Final report

Demonstrating the productivity and profitability of cattle grazing Redlands leucaena in northern Queensland

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Abstract

Leucaena can double liveweight gains and increase carrying capacity for beef enterprises. Adoption of leucaena in northern Australia has been inhibited by production losses from psyllids and producer inexperience. The 'Redlands' psyllid resistant cultivar, available since 2017, offers potential to increase profitability and resilience of northern beef enterprises. However, Redlands was untested commercially, and there was concern about its palatability.

On a commercial property, at a 61 ha trial site previously developed in a pre-cursor project, the liveweight performance of steers grazing Redlands and Wondergraze cultivars was compared over 4.5 years. Redlands was readily eaten by cattle and had equivalent liveweight gains to Wondergraze. Three cohorts of weaner steers were grazed for 12-months each achieving an average annual liveweight gain of 223 kg (ADG=0.610 kg) at a stocking rate of 0.44 AE/ha. A cohort of heavyweight steers was successfully 'finished' to slaughter weight and carcass characteristic data obtained (MSA grading).

A supposed advantage from Redlands in a psyllid prone environment was not demonstrated as psyllids did not affect Wondergraze at the site during the entire grazing period. However, producers now have assurance in using Redlands leucaena. More broadly, the high liveweight gains achieved, underpins the economic case for leucaena adoption in the region and opens up marketing opportunities for northern producers. Increased knowledge gained through the project, has reduced the risks for leucaena adoption in the north. New producers can be better advised of requirements and techniques for leucaena establishment particular to their situation, and the likely costs and benefits.

Executive summary

Background

Many beef businesses in north Queensland have financial pressures of debt and rising costs. Feedbase productivity is highly seasonal and has been in long-term decline resulting in low annual liveweight gains. Progressive producers are seeking to improve herd performance and business sustainability. Where applicable, leucaena is one of the most attractive options for improving feedbase productivity and business resilience.

Leucaena adoption can dramatically improve productivity (liveweight gains) with increased stocking rates. Leucaena produces high quality, palatable forage and can do so during dry conditions due to deep rooting. Whilst widely adopted in central Queensland, in 2017 there was less than 2,500 ha established in north Queensland.

Notwithstanding a lack of suitably cleared country, low adoption is primarily due to low producer confidence and lack of farming experience and equipment required for establishment. Leucaena establishment involves substantial costs and is subject to weather, pest and weed risks. Overriding this, northern environments are more prone to attacks by leucaena psyllids which can severely reduce productivity of established leucaena. The psyllid problem has been an impediment to leucaena adoption in the north, and along the Queensland coast.

All previous commercial leucaena varieties were susceptible to psyllid attack. A breeding program began in 2002 to develop plant-based genetic resistance to psyllids and reduce productivity losses caused by attacks. The University of Queensland (UQ) in partnership with Meat and Livestock Australia (MLA) developed several promising lines. In 2016 Redlands was selected for release as a commercial psyllid resistant cultivar.

With Redlands available to beef producers through licensed seed producers, the opportunity existed for increased adoption of leucaena in northern and coastal environments. However, the relative productivity (economic) advantage from using Redlands was not confirmed and there was some concern about its palatability under commercial grazing. Many producers also lacked the skills and knowledge required for successful leucaena establishment and management.

This project was primarily aimed at addressing these constraints. More generally, information was also needed on the practicalities and profitability of leucaena in northern environments. Verifying these aspects, should increase producer confidence and adoption, leading to increased sustainability of northern beef businesses through higher feedbase productivity and enabling access to premium slaughter markets.

Objectives

The main objective of this project was to determine the liveweight gain performance of cattle grazing the Redlands psyllid tolerant leucaena cultivar (released 2017) in comparison to the conventional Wondergraze cultivar, in northern Australia.

Three consecutive cohorts of steers were grazed at a previously established, commercial scale, replicated trial site in north Queensland over 4.5 years. Average annual liveweight gains were determined. A fourth cohort of heavyweight steers was 'finished' on leucaena and carcass characteristic data acquired.

Results from the study would demonstrate the potential productivity advantage offered by the new Redlands cultivar and validate industry adoption in psyllid prone environments.

There were no sustained psyllid populations at the site during comparative grazing. Damage to Wondergraze was negligible, and no productivity advantage of Redlands was conferred. Productivity and acceptability of Redlands was equivalent to Wondergraze. However, cost-benefit analyses show that even if expected productivity losses from psyllids are minor (approximately 10%), the small extra cost of planting Redlands would be justified.

The project and results would be communicated directly to industry through on-site inspections and workshops aimed at increasing industry knowledge of the costs, benefits, and opportunities of leucaena in northern Australia.

On-site field days were held annually, and workshops were conducted on leucaena establishment in north Queensland. A site visit for key industry participants (non-producers) was held in the final year of the project. Based on the liveweight gain results and drawing on experience from establishing and managing leucaena at the site and from assisting early adopters of leucaena; northern producers can now be advised of the requirements, techniques and likely costs and benefits of leucaena establishment particular to their situation.

Methodology

Successive cohorts of weaner steers were grazed at a previously established 61 ha trial site comprising replicated paddocks of Redlands and Wondergraze leucaena. The site was at Pinnarendi in north Queensland. The design and development of the site occurred under a Phase 1 project (MLA project B.NBP.1618) over three years (2015-17), with details in the final report for the project (Lemin, 2017).

Each cohort was grazed for at least 12-months and liveweight gains determined from regular weighing. An opportunity to graze a sub-group of second and third cohort steers in an adjoining 25 ha improved pasture paddock provided additional productivity data for comparison.

A final cohort of heavyweight steers was fattened on the trial for 5 months and consigned to slaughter. Carcass characteristic data was obtained.

During the grazing phase, site measurements and monitoring included: weather conditions; inter-row pasture composition and yield; leucaena yield; soil testing and survey; psyllid incidence and faecal sampling.

Annual on-site field days targeting local producers were conducted at the site including an official ‘launch’ of Redlands in 2018. Workshops/presentations on leucaena establishment principles were conducted at Innisfail, Charters Towers and Townsville. High profile presentations on the project were given at the 2020 Leucaena Network Conference and Beef 2021. There were also interviews with ABC rural radio and articles by Beef Central.

