Tools for the soil: Timely Operations

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Executive Summary

The aim of this Nuffield research was to find and test ways to ensure the consistent and timely planting of crops, primarily cotton, during very trying and extreme climatic and field level (soil) conditions in the tropical Ord region in Western Australia.

Farming system change can take 25 to 30 years to implement. Change is good for the next generation and needs to be practiced and executed. It means engaging in a journey of many failures and deciding to embrace the pain and the cost of failure and enduring that pain because there is a dim light at the end of the tunnel.

Many different businesses and scenarios have been seen over these last two years, and the businesses that have a culture that accepts change are “leading the pack”.

The research program focused on three ways to build a foundation for a paradigm change towards new industries. **Adopting and investing in new machinery and sexy technology** seemed the most pleasing and fastest solution to managing restraints, and the natural inclined direction.

Soil health and improvement is also a natural passion of the author. When reviewing information and research on this topic it becomes complicated, and changing soil takes 25 to 30 years. It must be a continuum of change, so again, improvements will be seen in the long-term.

Working with people. Respect and trust are paramount to go on a journey of change, as is communicating, setting goals, managing emotions and egos. Owning another person’s mistakes and paying for them is a challenge. The lightbulb moment of this scholarship was visiting an Amish farm and not seeking a complicated, emotional solution and journey. That is the backbone of this report. Enjoy the results, just don’t expect them quickly. A good foundation built on collaboration will last for many generations to come.

CropShielding, Aquatill planting, controlled traffic, soil amelioration practices and using lighter machinery are encouraged to be adopted. The autonomous vehicle industry is at a stage where it can be adopted over the next five to ten years, not to save on labour but to reduce weight on the soil. This will reduce the speed of doing highly precise tasks. It will increase precision, efficiency, and productivity. It will be fun and profitable.

Collaboration will be the key to executing timely operations! In isolated, remote areas with extreme climatic conditions, farmers must work together to successfully adapt to the challenges.

Tools for the soil: Timely Operations

Keywords:

CropShielding

Aquatill planting

Controlled Traffic farming

Soil amelioration practices

Lighter machinery (Not sexy big gear)

Autonomous vehicles

Collaboration

Feel the Soil

Wear out a pair of boots

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Foreword

We operate an irrigated row crop farm that produces grain and fibre in the Ord River Irrigation Area (ORIA) in Western Australia. Oasis Farms was started by my parents in the Ord in 1981. I took over in 2010 having joined the farm full-time in 1993.

There are two unique characteristics that need to be understood about farming in the remote tropical ORIA. We moved here because there is a good supply of irrigation water. Farmers have been looking for a base crop since the inception of the town of Kununurra just over 60 years ago.

I have personally grown over 27 different crop types. Each new crop requires new agronomic and marketing knowledge, but most importantly it requires different planting and harvesting machinery. From the outside it might appear that we know what we are doing but we have never grown one major crop for long enough to refine machinery requirements, let alone understand true agronomic or marketing potential of new crops. On the upside, we are nothing if not adaptable!

There is excitement of a new cropping system that has enough agronomic, mechanical, economic background and resilience to sustain the north for generations to come. This is the “Cotton-Corn-Cattle” cropping and integrated farming system.

Due to the development of the Bollgard3 cotton variety, cotton production is now possible in the north. Before this genetically modified (GM) technology was not able to protect from different populations of insect pests encountered in the tropics compared to other cotton growing production systems further south.

With the Bollgard3 opportunity came good crop modelling, made possible by strong collaborative efforts and investment in research by local farmers, research organisations and government. It showed that cotton should be planted in mid-February and no later than early March to ensure maximum utilisation of radiation and day degree units and maximum sunlight and energy at peak boll production and filling. In the past we have always planted crops in late April or early May after the wet season has finished.

So, crops are now planted in February – the wettest month with an average 200-250mm of rain. Generally, it rains twice a week, and we need five to seven days of dry weather to access our heavy vertosol clay soils for seeding. The change in practices and shift in paradigm around planting operations is paramount.

Ord-based farmers Kimberley Agricultural Investment (KAI) under the leadership of Jim Engelke and Luke McKay (Nuffield Scholar, 2018) proved otherwise. They conducted commercial trials in 2019 which were assumed would fail, but instead a great result was had.

To put the importance of this into context. A current cotton gin development in the region, which is owned by the local farming community, will add $90m in revenue from lint. It will also add over $100m in other agricultural revenue annually due to value add from cotton seed fed to cattle during the protein drought in the dry season. Corn is added to the mix for cattle feed energy and for cotton cropping rotations. Animal health outcomes are very positive.

Cotton is a secure cash flow option because of good global marketing and trading precedents. It will ensure secure employment for the local community.

I have traveled through Singapore, The Netherlands, Canada, the USA, Australia, Germany, and New Zealand as part of this scholarship. There are more questions to answer now than before this journey started so I will be conducting more independent study to identify the solutions and possibilities are for us up here in the remote far north of Australia.

Table 1. Travel itinerary

Travel date	Location	Visits/contacts
5-8 June (2022)	Singapore	National University of Singapore MLA ANZ headquarters David Leong, Joint head of Coverage
8-15 June	Netherlands	
16-21 June	Canada, Ontario	
22 June-2 July	USA, Kansas and Washington DC	
3-8 July	USA, Peoria Illinois	Transit. Meet Jason Stoller Precision Planting. Various other meetings
9-12 July	USA, Texas Dallas	Visit Jorg Keller Texacano. Cotton Corn cattle farm with overhead and pipe irrigation
20-23 February (2023)	Australia, Adelaide	EvokeAg 2023
5-19 March	Canada	Pre-Contemporary Scholars Conference (CSC) and CSC week
20-21 March	Australia, Dubbo	Richie Quigley visit Bobby Browne visit
22 March	Australia, Sydney	Rabo Bank, Sydney Farm to Fork Conference
23-30 March	New Zealand, Christchurch	Nuffield Triennial International Conference
22-25 May	Australia, Northern Food Futures Conference Darwin	Spoke at the opening ceremony at Parliament and presented at the conference
1-16 June	Germany	Visited various businesses in Northern and Southern Germany
2 July	Nacra field days	Spend the day with Dr Oliver Knox discussing soil's especially soil trafficability

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Andrea Bolten

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Albertus Hanekom, 2020 Scholar

Abbreviations

C	Celsius
CEC	Cation exchange capacity
cm	Centimeter
CRCNA	Cooperative Research Centre for Developing Northern Australia
CRDC	Cotton Research and Development Corporation
CSIRO	Commonwealth Scientific Industrial Research Organisation
DPIRD	Department of Primary Industries and Regional Development
GRDC	Grains Research and Development Corporation
GM	Genetically Modified
ha	hectare
KAI	Kimberley Agricultural Investment Pty Ltd
m	Metre
mm	millimeter
N	Nitrogen
NACRA	Northern Australia Crop Research Alliance
ORDCO	Ord River District Cooperative Limited
ORIA	Ord River Irrigation Area
R&D	Research and development
WA	Western Australia

Objectives

The objectives of this research are to find ways to sustain the agricultural system in the Ord River Irrigation Area of Northern Australia through:

- Ensuring that soil health is maintained and improved.
- Ensuring that timely planting during the February planting window is consistently achieved.
- Ensuring that plant establishment is of an excellent standard.
- Setting a culture of innovation and collaboration.
- Ensuring a new, integrated cotton, corn and cattle farming system that can reliably produce output every year.

Chapter 1: Introduction

The expansion of the cotton industry in the Ord River Irrigation Area (ORIA) has been the subject of significant research and excitement over the last decade, focusing heavily on time of sowing to optimise wet season moisture and to maximise flowering and boll growth when weather conditions are most suitable.

Late January to early March sowing takes the best advantage of the seasonal conditions through to picking in July and August. Work undertaken by the Commonwealth Scientific Industrial Research Organisation (CSIRO) and local agronomists for the locally owned Northern Australia Crop Research Alliance (NACRA) between 2017 and 2021 evaluated the best time of sowing options, the efficacy of Bollgard 3 varieties on *Spodoptera litura,* and validated and calibrated modelling tools for climatic risk assessment for growing cotton in Northern Australia (Yeates, 2021).

The work by CSIRO and others has shown that climate challenges to growing cotton in the Ord include:

- February has the highest and most intense rainfall periods in Kununurra.
- There is less solar radiation than southern Australia during boll growth.
- Higher minimum temperatures during sowing than other growing areas in Northern Australia, including Richmond, Burdekin, Georgetown, and Gilbert River.
- Higher maximum temperatures than other northern cotton growing areas during the sowing window, with the exception of Richmond (Queensland).
- High risk of nitrogen (N) losses before the root system is established.
- Extremely variable rainfall patterns during the wet season sowing window, which makes it very difficult to manage crop N.

Figure 1. Wet season planting conditions in the Ord (source: author)

These challenges were a motivation to become a Nuffield Scholar and investigate how best to manage new farming systems being developed in the Ord.

There is good science around growing cotton in the north, and it was critical to take that knowledge and turn it into opportunities for farming operations. Wet season sowing requires careful soil management in extreme environmental conditions, tailored use of mechanical options and strong industry collaboration to ensure planting windows are kept and the genetic traits of the cotton varieties are kept strong. This Nuffield project investigated all three of these areas.

Figure 2. More Ord wet season planting conditions (source: author)

Chapter 2: Climate Challenges

Figures 3, 4, 5 and 6 were presented to Ord farmers by CSIRO researcher Stephen Yeates (2016), show some of the challenges to successfully growing cotton in northern Australia.

