cotton-pest-management-guide).

Tropical Cotton Production (Tropical cotton production | CottonInfo

WATERpak (WATERpak | CottonInfo)

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Acknowledgements

This guide has been produced with the financial support of the Cooperative Research Centre for Developing Northern Australia which is part of the Australian Government's Cooperative Research Centre Program (CRCP). The CRCNA also acknowledges the financial and in-kind support of the project participants – the Grains Research and Development Corporation, the State of Queensland, Department of Agriculture and Fisheries and Fry Bloodline Trust.

Agronomy Guide - Mungbean (Gulf Rivers)



Figure 1 – Irrigated mungbean trial on Forest Home Station, Georgetown 2020

This Agronomy Guide summarises information relevant to mungbean production within the Gulf River catchments of north Queensland. More detailed information related to mungbean agronomy is found in the GRDC 2018 Grownotes Mungbeans – Northern publication (https://grdc.com.au/GN-Mungbeans-North)

Planning

Mungbeans are a quick maturing summer grain legume. Raingrown crops must be planted into good subsoil moisture and receive rain or irrigation near flowering to do well.

Select paddocks with relatively uniform soil types – non-uniform soils will produce an unevenly maturing crop. Avoid rough paddocks with rocks and sticks as these can result in large harvest losses.

Mungbeans are sensitive to several residual herbicides, so caution is needed when selecting paddocks where residual herbicides have been used. In particular avoid residues of sulfonylurea (Group B herbicides), triazine (Group C) and picloram (Group I herbicides).

Mungbeans do not tolerate waterlogging so good irrigation management is critical. Field selection and fast watering practices are needed to minimise crop death from waterlogging. Plant on hills or beds if intending to furrow irrigate. Overhead irrigation is a preferred alternative.

Pre-planting

Mungbean varieties should be clearly separated at planting. Varietal mixtures are unacceptable in the market, and will incur substantial price discounts.

Select varieties based on yield, height, disease tolerance, grain quality, market opportunities and seed availability.

Mungbean is the term used for green-seeded types with pods borne at the top of the plant. Black gram is a closely related species to mungbean, but with dull grey-black seeds, and pods borne throughout the bush. It is more difficult to harvest as pods are set lower on the plant and maturity is often uneven.

Varieties

Jade-AU (released 2013):

- Large-seeded, bright green mungbean
- Highly acceptable to the market
- Best available resistance to powdery mildew, tan spot and halo blight
- Equivalent plant type and production agronomy to Crystal

Crystal (released 2008):

- Large-seeded, bright green mungbean
- Attractive to cooking and processing markets
- A tall erect variety with lodging resistance similar to Emerald

Berken (released 1975)

- Favoured variety for sprouting
- Susceptible to all three key diseases (tan spot, powdery mildew, halo blight)
- Prone to lodging, weather damage and cracking.

Satin II (released 2008)

- Pale, dull green seed, slightly smaller than Berken, but can be more variable.
- Better weathering resistance than Berken
- Flowering and maturity is more even than Berken.
- Generally grows taller than other varieties.
- Is a niche variety with limited market.

Celera II-AU (released 2014)

- Small seeded variety with low levels of hard seed
- A niche variety with limited market
- Good resistance to cracking and weather damage.
- Moderately resistant to halo blight
- More uneven flowering and maturity than other varieties.

Reselected Emerald (released 1993)

- medium-large, bright green seed – almost identical to Berken.
- Levels of hard seed may be quite high which limits its acceptance into sprouting markets
- Is taller than most varieties and less prone to lodging than Berken.
- Resistant to cercospora leaf spot and has some resistance to powdery mildew.
- Yields on average 16% more than Berken under good conditions or when powdery mildew is present.
- Flowers at about the same time as Berken but matures a few days later.

Green Diamond (released 1997)

- Small seeded variety with very high levels of hard seed (70%)
- Moderately susceptible to all three key diseases
- Relatively quick maturing variety that has an even podset
- Erect growth habit with pods carried high in the canopy
- Performs better than other varieties in dry situations.

Regur

- Dark grey seed with good resistance to cracking and weather damage at maturity
- Is more tolerant to drought, waterlogging and weathering than other varieties.
- Can have excessive vegetative growth under favourable growing conditions and is prone to lodging
- Is harder to harvest because pods are set lower than the green-seeded varieties and it flowers over a longer period.
- Markets are limited, but good seed quality is often easier to attain than with green-seeded varieties.

Seed quality

- Varietal purity is essential as mixtures are unacceptable to the market
- Quality of grower retained seed can deteriorate over 2-3 years
- Replace planting seed every 2-3 years

- Purchase only seed that is clearly labelled as Australian Mungbean Association (AMA) approved seed
- All seed offered for sale must clearly state the germination percentage and purity of the seed line
- The level of hard seed (by test) should be kept to a minimum

Planting

- Even establishment means even maturity and a crop that is easier to harvest.
- Marginal soil moisture at planting will result in poor emergence and crop growth.
- Use a rubber tyre roller to even out the soil surface and encourage even crop establishment.

Inoculation

- Mungbeans require the correct strain of Rhizobia bacteria to fix atmospheric nitrogen
- The seed should be inoculated with Group I mungbean inoculant (Rhizobium strain CB 1015)
- Seed should be sown as soon as possible after inoculation into moist soil to increase rhizobia survival
- Poor nodulation can result in significant yield reductions (up to 50%)
- Inoculum should be mixed with water and a sticker (e.g. methyl cellulose) to produce a slurry which will give good seed coverage.
- Attempting to coat the seed with dry inoculum is inadequate.
- Rhizobium inoculum is a living bacteria. Do not expose the inoculum, slurry or treated seed to sunlight and high temperatures as this will kill it.
- MAP with the seed at planting will not adversely affect the inoculum.
- Ideally only inoculate sufficient seed for one day's planting.
- If planting is delayed always re-inoculate.
- Beware of certain airseeders which use hot air to blow seeds. Temperatures greater than 30^{o}C may kill inoculum during the planting operation.

Planting time

The requirements for a good mungbean crop are:

- a soil temperature of at least 15^{o}C at planting. In north Queensland too high a soil temperature can impact crop establishment and performance.
- a full soil profile of moisture before planting (usually in mid- to mid-March);
- at least 25–50 mm of rain or irrigation at the start of flowering (around 5 weeks after planting);
- a dry period at harvest: 75–95 days after planting. The main planting time is mid-February to mid-March.
- Crops planted towards the end of this window will produce shorter plants and there is more likelihood of powdery mildew.

Row spacing

Row spacings of 18–100 cm are used. Narrow rows (up to 50cm) have a yield advantage where there is high yield potentials (> 1 t/ha). They provide greater weed competition particularly in late sowings when canopy closure is more difficult to achieve.

Use wide rows when:

- Yield potentials below 1 t/ha are expected;
- planting into heavy stubble residue in no-till situations;
- inter-row cultivation and band spraying are necessary to manage weeds;
- needing to use ground rigs for pesticide applications

Planting depth

- Plant into moisture at a depth of 30–50 mm.
- Do not use press wheels that exert pressure directly over the row

Planting rate

- Aim to establish 20 to 30 plants/m^2 in raingrown crops and 30 -40 plants/m^2 in irrigated crops
- Establishing a uniform plant density is critical to achieving uniform plant maturity across the paddock

- Ensure the planting depth across the width of the sowing machinery is even to aid the timing and consistency of crop emergence
- The number of mungbean seeds per kg can vary widely. Adjust planting rate accordingly to achieve the optimal plant populations
- Lodging can be a problem when populations exceed 40 plants/m^2 especially on wider row spacings.
- Target populations on 1-m wide rows are ideally 20-25 plants/m^2

Irrigation

Mungbeans are sensitive to waterlogging and good layout and drainage are crucial.

Surface irrigation

Surface irrigation is best suited to medium to heavy clay soils. Field layout and management can minimise the effect of waterlogging on mungbeans:

- Select fields with reasonably steep grades
- Fields should have no low spots (ideally they should be laser levelled)
- Form up high-volume hills or beds, which drain quickly after rain
- Select fields with short runs – preferably 200 to 400m
- An efficient tail-water system that will rapidly drain water away from the paddock is essential
- Irrigate down every alternate furrow
- Apply water quickly, preferably in 4-8 hours (use multiple siphons per furrow)
- Apply the first irrigation before soil cracks open up

Other considerations are:

- Jade-AU and Crystal have a greater yield potential than other varieties
- Narrow rows will maximise yields under favourable conditions
- Aim for a plant population > 30 plants/m^2
- Irrigating too early can delay or inhibit nodulation
- Coordinate irrigation with insect-control strategies

Irrigating too early in crop growth will encourage excessive vegetative growth. The preferred strategy is to pre-water to fill the profile and apply the first in-crop irrigation about 7 days before the start of flowering. Moisture stress during grain-filling can reduce yields and increase hard-seed levels. Excessive late irrigation can considerably delay maturity.

Overhead Irrigation

Overhead irrigation systems can be used on all soil types. The advantage is the ability to apply smaller amongst of water more frequently than surface irrigation. This reduces the waterlogging risk. Avoid heavy overhead applications to young plants because the caked-on dirt from mud-splash can reduce growth and thus plant stands. Applications of around 50mm water/week will be required during flowering and podfill.

Nutrition

Fertiliser recommendations need to be based on soil test results, fallow length, yield potential and paddock history.

Table 1 presents the quantity of nutrients required to produce 1.5 t/ha mungbeans and the amount of nutrients removed in the grain

Mungbean is highly dependent on beneficial fungi for the extraction of phosphorus (P) and zinc (Zn) from the soil. The combination of the fungus and crop roots is known as arbuscular mycorrhiza€ (or AM). AM levels are depleted by long fallows. If AM levels are likely to be low, assess P and Zn requirements using a soil test.

Mungbean is a legume, and when properly inoculated and planted into situations with low background soil nitrogen (N) levels, mungbean plants should fix sufficient atmospheric N to support their own growth, and may even leave some residual N for the following crop.

Application of starter fertilisers containing low rates of N as well as P, sulfur (S) and Zn are often recommended.

On P-deficient soils 5-10 kg P/ha is applied to dryland crops, with higher rates on irrigated crops.