Results/key findings

Liveweight gains were equivalent for steers grazing Redlands and Wondergraze leucaena at Pinnarendi. Redlands was readily accepted and grazed by cattle which were previously naive to leucaena. A productivity advantage from using Redlands was not demonstrated as there were no sustained psyllid populations at the site during grazing.

Annual liveweight gains on leucaena averaged 223 kg (ADG=0.610 kg) and were achieved at an average stocking rate of 0.44 AE/ha (2.27 ha/AE). A cohort of heavyweight steers was ‘finished’ to slaughter weight and had an ADG over 138 days of 0.75 kg. Annual liveweight gains from an adjoining improved pasture paddock (previously fertilised) were remarkably similar to the leucaena but at lower stocking rates.

The red-earth soils at the Pinnarendi leucaena site, represent a significant area of country which could be used for leucaena adoption. Leucaena productivity on these soils is constrained by the seasonality of rainfall and low soil water holding capacity. Low fertility and difficulty in raising fertility sustainably are also issues. Despite this, animal performance and indicated economic returns are much higher than for native pasture and strongly support leucaena development.

Benefits to industry

The project has demonstrated productivity of Redlands is equivalent to Wondergraze. Producers will have assurance in using Redlands for leucaena adoption. Whilst a production advantage was not demonstrated from Redlands, early adopters are convinced of its worth, citing they wouldn’t consider other cultivars which have historically been seasonally decimated by psyllids in these environments.

More broadly, the project has demonstrated high liveweight gains for weaner and heavyweight steers grazing leucaena in a sub-coastal north Queensland environment. This underpins the economic case for leucaena adoption in the region and opens up marketing opportunities for northern producers.

Increased knowledge and experience has resulted from establishing and managing leucaena at the Pinnarendi site and engaging with producers planting leucaena. This has identified better options and reduced the risks for leucaena adoption in the north, particularly related to seedbed preparation, timing of planting and weed control.

During the project, an estimated 2,000 ha of leucaena has been established in north Queensland producing an estimated 110-120 t of additional liveweight gain/year (valued at $0.5M at current prices). There is scope for future expansion, particularly on red-earth soils closer to the coast and on alluvial frontage soils further inland. There is larger potential on extensive areas of fertile basalt soils (lightly timbered) if management challenges can be addressed.

Liveweight gain of steers in the improved pasture paddock at Pinnarendi was better than expected, and is an indication to industry of the productive potential of improved pastures in northern environments.

Future research and recommendations

No reliable, long-term animal performance data is available from Redlands plantings on the Wet Tropical Coast (WTC) and Atherton Tablelands relative to existing highly productive improved (predominantly grass) pastures in the region. This data is needed to more thoroughly assess the economics of leucaena adoption in these regions, particularly considering that commercial Redlands plantings are being periodically damaged by psyllids on the WTC.

There was an alarming decline in desirable inter-row pasture species during the first three years of grazing at Pinnarendi. There is a need to investigate strategies which seek to best utilise leucaena when it is seasonally productive whilst preserving the quality of inter-row pasture species. This has wider implications for leucaena in the northern environments where it will often be grown in areas with highly seasonal rainfall and on soils which have low water holding capacity.

Maintaining adequate soil fertility for leucaena at Pinnarendi and other sites with low fertility in northern environments is likely to be challenging. Further work is required to investigate timing, type, and methods of fertiliser applications with regard to leucaena response, cost, and long-term effects on soil chemistry.

Factors contributing to the impressive performance of animals in the improved pasture paddock at Pinnarendi include the contribution of legumes (mainly Seca stylo), applied superphosphate fertiliser, and conservative stocking. Promoting adoption of improved pastures and measuring resulting animal performance is the principle focus of proposed pasture resilience projects in northern Queensland over the next several years.

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1. Background

1.1 Constraints to leucaena adoption in northern Queensland

Beef businesses in north Queensland can be characterised as having financial pressures of historical debt and rising costs in an environment of highly seasonal feedbase productivity. The feedbase has been in long-term decline due to a legacy of overgrazing and climate variability which combined with highly seasonal quality of native pasture species, results in low annual liveweight gains.

Despite recent high cattle prices easing the financial pressure on businesses, progressive producers are seeking to improve herd performance and business sustainability. Improving feedbase productivity and utilisation, supplementary feeding and use of improved pastures and legumes are options available to producers. Recently, a thorough economic analysis of options for northern beef businesses to increase resilience to drought, identified the addition of legumes – including leucaena where applicable, as having the most attractive internal rates of return over a 30-year period (Bowen et al., 2019).

Leucaena adoption can dramatically improve productivity (liveweight gains) with increased stocking rates. Leucaena (*Leucaena* sp.) is an exotic tree legume, which is substantially more productive than either existing native pastures or improved pasture systems. Leucaena produces high quality, palatable forage and can do so during dry conditions due to deep rooting. Leucaena has been widely adopted in southern and central Queensland, typically on heavier cropping soils of moderate fertility where an estimated 200,000-300,000 ha is now established (Shelton et al., 2021), resulting in about 55,000 t of liveweight gain worth $250M annually. However, there has been less than 2,500 ha established in north Queensland (Keating, 2017).

Whilst most northern graziers are aware of the productivity benefits of leucaena, the low adoption rate is attributed to low producer confidence and lack of farming experience; a predominance of extensive breeding operations not focussed on producing slaughter cattle; relatively high establishment costs and risk; lack of suitable machinery for establishment; the limited availability of cleared land and limited local marketing options for finished cattle. Overriding all of this, northern environments are more favourable for leucaena psyllids which can severely reduce productivity of leucaena, even when established.

Verifying the productivity and profitability of leucaena in northern environments should increase producer adoption leading to increased sustainability of northern beef businesses through higher feedbase productivity and enabling access to premium slaughter markets.

1.2 Release of psyllid tolerant leucaena

The leucaena psyllid (*Heteropsylla cubana*) is a small insect that feeds by sucking sap from leucaena, initially targeting new shoots and young foliage but progressing to leaf stems and older foliage when infestations are heavy. All previous commercial leucaena varieties were susceptible to psyllid attack. In some seasons, such attacks can defoliate trees and stop plant growth (Dalzell et al., 2006), resulting in yield losses (Bray and Woodroffe, 1991) and reduced palatability to cattle. Psyllid insects are more prevalent in humid, northern environments (during cooler weather) and their presence has constrained leucaena adoption to drier areas (within the 600-800 mm rainfall zone).