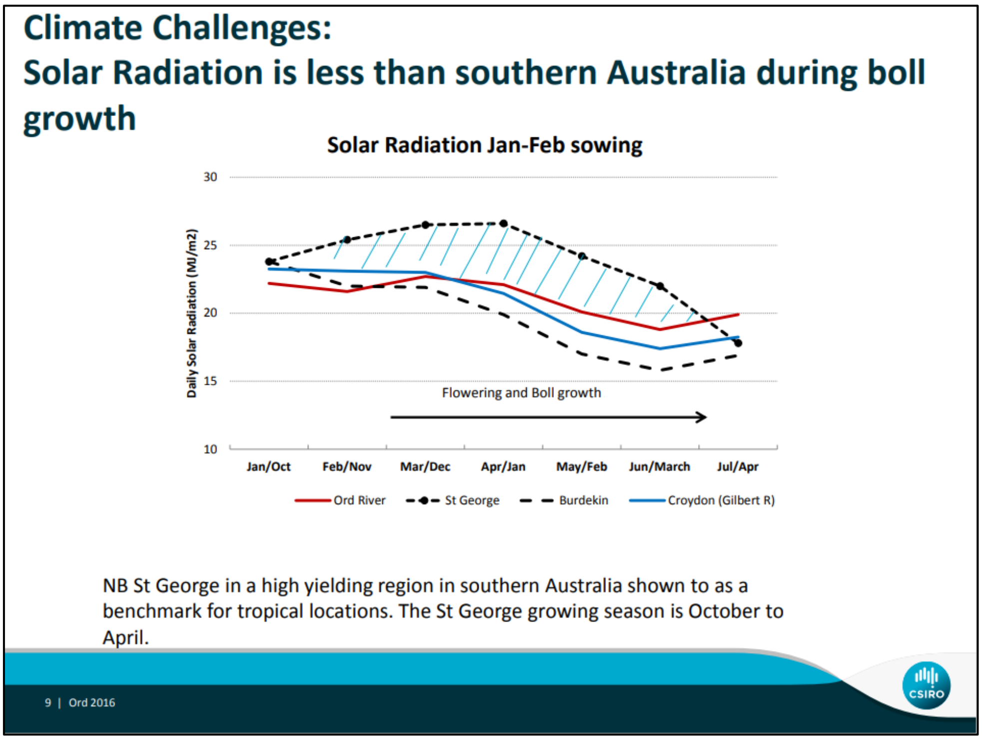

Figure 3. Comparative solar radiation during the cotton growing season (CSIRO)

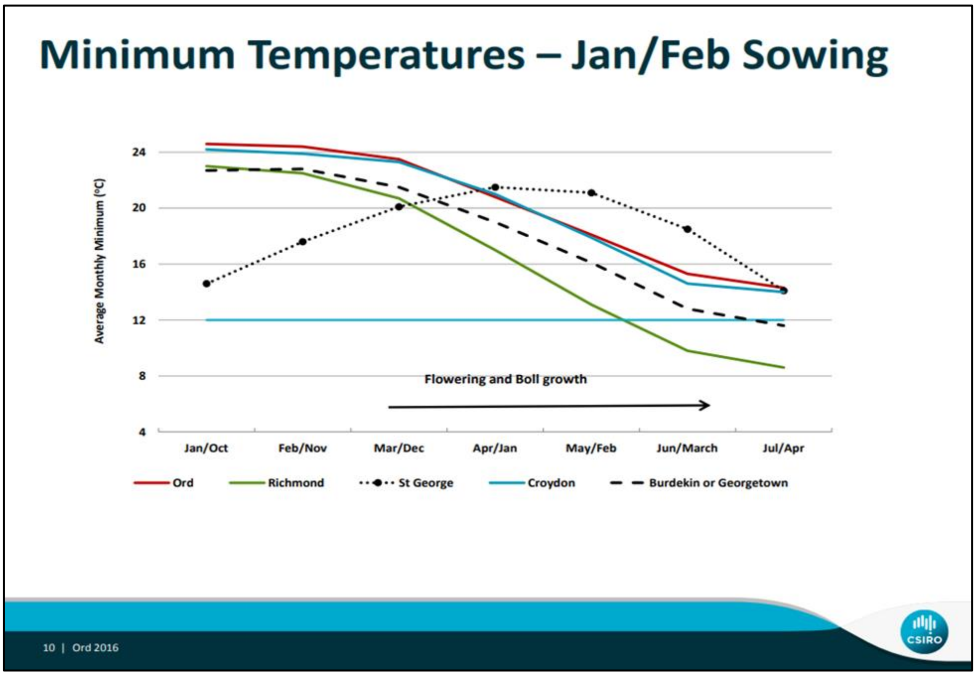

Figure 4. Comparative minimum temperatures in the northern cotton planting periods (CSIRO)

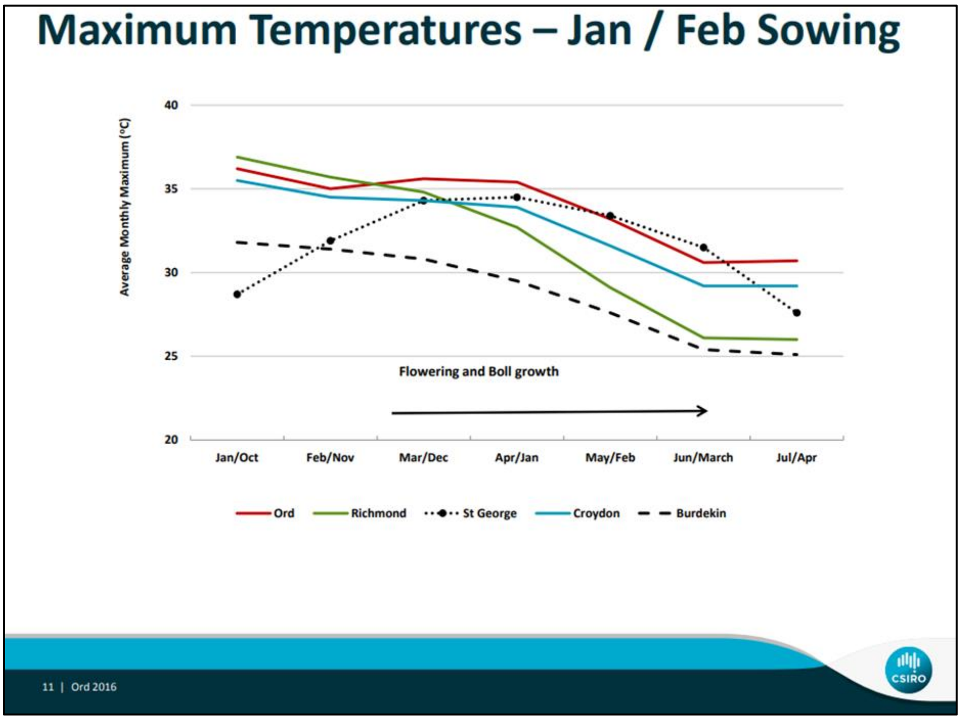

Figure 5. Maximum temperatures following January and February planting (CSIRO)

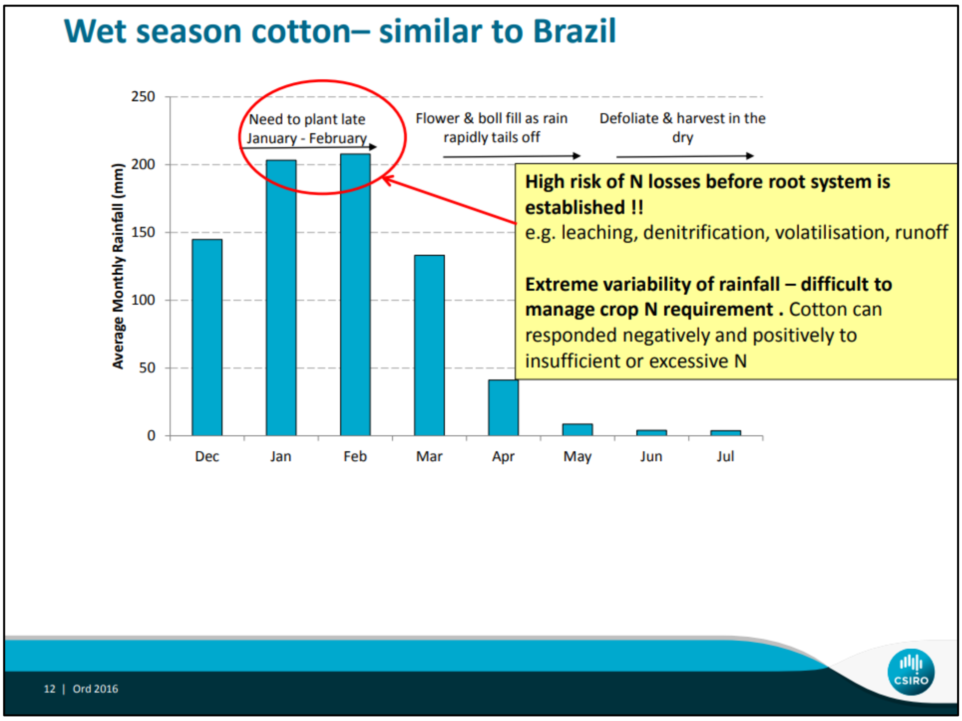

Figure 6. Wet season rainfall in the Ord (CSIRO)

(Figures 3-6 source: Yeates, 2016)

These climate challenges were investigated to apply to farm operations in this region.