Table 1 Mungbean nutrient removal for a crop yield of 1.5 t/ha

Nutrient	Removed in grain (kg/ha)	Total crop requirement (kg/ha)
Nitrogen	53 - 60	90 - 105
Phosphorus	5 - 8	9 - 14
Potassium	18 - 21	70 - 75
Sulfur	3 - 4	5 - 11
Calcium		27 - 45
Magnesium		12 - 20

Mungbean is responsive to zinc, and deficiency symptoms appear as stunted plants and dead tissues between the veins. Foliar sprays can assist to overcome mild deficiencies in-crop. Foliar zinc applications of 1 kg zinc sulphate heptahydrate with 1 kg of urea in at least 50 L of water/ha plus wetting agent will correct a mild deficiency. Spray once or twice within four weeks of emergence.

Regular applications containing Zn are a longer term solution. Apply 3 kg/ha of zinc sulphate monohydrate to the soil to correct deficiencies for up to 8 years. It should be well worked in at the start of the fallow before mungbeans.

Weed management

Mungbean is a poor competitor with weeds, which can impact yield potential, interfere with harvesting and contaminate the seed sample.

Limited broadleaf herbicide options exist for use in mungbean either pre- or post-emergence (see Table 2). Select paddocks clean of broadleaf weeds and develop a weed management strategy prior to planting.

A range of post-emergent options is available for grass weed control (see Table 3).

Always follow herbicide label directions and note warnings.

The cheapest methods of weed control are weed free fallows and rapid early ground cover using high plant populations and narrow row spacings. Use wider rows (up to 70 cm) when inter-row cultivation and band spraying are used or when bad weed infestations are expected. If using inter-row cultivation, do not produce deep furrows that the plants can fall into, making harvesting difficult.

The problem of herbicide resistance should be considered, particularly as most options for grass weed control are Group A herbicides. Herbicide rotation and an integrated weed management (IWM) strategy are important to reduce the likelihood of herbicide resistance developing.

Mungbean do not tolerate sulfonylurea (Group B), triazine (Group C) or picloram (Group I) residues. Residues will tend to persist for longer in alkaline soils and dry conditions. Consider the past herbicide usage on a paddock prior to planting mungbean.

Weed seeds in the harvested sample cause several serious problems in mungbean:

- They increase grading costs and grading losses
- Heavy discounts apply to weed seeds that are difficult to grade out (including grain sorghum seed)
- Samples containing prohibited seeds cannot be sold by classification, and can only be sold by forwarding a sample to the intending buyer. This will delay payments to the grower.

Table 2 Broadleaf weed control options in mungbean

Chemical	Pre Emergent			Post Emergent
	Pre-Plant		Post-Plant	
	pendimethalin	trifluralin	imazethapyr	acifluorfen
Group	D	D	B	G
Trade Name	STOMP® 440 & other products	Trifluralin 480 & other products	SPINNAKER® WDG	BLAZER®
Annual ground cherry				R
Anoda weed			R*	
Apple of Peru			R*	R
Bellvine			R*	R
Blackberry nightshade	R*			R
Bladder ketmia			R	R
Caltrop	R*	R		
Common heliotrope	R			
Common Sida			R	
Crested goosefoot	R			
Dwarf amaranth	R	R		
Fat hen	R		R	
Green amaranth	R		R	
Jute			R*	R
Mintweed	R*		R*	
Noogoora burr			R*	R
Nutgrass			R*	
Pigweed - black				R
Pigweed - red	R	R	R	R
Redroot Amaranth			R	
Redshank				R
Sesbania				R
Starburr			R*	
Thornapple			R*	R
Turnip weed				R
Wild gooseberry			R	R
Wild radish			R*	R
Wireweed	R	R		

- R = registered; * = suppression only

Table 3 Grass weed control options in mungbean

	Pre Emergent			Post-emergent			
	Pre-Plant		Post-Plant				
Chemical	pendimethalin	trifluralin	imazethapyr	clethodim	butroxydim	quizalofop-P-ethyl	haloxyfop
Group	D	D	B	A	A	A	A
Trade Name	STOMP® 440 & other products	Trifluralin 480 & other products	SPINNAKER® WDG	HAVOC & other products	FACTOR WG	TARGA	VERDICT 520
Awnless barnyard grass			R*	R	R	R	
Barnyard grass	R	R		R	R	R	R
Couch grass						R	
Crab Grass		R			R		
Crowsfoot grass	R			R	R	R	R
Dwarf setaria					R		
Feathertop Rhodes Grass				R	R		
Grader grass					R		
Green panic							R
Green summer grass					R		
Johnson grass				R	R	R	R
Liverseed grass	R			R	R	R	R
Mossman River grass	R						R
Rhodes grass						R	
Stink grass	R				R	R	
Summer grass				R	R		R
Volunteer cereals				R	R		R
Windmill grass					R		

R = registered

Insect management

Insects can reduce both yield and seed quality, impacting mungbean profitability. Crops should be inspected weekly from the vegetative stage through to budding and twice weekly from the start of budding-flowering through to the completion of podfill.

Mungbean also support populations of beneficial insects, a consideration when selecting insect control measures.

Although mungbean are attacked by a number of serious pests, top yield and quality can be achieved with timely and appropriate pest control. Unnecessary over-spraying can lead to secondary pest outbreaks and increase pest-management costs. It can also increase the risk of pesticide resistance.

The major mungbean insects pests are mirids, Helicoverpa, podsucking bugs (green vegetable bug, red shielded bean bug, large and small brown bean bug), bean pod borer and lucerne seed web moth. Beanfly can be a serious pest – the adults lay eggs in the mungbean leaf. The larvae which hatch tunnel into the lower stem where they pupate – this causes seedling death and reduced plant vigour.

Bruchid beetles are a major storage pest if best practice post-harvest storage is not practiced. Mungbean are often infested in the field but infestations not detected until after 3 months post-harvest. Infestations can also start post-harvest if harvesting equipment and storage facilities are not regularly cleaned to remove old seed.

Minor insects such as lucerne jassids, vegetable jassids, flower thrips and cutworms are occasionally found in mungbeans, but are rarely of economic importance.

For more detail refer to the GRDC GrowNotes *Mungbeans* publication.

Table 4 summarises the insecticide control options for mungbean.

Diseases

Diseases are more of a problem in late summer crops and if home-grown seed is used year after year.

Various management practices are used to reduce the impact of mungbean diseases. The aims of integrated pest management (IPM) are:

- Reduction of inoculum (rotations, residue management, volunteer destruction)
- Exclusion of causal agent (seed source, quarantine)
- Protection of host (resistance, pesticides).

Some varietal resistance is available to protect mungbean crops against diseases such as tan spot, halo blight and powdery mildew. These are the most common disease issues in mungbean. Charcoal rot is another disease that causes downgrading of Sprouting grade beans. It can also cause yield loss when it infects plants in the field.

There are two pod disorders which can occur in mungbean. Puffy pod appears as enlarged, blotchy and soft pods. Affected pods do not produce mature seed and commonly become infected by secondary rots. Growing points are often stunted and no flowers are produced from the deformed buds. The cause remains unknown, but appears to be stress-related. If the level of puffy pod is significant, do not wait for affected pods to mature. Desiccate the crop , and ensure a suitable drum speed and airflow to eject unthreshed puffy pods out behind the header.

Gummy pod results from the over-production of sugar by the flower nectaries in the plant in response to a Gluconobacter bacterial infection. This produces a sticky foam which oozes from the flowers and nectaries near the point of attachment of the pods with the stalks. The result is a soft, wet rot of the flowers, stalks and stems. This condition is triggered by excess heat and/or moisture stress. There are no control measures. Regular cleaning of harvesting equipment is recommended to prevent gum build-up during harvesting. Desiccation may be an option to minimise harvest problems.

Table 4 Insect control options in mungbean

Pest	Insecticide	Concentration	Example Product (Trade Names)	Days to harvest Withholding Period
Heliocoverpa	alpha-cypermethrin	100 g/L	Astound Duo	7
	beta-cypermethrin	100 g/L	Banshee EC insecticide	7
	BT		DiPel SC	0
	chlorantraniliprole	350 g/kg	Altacor Insecticide	14
	cypermethrin	250 g/L	Cyper Plus 250	7
	deltamethrin	27.5 g/L	Deltamethrin Duo	7
	esfenvalerate	50 g/L	Sumi-Alpha Flex	14
	gamma-cyhalothrin	150 g/L	Trojan	14
	Heliocoverpa NPV		Vivus Max	0
	indoxacarb	150 g/L	Steward EC	21
	lambda-cyhalothrin	250 g/L	Matador	14
	spinetotam	120 g/L	Success Neo	14
	thiodocarb	375 g/L	Larvin 375	21
	zeta-cypermethrin	100 g/L	Fury 100 EC	7
Green vegetable bug and pod sucking bugs	deltamethrin	27.5 g/L	Deltamethrin Duo	7
	dimethoate	400 g/L	Dimethoate 400	14
	methomyl	225 g/L	Methomyl 225	7
Bean pod borer	chlorantraniliprole	350 g/kg	Altacor Insecticide	14
	emamectin	17 g/L	Affirm	21
	methomyl	225 g/L	Methomyl 225	7
Mirids	alpha-cypermethrin	300 g/L	Alpha-Scud 300	7
	dimethoate	400 g/L	Dimethoate 400	14
	indoxacarb	150 g/L	Steward EC	21
Aphids	dimethoate	400 g/L	Dimethoate 400	14
	sulfoxaflor	240 g/L	Transform	14
Jassids/Leafhoppers	dimethoate	400 g/L	Dimethoate 400	14
Thrips	dimethoate	400 g/L	Dimethoate 400	14
Loopers	deltamethrin	27.5 g/L	Deltamethrin Duo	7
	BT		DiPel SC	0
	chlorantraniliprole	350 g/kg	Altacor Insecticide	14
	spinetotam	120 g/L	Success Neo	14

Desiccation

Mungbean has an indeterminate flowering habit. Flowers, green pods and black pods can all be present on the plant at the same time. This can make the harvesting decision difficult.

The ideal stage for harvest is when the majority of pods are mature, and 90% have turned either yellow or black. The crop is then ready for either desiccant application, or direct harvest.

Desiccation involves the use of a chemical defoliant green leaf from the plant and dry the tips of the stem. This minimises problems associated

with green leaf or stem interfering with the threshing action, and/or staining the beans.

Use a robust rate of desiccant and allow sufficient time for the crop to dry down before starting harvest.