Plant-based genetic resistance to psyllids was sought to reduce productivity losses caused by attacks. In 2002, the University of Queensland (UQ) in partnership with Meat and Livestock Australia

(MLA) began a breeding program based at Redlands Research Station, Brisbane. Several lines were developed which showed specific resistance or tolerance to psyllids. *Leucaena leucocephala* lines were back crossed with *Leucaena pallida* to develop psyllid tolerance whilst maintaining productivity and palatability. Based on testing of the most promising lines in project B.NBP.0791 and palatability trials at Whitewater Station in north Queensland, UQ and MLA proceeded to commercialise the Redlands cultivar.

With Redlands psyllid resistant leucaena available to beef producers through licensed seed producers from 2017, there existed an opportunity for increased adoption of leucaena in northern environments. However, the relative productivity (economic) advantage from using Redlands was not confirmed and there were some concerns about its acceptability to cattle under commercial grazing situations. This project was primarily aimed at addressing these questions. More generally, information was also needed on the practicalities and profitability of leucaena in northern environments.

1.3 Redlands performance and leucaena economics

The basis of the project was to compare liveweight performance (productivity) of cattle grazing the psyllid tolerant Redlands, with the industry-standard (but psyllid susceptible) cv. Wondergraze. The project has been conducted in two phases. Phase 1 (MLA project B.NBP.1618) was carried out over the period 2016-2018 encompassing the establishment of a 61 ha replicated grazing trial at Pinnarendi Station in the Mount Garnet district of north Queensland. Phase 1 included site layout and preparation, leucaena planting and establishment, infrastructure set-up for grazing, psyllid monitoring and initial introduction of cattle to the trial in April 2018. Phase 2 (MLA project B.GBP.0040) continued with grazing performance measurements until mid-2022, using four cohorts of steers.

Whilst B.NBP.1618 finished in October 2018, the follow-on Phase 2 project was contracted in July 2019. In the interim, the first cohort of cattle remained on the trial, with liveweight measurements and trial management activities wholly supported by the Department of Agriculture and Fisheries, Queensland (DAF).

To obtain additional comparative data, the leucaena liveweight gain trial was expanded to include an improved pasture paddock (no leucaena) which was adjacent to the leucaena paddocks at the site. This was decided in early 2019, which allowed this paddock to be stocked with a sub-group of second cohort animals at the same time as the main group were introduced to the leucaena trial (April 2019). A sub-group of third cohort animals were also grazed in this paddock.

Productivity data from the trial, combined with knowledge from leucaena establishment and on-going management at the site has been used to evaluate the likely cost-benefit for leucaena adoption (specifically Redlands) in key northern environments. Confirming the feasibility and economics of leucaena in northern environments should improve producer confidence and adoption.

1. Objectives

The original principle objectives of the project were as follows:

a) *The project will evaluate liveweight gain performance of cattle grazing leucaena, under commercial-like conditions in north Queensland and communicate directly to industry through on-site inspections and workshops.*

This objective was met. Average daily liveweight gain (ADG) of three cohorts of weaner steers was determined from regular weighing over a period of at least 12 months for each cohort. Additionally, a fourth cohort of steers was 'finished' to slaughter weight with ADG gain monitored over six months of grazing. Producer field visits were held at the site annually, three workshop presentations were made on leucaena establishment in north Queensland (drawing on experience from the trial) and an industry field day was held at the site in the final year of the project.

b) *The potential productivity advantage offered by the new Redlands cultivar can be confirmed thereby validating industry adoption.*

This objective was partially confirmed. Whilst equivalent liveweight performance was achieved between Redlands and Wondergraze at the site, there was no sustained (>2 weeks) psyllid populations at the site during four years of replicated grazing. As such, there was no significant psyllid damage to Wondergraze and the supposed productivity advantage conferred from the psyllid tolerance of Redlands was not able to be tested.

c) *This information combined with the experience from establishing and managing leucaena at the site will directly contribute to better industry knowledge of the costs, benefits, and opportunities for leucaena production systems in northern Australia.*

This objective was achieved. Activities from the successful establishment of leucaena at the site and experience from subsequent management and monitoring has provided information on costs and site status. This has been used with the measured productivity data (kg/ha/year) to develop a gross margin analysis for leucaena on red-earth soils in north Queensland (compared to native pasture and fertilised pasture with stylos). This information has been extrapolated to estimate the potential cost-benefit offered by Redlands leucaena versus Wondergraze leucaena in psyllid-prone environments, in particular on the Wet Tropical Coast – a key region for adoption.

2. Methodology

2.1 Trial site and design

2.1.1 Site description

The trial site was located on 'Pinnarendi Station', 50 km south-west of Mount Garnet in north-east Queensland and about 250 km from the coast (18.043oS, 144.876oE). The site is at 760 m elevation and receives about 700 mm average annual rainfall. The trial was developed in paddocks previously cleared and used for maize and peanut cropping during the 1980-90's. The soils are red-brown sandy earths (pH ~6.4) of granitic origin with low fertility (P ~5 mg/kg; S ~3 mg/kg); they have low moisture holding capacity and are well drained despite being highly consolidated at depth. Although these soils would not generally be recommended for leucaena, they represent the most widely cleared land-type in north Queensland and are used for both cropping and grazing. Whilst there was no history of leucaena planting on the property, 1,200 ha of leucaena had been established at nearby 'Meadowbank' in the early 1990s. Psyllids were known to occur locally, with some level of production loss experienced at Meadowbank in most years.

Since being cropped, the site had been used for grazing and had a good cover of pasture species comprising a mixture of introduced and native grasses: naturalised Indian couch (*Bothriochloa pertusa*), Sabi grass (*Urochloa mosambicensis*), Rhodes grass (*Chloris gayana*) and black spear grass (*Heteropogon contortus*); together with introduced legumes: wynn cassia *(Chamaecrista rotundifolia); and Stylosanthes* sp. (mostly Seca).

2.1.2 Summary of site establishment

The design and development of the trial site up to introduction of cattle for grazing is described in detail in the final report for Phase 1 of the project (Lemin, 2017).

The site was prepared during the storm season of 2016 (October-December) with leucaena sown in January 2017. Leucaena was left to establish without grazing over the following 15 months during which time infrastructure installation was for grazing was completed.