Chapter 3: Environmental Factors

3.1 Soil management

3.1.1 Erosion

February has the highest and most intense rainfall in the region. This means rain events of up to 377mm per hour (recorded on 31 January 2003 during Tropical Cyclone Fay). Average wet season rain is 11.6mm/hour noting that this can vary greatly within fields and within short distances.

For soil to be healthy and resilient, the main requirement is oxygen. One of the main techniques used to maximize oxygen level in these tropical conditions is to ridge or hill the field so the part of the field which is planted is essentially raised about 20cm. This gives furrows which drain water away from the surface. The hills stay dryer and does not get waterlogged to the same extent during wet conditions.

Figure 7. Raised planting beds help manage in-field drainage (source: author)

These intense rainfalls cause not only water logging, but also erosion. Over time, soil movement is prevalent but does not move far. Mostly, soil moved by intense rain events moves the soil off the top of the “ridge” into the furrow, with the result being that the “ridge” is not the desired 20cm above furrow height.

Ridges that are not 20cm above field height can be built up with a cultivation at a later stage, but it’s always more desirable to reduce the soil movement and erosion in the first place. This also greatly increases the risk of tending to the crop because it decreases the efficiency and speed at which the crop can be irrigated if the need arises.

There are a few ways that erosion can be reduced or managed:

a. Stubble retention. This means crop residue is retained from the previous crop. Corn stubble retention is associated with risks. If stubble is not incorporated with the soil because there is so much of it (10-14 tonnes per ha) it causes severe anerobic conditions. Past best practice with corn stubble has always been to burn the stubble but this is not desirable or advantageous anymore. Since learning to incorporate and mix this huge amount of organic matter in with the soil and still achieve good soil drainage and oxygen levels there has been a reduction in soil erosion and a marked improvement in ridge height after intense rain events. The author did not come across the same issues when meeting farmers around the world. World's best practice for soil conservation and erosion control is minimum tillage but it would be difficult to maintain a clean and well-draining furrow and result in waterlogged and unhealthy soil. When trying this in the past, the formaldehyde and sulphur smells from soil was a major concern. The soil health declined quickly.

b. Cover crops have been grown in many variations in this tropical monsoonal region in the past. Cover crops ensure erosion reduction and maintain good soil temperature, but they also keep the top 5-8cm of soil very wet. This is a very natural allelopathic response from the established plants. It reduces competition from other plants. So, cover cropping is not a desirable technique in the region as it facilitates water logging. And in Northern Australian conditions this will mean missing the optimal planting period.

Cover crops also harbor a huge abundance of soil and other insects. Since adopting a clean wet season fallow approach, soil insects and timeliness have been manageable. This approach has been successful for the last 35 years, but it is certain that it will not last another 35 years so changes to the cropping system need to be made.

3.1.2 Drainage

It has become apparent that drainage is a main contributor to world food production. Most high agricultural production areas are in high rainfall, highly humid areas. For timely cropping operations to occur tile drainage, or sub soil drainage infrastructure, has been installed on farms.

Examples observed in The Netherlands at the Peat Land Innovation Centre, and advice from the centre's 2020 Nuffield Scholar Frank Lenssinck (pers. comm.) provided insight into improved tile drainage opportunities in Northern Australia. Frank is uniquely using tile drainage for irrigation, which shows there is the potential for tile drainage in the Ord's farming system. This gave the author the idea of using tile drainage in our table drains. Table drains are the traditional way to remove water from fields.

Figure 8. Peat Land Innovation Centre tile drainage and irrigation plan (source: author)

In sub-tropical Northern Australia with monsoonal weather conditions, a number of factors are critical for drainage efficiency:

a. Levelled or lasered fields are critical to operate in a timely manner after rain, as well as for irrigating evenly and efficiently without water logging or eroding the soil. In other words, surface drainage or superficial drainage which moves water off the field slowly without causing erosion while not retaining water on farm for long periods. The gradients (slopes) desired for achieving this affect are around 0.001% slope, or 1 metre (m) fall in 1666m to 1m fall in 2000m. The effect needs to be that water flows off without causing erosion, so it is a combination of controlling the volume and velocity of water.

b. In a high rainfall event, field and drainage outlets need to be designed so water is retained for 12-24 hours to ensure erosion is minimal.

   Ridges of fields “pulled up” are essential so water runs off in the furrow and not the entire field. This ensures that crops planted will not be waterlogged. At Oasis Farms, there is a trial underway with border check irrigation - fields without furrows and ridges. Advantages include ease of harvesting and operating “on the flat” compared to highly accurate and inflexible row cropping. Generally, field crops that need harvesting with an open front (draper front) are much easier to harvest if the header draper can be placed on, or close to, the soil. Where permanent ridges of beds are required the crop often falls in the furrow and is difficult to harvest.

c. A recommendation for timely operations is to convert fields from the current 1.8m wheel track configuration to a 2m wheel track and 1m ridges configuration. The area of furrow is increased by over 20% in comparison to having one furrow every 1.8m. This improves drainage capacity significantly. See Table 3. Payback for this changeover is calculated to be around five years based on harvest and machinery efficiency as well as reduction in compaction of the soil, but it comes with other risk and problems associated with wider working widths and heavier equipment.

d. Row length is another factor for consideration when assessing risk for timely operations. The longer the row length the better the machinery efficiency and land utilisation. But the longer the row length the more water is captured per field and the longer the water takes to accumulate and run off. The most efficient fields are between 500-750m long and range in size from 40-80 ha.

e. Drainage / tail drain design, which follows on from all the above-mentioned points. The bigger the drainage capacity the quicker the water can run off. This needs to be calculated by a professional to ensure that water does not cause erosion or sit in the field for too long to cause water logging issues.

f. Install ‘tile drainage’ in strategic places in the tail drain infrastructure to alleviate water logging issues in areas where water sits for longer periods. This has not been an issue in the past as cropping operations took place after the monsoonal wet season had finished, allowing time to dry out fields. Planting could be undertaken two or more days earlier with better soil conditions for the seed to germinate if strategically located sections of tail drains were installed with tile drainage. It’s totally unconventional to have tile drainage if above ground drainage works, but the system is pushed to its limits.

   Tile drainage requires good field levels. Conventual field layouts vary greatly and depend on natural slopes, head water and outlet parameters and levels. Tile drainage is normally only required in sub surface drainage systems. Oasis Farms will be testing the concept of putting tile drainage in strategic table drain areas of fields. This will be in drain outlet areas that normally hold water for an extra day or two due to outlet restrictions. This will hopefully allow efficient and neat entry to the field, thus making it possible to enter a field for planting one or two days earlier.

Figure 9. A tail drain that would benefit from tile drainage (source: author)

3.1.3 Other irrigation systems

A limiting factor in managing fields in ORIA are the furrows, which run water off and onto fields. These soils are designed for furrow irrigation. High clay soils suck water into their profile when it gently runs past, leaving a spectacular fine, aerated and healthy soil structure. Qualities of clay shrinkage and expansion helps immensely.

Figure 10. 360Rain irrigator, Illinois, USA

Many different irrigation methods have been researched for this study. Overhead irrigation systems would be extremely useful and achieve more than current furrow irrigation at certain times, for example to give a quick 10mm irrigation over a freshly planted crop to help germination, or to cool the crop during extreme hot conditions. However, the costs of pumping and pressurizing water and the capital cost of the irrigation equipment are prohibitive. In addition, the soil is not ideal for trafficability of lateral move irrigators. '360Rain' (Figure 10) is a system seen in Illinois USA, which has huge potential and does not travel over irrigated soil. This could be a fit for the future, although the product is only just now commercially available. Further information can be found at https://www.360rain.com

Figure 11. 360Rain irrigator water placement to crop, Illinois, USA

The author has looked at ways to farm without a "raised bed system", but it appears that this can be possible for crops *other than cotton*. However, cotton needs to be planted on raised beds as it is very susceptible to water logging. So, the furrow is here to stay to drain fields efficiently and sustainably.

3.1.3 Temperature

In ORIA, conditions are the opposite of other conventional cropping areas around the world. Summer crops are grown in winter, or dry season. Normally crops are planted after a cold winter or dry summer. The Australian cotton industry plants the crop in conditions based on soil temperature above 15.5 degrees Celsius (°C). Anything below that means seeds don't germinate and can decay in moist conditions before they germinate and grow. There are hot soil temperatures averaging closer to 30°C, but with that comes soil surface temperatures in the region of 77°C when conditions are extreme.

Oasis Farms has invested and planted many cover crops to see what would work in these tropical conditions. During the 2021 cotton cropping season, Oasis Farms experienced cotton that was very young (2-4 leaf stage) which was ring barked and died due to the surface temperature being so hot it burned through the bark of the young plant and then killed it.

A timely irrigation would have prevented this but there is inherent risk associated with irrigating during these extreme and hostile weather conditions. After irrigation, the soil profile is full so any amount of rain could cause water logging and / or flooding in the tail drain areas of a field.

Something that is not often understood is that temperature conditions can be so extreme that *a risk to human wellbeing is real.* It can be extremely stressful and tiring to physically irrigate a field and the human body and mind pushed to its limit. This must be considered when making management decisions to irrigate a field.

A solution to alleviate and reduce soil surface temperature is to implement the CropShield cropping system.