Desiccation is needed on large, well-grown crops. It is generally unnecessary on low-yielding crops that are smaller in stature with small amounts of leaf and stem. Reglone® and various glyphosate products are registered for mungbean desiccation. Dry-down of leaf moisture can take as long as 5-6 days with Reglone® and 7-17 days with glyphosate.

It is essential to observe the withholding period between desiccant application and harvest.

Harvest

The average time from planting to maturity is 70–95 days. Care needs to be taken to ensure a quality beans are harvested, stored and delivered. Care needs to be taken to minimise the staining of the seed coat from dust sticking to the sap of the mungbean plant which can form a film over seeds during harvest. Experience in the Gulf River catchments shows this to be less of a problem because of terminal drought stress as the crop matures in the early dry season.

Header set-up is critical to avoid over threshing. The preferred moisture content for delivery to the packing shed is in the range of 12-14%. There are a range of harvester aids that can improve seed quality and minimise losses. These include:

- Double-cut knife guards
- Extension fingers
- Reduced ground speeds of 6-7 kph
- Air fronts
- Vibra-mat

Mungbean seed is easily damaged during harvest, with the risk of damage increasing as the seed dries out. Cracked grain and hairline fractures in the seed coat will significantly downgrade seed quality, resulting in lower prices. Care is needed to minimise this damage.

Yields

Research and commercial experience in the Gulf River catchments suggest an irrigated yield range of 1.2 to 2.6 t/ha. Raingrown:yields of 0.5 to 1.5 t/ha are likely.

Storage

Long-term storage (3 to 6 months) in the Gulf River catchments is not recommended. Mungbean quality deteriorates over time. Darkening of the seed coat is accelerated by:

- High seed moisture content
- High temperatures
- Relatively high humidity
- Condition of the seed at harvest

Seed subject to weathering prior to harvest will deteriorate a lot quicker in storage, even when stored under ‘acceptable’ conditions of temperature and relative humidity. Avoid even short to medium -term storage of weather-damaged grain.

Store only grain that is dry and clean. Regularly check the moisture content of grain entering storage. Aerate as the silo is filled and during the storage period. This maintains the grain at lower temperatures and uniform moisture conditions. Inspect grain in storage at least once per month. Sample grain from the top and bottom of a silo, visually checking for quality and sieving for insect pests. Keep storage records. When insects are detected, fumigate grain in a sealable storage.

Bruchids are the major insect pest of stored mungbean. Other storage insect pests can also infest mungbean. The key to control is to ensure that all handling equipment and storages are cleaned of old cereal grain before they are used to handle mungbean. If insects are detected in stored mungbean, phosphine fumigation is the only registered treatment. It can only be successfully used in a sealed, gas-tight storage. Phosphine is very toxic to people as well as insects, so do not handle treated grain before completion of the 7-10 day exposure period and 1-day fan-venting period to remove the gas.

Marketing

Australia is a small supplier compared with the main exporters of mungbean - China and Myanmar. The small size of the industry means prices are largely dictated by world market demand, and the fluctuating supply from the harvest in China (September-November) and Myanmar (January-May).

The main uses of mungbean are as a green vegetable, bean sprout, in cake manufacture, bean flour and livestock feed. The grain is graded, cleaned, bagged and packed in shipping containers.

Marketing involves the trade of seed parcels in an individual basis, typically in 25 kg bags.

Mungbean buyers focus on visual appearance, with bright, even green colour, varietal purity and size being critical. As a result, prices are usually determined by the final graded quality, as opposed to an agreement prior to grading.

Mungbean are sold into three main grades:

1. Sprouting – Premium or No.1 attracts the highest price. Strict specifications focus on colour, germination, purity, charcoal rot, size and oversoaks.
2. Cooking – classified on appearance, size, range and purity.
3. Processing - classified on appearance, size, range and purity.

Only 20% of the Australian crop meets the strict quality criteria for the Premium Cooking and Sprouting grade. The remaining 80% fall into the Processing grade. Processing grade beans have a lower price difference from sprouting of $150 - $350/t.

To achieve high prices production, harvest and storage should focus on minimising:

- Soil contamination
- Insect-, disease or weather damaged grain
- Cracked or split grain
- Uneven crop maturity
- Contamination from animals such as birds and rodents
- Weed seed contamination.

Further reading

Australian Mungbean Association – www.mungbean.org.au

GRDC 2020 GrowNotes Grain Storage (https://grdc.com.au/grain-storage-grownotes)

GRDC 2018 GrowNotes Herbicide Use (https://grdc.com.au/grownotes-herbicide-use)

GRDC 2018 GrowNotes Mungbeans – Northern (https://grdc.com.au/GN-Mungbeans-North)

GRDC 2017 GrowNotes Spray Application manual for Grain Growers (https://grdc.com.au/spray-application-manual)

Harris, G. and Mace, G. (2012) Irrigated mungbeans – best practice guide in *WATERpak - a guide for irrigation management in cotton and grain farming systems,* CRDC

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Acknowledgements

This guide has been produced with the financial support of the Cooperative Research Centre for Developing Northern Australia which is part of the Australian Government's Cooperative Research Centre Program (CRCP). The CRCNA also acknowledges the financial and in-kind support of the project participants – the Grains Research and Development Corporation, the State of Queensland, Department of Agriculture and Fisheries and Fry Bloodline Trust.

Agronomy Guide - Sesame (Gulf Rivers)



Figure 1 – Irrigated sesame trial on Forest Home Station, Georgetown 2022

This Best Practices Guide summarises information relevant to sesame production within the Gulf River catchments of north Queensland.

Sesame (Sesamum indicum) is a broadleaf crop well adapted to the semi-arid tropical regions of the world. Production has been based on small scale agriculture with India, China, Burma, Sudan and Tanzania the largest producers. Mechanised production occurs in Texas, Oklahoma and Kansas, and more recently in Australia.

Sesame grows to a height of 1 to 2 metres, and bears flowers in the axil of the leaves, with seeds contained in pods. Sesame seed can be black, brown or white in colour, and contain about 50% oil and 21% protein. Sesame is used for confectionary, culinary and cosmetic purposes.

China and Japan are the major importers of sesame, the majority of which comes from African countries. In 2016 China imported around 1 million tonnes of seed, and Japan imported 152,000 tonnes.

Planning

Sesame is suited to the growing conditions experienced during the wet season in the Gulf Rivers. It is well adapted to high temperatures experienced in this region. Growth and fruiting are favoured by average daily temperatures between 30°C and 33°C. Growing season length is around 120 to 150 days. The crop is fairly drought-tolerant and once established it

appears to withstand a higher degree of moisture stress than other field crops.

The crop should be planted into a full profile of moisture. It is well adapted to a range of soils but performs best on well-drained , moderately fertile soils with light to medium texture and a neutral pH. It is very sensitive to waterlogging. Even short periods of waterlogging will reduce plant stands and seed yield. Planting on beds is recommended to aid surface drainage – this is essential on clay soils and where surface irrigation used. It is not salt tolerant, and prefers neutral to slightly alkaline pH.

Select fields free of broadleaf weeds as sesame is a poor competitor until early bloom stage (around 40 days after planting). It is also very sensitive to a range of residual herbicides used on other crops. Do not plant where residues of imazethapyr (Pursuit), imazapic (Cadre), trifloxysulfuron (Envoke) and sulfuron are likely. Soilborne diseases such as such as Fusarium, Phytophthora and Charcoal rot (Macrophomina phaseoli) can cause sesame root rot – do not plant into fields where these diseases have been observed in other crops..

Pre-planting

The older sesame varieties are prone to shattering. This has prompted the development of several non-dehiscing varieties which are being evaluated under Australian conditions. There are both whites seeded and black seeded varieties available. The black seeded sesame varieties attract a premium price over white seeded types.

Varieties

There are white seeded and black seeded varieties of sesame available in Australia.

Seed supplies can be sourced from two suppliers:

- AgiVentis Technologies (suppliers of black sesame seed)
- Equinom

Planting

Use planting equipment with:

- Accurate depth control – do not use planters where depth control less than 1cm is not possible
- Ability to adjust to the low planting rates needed for the small size of sesame seed. In vacuum/air planters the disk hole diameter should be 1.5mm or less
- A proper seed-trench closing mechanism necessary for good seed-soil contact
- Raised beds are preferred to provide good surface drainage around plants
- Sesame seed are small and easily crushed, clogging the planter plates. Use small seed plates (sugar beet or canola) in row crop planters and do not fill planter boxes above 150 to 200mm to avoid churning seed.

Do not plant into dry soil and wait for rain – sesame will not break through a surface crust. It is a poor competitor with weeds in the first month after emergence – select weed-free seedbeds to minimise early weed competition.

Planting time

Soil temperature needs to be at least 21oC at planting depth. Sesame requires 90 to 110 days from planting to reach physiological maturity. A further 20 to 40 days of dry weather is needed to allow the plant to dry down for harvest. In northern Australia the preferred planting time is mid-December to mid-January which allows for the crop to dry down during the start of the dry season.

Row spacing

Row spacings of 18–100 cm are used. Narrow rows (up to 50cm) have a yield advantage where there is a high yield potential (> 1 t/ha). They provide greater weed competition particularly in late sowings when canopy closure is more difficult to achieve.

Use wide rows when:

- Yield potentials below 1 t/ha are expected;
- inter-row cultivation and band spraying are necessary to manage weeds;
- ground rigs are needed for pesticide applications

Planting depth

Sesame seed is very small and must be planted accurately into moist soil no deeper than 4cm. Very accurate seed placement with good seed-soil contact is critical for even germination and establishment. The seed trench should be covered with a thin layer of loose dry soil to maintain soil moisture in the seed zone and aid seedling emergence.

The deeper seed is planted the longer it will take to emerge. When planted at 5cm depth it can take up to 10 days to emerge. If planted too shallow the emerging seedling may run out of moisture before establishing – it requires 72 hours of good soil moisture conditions to planting depth on a full profile.

Planting rate

Aim to establish 30 plants/m^2 for high yields and effective weed control. Depending on the germination percentage of the seed used, a sowing rate of 2 to 2.5 kg/ha of good quality seed will give the desired plant density

Irrigation

Sesame is sensitive to waterlogging and good layout and drainage are crucial .

The timing of irrigation affects plant structure and final yield. Planted into good subsoil moisture sesame should not require irrigation until flowering. Pre-irrigation can be used to fill the profile prior to planting and germinate weeds that can be controlled with a fallow spray before planting. Withholding irrigation prior to flowering will control excessive vegetative growth and enhance deep root development.