The trial was configured as eight paddocks established with either cv. Redlands or cv. Wondergraze leucaena in a randomised, paired block design totalling 61 ha as per Fig. 1. There are six northern paddocks (Paddocks 1-6) of 7.4 ha each and two southern paddocks (Paddocks 7 and 8) of 8.3 ha each. Wondergraze is established in Paddocks 1, 3, 6 and 7 and Redlands is established in Paddocks 2, 4, 5 and 8.

Leucaena is planted in single rows at 10 m centres. Respective paired paddocks have the same total row lengths of leucaena and areas of interrow pasture. The existing inter-row pasture was retained in undisturbed strips between the cultivated leucaena planting rows. It had re-colonised a cultivated area adjacent leucaena rows by the time cattle were introduced in April 2018 (with the final cultivation for weed control in May 2017).

2.1.3 Comparison with improved pasture paddock

A 25 ha improved pasture paddock adjoins the trial immediately north of Paddock 7 and south of the main driveway into the property (Fig. 1). It was not initially included in the trial but provided an opportunity to monitor liveweight performance of cattle grazing pasture only (no leucaena) in the same environment. This previously cleared paddock comprised 21 ha previously sown with buffel grass (*Cenchrus ciliaris)* cv. USA and Gayndah and had also been colonised by S*tylosanthes sp*. (mainly Seca) and wynn cassia (*Chamerchrista rotundiflora*). The balance is an area of regrowth at the eastern end with mainly native grasses: black spear (*Hetropogon contortus*), kangaroo grass (*Themeda triandra*) and golden beard grass (*Chryopogon fallax*).

Although not replicated, data from this paddock provided a direct comparison between two grazing systems at the site. To improve the comparison, the cleared area of the paddock was fertilised with superphosphate (9% phosphorus (P), 11% sulphur (S)) at 300 kg/ha in January 2019. This was a similar rate of application of fertiliser previously applied to the interrow pasture in all leucaena paddocks.

Figure 1. Layout of Redlands-Wondergraze comparative liveweight gain trial at Pinnarendi.

2.2 Grazing and animal performance

2.2.1 Introduction

Grazing in leucaena paddocks at the trial site started in April 2018, 15 months after leucaena sowing. Once started, grazing was continuous until August 2021 when paddocks were spelled for six months. Grazing re-commenced in March 2022 and continued to early September 2022.

Four cohorts of cattle were grazed. The first three cohorts were introduced as weaner steers and grazed for a minimum of 12 months with the aim of monitoring ADG at regular intervals and to determine the ADG over a full year for respective treatments (Redlands versus Wondergraze). There was some overlap between the first and second cohort animals and second and third cohort animals. The aim with the fourth and final cohort of cattle was to obtain carcass data after having been grazed on leucaena – there was no Redlands-Wondergraze comparison.

Grazing in the improved pasture paddock at the site started in April 2019 and was run in parallel with grazing in the leucaena trial for Cohorts 2 and 3 using a sub-group of the same cattle. The improved pasture paddock had not been grazed for two and a half years prior to cattle being introduced (three consecutive wet-season spells).

2.2.2 Liveweight measurement and handling

Liveweight of all individual animals in the trial was measured at about six-weekly intervals. The maximum period between weighing events was 76 days. All weigh dates for respective cohorts are given in Appendix 9.1. Animals were individually identified with management tags for record keeping.

A segregated laneway runs along the eastern end of all trial paddocks (Fig. 1). Water points for each trial paddock were located in the laneway. On weigh days, cattle were ‘captured’ in the laneway adjacent to their respective paddocks before being ‘mobbed’ and moved to yards located at the south-east corner of Paddock 6. To assist this process, all animals were fed small quantities of molasses (weekly to fortnightly) for habituation to routine handling. Timing and quantity of molasses fed was recorded for each cohort on a paddock basis.

At the yards, animals were penned in one mob and weighed in random order as they were processed through the yards. Animals were drafted back into pens according to paddock allocation immediately after weighing (Fig. 2) and returned to respective paddocks in successive groups.

Cattle were weighed within 1-3 hours of mustering so that recorded weights were ‘paddock weights’ (without curfew). The exception was when cattle were first weighed into the trial and had been either held in the property yards or trucked to the site for variable periods up to 24 hours. These weights were used to allocate animals to treatment groups but not as a basis for the determining annual ADG. Annual liveweight gain was based on weights from the subsequent weighing conducted 3-5 weeks later, i.e., ‘paddock weight’.

Animals were weighed in a crush mounted on electronic weigh-beams. The weigh beams were connected to a Gallagher TSi unit (model G01902). Individual weights were manually recorded for all animals at every weighing.

Figure 2. First cohort steers drafted into treatment pens after weighing.

3.2.2.1 Walk over Weigh unit

A commercial walk-over-weighing (WOW) system was purchased, from Tru-Test™ using DAF funding. It was installed at the water point in the improved pasture paddock in June 2019. The system weighed individual animals against their electronic identification tags (EID's) as they passed through the unit to access water (Fig. 3). A two-week training period was required before animals had to use the unit exclusively.

Notwithstanding implementation of this unit, the WOW data was not used for calculating reported ADG's. Manual weighing of animals in the improved pasture paddock was continued in conjunction with weighing of animals from the leucaena trial. The unit was installed principally for demonstration purposes as well as to gauge its reliability. Weights from the unit were compared manual weights to see how well they correlated.

Figure 3. Walk over weigh installation at water point to improved pasture paddock.

2.2.3 Animal sourcing and characteristics

The first three cohorts comprised Brahman cross (*Bos indicus*) and Droughtmaster (*Bos indicus x Bos taurus*) weaner steers 200-250 kg liveweight at introduction. The Brahman steers were sourced directly from the herd at Pinnarendi and the Droughtmaster steers were sourced from DAF's Spyglass Beef Research Facility located about 180 km south-east of Pinnarendi.

The fourth cohort animals were Brahman cross and Brangus (*Bos indicus x Bos taurus*) heavy weight steers approximately 510 kg liveweight sourced from Wombinoo Station located about 40 km east of Pinnarendi.

Candidate animals for use were in the trial (steers in the desired weight range) were primarily selected on the basis of quiet temperament for ease of regular handling.

None of the animals had previously been grazed on leucaena.