Figure 12. Temperature over bare soil: too hot (source: author)

In early 2023, Oasis Farms worked closely with King Yin Lui, a Research Scientist from the WA Department of Primary Industries and Regional Development (DPIRD), taking a preliminary look at the ability of cover crops to reduce soil temperature during the wet season.

Data loggers were installed 3cm deep to monitor soil temperatures under teff, millet and sun hemp, and fallow field conditions from 7 February to 13 March, logging data every 20 minutes. While the trial was preliminary and not replicated due to the availability of data loggers, the findings showed that the mean daily soil temperatures dropped 2-3°C under most of the cover crops tested. The most significant finding was that the cover crop combination of millet and sun hemp reduced the daily maximum soil temperature almost 8°C – from 42°C to 34°C. The average daily minimum for all the treatments monitored was 3°C higher than the fallow field (Lui, 2023, unpublished data for Oasis Farms).

Figure 13. Temperature over a green canopy (source: author)

3.1.4 Biology

Over the last 25 years much has been done educating farmers how important soil biology is to soil structure, health, and nutrition cycling. This was evident worldwide as part of this research. High temperatures, water logging and low carbon (organic matter) in the soil all detract from good, healthy soil biology.

Measurement of soil biota is calibrated reasonably well for more temperate climates. This is not the case for low organic matter hot tropical soils. Although measuring soil biology parameters is difficult, soils are living complex organisms surviving in extremely complex ecosystems. One key is organic matter. This is inherently low in tropical soils as it metabolizes quickly in hot soil and does not respond well to cultivation. Nevertheless, it is important to stay connected to soil biology, even if currently there are no perfect soil biota measuring tools.

Dr Oliver Knox has designed a great measuring tool, called *Soil Your Undies.* A pair of cotton underpants are buried in the soil and dug up after a couple of months. If the cotton has been consumed by the soil microbiology, there is active healthy soil biology.

Figure 14. Soiling my undies in July 2023 (source: author)

3.2 Trialling solutions to environmental challenges

3.2.1 Cover crops and the CropShield cropping system

Oasis Farms has done extensive trial work growing different cultivars during the December-January period on the heavy black vertosol soils during monsoon rainy season.

Table 2 (below) summarises what grew well and survived these conditions. Interestingly, after evaluation only millet, sun hemp and teff are adequate.

It is possible that a grazing variety of rape might also be suitable as this survived the conditions, although it may have been affected by Spinnaker herbicide residue. The cultivars used for the CropShield program must be easily controlled by Glyphosate. The cultivars must be upright to enable modern planting technology to work very well. Sorghum grew very well but it was deemed to be too competitive in a CropShield system.

Table 2. Cover crops: what will grow?

Cover crop 2021 trail la	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	9 beds	6 beds ??
Bay/treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Top halve of bay	US Tetelia Rye 55/kg	Ceryal Rye 55kg/ha	Shirophie Millet 55 kg/ha	Barley 55 kg/ha	Brassica 55 kg/ha	Oats 55 kg/ha	Forage Corn 55 kg/ha	Common Vetch 55 kg/ha	Wolly Pod Vetch 55 kg/ha	Forage Pea 55 kg/ha	Mungbeans 55 kg/ha	Pigeon Pea 55 kg/ha	Dessert seed Finerdan sorghum 55 kg/ha	Katherine Millet 55 kg/ha	Bell seeds Baroota 55 kg/ha	Red Pannicum 55 kg/ha
Bottom halve of bay	US Tetelia Rye34/ kg	Ceryal Rye 34kg/ha	Shirophie Millet 34 kg/ha	Barley 34 kg/ha	Brassica 34 kg/ha	Oats 34 kg/ha	F1 Corn 55 kg/ha	Common Vetch 34 kg/ha	Wolly Pod Vetch 34 kg/ha	Forage Pea 34 kg/ha	Mungbeans 34 kg/ha	Pigeon Pea 34 kg/ha	Dessert seed Finerdan sorghum 34 kg/ha	Katherine Millet 34 kg/ha	Guar 55 kg/ha	Red Pannicum 34 kg/ha
Amount og seed	25	25	25	25	25	25	20	25	25	25	50	50	25	25	25	
Area in ha	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	0.339	
Double planting rate	34.5	34.5	34.5	34.5	34.5	34.5	27.6	34.5	34.5	34.5	69.0	69.0	34.5	34.5	34.5	
Planting rate maximum	58.9	58.9	58.9	58.9	58.9	58.9	47.2	58.9	58.9	58.9	117.9	117.9	58.9	58.9	58.9	
Cost per kg	$ 3.80	$ 1.20	$ 3.80	$ 2.25	$ 13.30	$ 2.50	$ 3.90	$ 3.00	$ 3.95	$ 2.95	$ 2.00	$ 2.50	gift	gift	gift	

Source: Author.

Acknowledgement: Thanks to Living Seeds, Bell Seeds (Rob Bell. 2021 Scholar) and Kununurra's Desse Seeds for supplying seed for trials.

At Oasis Farms, magpie geese and other birds are considered a risk. The CropShield system must be able to be planted dry and germinate and grow on wet season rain. This means sometimes rain wets only the top few centimeters of the soil, so if seed the germinates it must be resilient enough to survive hostile hot and dry conditions.

Soil insects have been a severe drawback in past cropping systems. If insect pests are harbored and the system doesn't maintain a good natural break from insect populations, problems emerge.

It is desirable to have as much cover to protect the soil. One advantage of a clean fallow is that weeds are always fully visible and accessible. This will not be the case with a CropShield system. One weed can produce a thousand seeds, so vigilance is needed to ensure there is no encouragement of new, herbicide resistant or system tolerant weed species.

Weed management is going to be a challenge in this system as the CropShield species needs to grow while not having the same tools available to control new weeds.

Nutrition is easily overlooked when growing a CropShield cultivar and it is important to add nutrients to these crops to avoid fluorescent plants, as shown in Figure 15:

Figure 1

Figure 15. Severe nutrient deficiency visible (source: author)

Drainage and irrigation are paramount for a free-flowing furrow. Sunshine and wind are needed to dry the furrows, which should not be overgrown with even the most reliable and beneficial cover crop mix as water will back up and not flow as required. This will cause total loss of opportunities to grow any crop successfully.

3.2.2 Soil amelioration options

Gypsum

In high pH soils with extremely high magnesium and clay content, there are sticky soils when wet, and hard (baked) and crusting soils when dry. This effect can be managed by good soil amelioration. This concept has been instrumental in turning most agricultural soil in Brazil and Europe to become highly productive.

Gypsum is a commonly used soil ameliorant that can improve soil properties and fertility. It primarily affects soil structure, nutrient availability, and water movement in the soil. Here's how gypsum increases soil amendments:

- Soil structure improvement: Gypsum helps improve soil structure by reducing soil compaction and increasing soil porosity. It does so by promoting the flocculation of clay particles which causes them to aggregate into larger, more stable clumps. This improves soil aeration, drainage, and root penetration, creating a more favourable environment for plant growth.
- Alleviation of soil sodicity: Gypsum is beneficial in soils with high levels of sodium (sodic soils). Sodium can disperse soil particles, leading to poor soil structure and reduced water infiltration. Gypsum helps in displacing sodium from soil particles, reducing sodicity and improving soil structure.
- Nutrient availability: Gypsum does not provide significant amounts of nutrients itself, but it can enhance nutrient availability in the soil. It increases the solubility of certain nutrients, such as calcium, which is essential for plant growth. Gypsum can also improve the availability of other nutrients, such as sulphur, by preventing their leaching from the soil.
- pH adjustment: Gypsum is neutral in pH and does not significantly alter the soil's acidity or alkalinity. However, in soils with high pH (alkaline soils), gypsum can help moderate the pH by displacing sodium and reducing alkalinity. This can create a more suitable pH range for nutrient uptake by plants.
- Water management: Gypsum can improve water management in soils by reducing surface crusting and improving water infiltration. It helps prevent surface sealing which can lead to water runoff and erosion. By enhancing soil structure and promoting better water movement, gypsum can increase water retention capacity and reduce the risk of waterlogging in poorly drained soils.

However, in the Ord it is economically difficult source gypsum due to long haulage distances and cost. The author can access a finely ground gypsum that is mixed with water and sprayed out as a slurry and is working with the supplier to develop a machine that can apply a narrow band (10-15 cm) on top of hills where the seed / crop is planted. This affects the soil structure in a positive way to increase seed germination in extreme conditions.

Silica

Silica and water gel products have traditionally been used in silviculture with great results. Amorphous silicates can be used to improve water retention in soils. When incorporated into the soil, amorphous silicates can act as soil amendments or conditioners that enhance water-holding capacity and improve soil structure.

The high surface area of amorphous silicates allows them to absorb and retain water molecules on their surfaces. This can prevent water runoff and increase the availability of moisture to plants' root systems. By holding onto water, amorphous silicates can mitigate drought and promote better plant growth.

Additionally, amorphous silicates can contribute to soil aggregation, which improves soil structure. This enhances the soil's ability to hold and store water, making it more resilient to water stress and improving its overall water retention capacity.

Furthermore, amorphous silicates can enhance nutrient availability in the soil. They have cation exchange capacity (CEC), which means they can attract and retain positively charged nutrients, such as potassium, calcium, and magnesium. By retaining these essential nutrients, amorphous silicates can help sustain plant growth and reduce nutrient leaching.