For best yields the crop should not be stressed during flowering and pod formation. Ideally applications should be quick and light (up to 25mm applied by overhead irrigation). Over irrigation and waterlogging will delay plant development and lower yield potential. High humidity induced by excessive irrigation or rainfall can encourage the development of Cercospora Leaf Spot.

Nutrition

Fertiliser recommendations need to be based on soil test results, fallow length, yield potential and paddock history.

Nitrogen should be applied at 30 to 100 kg nitrogen/ha for crops, with the higher rate used for irrigated crops. Two-thirds of this should be applied prior to planting with the remainder side - dressed just prior to flowering. Do not apply any fertiliser with the seed at planting as this will result in poor establishment.

Phosphorus and potassium should be applied pre-plant based on soil test results and yield potential. Irrigated crops should be supplied with up to 30 kg phosphorus and up to 100 kg potassium/ha .

Low soil sulphur can impact sesame oil content.

Weed management

Sesame is a poor competitor with weeds in the first 40 days after planting. They will start to compete with weeds only from the beginning of flowering.

The crop should be planted into weed free fields as there are few herbicide options available for weed control. At present there are no registrations for weed control in sesame. There are permits (all expire in early 2024) for a limited range of herbicide products. There is a permit for use of Haloxyfop to control annual grass weeds. It is safe on sesame but must be applied pre-flowering to ensure no chemical residues in harvested seed. Several other herbicides are currently being evaluated for effectiveness and safety for use in sesame.

Consider inter-row cultivation where possible and discuss weed control options with your agronomist before planting sesame.

Insect management

The two major pests of sesame are Helicoverpa and sesame leaf-roller. Heliocoverpa larvae can severely damage sesame in the flowering and pod fill stages. Sesame leaf-roller caterpillars roll up young leaves, web them together with silk and then feed in the rolled-up mass. It can infest sesame within a few days of emergence. Severe defoliation can occur if the pest is not controlled. In addition to leaf damage the caterpillars also feed on flowers and bore into pods causing yield losses.

Other possible insect pests include wireworms and cutworms which can feed on young seedlings and reduce crop establishment. Fall armyworm larvae can also feed on developing pods. Green vegetable bug also attacks sesame. Aphids can also be a major pest in some years. There are limited insecticide options in sesame at present (see Table 1)

Good yield and quality can be achieved with timely and appropriate pest control. Unnecessary over-spraying can lead to secondary pest outbreaks and increase pest-management costs. It can also increase the risk of pesticide resistance

Diseases

To date disease has not been a significant issue in sesame crops grown in the Gulf Rivers.

The diseases that could be found are:

- Large Cercospora Leaf Spot
- Small Cercospora Leaf Spot
- Target Spot
- Powdery Mildew
- Charcoal Rot
- Little leaf (Mycoplasma)
- Target spot

Table 1 Insect control options in sesame

Pest	Insecticide	Concentration	Example Product (Trade Names)	Days to harvest Withholding Period
Aphids	pirimicarb	800 g/L	Aphidex 800	21
Heliocoverpa	chlorantraniliprole	350 g/L	Altacor	14
	Heliocoverpa NPV		Vivus Gold	0
	methomyl	225 g/L	Lannate L	14
Green vegetable bug	methomyl	225 g/L	Lannate L	14
Sesame Leaf-roller	No registered product			

Large Leaf Cercospora (caused by the fungus Mycosphaerella sesamicola) produces spots on foliage that are large and irregularly shaped. These can merge together killing a large portion of leaves in susceptible varieties during humid conditions produced by rainy weather or overhead sprinklers. Choose varieties with some resistance to this disease.

Small Cercospora leaf spot (caused by the fungus Mycosphaerella sesami) shows up as scattered lesions on both leaf surfaces.

Target spot (caused by the fungus Corynespora cassilcola) can severely affect yields. It first appears as dark (often purplish) spots on leaves, stems and pods. As spots enlarge they develop lighter coloured centres.

Powdery mildew (caused by the fungus Odium sp) produces a white powdery coating on sesame leaves.

Charcoal rot (caused by the fungus Macrophomins phaseolina) shows up as girdling of the sesame stem at or just above the soil line. This can lead to wilting and plant death.

Little leaf caused by mycoplasma transmitted by the common brown leafhopper. It causes greening of flower parts, proliferation of buds in leaf axils and little leaves. Control not necessary as levels of infection are usually very low.

Desiccation

There is a current APVMA Permit (expires 31 March 2024) for the use of glyphosate as a pre-harvest desiccant for sesame. This ensures even drying down of the crop and maintains seed quality. It should be applied as a foliar spray when at least 70 per cent of the seed capsules have changed colour from dark green to light green or yellow. Do not apply too early as this will cause significant yield losses. The application rates vary with the concentration rate of the product chosen – for Roundup Herbicide (360 g/L glyphosate) the application rate is 4.3 L/ha applied in a spray volume of 50 to 100 L/ha. Do not harvest for 7 days after application.

Harvest

Harvested sesame seed moisture must be below 6 per cent in the combine bin. If higher than this damage will result lowering seed quality.

Sesame is ready for harvest when dry plants and pods are golden brown, and the top tip of the pods are open.

All conventional combine harvesters can be adjusted to harvest sesame. As sesame seed is small and delicate care must be taken to minimise seed loss and damage during harvest.

To minimise seed loss set the combine as gentle and slow as possible from the header to back of the machine. The reel should be placed at the highest back position for minimal contact with the plants to minimise seed losses at the front of the harvester. The rotation speed should be the same as the combine's ground speed – do not exceed a forward speed of 6 km/hour.

To minimise losses from the back of the harvester use a low cleaning fan RPM setting.

- Avoid seed damage by ensuring:
- The cylinder is not running too fast
- The concaves are not too tight
- The seeds in the bin do not rise above the inlet auger
- The combine speed is not set too high

Check seed while harvesting. If you find broken or scuffed seeds, adjust combine settings.

It takes little threshing effort to remove seeds from the pods. Keep the concaves relatively open. Empty pods, some still connected to stalks, should exit the combine in one piece. Some trash in the combine bin is not an issue – cleaning all trash out will result in some seed loss. Sieve modifications can be done to improve cleaning.

Seed leaks must be found and sealed before harvest. Inspect tailings at the end of the field where the combine turns around. Tailings of 33

seeds per square metre equates to a loss of 1 kg/ha.

Yields

Yields of 2.5 t/ha are achievable for well managed crops, planted early with current available varieties.

Marketing

At present contracts are 100% buyback (no seed retention) on a clean seed basis at 6% moisture.

Oil content (when seed is pressed for oil) and seed condition are important attributes of good quality sesame seed. Oil scales for premium/discounts above/below 50% are not built into the local market as yet. There is no rapid oil testing available at this time so oil content is not a receival standard at present.

Further reading

Equinom 2021 Smarter Sesame Agronomy Guide

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Acknowledgements

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Agronomy Guide - Soybean (Gulf Rivers)



Figure 1 – Irrigated soybean trial on Forest Home Station, Georgetown 2019

This Agronomy Guide summarises information relevant to soybean production within the Gulf River catchments of north Queensland. More detailed information related to soybean agronomy is found in the GRDC 2016 Grownotes Soybeans – Northern Region publication (https://grdc.com.au/GN-Soybeans)

Planning

Soybean is a legume crop native to eastern Asia. It is used as a source of vegetable oil for human and industrial uses, as a protein source in livestock production and in a range of human foods. Soybeans typically contain about 40% protein, 20% oil and 35% carbohydrates. Soy oil is the major food products used worldwide and after extraction the protein is used as a meal for livestock. It is also used in soy products such as tofu and soy milk.

Crushing soybean is processed into vegetable oils for further processing into table oils and margarine spreads and also for animal feed. Soybean varieties with a dark coloured hilum can only be sold for oil and crushing. Grain soybean can also target the human food sector. This market prefers high protein beans of a large size and only clear or pale coloured hilum varieties are accepted. Soybean that does not meet the

quality required for milk and tofu but still meet the other quality specifications for colour, protein and size can be sold into the edible flour market.

Good crop establishment is the hardest part of growing a good soybean crop. This has certainly proven to be the case in trials planted on the sandy loam alluvials in the Gilbert River catchment in recent years. Soybean is very sensitive to soil water during the establishment stage up until the four leaf stage. If too wet seed will rot and if too dry it will fail to germinate and/or die before emergence.

Conventional tillage aims to produce 20 to 25 cm of loose soil allowing the formation of raised hills or beds. Avoid excessive tillage on light sandy soils which can lead to surface crusting that make crop establishment difficult. Heavier soils may require more working to make a suitable seedbed. Avoid leaving the seed bed with large clods as they will harbour weed seeds that will not be controlled by pre-emergent herbicides and reduce seedling population as the crop emerges.

Controlled traffic and permanent beds are an alternative system that benefits soybeans. Planting on beds allows for better drainage particularly where heavy wet season rainfall occurs.

Avoid rough paddocks with rocks and sticks as these can result in large harvest losses and risks harvester damage.

Soybean are sensitive to several residual herbicides, so caution is needed when selecting paddocks where residual herbicides have been used. In particular avoid residues of sulfonylurea (Group B herbicides), triazine (Group C) and picloram (Group I herbicides).

Soybeans are intolerant of salt. Yield are reduced at soil salinities greater than 2.0 dS/m and irrigation water greater than 1.5 dS/m.

Pre-planting

If a large area of soybean is planned, consider selecting two varieties of different maturity to spread planting, maintenance and harvesting operations.

There are a range of soybean varieties developed to cover the wide range of latitudes and climates used for growing soybeans in Australia. In addition, processors in the human consumption sector of the market are becoming more specific about the varieties they wish to use.

Soybean plants commence flowering and mature in response to increasing length of darkness. Current commercial varieties are photosensitive and in general the later they are sown in their recommended planting window the fewer days until flowering commences. They will also be shorter and set pods closer to the ground.