2.2.4 Animal welfare

Applications and approvals for the experimental use and handling of animals in the trial were made through the DAF Animal Ethics Committee (AEC). The approvals and associated amendments were as follows:

- AEC Ref. No. SA 2017/12/628 (1 February 2018 to 28 February 2021)
- AEC Ref. No. SA 2021/02/772 (10 February 2021 to 9 February 2024)

Cattle were monitored by the proprietors of Pinnarendi under the terms of a Field Trial Agreement. Additionally, DAF officers based at Mareeba made regular (weekly or fortnightly) visits to the site. The site was also remotely monitored via cameras mounted at each of the five water points and a water level sensor in the supply tank. The cameras automatically captured four images per day at regular intervals during daylight hours. This imagery (archived for one week) and the real-time tank water level was accessible on-line. Additionally, automatic low tank level alerts were notified by text message.

2.2.5 Stocking

The basis for determining stocking rate in the leucaena trial was given in the final report for Phase 1 of the project (Lemin, 2018). This method was based on an estimated annual liveweight gain of 220 kg for a leucaena-grass pasture system and an average entry weight of 200 kg/head. This resulted in an estimate of seven head for each of Paddocks 1-6, and eight head for the larger Paddocks 7 and 8; i.e., 58 head in total.

Notwithstanding above, a more conservative stocking rate was adopted for the first cohort of cattle, as leucaena at the site had not reached full productivity. For the second cohort, the intention was to stock as per the calculated rate, however drought conditions during 2019 necessitated a much lower stocking rate. For the third cohort, conditions allowed stocking at close to the calculated stocking rate. For the fourth cohort, stocking was to prioritise weight gain to 'finish' cattle to slaughter weight.

The stocking rate adopted for the improved pasture paddock was about half the calculated rate for the leucaena and was based on local experience. This was implemented for both cohorts of cattle in this treatment (second and third cohorts).

The calculation of reported stocking rates for respective cohorts was done at the treatment level. The overall stocking rate for a cohort and treatment was the time weighted average of stocking rates for 'grazing periods' applicable to the cohort. The respective 'grazing periods' were times for which the number of animals grazing in the trial was unchanged. This accounted for the staggered introduction of cohort source animals as well as any overlap between cohorts.

Stocking rates were calculated on an adult equivalent (AE) basis i.e., 450 kg steer at maintenance based on the average mid-weight for each grazing period, the number of head for the grazing period, and the area being grazed.

2.2.6 Cohort details

3.2.6.1 First cohort – leucaena only

Cattle were first introduced to the trial on 19 April 2018 comprising 24 head of Pinnarendi steers selected from a limited pool of 30 head. However, the 24 head were reduced to 12 after seven head immediately escaped and a further five were subsequently removed (all because of unsuitable temperament).

On the 28 June 2018, the remaining 12 head were combined with 16 steers trucked from Spyglass Research Facility and allocated into four even groups of seven animals (A, B, C and D). Groups A and C were assigned to Wondergraze and groups B and D to Redlands. For allocation to groups, steers were first blocked by source and weight then randomly assigned between treatments from each block. Allocation by this method resulted in the same number of head by source and minimal difference in the mean liveweight for treatments (Table 1).

Table 1. Composition and average weights of first cohort groups of steers at Pinnarendi on 28 June 2018.

28 June 2018	*Source of animals*		*Average weight*
	Pinnarendi	*Spyglass*	*(kg ± s.e.)*
Group A	3	4	235 ± 18
Group C	3	4	228 ± 12
Wondergraze	***6***	***8***	***232 ± 10***
Group B	3	4	225 ± 12
Group D	3	4	226 ± 10
Redlands	***6***	***8***	***225 ± 7***

These groups were rotationally grazed (remaining within treatments) through five rotations ending 1 April 2019 as per Table 2. First cohort animals on 1 April 2019 are shown in Fig. 4. Animals were weighed at each rotation date. For the first rotation, animals were grazed in Paddocks 7 and 8 as two groups of 14 head in each paddock to help Spyglass animals settle in. For ease of handling, rotational grazing using fewer groups with higher numbers was carried out in preference to set-stocking all paddocks with small, difficult groups.

On 1 April 2019 a new (second) cohort of weaner steers was introduced to the trial. These animals were integrated with the original cohort of 28 head and split into eight groups as per Table 3. Animals remained within the same treatment (Redlands or Wondergraze) and where possible, animals from the original groupings were kept together. From 1 April 2019 until 29 August 2019, these groups remained in the same paddocks as independent replicates with no further rotation (as per Table 2). After 1 April 2019, all animals were weighed on three more occasions: 13 May, 1 July and 29 August. The 29 August weighing was the last for the first cohort of animals which were removed from the trial on 3 September 2019. First cohort Pinnarendi and Spyglass animals were grazed in the trial for a total of 497 and 427 days respectively.

Table 2. Rotation of groups of steers through replicates in the leucaena trial at Pinnarendi from 28 June 2018 to 29 August 2019.

Rotation and date	*Paddock 1 (W)*	*Paddock 2 (R)*	*Paddock 3 (W)*	*Paddock 4 (R)*	*Paddock 5 (R)*	*Paddock 6 (W)*	*Paddock 7 (W)*	*Paddock 8 (R)*
1st rotation 28 Jun to 7 Aug (40 days)							A + C 6 x Pin 8 x Spy	B + D 6 x Pin 8 x Spy
2nd rotation 7 Aug to 20 Sep (44 days)	A 3 x Pin 4 x Spy	B 3 x Pin 4 x Spy	C 3 x Pin 4 x Spy	D 3 x Pin 4 x Spy				
3rd rotation 20 Sep to 8 Nov (49 days)					B + D 6 x Pin 8 x Spy	A + C 6 x Pin 8 x Spy		
4th rotation 8 Nov to 19 Dec (41 days)	A 3 x Pin 4 x Spy	B 3 x Pin 4 x Spy	C 3 x Pin 4 x Spy	D 3 x Pin 4 x Spy				
5th rotation 19 Dec to 5 Mar (76 days)					B 3 x Pin 4 x Spy	A 3 x Pin 4 x Spy	C 3 x Pin 4 x Spy	D 3 x Pin 4 x Spy
6th rotation 5 Mar to 1 Apr (27 days)	A 3 x Pin 4 x Spy	B 3 x Pin 4 x Spy	C 3 x Pin 4 x Spy	D 3 x Pin 4 x Spy				
7th rotation 1 Apr to 29 Aug (150 days)	1 1 x Pin 2 x Spy 2 x Pin (2)	2 1 x Pin 2 x Spy 2 x Pin (2)	3 1 x Pin 2 x Spy 2 x Pin (2)	4 1 x Pin 2 x Spy 2 x Pin (2)	5 1 x Pin 2 x Spy 2 x Pin (2)	6 1 x Pin 2 x Spy 2 x Pin (2)	7 3 x Pin 2 x Spy 3 x Pin (2)	8 3 x Pin 2 x Spy 3 x Pin (2)

W = Wondergraze; R = Redlands; Pin = Pinnarendi (first cohort); Spy = Spyglass (first cohort); Pin (2) = Pinnarendi (second cohort).