3.2.3 Be connected

During study visits it became very apparent that it’s important to “*wear out a pair of boots each season*”. The best fertiliser is ‘boots on the ground’ and a shovel in the ground looking at soil and the plant roots. Know the farm, walk the farm, and use modern technology.

In summary, successful farm businesses feel the soil frequently.

Understanding weather forecasts is also vital, and during the wet season a fair bit of time is spent trying to understand rain patterns, especially patterns that show dry spells.

Chapter 4: Mechanical Tools

"*Just get the right equipment and new technology and all will be fixed*" is a common methodology but is not the solution. Oasis Farms has been involved in starting an array of new cropping systems in the past, and most of the machinery is now being picked up by a scrap dealer.

Many different farming enterprises seen as part of this research were efficient and resilient and it paid for conventional equipment. Farm equipment needs to be modern to attract and retain good staff while having the ability to be repaired when required.

There are several mechanical solutions available for wet season cropping.

4.1 Controlled traffic

It is difficult to consistently drive heavy equipment in the same wheel tracks. It is the attention to detail which makes the biggest differences to operations all over the world, and this relates to field traffic.

It is not possible to operate in a timely manner without the same compacted soil under controlled traffic wheel tracks. In the Ord, field access is possible two to three days earlier on these "areas" with less power requirement to do a better, cheaper, and more stable and exact job.

The controlled traffic areas adjacent to the cotton plants have reduced cotton yield of between four and 10% depending on climatic conditions.

Figure 16. Controlled traffic in-field (source: author)

A study by Mohammed et al (2021), illustrated in Figure 17, on the impact of soil compaction due to cotton picker traffic on cotton yield found that:

'the traffic of JD7760 round-bale cotton picker caused significant compaction in cotton rows and furrows located between, adjacent to, and in wheel tracks under both random traffic farming (RTF) and controlled traffic farming (CTF) systems, particularly for the top 30-cm depth. Because of the soil compaction, the yield was more significantly reduced (7~10% by the machine-pick method) in the rows between the dual-wheel than in those adjacent to the wheel track. Adopting CTF reduces the area of soil compaction and ensures the maintenance of soil characteristics of the cultivated portions of the farm, hence enhancing cotton yield'. (Mohammed et al, 2021, page 517).

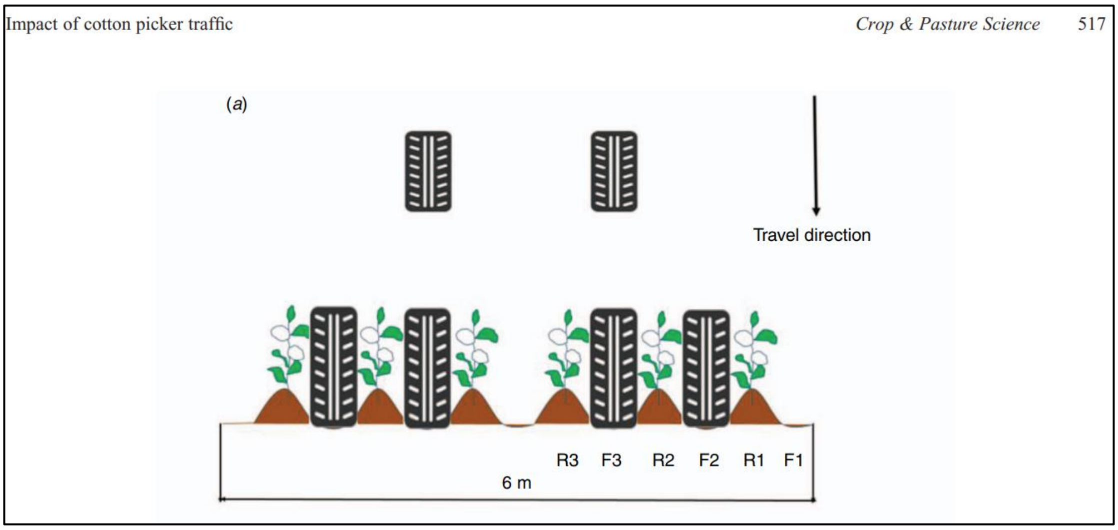

Figure 17. Impact of cotton picker traffic on vertosol soil (source: Mohammed et al)

This study found the yield in the rows to be:

Yield Row R1 9.37 bales / ha	+6.7%
Yield Row R2 8.21 bales / ha	-6.46%
Yield Row R3 8.65 bales / ha	-1.04%

The average yield of those three rows is 8.74 bales. So, in theory, if traffic can be contained to be in furrow three only during wet conditions, *our total average yield will increase significantly*. Oasis Farms has used this information to transition from 1.8m beds and 9m-wide equipment to 1m Ridges and 12m-wide equipment. This will increase machinery efficiency per hour worked and reduce total field compaction as per table below.

It will also unfortunately increase equipment weight and ground pressure per surface area, but this is an acceptable compromise. The payback for such is move is approximately five years.

Table 3. Drainage and compaction comparison with hill widths

	Working width of equipment	Furrows per ha	furrow area per ha at 480 wide tyres	Wheel tracks compaction area in square m/ha	Wheel track compaction % of whole field	furrow area percentage at 460 mm wide
0.9	9	11111	5333	1067	10.7%	51.1%
1	12	10000	4800	800	8.0%	46.0%
1.8	9	5556	2667	1067	10.7%	25.6%
2	12	5000	2400	800	8.0%	23.0%
1.5	12	6667	3200	800	8.0%	30.7%
3	12	3333	1600	800	8.0%	15.3%

(source: author)

Table 4. Payback calculations to convert to one metre hill widths

Cotton Yield	Cotton price	Yield reduction of tractor runs	Total cost of yield reduction at different working withds	Gain	Picking Savings	Efficiency gains 10 % to 20 % less tractor costs ?	Total savings per ha	500 ha savings
11	550	10%	$ 242.00					
11	550	10%	$ 201.67	$ 40.33	$ 30.00	$ 25.00	$ 95.33	$ 47,666.67
11	550	10%	$ 242.00					
12	550	10%	$ 220.00	$ 22.00				
11	550	10%	$ 201.67	$ 40.33				
11	550	10%	$ 311.67					

(source: author)

4.2 Tracks versus tyres

One of the easiest ways to increase trafficability would be to switch to tracks instead of single tyres. Tracks increase the surface area and give great floatation and traction. Tracks also add a huge cost, weight (1 tonne per axle) and some complexity in relation to trafficability on bitumen roads.

Soil experts and farmers with experience using track machines in row cropping advise that tracks leave a very square and flat-bottomed furrow that tends to decrease water infiltration efficiency. Tyre-equipped tractors roll through the furrow and leave it in a rounded shape which is very efficient in assisting infiltration of water into the soil profile during an irrigation.

People have commented that the compaction caused by tracks is often much more violent and intense than conventional tyres. This is due to the extra weight and the intense vibration over the whole length of the track, whereas a tyre rolls over the soil and is gone. It pushes and compacts the soil. It does not vibrate the soil like a track does. Tracks have their place, especially in high draft situation and where controlled traffic is implemented. Tracks are not as wide as dual or triple tyres, and if the compaction is kept to within that area it's a small price to pay for timely operations.

Tracks don’t compact evenly. The rollers distribute the bulk of the weight, so some of the surface area (flotation) numbers quoted are not quite correct. This is illustrated in Figure 18.

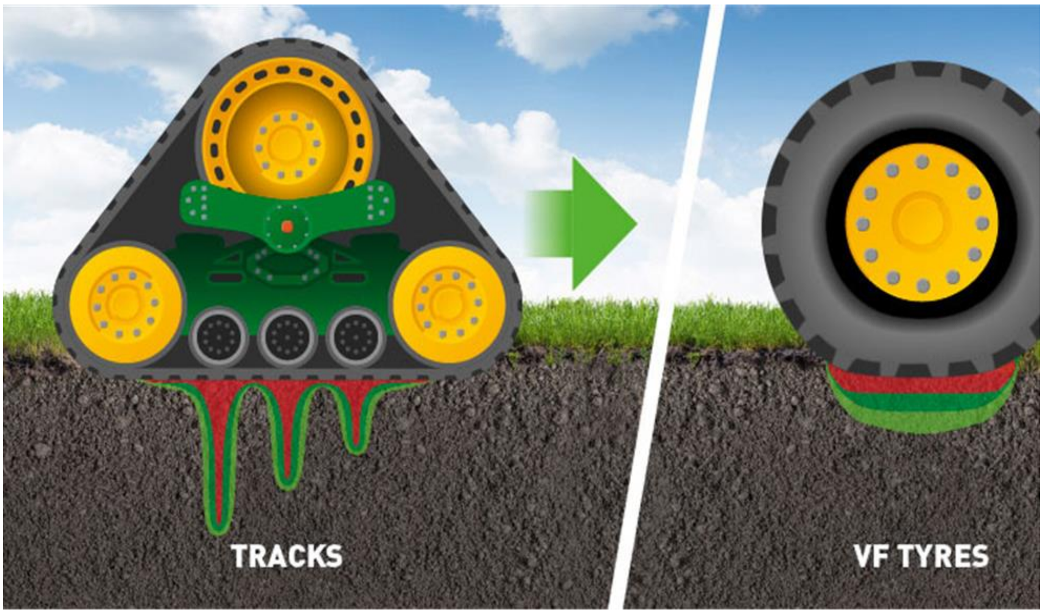

Figure 18. Tracks versus tyres: pressure on soil (source: Bridgestone)

The relationship between soil elasticity, weight and surface area is critical to understand. As soil moisture content declines trafficability increases, but it is relative to weight. The author would rather have a Swarmbot with small tyres and high air pressure traffic the soil than a heavy track machine with huge flotation. The damage is less with less weight. It’s one of the real risks with going to wider 12m equipment.