Varieties

Kuranda

- Suited for trialling in Gulf Rivers
- Planting early December through to early February
- Medium to long crop duration
- Tall growing and high biomass with high grain yield potential
- Bright white seed with a shiny coat and clear hilum
- Quick to mature pods

Mossman

- Suited for trialling in Gulf Rivers
- Planting late November to early February
- Long duration and big bush
- Small to medium sized seed with a yellow seed coat and light grey hilum

Stuart (released 2006)

- Long-duration variety adapted to tropics
- Light-coloured hilum
- Lower yielding than Kuranda

Seed quality

- Soybean seed is relatively short-lived and can rapidly lose germination and vigour after a few months in storage
- Always get a reliable germination and vigour test within 4 to 8 weeks of sowing
- Soybean seed has a thin seedcoat making it very susceptible to damage if handled incorrectly. Do not use spiral augers or drop seed onto hard surfaces.
- Only keep seed with an after harvest germination test of more than 90% to plant the next crop.

- Consider purchasing industry approved seed from suppliers at least every three years

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- Consider purchasing industry approved seed from suppliers at least every three years

Planting

MAP is generally used as the planting fertiliser. Ideally the seed and fertiliser should applied through separate delivery hoses. If seed and fertiliser cannot be separated do not exceed 50 kg MAP/ha in row crops planted in one metre rows under good moisture conditions. Reduce this rate in loamy soils.

Inoculation

- Soybean requires the correct strain of Rhizobia bacteria to fix atmospheric nitrogen
- The seed should be inoculated with Group H inoculant (Rhizobium strain CB 1809)
- Apply the inoculant at the correct application rate and check the expiry date. Store refrigerated (not frozen). In the paddock store inoculant in an esky with ice to keep it cool but not frozen.
- Once inoculated seed should be kept in a cool shady place out of direct sunlight and planted as soon as possible after inoculation. Due to high summer temperatures only treat enough seed to plant a small area at a time.
- Exercise caution when using air seeders, as hot air in the distribution system of some air seeders can kill the inoculum.
- There are a range of inoculation methods that can be used. These include:
    - Slurry inoculation
    - Water injection and in-furrow sprays
    - Pelleted seed
    - Nodulator® granules
- Hot, dry weather at planting can kill the Rhizobium bacteria before they come in contact with the plant roots. This is why soybeans must be planted in moist soil or irrigated immediately as planting dry and waiting for rain increases the risk the bacteria will die before seed can germinate.
- Waterlogging can kill the rhizobia. However soybeans have some tolerance to waterlogging, especially if grown on raised beds that allow the root zone to drain and remain aerated.

Planting time

Soybean should be planted in mid-December to January. Planting earlier than this will result in tall crops prone to lodging, making insect control and harvesting difficult. Planting at this time has presented establishment challenges in trials to date owing to high soil temperatures and rapidly drying seedbeds, particularly on lighter soil types.

Soybean have a longer growing period than shorter-season crops like mungbean. The growing season is around 135 to 150 days.

Row spacing

Soybean should planted with a row-crop planter to achieve uniform seed depth and placement along the row. Row cropping allows more options for weed control including banded sprays, shield sprayers and inter-row cultivation. It also facilitates the use of directed sprays for insect control and aeration of the crop, which is important to minimise fungal disease development in humid environments.

Row spacings of 50–100 cm are used. There is a potential yield advantage in using the narrower spacing.

Planting depth

- Plant into moisture at a depth of 30–50 mm.
- Do not use press wheels that exert pressure directly over the row

Planting rate

- Seed size can vary considerably so adjust seeding rate accordingly. Refer to the seed packaging label for an accurate count.

- Aim for plant populations of 250,000 to 300,000 plants/ha (25-30 plants/m^2)
- Higher populations produce plants more prone to lodging, making insect management and harvesting more difficult. It can also increase disease risk.

Irrigation

Soybeans are suited to a range of irrigation systems including raised beds, furrow and overhead irrigation. They have a peak water demand during flowering and early pod fill. Irrigated production is preferred in the Gulf River catchments owing to the highly variable rainfall received.

Ideally soybean should be planted into a full profile. Grain yield and protein content are dependent on timely irrigations throughout the life of the crop and avoiding moisture stress. Mild moisture stress in the early vegetative stage has little impact on yield and can encourage the plant to develop a deeper root system. Intermittent moisture stress reduces grain protein content as the plant shuts down nodules in its root system in response to the stress. They will not reactivate until there is adequate moisture. This can have a negative impact on total nitrogen content within the plant and hence grain protein content.

Moisture stress during flowering and pod fill reduces the number of retained pods and seed weights. Plants must not experience moisture stress from the start of flowering, through pod development and filling to physiological maturity. In the Gulf Rivers for a crop planted in mid-January the peak demand is from the end of February to the end of April.

Irrigation scheduling should be based on irrigation monitoring equipment.

The timing of the last irrigation is also critical. Soybeans require adequate moisture through until physiological maturity which takes place after the first maturing (pale yellow) leaves appear in the crop. Stopping irrigation too early results in shrunken seed and reduced yield.

Nutrition

Fertiliser recommendations need to be based on soil test results, fallow length, yield potential and paddock history.

Table 1 presents the quantity of nutrients required to produce 3.5 t/ha soybeans and the amount of nutrients removed in the grain.

Soybeans have a large nitrogen requirement which is fixed from the air via the *Rhizobium* bacteria forming nodules on their root system. High soil nitrogen levels will delay soybean nitrogen fixation. A small amount of starter nitrogen (up to 15 kg N/ha) can benefit a crop sown into high crop residue loads.

Phosphorus should be drilled with or banded close to the seed at planting. Note that there are limits to how much should be applied with the seed as this can damage the germinating seedling and the rhizobium inoculant (do not exceed 50 kg MAP/ha under good moisture conditions).

Table 1 Soybean nutrient removal for a crop yield of 3.5 t/ha

Nutrient	Removed in grain (kg/ha)	Total crop requirement (kg/ha)
Nitrogen	210 - 240	310 - 380
Phosphorus	17 - 21	21 - 28
Potassium	56 -70	140 - 170
Sulfur	13 - 17	21 - 28

Sulphur deficiency can limit yields. Refer to soil tests to determine sulphur rates that may be needed.

Potassium is also needed in large amounts. Yields may be limited by potassium deficiencies on sandy soils and those soils with a long history of intensive cropping where heavy export of potassium in hay, silage or grain has occurred. There are several forms of potassium fertiliser that can be used. If using muriate of potash never place it in contact with the seed as plant establishment will be impaired by the salt effect of the fertiliser.

Soybean is responsive to zinc. Zinc can be applied either to the soil or to the foliage. The best approach is determined by the soil type. In lighter textured, neutral to acidic soils soil applications of 30 kg/ha of zinc oxide every 5-7 years will fix any problems. In heavier, alkaline soils it is more effective to apply zinc with your starter P fertiliser.

Weed management

Weeds compete with soybeans for moisture, nutrients and light. Weeds in the crop can also increase harvest costs from mechanical blockages. Costs may be increased if weed seeds have to be graded out of harvested grain.

Soybeans are most sensitive to weed competition four to seven weeks after emergence.

No single herbicide or management option will control all weeds. An Integrated Weed management (IWM) approach should be used to manage the weed seed bank in the soil. This approach should include:

- Crop rotation
- Pre-plant application of knockdown herbicides using glyphosate (beware of herbicide resistance implications if relied on too extensively)
- Appropriate cultivation practices in sync with herbicide options
- Establishment of a uniform, robust plant stand at the targeted plant population
- Use of appropriate row spacings for your farming system/equipment

There are a range of herbicide options available for control of broadleaf and grass weeds, either pre- or post-emergent. Always follow herbicide label directions and note warnings. A summary of these is provided in Tables 2, 3, 4 and 5.

The problem of herbicide resistance should be considered, particularly as most options for grass weed control are Group A herbicides. Herbicide rotation and an integrated weed management (IWM) strategy are important to reduce the likelihood of herbicide resistance developing.

Insect management

Soybeans can be attacked by insect pests at any stage from seedlings to harvest. However, they are most attractive to insect pests from flowering onwards. They are more tolerant of insect damage than other grain legumes and noticeable damage (particularly leaf damage) does not necessarily result in yield loss. The basic integrated Pest management (IPM) strategy for soybeans is to avoid non-selective insecticides for as long as possible to encourage a build-up of beneficial predators and parasites. This buffers the crop against insect attack during later crop stages, greatly reduces the risk of subsequent helicoverpa, silverleaf whitefly and mite attack.

However there are several pests that can have a major impact on yield and quality, and insecticide application may be inevitable.

Major pests in soybeans are helicoverpa (heliothis) and podsucking bugs (green vegetable bug, large and small brown bean bug and the redbanded shield bug). Other lesser and/or infrequent pests include aphids, loopers and cluster caterpillar.

For more detail refer to the GRDC GrowNotes *Soybeans* publication.

Table 6 summarises the insecticide control options for soybean..

Table 2 Broadleaf weed pre-emergent control options in soybean

Chemical	pendimethalin	trifluralin	flumetsulam	imazethapyr
Group	D	D	B	B
Trade Name	STOMP® 440 & other products	Trifluralin 480 & other products	BROADSTRIKE	SPINNAKER® WDG
Annual ground cherry				
Anoda weed				R*
Apple of Peru				R*
Bellvine				R*
Blackberry nightshade	R*			
Bladder ketmia			R*	R
Caltrop	R*	R	R*	
Common heliotrope	R			
Common Sida				R
Crested goosefoot	R			
Dwarf amaranth	R			
Fat hen	R			R
Green amaranth	R			R
Jute				R*
Mintweed	R*			R*
Noogoora burr				R*
Nutgrass				R*
Pigweed - black			R*	
Pigweed - red	R	R		R
Redroot Amaranth		R		R
Redshank				
Sesbania				
Starburr				R*
Thornapple				R*
Turnip weed				
Wild gooseberry				R
Wild radish				R*
Wireweed	R	R		

* = suppression only

Table 3 Broadleaf weed post-emergent control options in soybean

Chemical	acifluorfen	bentazone	imazamox	imazethapyr
Group	G	C	B	B
Trade Name	BLAZER®	BASAGRAN®	RAPTOR®	SPINNAKER® WDG
Annual ground cherry	R	R		
Anoda weed		R	R	R
Apple of Peru	R	R		
Bellvine	R	R	R	R
Blackberry nightshade	R		R	
Bladder ketmia	R			
Caltrop			R	
Common heliotrope				
Common Sida				R
Crested goosefoot				
Dwarf amaranth			R	
Fat hen			R	
Green amaranth			R	
Jute	R			R
Mintweed				
Noogoora burr	R	R	R	
Nutgrass				
Pigweed - black	R			
Pigweed - red	R			
Redroot Amaranth			R	
Redshank	R			
Sesbania	R			
Starburr		R		
Thornapple	R	R	R	R
Turnip weed	R		R	
Wild gooseberry	R		R	R
Wild radish	R		R	
Wireweed			R	