Table 3. Allocation of first and second cohort steers on 1 April 2019.

Paddock	*Cohort and source[A]*			*Total number*	*Paddock average weight (kg)*	*Treatment total and average weight (kg)*
	First Pinnarendi	*First Spyglass*	*Second Pinnarendi*			
1 W	1(A)	2(A)	2	*5*	324	Wondergraze 7,526 kg 220 ± 23.7
3 W	1(C)	2(C)	2	*5*	354	
6 W	1(A)	2(A)	2	*5*	354	
7 W	1(A),2(C)	2(C)	1	*6*	426	
2 R	1(B)	2(B)	2	*5*	331	Redlands 7,299 kg 206 ± 23.6
4 R	1(D)	2(D)	2	*5*	358	
5 R	1(B)	2(B)	2	*6*	350	
8 R	1(B),2(D)	2(D)	1	*6*	379	
Total	***12***	***16***	***14***	***42***	-	-

[A] groups A, B, C, D from Table 2.

Figure 4. First cohort animals in yards on 1 April 2019.

Industry standard animal health treatments were administered to first cohort animals as per Appendix 9.2.1. They received no dietary supplementation. There was one unexpected adverse event with an apparently healthy Pinnarendi steer found dead in Paddock 7 on 1 August 2019, having apparently died suddenly in the previous 12 hours. No post-mortem examination was conducted. This animal was not replaced as the final weighing (and subsequent removal) of first cohort animals was on 29 August.

3.2.6.2 Second cohort - leucaena

The second cohort animals were introduced on 1 April 2019. They were 14 Brahman cross weaner steers sourced from Pinnarendi with an average weight (± s.e.) of 213 ± 12 kg. They were integrated with the first cohort animals as described in the previous section (3.2.6.1 and Table 3). For allocation to paddocks/treatments, animals already on the trial were kept within the same treatments and all animals were evenly allocated according to source (cohort and property of origin) and to achieve similar average weights between paddocks. Nonetheless, this process was constrained by the different numbers of animals within each cohort and the need to allocate an extra animal to Paddocks 7 and 8 due to the larger area of these paddocks.

The groups shown in Table 3 were grazed within their respective paddocks for 108 days until removal of first cohort animals from the trial on 29 August 2019. After 1 April 2019, the second cohort animals were weighed in conjunction with first cohort animals on three occasions: 13 May, 1 July and 29 August. The second cohort animals were then recombined into two groups of seven head based on treatment, and rotationally grazed through their respective treatment paddocks for 238 days.

Rotations nominally occurred every two weeks, with the shortest and longest rotations being 10 and 21 days respectively. During this period, there was no effective replication in the trial, as there was just one group of animals grazing within each treatment. This low stocking rate was deliberate, due to dry conditions and low leucaena-pasture productivity. These conditions persisted until rain in mid-January 2020 promoted leucaena and pasture recovery over several weeks. Higher stocking rates were not resumed until 23 April 2020 when additional animals became available. In the meantime, second cohort animals were weighed on six occasions up to and including 23 April 2020.

The animals introduced on 23 April 2020 were an initial group of third cohort animals (refer 3.2.6.4). When combined with the existing 14 head from the second cohort, there were 41 head in total (Fig.5). These were split into eight groups with each group allocated to a treatment paddock as per Table 4. In allocating animals to groups, animals already on the trial were kept within the same treatments and all animals were evenly allocated according to source (cohort and property of origin) and to achieve similar average weights between paddocks. Nonetheless, this process was constrained by the different numbers of animals within each cohort and the need to allocate an extra animal to Paddocks 7 and 8 due to the larger area of these paddocks. Also, because there was an odd number of animals introduced, a 'spare' animal was allocated to the Wondergraze Paddock 8 treatment. This extra animal was included as a potential replacement for any animals which exhibited unsuitable temperament. It was allocated to Paddock 7 since this paddock was the most productive in the trial.

Table 4. Allocation of second and third cohort steers on 23 April 2020.

Paddock	*Cohort and source*		*Total number*	*Paddock average weight (kg)*	*Treatment total and average weight (kg ± s.e.)*
	Second Pinnarendi	*Third Pinnarendi*			
1 W	2	3	*5*	300	Wondergraze
3 W	2	3	*5*	290	5870 kg
6 W	2	3	*5*	321	280 ± 27.5
7 W	1	4	*5*	220	
2 R	2	3	*5*	294	Redlands
4 R	2	3	*5*	292	5653 kg
5 R	2	3	*5*	328	283 ± 28.4
8 R	1	5*	*6*	216	
Total	***14***	***27***	***41***	-	-

*1 extra animal in Paddock 7 included as a potential replacement

The groups in Table 4 were grazed within their respective paddocks for 57 days. During this period they were weighed on 19 May 2020 and finally on 19 June 2020 when the second cohort animals were removed. This was the completion of grazing for the second cohort animals. They were grazed for a total of 445 days during which time they were weighed 11 times.

Industry standard animal health treatments were administered to second cohort animals as per Appendix 9.2.2. On introduction to the trial, second cohort animals were supplied with commercial LNT Uramol® blocks containing 30% urea, through to about the end of January 2020. In February 2020, these were replaced with commercial Olsson's Superphos blocks containing 8% P which were provided for the remaining time the animals were in the trial. There were no unexpected adverse events.

3.2.6.3 Second cohort – improved pasture

Animals were first introduced to the improved pasture paddock on 1 April 2019. They comprised 12 Brahman cross weaner steers with an average weight (± s.e.) of 212 ± 13 kg. They were a sub-group of the second cohort animals introduced to the leucaena trial at the same time and sourced from

Pinnarendi. Although they were the first mob grazed in the improved pasture paddock, they are referred to as the second cohort since grazing and weighing was conducted concurrently with the second cohort leucaena steers.

These animals were removed from the trial on 19 April 2020 after 445 days. Duration of grazing, weigh dates, animal health treatments and supplementation were as per the second cohort leucaena steers (refer 3.2.6.2).