Table 5 shows the relationship of different machine and trye track options.

The ultimate solution would be to have a *low horsepower tractor with a wide and modern planter that has no more weight than 1.3kg per square centimetre*. It seems when we go to weight levels of 2-2.2kg per square centimetre issues arise with the ability of the soil to carry that weight. These are observations made over years of farming.

Table 5. Tyre and track comparisons for select farm machinery

			Weight per square cm																		
option	Footprint per axle	**Pressure PSI range**	1300	Pressure PSI	1700	Pressure PSI	2000	Pressure PSI	2400	Pressure PSI	3000	Pressure PSI	3400	Pressure PSI	5100	Pressure PSI	7350	Pressure PSI	8000	Pressure PSI	Weight per axle
520 tyres	**2832**	**31 to 35**	0.46	6.53	0.60	8.54	0.71	10.04	0.85	12.05	1.06	15.07	1.20	17.08	1.80	25.61	2.60	36.91	2.82	40.18	
Rear 480 tyre	**2329**	**32 to 35**	0.56	7.94	0.73	10.38	0.86	12.21	1.03	14.66	1.29	**18.32**	1.46	20.76	2.19	**31.15**	3.16	44.89	3.43	48.86	
Rear 480 Duals	**4658**	**16**	0.28	3.97	0.36	5.19	0.43	6.11	0.52	7.33	0.64	9.16	0.73	10.38	1.09	**15.57**	1.58	22.44	1.72	24.43	
Front tyre	**1935**	**27 to 32**	0.67	9.56	0.88	12.50	1.03	**14.70**	1.24	17.64	1.55	22.05	1.76	**24.99**	2.64	37.49	3.80	54.03	4.13	58.80	
8RX rear 18 inch rear axle	**9000**	**12**	0.14	2.05	0.19	2.69	0.22	3.16	0.27	3.79	0.33	4.74	0.38	5.37	0.57	8.06	0.82	**11.62**	0.89	12.64	
8RX front 18 inch front axle	**6000**	**12**	0.22	3.08	0.28	4.03	0.33	4.74	0.40	**5.69**	0.50	7.11	0.57	8.06	0.85	12.09	1.23	17.42	1.33	18.96	
406 rear track snall tractor	**6090**	**7 to 12**	0.21	3.04	0.28	3.97	0.33	4.67	0.39	5.61	0.49	7.01	0.56	**7.94**	0.84	**11.91**	1.21	17.17	1.31	18.68	
406 front track small tractor	**5053**	**6 to 10**	0.26	3.66	0.34	4.79	0.40	**5.63**	0.47	6.76	0.59	8.44	0.67	**9.57**	1.01	14.36	1.45	20.69	1.58	22.52	
Swarmbot	**916**	**20to 26**	1.42	**20.19**	1.86	**26.40**	2.18	31.05	2.62	37.27	3.28	46.58	3.71	52.79	5.57	79.19	8.02	114.13	8.73	124.22	

	planter weight			tractor weight	rear axle load	front axle load
6 row planter	3000 kg		500 kg per row	7000	3000	2000
12 row planter	5000 kg		416 kg per row	12000	5100	3400
Swarm Bot	2500 to 3000 kg		417 kg per row	3000	1700	1300
8RX	5000		416	19500	7350	4900

(source: author)

4.3 Autonomous vehicles and robots

4.3.1 Swarmbots

The author met Andrew Bate from Swarmfarm (www.swarmfarm.com) at the Australian Cotton Conference in 2022 and it was an original and 'new thinking' farming system discussion.

Andrew Bate spent a season in the Ord providing agronomic crop advice and he says that bigger is not better. He states that the rip tear and bust attitude towards solving time-sensitive and agronomic problems needs to change. He suggests being gentle, have less weight, work on a smaller scale while maintaining the same of more capacity to achieve large scale world competitive operations.

His attitude towards working the soil and facilitating changes to give farmers more options for achieving great timely and long-term results was refreshing.

It is not clear that autonomous, or robots are ready to work price efficiently and reliably on relatively low turnover low margin irrigated row cropping just yet. This technology will mature and get used in high value horticulture and other repetitive all-season systems. It is not an option for ten days of planting a cotton crop in the wet season.

This technology will be utilised in the future, with 6m wide equipment being used on a large scale achieving daily production targets well beyond conventional equipment. One operator may be controlling three or more machines, and a business – in collaboration with neighbours – employing an auto electrician who will be able to fix harnesses, sensors, and monitoring equipment in a timely manner.

Farms may employ computer experts to set up operating systems and maintain them to monitor and measure efficiency of this technology. This is what Rio Tinto and Komatsu have achieved in having autonomously operated mining operations a few thousand kilometres out of an office in Perth.

The author is comfortable having 12m wide three-point linkage equipment presently as in the next five to ten years it is likely the business will have autonomous vehicles 6m wide that will add to soil health and sustain a workload that is conducive to attracting new and vibrant people into the agricultural industry.

4.3.2 Other autonomous options

There are many autonomous and new technology providers, including:

1. Kubota, who are very advanced in autonomous vehicles and also picking horticultural crops.
2. Sabanto.
3. John Deere, CNH, Agco.
4. Project Xaver.
5. Nexat farming gantry system tractor (Figure 19).
6. Naio Technologies.
7. Tevel Aerobotic technologies.

Figure 19. Nexat Gantry harvesting corn (source: Nexat)

Not all technology suppliers are market-ready or can answer the questions that farmers have, but there are more possibilities of what autonomous vehicle and robots can do for agriculture. Crop monitoring in real time means applying insecticide or fungicides only where and when needed. Technology can:

a. Monitor insect populations in real time.
b. Monitor plant nutrition requirements.
c. Plant pathogen pressure.
d. Crop canopy temperature and other climatic conditions.

4.3.3 Drones

The author saw many operations now using drones to apply plant protection products, which before now only considered using a large scale high, wide, heavy, and very expensive spraying machine. The best example of drone application observed was in Illinois, USA, at the Precision Planting research and trial farm (www.precisionplanting.com). A drone - set up correctly – can have similar application efficiency to a ground rig. Options of precision planting of seed from a drone was also investigated, which could mitigate some of the wet season bog issues. Essentially, this uses a nail gun type technology to shoot the crop seed into moist soil just after rain. This was not pursued further because compaction directly under a seed is a big issue. Driving seed into the soil with such a technique would compact the soil under the seedling and affect it early root development and end up with less-than-ideal plant growth.

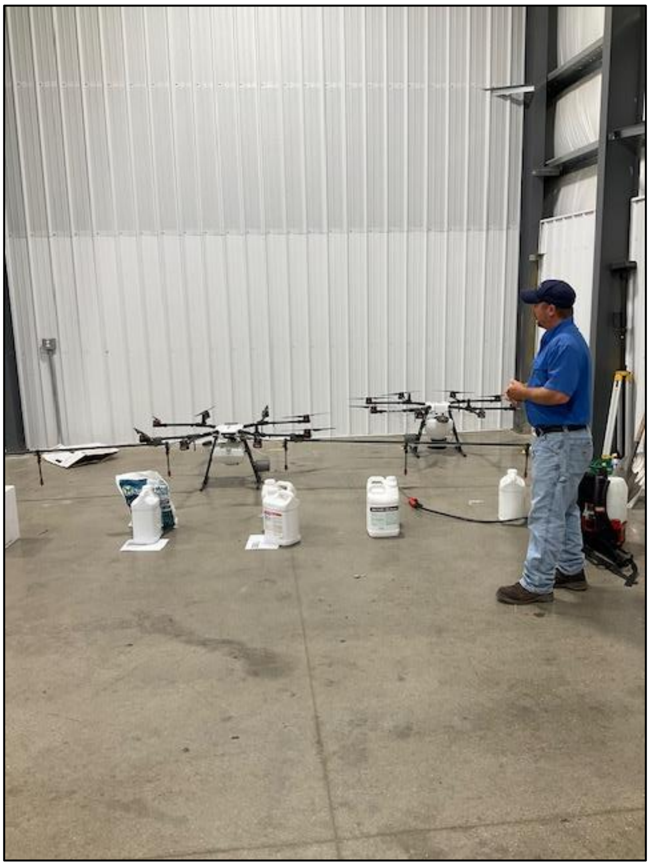

Figure 20. Jason Webster discussing Precision Planting research farm drones, Illinois, USA (source: author)

4.3.4 Seeding tape

This a technique used in horticulture where seed is placed between biodegradable tape along with nutrients and other ameliorating soil additives. This works well when planting on solid ground with capabilities to carry heavy weight and refill often.

4.3.5 New planting technology

When looking for new ideas on how to plant in the Ord it quickly became apparent that no fundamental changes have been made over recent decades. Soil is opened using a steel tyne or disc, seed is placed in the soil and covered, firmed, and conditioned to facilitate the seed to germinate.

Planting technology has been greatly refined. and adopting new technologies is encouraged, especially electric driven planters that can measure seed spacing, skips and doubles. Technology exists that is user-friendly and firms the seed in the trench, with adjustable down pressure and stability control. Technology that removes trash and dry soil to ensure seed germination is even and excellent.

The author acknowledges the time spent in the research laboratory with Precision Planting in Illinois USA as their technology is now being successfully used in the Ord.