* = suppression only

Table 4 Grass weed pre-emergent control options in soybean

Chemical	S-metolachlor	pendimethalin	trifluralin	imazethapyr
Group	K	D	D	B
Trade Name	Dual Gold ®	STOMP® 440 & other products	Trifluralin 480 & other products	SPINNAKER® WDG
Awnless barnyard grass	R			R*
Barnyard grass	R	R	R	
Couch grass				
Crab Grass			R	
Crowsfoot grass	R	R		
Dwarf setaria				
Feathertop Rhodes Grass	R			
Grader grass				
Green panic				
Green summer grass				
Johnson grass			R	
Liverseed grass	R	R		
Mossman River grass		R	R	
Rhodes grass				
Stink grass	R	R		
Summer grass	R		R	
Volunteer cereals				
Windmill grass				

Table 5 Grass weed post-emergent control options in soybean

Chemical	butroxydim		clethodim	fluazifop	haloxyfop	quizalofop-P-ethyl	sethoxydim
Group	A		A	A	A	A	A
Product Example	Factor WG®		Select®	Fusilade Fort®	Verdict® 520	Targa®	Sertin®
Awnless barnyard grass	R		R			R	R
Barnyard grass	R		R	R	R	R	R
Couch grass				R		R	
Crab Grass	R						
Crowsfoot grass	R		R	R	R	R	R
Dwarf setaria	R						
Feathertop Rhodes Grass	R		R				
Grader grass	R						
Green panic				R	R		
Green summer grass	R						
Johnson grass	R		R	R	R	R	R
Liverseed grass	R		R	R	R	R	R
Mossman River grass					R		
Rhodes grass				R		R	
Stink grass	R			R		R	
Summer grass	R		R	R	R	R	R
Volunteer cereals	R		R		R		R
Windmill grass	R						

Table 6 Insect control options in soybean

Pest	Insecticide	Example Product (Trade Names)	Days to harvest Withholding Period
Heliocoverpa	alpha-cypermethrin	Astound Duo	7
	BT	DiPel SC	0
	deltamethrin	Deltamethrin Duo	7
	esfenvalerate	Sumi-Alpha Flex	14
	gamma-cyhalothrin	Trojan	14
	Heliocoverpa NPV	Vivus Max	0
	indoxacarb	Steward EC	21
	lambda-cyhalothrin	Matador	14
	methomyl	Lannate	7
	spinetotam	Success Neo	14
	thiodocarb	Larvin 375	21
	zeta-cypermethrin	Fury 100 EC	7
Green vegetable bug and pod sucking bugs	deltamethrin	Deltamethrin Duo	7
	dimethoate	Dimethoate 400	14
	emamectin	Affirm	21
	methomyl	Lannate	7
Aphids	sulfoxaflor	Transform	14
	dimethoate	Dimethoate 400	14
Jassids/Leafhoppers	deltamethrin	Deltamethrin Duo	7
Loopers	BT	DiPel SC	0
	chlorantraniliprole	Altacor Insecticide	14
	methomyl	Lannate	7
	spinetotam	Success Neo	14
	zeta-cypermethrin	Fury 100 EC	7
Soybean Loopers	BT	DiPel SC	0
	chlorantraniliprole	Altacor Insecticide	14
	indoxacarb	Steward EC	21
	spinetotam	Success Neo	14

Diseases

Soybean crops are prone to a range of fungal and bacterial diseases. Good rotational practices, careful variety selection and thorough decomposition and incorporation of crop residue will minimise disease occurrence. Avoid planting soybeans after other legumes or sunflowers.

Seedling root rots can cause rotting in the ground and death of young seedlings after emergence. There are a range of fungal species responsible – *Rhizoctonia solani, Phytophthora sojae* and *Pythium* species). Rhizoctonia is favoured by rainfall followed by warm weather. It survives mainly in infected stubble so soybeans growing through soybean or other stubble are at high risk. To minimise losses:

- Avoid sowing deeper than 50mm
- Use high-quality seed
- Minimise the amount of stubble in the sowing line

- Use crop rotation.

Charcoal rot appears as premature dying of plants from pod-fill to maturity. Crops under severe moisture stress or heat stress are most susceptible. Waterlogging can also predispose plants to infection. To minimise disease irrigate regularly and control weeds.

Other fungal diseases include:

- Sclerotinia stem rot
- Sclerotium base rot
- Phomopsis pod and stem blight and seed decay
- Rhizoctonia root rot
- Rust
- Downy mildew
- Purple seed stain
- Powdery mildew

Other diseases include:

- Bacterial blight
- Bacterial pustule
- Big bud or little leaf

For more detail on these diseases and their management refer to the GRDC GrowNotes Soybeans publication

Desiccation

Some herbicides are registered for the desiccating the crop to aid harvest. This is generally only warranted where there are green weeds likely to cause harvesting difficulties. These difficulties include mechanical blockages in the header, grain quality downgrading from contamination by declared weed seeds and from staining of the harvested grain by the weed sap.

The two options available are:

- Diquat (Reglone®) applied when 80% of pods are yellow/brown and seeds are ripe, yellow and pliable. Harvest 4-7 days after spraying.
- Weedmaster Argo or Weedmaster DST applied only after seed pods have lost all green colour and 80-90% of leaves have dropped. Do not harvest within 7 days of application. Do not apply to seed crops.

It is essential to observe the withholding period between desiccant application and harvest.

Harvest

Harvest is critical to achieving high quality soybeans for the food grade market. The aim is to produce the highest possible sample quality and purity, with the lowest possible losses. Grower payment is conditional on tonnages delivered, moisture content, test weight and on seed sample and purity. Crop establishment and harvest management have a major effect on all these.

Harvesting soybeans to maximise yield and quality can be achieved by:

- Using the best agronomic practices, compatible with harvest
- Minimising pre harvest losses. For example if desiccating the crop, timing is critical and using the widest boom possible to minimise seed losses from trafficking during the spray-out operation.
- Correct set up of the harvester – use a floating cutterbar and a ‘feathering’ pickup reel correctly adjusted to forward speed of the harvester
- Minimise processing losses – soybeans are easy to thresh and separate but excessive green stems will negatively affect the feeding of the crop. Adjust the rotor or cylinder settings to minimise excessive damage or splits to the seed.
- When unloading, slow the engine to reduce seed damage by the unloading auger.
- Use belt conveyors and avoid augers when moving soybeans around the farm

Yields

Research trials at Forest Home station have recorded irrigated yields of 3.1 to 3.9 t/ha. Crop establishment has been a significant issue in achieving good commercial yields in the Gulf River catchments.

Storage

Soybean seed is prone to splitting and breakage during mechanical handling. Bucket elevators and belt conveyors result in less damage compared with a standard auger.

Over-dry soybeans or those that have been subjected to a number of rain events just prior to harvest are also more likely to split. The storability of soybeans is affected by the degree of damage to the seed coat. Damaged seed favours storage insect pests and moulds. Inspect soybeans for mechanical and other forms of damage prior to storage.

Ideal storage for soybeans is a well designed cone based 'sealable' silo with aeration. The aim is to minimise damage to seed when moved, ease of cleaning/hygiene for empty storages and suitability of effective use of aeration cooling.

If seed requires insect control, the silo is then sealed (gas tight) for the required period as stated on the pesticide label (usually 7 – 10 days) to enable effective phosphine fumigation to take place. Phosphine is very toxic to people as well as insects, so do not handle treated grain before completion of the 7-10 day exposure period and 1-day fan-venting period to remove the gas.

Marketing

The two main uses of Australian soybeans is the crush market for oil and meal, and the edible market. The Australian soybean market is a small part of the large global market dominated by the US and Brazil.

A large proportion of the Australian crop is consumed domestically, with around half used for the domestic crush market. The crush market generally sets the market price. The edible market continues to expand. Culinary grade soybeans are both exported for the edible trade and consumed locally. The darker hila varieties are used by oilseed crushers, with soymeal produced as a by-product and used for stockfeed. The lighter hila varieties are typically used in the edible trade.

Local values are heavily impacted by global values due to the large volumes of soybean meal imported into Australia each season. The largest user of soybean meal is the poultry industry which drives the volume of meal imported each season.

The edible trade is usually priced at a premium based on buyer's preference for particular varieties.

Further reading

Soy Australia Ltd – www.australianoilseeds.com/soy_australia

GRDC 2020 GrowNotes Grain Storage (https://grdc.com.au/grain-storage-grownotes)

GRDC 2018 GrowNotes Herbicide Use (https://grdc.com.au/grownotes-herbicide-use)

GRDC 2016 GrowNotes Soybeans – Northern Region (https://grdc.com.au/GN-Soybeans)

GRDC 2017 GrowNotes Spray Application manual for Grain Growers (https://grdc.com.au/spray-application-manual)

Mace G. and Harris, G. (2012) Irrigated soybeans – best practice guide in *WATERpak - a guide for irrigation management in cotton and grain farming systems,* CRDC

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Acknowledgements

This guide has been produced with the financial support of the Cooperative Research Centre for Developing Northern Australia which is part of the Australian Government's Cooperative Research Centre Program (CRCP). The CRCNA also acknowledges the financial and in-kind support of the project participants – the Grains Research and Development Corporation, the State of Queensland, Department of Agriculture and Fisheries and Fry Bloodline Trust.