Figure 5. Second and third cohort Pinnarendi steers in yards on 19 May 2020 (41 head including improved pasture steers) – smaller animals were initial group of third cohort steers.

3.2.6.4 Third cohort – leucaena

The third cohort animals comprised an initial group of steers from Pinnarendi and a second group of steers from Spyglass which entered two months later. Once combined and allocated, the trial was fully replicated for the first time, with subsequent set-grazing (no rotation) for a total period of 405 days (367 days excluding a 38 day period after introduction of the second group).

Sourcing and allocation

The first group of third cohort animals were introduced on 23 April 2020 comprising 27 Brahman cross weaner steers sourced from Pinnarendi with an average weight (± s.e.) of 196 ± 4 kg. They were integrated, grazed, and weighed with the second cohort steers as per 3.2.6.2 and Table 4.

The second group of third cohort animals were introduced 23 June 2020, 61 days after the first group. With removal of the second cohort animals on 19 June 2020, there was a four day period when only the first group of third cohort animals (27 head) were on the trial. During this period, animals were split into two groups according to treatment and grazed in Paddocks 5 (Redlands) and 6 (Wondergraze) i.e., 13 and 14 head respectively.

The second group of third cohort animals comprised 16 Droughtmaster steers sourced from Spyglass with an average weight (± s.e.) of 194 ± 2 kg. When combined with the existing 27 head in the first group, there were 43 head in total on 23 June 2020. However, a first group steer formerly in Paddock 1 and displaying poor temperament was removed and re-allocated to the improved pasture paddock (refer 3.2.6.3). It was replaced with the 'spare' first group animal formerly in Paddock 7 (refer 3.2.6.2) resulting in 42 head for allocation across the trial. They were split into eight groups with each group allocated to a treatment paddock as per Table 5. In allocating animals to groups, animals already on the trial were kept within the same paddocks (with the exception of the animal swapped from Paddock 7 to 1) and all animals were evenly allocated according to source (cohort and source), and to achieve similar average weights between paddocks.

With introduction of the second group of third cohort animals, all replicate paddocks in the trial were stocked. The groups in Table 5 were grazed within their respective paddocks for 405 days and weighed on nine occasions up to the completion of grazing on 2 August 2021. Fig. 6 shows the group of five third cohort animals allocated to Paddock 6 (taken 27 January 2021).

On 2 August 2021, Spyglass animals were removed from the trial site. Pinnarendi animals from this cohort remained grazing on the trial until being sold in early December 2021, however there was no weighing or formalised grazing during this time.

Table 5. Allocation of third cohort steers on 23 June 2020.

Paddock	*Cohort and source*		*Total number*	*Paddock average weight (kg)*	*Treatment total and average weight (k ± s.e.)*
	Third Pinnarendi	*Third Spyglass*			
1 W	3	2	*5*	235	Wondergraze 4717 kg 225 ± 8.9
3 W	3	2	*5*	233	
6 W	3	2	*5*	245	
7 W	4	2	*6*	231	
2 R	3	2	*5*	242	Redlands 4691 kg 223 ± 8.4
4 R	3	2	*5*	234	
5 R	3	2	*5*	236	
8 R	4	2	*6*	223	
Total	***26***	***16***	***42***	-	-

Figure 6. Third cohort Pinnarendi and Spyglass steers allocated to Paddock 6.

Treatments and supplements

Industry standard treatments were administered to third cohort animals as per Appendix 9.2.3. Additionally, all third cohort animals in the leucaena trial received either 'Redlands adapted' or 'Wondergraze adapted' rumen inoculant according to their treatment allocation. Inoculant was supplied by the DAF Tick Fever Centre and was administered on 14 January 2020. The dose was administered by mouth (100 mL) under APVMA permit 11715. Inoculation of cattle was delayed until leucaena was growing actively in response to rainfall in mid-December 2020. This was to ensure an adequate level of leucaena in the diet, for the inoculant to be effective.

Third cohort steers were supplied with commercial blocks containing 8% P from May 2020 to about August 2020 and again from early January 2021 until animals were removed from the trial. During the intervening period (dry season) they were supplied with commercial blocks containing 30% urea (September-November 2021).

3.2.6.5 Third cohort – improved pasture

The second group of animals in the improved pasture paddock were introduced on 23 June 2020. They were principally a sub-group of the third cohort Spyglass steers introduced to the leucaena trial at the same time. Although they were the second mob grazed in the improved pasture paddock, they are referred to as the third cohort since grazing and weighing was conducted concurrently with the third cohort leucaena animals. They comprised nine Brahman cross weaner steers an average weight (± s.e.) of 212 ± 13 kg and one Pinnarendi steer formerly from the leucaena trial but removed due to poor temperament. This animal was significantly larger than the Spyglass steers and weighed 239 kg on 23 June 2020.

Duration of grazing, weigh dates, animal health treatments, and supplementation were as per the second cohort leucaena animals (refer 3.2.6.4). There was one unexpected adverse event. A Spyglass steer was injured in the yards on 28 October 2020. It subsequently escaped the trial in early January 2021 and could not be located. It was replaced with a steer from Pinnarendi on 14 April 2021. The replacement animal weighed 489 kg on 14 April versus a paddock average weight of 391 kg on the same date.

3.2.6.6 Fourth cohort – leucaena only

Sourcing and grazing

This cohort was grazed with the aim of obtaining carcass data from animals grazed on leucaena. Ideally, animals for this activity would have been on the trial for as long as possible (post weaning) and compared with animals in an equivalent but separately grazed (non-leucaena) group. However, the opportunity for grazing was constrained by the project completion date and slower than anticipated regrowth of leucaena after cutting in December 2021. The available grazing period was just five months from March to July 2022.

To reach slaughter weight, heavyweight animals (475-525 kg liveweight) were required for entry into which were 'finished' on leucaena. The early part of the grazing period encompassed the time that leucaena at the site was typically productive and liveweight gains were high. Animal performance (ADG) was monitored during grazing, but there was no Redlands-Wondergraze comparison.