4.3.6 Aquatill

Greg Butler presented at the Australian Cotton Conference on the Gold Coast in August 2022. There he announced that Precision Seeding Solutions had been awarded the distribution right to Aquatill technology, which stems from the steel cutting industry. Very high pressure (30 000 psi) and low volume water is used to cut steel. Greg uses this technology to cut stubble for his work with no-till farming. Following a meeting, a demonstration was held and there is now a two-row machine in the Northern Territory, in the Douglas Daly region.

The author was astounded how well and precisely soil can be cut and prepared in a seed trench in this way. It will take time for the technology to be refined. The advantages will include the ability to plant into wetter soil without it sticking. The technology uses about 60 litres per ha of water, which are not huge amounts. Surprisingly it prepares the seed trench into a nice moist environment.

Thanks to the generous time of David McGavin and Miguel Garrett of Precision Planting Services in trialing this concept.

Figure 21. Aquatill water jets cutting soil (source: author)

Figure 22. Aquatill seed trench (source: author)

The setup and running costs are now irrelevant and the next step is to identify a technology manufacturer for further development. This will determine if it's a solution for farming systems in the Ord. This technology is being used to cut cotton stubble and is being used in some no-till situations and has been commercialised for these purposes.

Chapter 5: Collaboration

In Ontario, Canada, the author visited Pure Flavor's very advanced greenhouse with robots, newest technology and products that looked great and tasted fantastic (www.pure-flavor.com). Following this there was an Armish community visit. It was a polarised day of research!

The Amish families were healthy, happy, and getting everything done in their businesses. The strong hierarchical and traditional ties were evident, and religion was the fibre that held all this together. The families all had ties to one another, formed a strong community that survived by a very unconventional and old way of life. There were no electricity or engines, and it was a lightbulb moment in the spirit of collaboration. They worked together believing in the greater good, with selfless long-term goals for a win:win outcome.

Nuffield 2007 Scholar John Gladigau produced a report titled "Collaborate to survive and thrive" (Gladigau, 2007) which provides excellent insights to collaboration.

Nuffield 2021 Scholar Mark Brock has also produced a report on "Farmer to farmer collaborations" (Brock, 2021), so the author is no stranger to this concept.

Local impact

The author is involved in co-operative business structures and sees great outcomes. For example, if all growers in the Ord irrigation area worked together, achieving 10,000 to 15,000 ha of annual cotton planted in 5-7 days is possible.

John Gladigau highlights that 14,000 combine harvesters are in the UK, for an area that could comfortably be harvested by 4,000 Class Challenger combines within an acceptable timeframe (Gladigau, 2007). But it would require a few human traits to change, with huge selfless vision, great communication, respect, and trust. It would mean risking planting for the neighbour when it's dry enough to plant your own farm, but the whole cropping sector would get planted on time!

To achieve collaboration the following needs to be understood and managed:

5.1 Respect

Respect entails valuing and acknowledging the contributions, expertise, and perspectives of all individuals involved (Gladigau, 2007; Hanlon and Rigney 2007, 2012 pers.comm).

Respect among the farmers themselves is fundamental. It involves recognising and appreciating each farmer's unique skills, knowledge, and experiences. This recognition creates an atmosphere of mutual appreciation and trust, fostering a sense of camaraderie and cooperation. Respect ensures that all farmers feel heard and valued, enabling them to contribute their insights and ideas to the collaborative effort. It also promotes a supportive and inclusive environment where individuals are treated with dignity and their opinions are considered in decision-making processes.

5.2 Trust

Trust plays a pivotal role in a farmer-driven collaboration that operates under the challenging conditions of extreme climate and tight time constraints. In such situations, where crops need to be planted promptly before the next rainfall, trust becomes a fundamental element for success.

First and foremost, trust is crucial among the farmers themselves. Each farmer must have confidence in their fellow collaborators' abilities, commitment, and expertise. This trust enables them to rely on one another's contributions and make collective decisions with confidence. When time is of the essence and decisions need to be made swiftly, trust allows for efficient coordination and effective allocation of resources.

Additionally, trust is essential between the farmers and support networks, such as agricultural advisors, suppliers, and weather forecasters. Farmers must trust the advice and information provided by these stakeholders to make informed decisions about the planting process. Relying on accurate weather forecasts, trustworthy suppliers, and expert guidance ensures that the collaborative effort remains aligned with the time-sensitive objectives.

Furthermore, trust extends to the farmers' relationship with the land itself. Farmers must trust their knowledge of the soil, climate patterns and the crops they are planting. This trust enables them to adapt their strategies and techniques to suit the extreme climatic conditions, maximising their chances of success. Trust in their understanding of the land allows them to make critical adjustments swiftly and effectively.

In summary, trust forms the foundation of a successful farmer-driven collaboration during extreme climatic conditions and tight planting timeframes. It fosters cooperation, effective decision-making, and reliance on critical information and resources. By establishing and nurturing trust among all stakeholders, farmers can navigate the challenges and time pressures they face, increasing their chances of planting crops in a timely manner and mitigating the risks associated with unpredictable weather.

5.3 Ego

Ego is a person's sense of self-importance or self-identity.

In the context of a group of farmers working together to accomplish a shared task, such as sharing machinery and experience to complete a job on time, the ego can be defined as the individualistic tendencies, pride or self-centeredness that may hinder effective collaboration and hinder the overall success of the group.

By leaving their egos behind, farmers can foster a spirit of cooperation, open communication, and mutual support. They can share machinery, skills, and experiences without seeking dominance or asserting superiority over others. This collaborative mindset allows for efficient problem-solving, better use of resources, and the achievement of the shared objective within the designated time frame. It requires a willingness to cooperate, compromise, and work harmoniously with others, recognising that the successful completion of the task is more important than personal desires or pride.

5.4 Emotions, Emotional Intelligence

Emotions are feelings or strong reactions that arise in response to specific situations, events, or stimuli. Emotions can encompass a wide range of experiences such as happiness, sadness, anger, fear, or love, and often influence thoughts, behaviours, and overall well-being.

Emotional intelligence refers to the ability to recognise, understand, and manage one's own emotions and navigate and respond to the emotions of others. It involves being aware of emotions, having the capacity to label and express them appropriately and using emotional information to guide thinking and behaviour. This includes being able to show empathy, communicate, compromise, and self-regulate. Being able to resolve conflicts in a mature way is also essential.

By exhibiting these qualities of emotional intelligence, farmers contribute to a positive and productive working environment, strengthens relationships within a group and enhances the overall effectiveness and success of the collaborative effort.

5.5 People

The right people are crucial in collaboration. The right people are the most important part of collaboration and managing emotional intelligence for a win-win outcome. Compatibility, trustworthiness, emotional intelligence, positive influence, diverse skills, and commitment form building blocks of effective teamwork, where collaboration can thrive and lead to mutually beneficial results.

5.6 Clear financial parameters

In a farmer collaboration, clear financial parameters are crucial for setting expectations, ensuring transparency, and promoting effective control over financial matters (Gladigau, 2007; Hanlon and Rigby, 2007, 2012). The steps to be considered include:

Define financial goals.

Establish a financial plan. It should specify how costs will be shared, how profits will be divided and any contingency measures in place to handle unexpected financial situations.

Allocate resources and responsibilities. Clearly define the responsibilities of each farmer regarding financial contributions and ensure that everyone understands their obligations.

Maintain financial records: Implement a system for recording and tracking financial transactions and expenditures.

Review and monitor financial performance: Regularly review and analyse the financial data to assess the collaboration's financial performance.

Transparent communication: Share financial information, reports and updates with all stakeholders.

Periodic financial reviews: Conduct periodic financial reviews or meetings where the group discusses financial performance, identifies areas for improvement and collectively makes decisions regarding financial adjustments or resource allocation. These reviews provide an opportunity to address financial issues proactively and make informed decisions as a group.

By following these steps, a farmer collaboration can establish clear financial parameters, maintain control over financial matters and promote transparency and accountability among the members. This helps ensure the financial success and sustainability of the collaborative effort.

5.7 Start with a clean sheet

Starting with a "clean sheet" refers to beginning a collaborative effort with a fresh and open-minded approach, without any preconceived notions or biases (Gladigau, 2007). Here's an explanation of how it works and the benefits it offers:

Openness to new ideas: Be receptive to new ideas and perspectives. It encourages individuals to approach the collaboration with an open mind, ready to explore different possibilities and solutions.

Fresh perspective: By wiping the slate clean, individuals can set aside any past conflicts, assumptions or judgments that may have hindered effective collaboration. This fresh perspective can lead to new insights, improved decision-making and more effective problem-solving.

Reduced baggage and conflicts: Starting with a clean sheet helps reduce conflicts and tensions that may have arisen from prior collaborations or personal histories. This reduction in baggage creates a healthier and more positive environment for collaboration.

Equal footing: All participants should start on an equal footing. It eliminates any perceived hierarchies or inequalities that might have existed in previous collaborations, fostering a sense of fairness, respect, and inclusivity.

Flexibility and adaptability: It encourages flexibility and adaptability in the collaborative process. With no pre-existing structures or fixed ideas, individuals are more willing to adapt to changing circumstances, incorporate new information and modify strategies accordingly.

Enhanced teamwork and trust: By starting with a clean sheet, individuals can focus on building strong relationships and trust within the group.

Overall, starting with a clean sheet offers the benefits of fresh perspectives, reduced conflicts, equal participation, flexibility, and enhanced teamwork. It creates an environment conducive to creativity, innovation, and positive working relationships, setting the stage for a successful and productive collaboration.