Appendix 2 Gulf River AgMargins



Cotton Surface / Syphon (Irrigated) Gulf 2020

Gross Margin: $3,776 /ha

QUEENSLAND GOVERNMENT

Income

	QTY	YIELD	PRICE	TOTAL
Lint		10 bales/ha	550 $/bale	$5500 /ha
Seed		3 t/ha	190 $/tonne	$570 /ha
				Total Income: $6070 /ha

Variable Costs

	QTY	RATE	COST	TOTAL
Fallow Management				
Operation: Mulcher + FWA Light FORM	1 operation	12 ha/hr	36.22 $/hr	$3 /ha
Middlebusting	1 operation	6 ha/hr	108.65 $/hr	$18 /ha
Operation: Self-propelled sprayer FORM	3 operation	30 ha/hr	65.57 $/hr	$7 /ha
Herbicide: Glyphosate 450 CT	2 application	1.6 L/ha	6.45 $/L	$21 /ha
Herbicide: Trifluralin	1 application	1.2 L/ha	8.75 $/L	$11 /ha
Operation: Discing	2 operation	6 ha/hr	130.65 $/hr	$44 /ha
Operation: Bed Shaping + Large FWA	1 operation	4.6 ha/hr	115.44 $/hr	$25 /ha
				Total Costs: $127 /ha
Planting				
Operation: planter (seed)	1 operation	10 ha/hr	139.58 $/hr	$14 /ha
Seed: Cotton		13 kg/ha	8 $/kg	$104 /ha
Seed: Cotton Bollgard II fee: Opt1		1 Portion	370 $/ha	$370 /ha
				Total Costs: $488 /ha
Nutrition				
Nutrient: Granulock Z		100 kg/ha	0.87 $/kg	$87 /ha
Operation: Spreader + FWA Light FORM	1 operation	30 ha/hr	34.95 $/hr	$1 /ha
Nutrient: Urea - Farm Gate	1 application	260 kg/ha	0.55 $/kg	$143 /ha
				Total Costs: $231 /ha
Crop Protection				
Operation: Self-propelled sprayer FORM	5 operation	30 ha/hr	65.57 $/hr	$11 /ha
Herbicide: Roundup Ready	2 application	1.5 kg/ha	10.6 $/kg	$32 /ha
Aerial Spray	1 application		15.53 $/L	$16 /ha
Insecticide: Indoxacarb (e.g. Steward)	1 application	0.65 L/ha	69 $/L	$45 /ha
Insecticide: Dimethoate (e.g. Dimethoate Nufarm)	3 application	0.35 L/ha	10.05 $/L	$11 /ha
				Total Costs: $114 /ha
Irrigation				
Irrigation: Surface (FORM)		5 ML/ha	53.35 $/ML	$267 /ha
				Total Costs: $267 /ha
Harvesting				
Plastic Wrap: Cotton Bale	10 bales/ha		8.8 $/bale	$88 /ha
Aerial Spray	2 operation		15.53 $/L	$31 /ha
Defoliant: Thiadazu	1 application	0.25 L/ha	52.75 $/L	$13 /ha
Defoliant: Crop Oil	1 application	2 L/ha	3.91 $/L	$8 /ha
Defoliant: Ethepon	1 application	1.5 L/ha	9.33 $/L	$14 /ha
Defoliant: Ethepon	1 application	2 L/ha	9.33 $/L	$19 /ha
Harvester: Cotton Round Bale		4 ha/hr	180.22 $/hr	$45 /ha
Round Bale Grab: Cotton	10 bales/ha		4 $/bale	$40 /ha
				Total Costs: $258 /ha
Other				
Crop insurance	1 %		5500 $/ha	$55 /ha
Contract: Consultant Irrigated Broadacre			65.2 $/hr	$65 /ha
R&D Levy	10 bales/ha		2.25 $/bale	$23 /ha
Voluntary Levy	10 bales/ha		1.5 $/bale	$15 /ha
5% Pigeon Pea Refuge			19.95 $/ha	$20 /ha
				Total Costs: $178 /ha
Post-Harvest				
Cartage: Cotton	10 bales/ha		9.86 $/bale	$99 /ha
Contract: Ginning	10 bales/ha		53.35 $/hr	$534 /ha
				Total Costs: $632 /ha
New Variable Cost Group				
				Total Costs: $0 /ha
				Total Variable Costs: $2294 /ha
				Gross Margin: $3,776 /ha

Effect of Yield and Price on Gross Margin ($/ha)

Lint Yield (bales/ha)	Seed Yield (t/ha)	$440.00/bale $152.00/tonne	$495.00/bale $171.00/tonne	**$550.00/bale $190.00/tonne**	$605.00/bale $209.00/tonne	$660.00/bale $228.00/tonne
7.00	2.10	$1,129	$1,550	**$1,971**	$2,392	$2,813
8.00	2.40	$1,610	$2,091	**$2,573**	$3,054	$3,535
9.00	2.70	$2,091	$2,633	**$3,174**	$3,715	$4,257
10.00	**3.00**	**$2,573**	**$3,174**	**$3,776**	**$4,377**	**$4,979**
11.00	3.30	$3,054	$3,715	**$4,377**	$5,039	$5,700
12.00	3.60	$3,535	$4,257	**$4,979**	$5,700	$6,422
13.00	3.90	$4,016	$4,798	**$5,580**	$6,362	$7,144

Effects of Yield and Price on Gross Margin per ML (assuming 5.0ML/ha is used).

Lint Yield (bales/ha)	Seed Yield (t/ha)	$440.00/bale $152.00/tonne	$495.00/bale $171.00/tonne	**$550.00/bale $190.00/tonne**	$605.00/bale $209.00/tonne	$660.00/bale $228.00/tonne
7.00	2.10	$226	$310	**$394**	$478	$563
8.00	2.40	$322	$418	**$515**	$611	$707

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Lint Yield (bales/ha)	Seed Yield (t/ha)	$440.00/bale $152.00/tonne	$495.00/bale $171.00/tonne	$550.00/bale $190.00/tonne	$605.00/bale $209.00/tonne	$660.00/bale $228.00/tonne
9.00	2.70	$418	$527	**$635**	$743	$851
10.00	**3.00**	**$515**	**$635**	**$755**	**$875**	**$996**
11.00	3.30	$611	$743	**$875**	$1,008	$1,140
12.00	3.60	$707	$851	**$996**	$1,140	$1,284
13.00	3.90	$803	$960	**$1,116**	$1,272	$1,429

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Mungbean (Irrigated) Gulf 2020

Gross Margin: $874 /ha

QUEENSLAND GOVERNMENT

Income

	QTY	YIELD	PRICE	TOTAL
No1 Processing		1.4 tonnes/ha	1100 $/tonne	$1540 /ha
Gradings		0.3 tonne/ha	200 $/tonne	$60 /ha
				Total Income: $1600 /ha

Variable Costs

	QTY	RATE	COST	TOTAL
Irrigation				
Irrigation: Surface (FORM)		2.5 ML/ha	53.35 $/ML	$133 /ha
				Total Costs: $133 /ha
Fallow Management				
Operation: Self-propelled sprayer FORM	2 operation	30 ha/hr	65.57 $/hr	$4 /ha
Herbicide: Glyphosate 450 CT	2 application	1.6 L/ha	6.45 $/L	$21 /ha
Operation: Discing	2 application	6 ha/hr	130.65 $/hr	$44 /ha
Operation: Bed Shaping + Large FWA	1 application	18.4 ha/hr	115.44 $/hr	$6 /ha
Herbicide: Trifluralin (e.g. Trifluralin 480 EC)	1 application	1.4 L/ha	8.75 $/L	$12 /ha
				Total Costs: $87 /ha
Planting				
Operation: planter (broad acre)		7 ha/hr	139.58 $/hr	$20 /ha
Seed: Mungbean		25 kg/ha	2.1 $/kg	$52 /ha
Inoculum: Group N		0.05 pkt/ha	35.6 $/pkt	$2 /ha
				Total Costs: $74 /ha
Nutrition				
Nutrient: Granulock Z - Farm Gate		50 kg/ha	0.88 $/kg	$44 /ha
Operation: Spreader + FWA Light FORM	1 application	30 ha/hr	34.95 $/hr	$1 /ha
				Total Costs: $45 /ha
Crop Protection				
Operation: Self-propelled sprayer FORM	3 operation	30 ha/hr	65.57 $/hr	$7 /ha
Herbicide: Verdict 520	1 application	0.15 L/ha	57 $/L	$9 /ha
Insecticide: Dimethoate	2 application	0.5 L/ha	10.05 $/L	$10 /ha
Insecticide: Steward	1 application	0.4 L/ha	69 $/L	$28 /ha
				Total Costs: $53 /ha
Harvesting				
Operation: Self-propelled sprayer FORM	1 operation	30 ha/hr	65.57 $/hr	$2 /ha
Herbicide: Roundup ULTRA MAX	1 application	1.1 L/ha	7.45 $/L	$8 /ha
Operation: Harvest Draper Front		4 ha/hr	161.31 $/hr	$40 /ha
Operation: Chaser Bin		4 ha/hr	107.26 $/hr	$27 /ha
				Total Costs: $78 /ha
Post-Harvest				
Operation: Grains on farm cartage	1.4 tonnes/ha		0.38 $/t	$1 /ha
Operation: Processing and Bagging (beans)	1.4 tonnes/ha		113.4 $/hr	$159 /ha
Transport: Heavy Haulage (60t)	1	1	0.01 $/L	$0 /ha
				Total Costs: $159 /ha
Other				
Levy	1.02 %		1540 $/ha	$16 /ha
Contract: Consultant Irrigated Broadacre			65.2 $/hr	$65 /ha
Crop insurance	1 %		1540 $/ha	$15 /ha
				Total Costs: $96 /ha
				Total Variable Costs: $726 /ha

Gross Margin: $874 /ha

Effect of Yield and Price on Gross Margin ($/ha)

No1 Processing Yield (tonnes/ha)	Gradings Yield (tonne/ha)	$880.00/tonne $160.00/tonne	$990.00/tonne $180.00/tonne	$1,100.00/tonne $200.00/tonne	$1,210.00/tonne $220.00/tonne	$1,320.00/tonne $240.00/tonne
0.98	0.21	$184	$294	**$404**	$513	$623
1.12	0.24	$309	$435	**$560**	$686	$812
1.26	0.27	$435	$576	**$717**	$859	$1,000
1.40	**0.30**	**$560**	**$717**	**$874**	**$1,031**	**$1,188**
1.54	0.33	$686	$859	**$1,031**	$1,204	$1,376
1.68	0.36	$812	$1,000	**$1,188**	$1,376	$1,565
1.82	0.39	$937	$1,141	**$1,345**	$1,549	$1,753

Effects of Yield and Price on Gross Margin per ML (assuming 2.5ML/ha is used).