5.8 Clear goals

Clear goals are crucial in any collaborative endeavor. They provide a sense of direction, purpose and focus for the group. Here's an emphasis on the importance of clear goals:

Alignment and cohesion: Clear goals ensure that all group are aligned and working towards a common objective. This alignment minimises confusion, reduces conflicts and promotes effective collaboration.

Decision-making and prioritisation: Clear goals serve as a framework for decision-making and prioritisation. When goals are well-defined, it becomes easier to evaluate options, make informed choices and allocate resources effectively.

Motivation and engagement: Clear goals provide motivation and a sense of purpose for the members of the collaborative group.

Measurement and accountability: Clear goals allow for objective measurement and evaluation of progress. With well-defined goals, it becomes easier to track milestones, measure achievements and hold individuals accountable, helping to ensure that the group remains on track and focused on the desired outcome.

Adaptability and flexibility: Well-defined goals enable the group to adapt strategies, change course if necessary and remain agile in the pursuit of the shared objective.

Communication and coordination: When goals are clearly articulated, it becomes easier to convey expectations, share progress updates and coordinate efforts towards the common objective. Clear goals serve as a reference point for communication, ensuring that everyone is on the same page and working towards the same desired outcomes.

In summary, clear goals are crucial for successful collaboration. They provide alignment, enable effective decision-making, motivate individuals, facilitate measurement and accountability, allow for adaptability and enhance communication and coordination. Clear goals serve as a guiding force that drives the collaborative effort forward, increasing the chances of achieving desired outcomes.

5.9 Who leads the collaboration?

The person leading such a collaborative group in deciding who goes where to work on which farm should possess certain qualities and skills to effectively manage the responsibilities of this challenging role. The skill sets to lead a group include:

- Strong leadership skills, including motivational skills and the ability to make tough decisions.
- Excellent communication and interpersonal skills.
- Strategic thinking and decision-making and the ability to make timely and well-informed decisions.
- Emotional intelligence to navigate conflicts, motivate the team and maintain a positive and supportive group dynamic.
- Organisational and time management skills.
- Flexibility and adaptability to optimise the group's performance and navigate unforeseen obstacles.
- Resilience and stress management, including strategies for managing stress and be able to support and motivate the group during challenging times.

It's worth noting that while certain qualities and skills are important for a leader in this context, leadership is a continuous learning process. The leader should be open to feedback, willing to learn and grow and committed to the success of the group.

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5.10 Collaboration in the Ord

The Northern Australia Crop Research Alliance (NACRA) is a collaborative partnership between the Ord River District Cooperative (ORDCO), Kimberley Agricultural Investment (KAI) and Fancy Plants (formerly The Chia Company, owned by 2001 Nuffield Scholar John Foss).

ORDCO has existed as a farmer cooperative since 1963. The growers work closely to secure bulk purchasing, handling, and marketing. This is a good example of a successful collaboration. In 2015, when ORDCO partnered with KAI and the (then) Chia Company to establish NACRA, the goal was to combine crop research and development (R&D) efforts for the benefit of all growers in the Ord Valley and across Northern Australia.

This partnership has resulted in significant advances in cropping in the region across many crops. The growth of the cotton industry in the north has benefitted from the NACRA collaboration, securing substantial State and Commonwealth R&D funding which has resulted in the CSIRO focusing its cotton work heavily on the Ord. Ord growers have invested heavily in this work, with the outcomes including better understanding of the climate-related and agronomic requirements of growing cotton in northern conditions.

Other benefits of this collaboration include providing a focus point for the Grains Research and Development Corporation (GRDC) and the Cotton Research and Development Corporation (CRDC) to invest in the region. The current Cooperative Research Centre for Developing Northern Australia (CRCNA) has a $8million cotton grains and cattle investment with its roots planted strongly in the earlier NACRA work and the collaborative efforts of the Ord growers in working with other agricultural regions across Northern Australia. The CRCNA program has 30 research and funding partners who are integrating the cotton, grains, fodder, and beef production systems. Further information on this program can be found here - https://www.crcna.com.au/news/revolutionary-cotton-grains-cattle-program-boost-livestock-nutrition-and-farming-sustainability

The shared goals and cooperative practices of the Ord farmers over decades has created a strong foundation which has triggered all this work with pride.

Conclusion

This Nuffield report underscores the significance of long-term commitment in sustainable agricultural practices for cotton production in tropical areas in Northern Australia, and in particular in the Ord region.

The report prioritises three key factors:

1. **Adoption of CropShielding and other soil management principles.** Implementing cropshielding techniques and embracing soil management principles allows farmers to protect their crops from adverse weather conditions and improve soil health.
2. **Transitioning to lighter, precise autonomous vehicles**. Farmers can achieve timely and reliable operations even during the challenging monsoon wet season by integrating lighter, precise autonomous vehicles to facilitate efficient and precise operations, enhance productivity and reduce environmental impact.
3. **Collaboration**. Through collaboration, individuals with a shared vision can pool their expertise and resources, fostering innovation and progress.

By committing to these strategies and principles, farmers can achieve sustainable and reliable agricultural practices, ensuring good stewardship. This report serves as a call to action for farmers, policymakers, and industry stakeholders to invest in long-term solutions that can transform the agricultural sector and secure a prosperous future.

Recommendations

To successfully grow cotton in the extreme monsoonal conditions of the Ord region for the long term, managing the climatic and soil conditions is critical.

Further, practical production recommendations include:

- Change to 1m row spacings when planting crops.
- Practice controlled traffic farming.
- Install strategically placed tile drainage.
- Implement CropShielding.
- Invest money and time on soil amelioration products.
- Reduce the weight of machinery.
- As the agtech sector continues to develop, seek suitable autonomous vehicles.
- Finally, as outlined in chapter 5, collaborate with the right people. Start small and watch it grow!

References

Bate, A., 2021, Personal communication. See www.swarmfarm.com for further information.

Bridgestone, 2022, VF Agricultural Tyres Versus Tracks: Pros and Cons. Available at https://blog.bridgestone-agriculture.eu/vf-agricultural-tyres-versus-caterpillars-pros-and-cons

Brock, M., 2021, Farmer to Farmer Collaborations. Nuffield Canada. Available at https://www.nuffieldscholar.org/sites/default/files/2021-10/2019%20Scholar%20-%20Farmer%20to%20Farmer%20Collaborations%20-%20Mark%20Brock.pdf

Butler, G., 2023, Cotton ratoon management with Aquatill Injecticide. Presentation to Australian Cotton Conference. Available at https://australiancottonconference.com.au/wp-content/uploads/Greg-Butler.pdf

Cooperative Research Centre for Northern Australia, 2023, *Revolutionary cotton grains cattle program to boost livestock nutrition and farming sustainability.* Available at https://www.crcna.com.au/news/revolutionary-cotton-grains-cattle-program-boost-livestock-nutrition-and-farming-sustainability

Garrett, M., 2023, Personal communication. Precision Seeding Solutions. See www.pssag.com for contact details and further information.

Gladigau, J., 2007, Collaborate to survive and thrive. Nuffield Australia, NSW. Available at https://www.nuffieldscholar.org/sites/default/files/reports/2007_AU_John-Gladigau_Collaborate-To-Survive-And-Thrive.pdf

Hanlon, D., and Rigney, J., 2007, The Power of Engagement (Training Course). www.therightmind.com

Hanlon, D., and Rigney, J., 2012, Rural Leaders Boot Camp (Training Course). www.therightmind.com

Knox, O., 2022, Soil Your Undies Challenge. University of New England School of Environmental and Rural Science, NSW. https://www.une.edu.au/connect/news/2022/08/standing-up-for-soil

Knox, O., 2023, Personal communication.

Larkin, J. and Saunders, G. 2022. Personal communication. www.360yieldcenter.com

Lenssinck, F. 2022. Personal communication. Veenweiden (Peatland) Innovation Centre, The Netherlands.

Lui, K.Y., 2023, Ability of cover crops to reduce soil temperature during the wet season: Preliminary observations from Oasis Farms. Unpublished report for Oasis Farms, Department of Primary Industries and Regional Development, Kununurra. *Attached as Appendix A.*

McGavin, David, 2018, Personal communication. Precision Seeding Solutions. See www.pssag.com for contact details and further information.

Mohammed A. M. Al-Shatib, John McL. Bennett, Guangnan Chen, and Troy A. Jensen, 2021, Impact of cotton picker traffic on vertosol soil and yield in individual rows, *Crop and Pasture Science* Vol. 72, 514-527. Available at https://www.publish.csiro.au/cp/pdf/CP20360

Nexat, 2023, Nexat Revolution – the system. Available at https://www.nexat.de/en/the-system/

Precision Planting, 2022, Personal communications. Josh Stoller (sales). Paul Wilder (product development). Jason Stoll (research and development). See www.precisionplanting.com for contact details and further information.

Pure Flavor, 2022, Personal communication. See www.pure-flavor.com for contact details and further information.

Swarmfarm, 2023, https://www.swarmfarm.com

Yeates, S., 2016, Wet season cotton – things to consider. Presentation to Ord farmers, Kununurra. CSIRO, Townsville.

Yeates, S., 2021, Crop Production System Report for CRCP-58604 Developing Sustainable Cropping Systems for Grains and Fodder. Unpublished report by CSIRO for the Northern Australia Crop Research Alliance, Kununurra.