No1 Processing Yield (tonnes/ha)	Gradings Yield (tonne/ha)	$880.00/tonne $160.00/tonne	$990.00/tonne $180.00/tonne	$1,100.00/tonne $200.00/tonne	$1,210.00/tonne $220.00/tonne	$1,320.00/tonne $240.00/tonne
0.98	0.21	$74	$118	**$161**	$205	$249
1.12	0.24	$124	$174	**$224**	$274	$325
1.26	0.27	$174	$230	**$287**	$343	$400
1.40	**0.30**	**$224**	**$287**	**$350**	**$412**	**$475**
1.54	0.33	$274	$343	**$412**	$481	$551
1.68	0.36	$325	$400	**$475**	$551	$626
1.82	0.39	$375	$456	**$538**	$620	$701

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Sesame (Irrigated) Gulf 2020

Gross Margin: $1,778 /ha

QUEENSLAND GOVERNMENT

Income

	QTY	YIELD	PRICE	TOTAL
No1 Processing		0 tonnes/ha	0 $/tonne	$0 /ha
Gradings		0 tonne/ha	0 $/tonne	$0 /ha
Clean seed	1	2 tonnes/ha	1200 $/tonne	$2400 /ha
				Total Income: $2400 /ha

Variable Costs

	QTY	RATE	COST	TOTAL
Irrigation				
Irrigation: Surface (FORM)		2.5 ML/ha	53.35 $/ML	$133 /ha
				Total Costs: $133 /ha
Fallow Management				
Operation: Self-propelled sprayer FORM	2 operation	30 ha/hr	65.57 $/hr	$4 /ha
Herbicide: Glyphosate 450 CT	2 application	1.6 L/ha	6.45 $/L	$21 /ha
Operation: Discing	2 operation	6 ha/hr	130.65 $/hr	$44 /ha
Operation: Bed Shaping + Large FWA	1 operation	3 ha/hr	115.44 $/hr	$38 /ha
				Total Costs: $107 /ha
Planting				
Operation: planter (broad acre)		7 ha/hr	139.58 $/hr	$20 /ha
Seed: Sesame		2.5 kg/ha	2.1 $/kg	$5 /ha
				Total Costs: $25 /ha
Nutrition				
Nutrient: Granulock Z - Farm Gate		50 kg/ha	0.88 $/kg	$44 /ha
Operation: Spreader + FWA Light FORM	2 application	30 ha/hr	34.95 $/hr	$2 /ha
Nutrient: Urea	1 application	220 kg/ha	0.54 $/kg	$119 /ha
				Total Costs: $165 /ha
Crop Protection				
Operation: Self-propelled sprayer FORM	3 operation	30 ha/hr	65.57 $/hr	$7 /ha
Herbicide: Verdict 520	1 application	0.15 L/ha	57 $/L	$9 /ha
Insecticide: Dimethoate	1 application	0.5 L/ha	10.05 $/L	$5 /ha
Insecticide: Steward	1 application	0.4 L/ha	69 $/L	$28 /ha
				Total Costs: $48 /ha
Harvesting				
Operation: Self-propelled sprayer FORM	1 operation	30 ha/hr	65.57 $/hr	$2 /ha
Herbicide: Roundup ULTRA MAX	1 application	1.1 L/ha	7.45 $/L	$8 /ha
Operation: Harvest Draper Front		4 ha/hr	161.31 $/hr	$40 /ha
Operation: Chaser Bin		4 ha/hr	107.26 $/hr	$27 /ha
				Total Costs: $78 /ha
Post-Harvest				
Operation: Grains on farm cartage	2 tonnes/ha		0.38 $/t	$1 /ha
				Total Costs: $1 /ha
Other				
Contract: Consultant Irrigated Broadacre			65.2 $/hr	$65 /ha
				Total Costs: $65 /ha
				Total Variable Costs: $622 /ha
				Gross Margin: $1,778 /ha

Effect of Yield and Price on Gross Margin ($/ha)

No1 Processing Yield (tonnes/ha)	Gradings Yield (tonne/ha)	Clean seed Yield (tonnes/ha)	$0.00/tonne $0.00/tonne $960.00/tonne	$0.00/tonne $0.00/tonne $1,080.00/tonne	$0.00/tonne $0.00/tonne $1,200.00/tonne	$0.00/tonne $0.00/tonne $1,320.00/tonne	$0.00/tonne $0.00/tonne $1,440.00/tonne
0.00	0.00	1.40	$722	$890	**$1,058**	$1,226	$1,394
0.00	0.00	1.60	$914	$1,106	**$1,298**	$1,490	$1,682
0.00	0.00	1.80	$1,106	$1,322	**$1,538**	$1,754	$1,970
0.00	**0.00**	**2.00**	**$1,298**	**$1,538**	**$1,778**	**$2,018**	**$2,258**
0.00	0.00	2.20	$1,490	$1,754	**$2,018**	$2,282	$2,546
0.00	0.00	2.40	$1,682	$1,970	**$2,258**	$2,546	$2,834
0.00	0.00	2.60	$1,874	$2,186	**$2,498**	$2,810	$3,122

Effects of Yield and Price on Gross Margin per ML (assuming 2.5ML/ha is used).

No1 Processing Yield (tonnes/ha)	Gradings Yield (tonne/ha)	Clean seed Yield (tonnes/ha)	$0.00/tonne $0.00/tonne $960.00/tonne	$0.00/tonne $0.00/tonne $1,080.00/tonne	$0.00/tonne $0.00/tonne $1,200.00/tonne	$0.00/tonne $0.00/tonne $1,320.00/tonne	$0.00/tonne $0.00/tonne $1,440.00/tonne
0.00	0.00	1.40	$289	$356	**$423**	$490	$558
0.00	0.00	1.60	$366	$442	**$519**	$596	$673
0.00	0.00	1.80	$442	$529	**$615**	$702	$788
0.00	**0.00**	**2.00**	**$519**	**$615**	**$711**	**$807**	**$903**
0.00	0.00	2.20	$596	$702	**$807**	$913	$1,018
0.00	0.00	2.40	$673	$788	**$903**	$1,018	$1,134
0.00	0.00	2.60	$750	$874	**$999**	$1,124	$1,249

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Soybean (Edible) (Irrigated) Gulf 2020

Gross Margin: $611 /ha

QUEENSLAND GOVERNMENT

Income

	QTY	YIELD	PRICE	TOTAL
Soybean		3 tonnes/ha	475 $/tonne	$1425 /ha
				Total Income: $1425 /ha

Variable Costs

	QTY	RATE	COST	TOTAL
Fallow Management				
Operation: Self-propelled sprayer FORM	5 operation	30 ha/hr	65.57 $/hr	$11 /ha
Herbicide: Glyphosate 450 CT	2 application	1.6 L/ha	6.45 $/L	$21 /ha
Adjuvant: Non-ionic (eg Hasten)	2 applications	0.2 L/ha	7.25 $/L	$3 /ha
Implement: Offset Disc	2 operation	4.4 ha/hr	27 $/hr	$12 /ha
Operation: Bed Shaping + Large FWA	1 operation	4.6 ha/hr	115.44 $/hr	$25 /ha
Herbicide: Trifluralin (e.g. Trifluralin 480 EC)	1 operation	1.4 L/ha	8.75 $/L	$12 /ha
				Total Costs: $84 /ha
Planting				
Seed: Soybean		50 kg/ha	1.75 $/kg	$88 /ha
Inoculum: Group N		0.05 pkt/ha	35.6 $/pkt	$2 /ha
Operation: planter (seed)	1 application	8 ha/hr	139.58 $/hr	$17 /ha
				Total Costs: $107 /ha
Nutrition				
Nutrient: Granulock Z - Farm Gate		50 kg/ha	0.88 $/kg	$44 /ha
Operation: Spreader + FWA Light FORM	1 application	30 ha/hr	34.95 $/hr	$1 /ha
				Total Costs: $45 /ha
Crop Protection				
Operation: Self-propelled sprayer FORM	4 operation	30 ha/hr	65.57 $/hr	$9 /ha
Herbicide: haloxyfop-R	1 application	0.15 L/ha	57 $/L	$9 /ha
Adjuvent: Adigor	1 application	0.5 L/ha	9.25 $/L	$5 /ha
Herbicide: Bentazone (e.g. Basagran)	1 Application	2 L/ha	50 $/L	$100 /ha
Insecticide: Deltamethrin	2 application	0.5 L/ha	11.2 $/L	$11 /ha
Insecticide: Dimethoate (e.g. Dimethoate Nufarm)	1 application	0.34 L/ha	10.05 $/L	$3 /ha
Aerial Spray	1 application		15.53 $/L	$16 /ha
Operation: inter-row cultivation	1 operation	5.4 ha/hr	104.65 $/hr	$19 /ha
				Total Costs: $171 /ha
Irrigation				
Irrigation: Surface (FORM)		5 ML/ha	53.35 $/ML	$267 /ha
				Total Costs: $267 /ha
Harvesting				
Operation: Harvest Draper Front		6 ha/hr	161.31 $/hr	$27 /ha
Operation: Chaser Bin		6 ha/hr	107.26 $/hr	$18 /ha
				Total Costs: $45 /ha
Post-Harvest				
Operation: Grains on farm cartage	3 tonnes/ha		0.38 $/t	$1 /ha
				Total Costs: $1 /ha
Other				
Levy	1.02 %		1425 $/ha	$15 /ha
Contract: Consultant Irrigated Broadacre			65.2 $/hr	$65 /ha
Crop insurance	1 %		1425 $/ha	$14 /ha
				Total Costs: $94 /ha
				Total Variable Costs: $814 /ha
				Gross Margin: $611 /ha

Effect of Yield and Price on Gross Margin ($/ha)

Soybean Yield (tonnes/ha)	$380.00/tonne	$427.50/tonne	$475.00/tonne	$522.50/tonne	$570.00/tonne
2.10	-$3	$94	**$192**	$290	$388
2.40	$108	$220	**$332**	$443	$555
2.70	$220	$346	**$471**	$597	$723
3.00	**$332**	**$471**	**$611**	**$751**	**$890**
3.30	$443	$597	**$751**	$904	$1,058
3.60	$555	$723	**$890**	$1,058	$1,225
3.90	$667	$848	**$1,030**	$1,211	$1,393

Effects of Yield and Price on Gross Margin per ML (assuming 5.0ML/ha is used).

Soybean Yield (tonnes/ha)	$380.00/tonne	$427.50/tonne	$475.00/tonne	$522.50/tonne	$570.00/tonne
2.10	-$1	$19	**$38**	$58	$78
2.40	$22	$44	**$66**	$89	$111
2.70	$44	$69	**$94**	$119	$145
3.00	**$66**	**$94**	**$122**	**$150**	**$178**
3.30	$89	$119	**$150**	$181	$212
3.60	$111	$145	**$178**	$212	$245
3.90	$133	$170	**$206**	$242	$279

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