The fourth cohort of animals were introduced on the 1 March 2022 after leucaena at the site had sufficiently grown back from cutting in December 2021 (refer 3.3.11.3). Sourcing candidate animals from the local area was difficult even with several months' lead time (suitable animals were not available from Spyglass). Eventually, 30 Brahman cross and Brangus (*Bos indicus x Bos taurus*) steers were sourced and trucked from Wombinoo Station located about 40 km east of Pinnarendi (100 km by road). On 1 March they had an average curfew weight (± s.e.) of 460 ± 3 kg. On the basis that animals lost 10% of body weight while yarded (Wythes, 1985), their average 'paddock weight' at this time would have been about 511 kg (i.e., 460/9 x 10). Fourth cohort animals are shown in Fig. 7, about a week after entry to the trial.

Stocking was based on exploiting the available leucaena and maximising weight gains. The cohort was grazed as one group and rotated sequentially through all leucaena paddocks at 6-8 day intervals. After introduction, all animals were weighed on four occasions: 12 April, 24 May, 20 June and 17 July 2022; and ADG's determined for all animals.

Following weighing on 17 July, all 30 head were kept in the yards overnight on feed and water. The following morning 24 head (full truck load) were loaded for transport to JBS Townsville for slaughter on 19 July. The balance of six head (selected for quiet temperament) were returned to the trial paddocks and remained on the trial until 5 September when they were weighed for the final time and trucked for local slaughter. The 24 head slaughtered 19 July were on the trial for a total of 138 days. The balance of six head remaining after 17 July were retained for an extra 50 days; resulting in a total of 188 days on the trial.

The fourth cohort animals received no treatments whilst on the trial. They had fly tags applied while yarded at Wombinoo. There were no unexpected adverse events. They were supplied with commercial blocks containing 8% P for the duration of their time on the trial.

Figure 7. Fourth cohort steers on 11 March 2021, 10 days after entering the trial.

Slaughter and MSA grading

For the 24 head slaughtered at JBS Townsville, MSA grading data was acquired. A subset of these animals were selected and entered into a producer carcass competition being run by DAF extension staff at the same time. Carcass data was not obtained for the six head which remained on the trial until 5 September.

3.2.7 Statistical analysis of liveweight performance

A statistical analysis was conducted for the first and third cohorts. Due to dry conditions and low stocking, there were not enough animals in the second cohort to allow replication of treatments. Analyses were conducted by a senior DAF biometrician using Genstat V19.1 data analysis software.

3.2.7.1 Summary of experimental design

The trial was established according to a randomised complete block design. There were eight paddocks, with treatments randomly allocated to one of two paddocks within four replicate blocks. Treatments were plantings of either Redlands or Wondergraze leucaena cultivars.

Each paddock was grazed with steers from two different sources (properties) - either Pinnarendi or Spyglass. Animals were allocated to paired blocks of paddocks evenly by source and also to attain similar total liveweights.

3.2.7.2 Analyses

First cohort

An analysis was completed for the first cohort steers from both sources. Variables analysed included average daily gain over 368 days (368ADG) from 28 June 2018 to 1 July 2019, and actual weight on 1 July 2019. The actual weight was analysed with and without the starting weight on 28 June used as a covariate. Data were analysed by analysis of variance (ANOVA). The block structure used was Replicate/Paddock/Source/Animal and the treatment structure was Cultivar (Redlands or Wondergraze). Differences between the Source of animals was not tested for 368ADG as there were too few measurements from each source within some of the paddocks – there was only one animal from Pinnarendi in six of the eight paddocks (Table 6).

Table 6. Number of head from first cohort per treatment and source.

Replicate	***Treatment at 1 July 2019***	***Source (no. head)***	
		Pinnarendi	***Spyglass***
1	Redlands	1	2
	Wondergraze	1	2
2	Redlands	1	2
	Wondergraze	1	2
3	Redlands	1	2
	Wondergraze	1	2
4	Redlands	3	2
	Wondergraze	3	2

Third cohort

An analysis was completed for the third cohort steers for both sources. Variables analysed included average daily gain over 367 days (367ADG) from 31 July 2020 to 2 August 2021, and actual weight on 2 August 2021. The actual weight was analysed with and without the starting weight on 31 July 2020 used as a covariate. Data were analysed by analysis of variance (ANOVA).

The aim of the analysis was to determine if there was a difference in the weights and ADG's of animals grazing the two leucaena cultivars. For this analysis, Cultivar was considered as the fixed factor (treatment structure) and Source was in the random structure (block structure). The effect of Source was also investigated (Table 7). For this, Source was considered in the fixed terms.

Table 7. Number of head from third cohort per treatment and source.

Replicate	***Treatment at 1 July 2019***	***Source (no. head)***	
		Pinnarendi	***Spyglass***
1	Redlands	3	2
	Wondergraze	3	2
2	Redlands	3	2
	Wondergraze	3	2
3	Redlands	3	2
	Wondergraze	3	2
4	Redlands	4	2
	Wondergraze	4	2

Data analysis was by analysis of variance (ANOVA). When considering Source as a random effect, the block structure used was Replicate/Paddock/Source and the treatment structure was Cultivar (Redlands or Wondergraze). When Source was investigated as a fixed effect, the same block structure was used, and Source was also included in the treatment structure (as Cultivar x Source).

3.2.8 Faecal sampling

For estimation of diet dry matter digestibility (DMD), crude protein (CP) and non-grass proportions, faecal samples were collected. Faecal samples were collected in conjunction with most weighing events for the second and third cohorts since March 2019. Fresh samples were collected from each replicate paddock (if it contained animals at the time). The samples were collected once animals had been trapped in the laneway and prior to them being mobbed and moved to the yards for weighing. Typically, this resulted in samples being obtained from 3-4 animals in each paddock.

Samples were refrigerated for short term storage (20 hrs maximum) and oven dried at 60-65°C on return from field. If samples could not be oven dried on return from field, they were frozen in a domestic deep freezer (for up to six months) prior to being thawed and dried at a later date.

To simplify and reduce costs of analysis, samples from the same treatment paddocks and weigh dates were combined. This was done by mechanically disintegrating samples (using a mallet), combining the material from respective treatment paddocks and milling the composite sample to ≤2mm particle size. Samples were freezer stored again prior to submission. This resulted in three samples for submission from most weigh dates i.e., i) Redlands; ii) Wondergraze; and iii) improved pasture. In December 2020, samples were submitted to the University of Queensland (UQ), Gatton (Dr. Peter Isherwood) for Near Infrared Reflectance Spectroscopy (NIRS) analysis and P estimation (by wet chemistry)

For the best prediction of the non-grass component (C3) in the diet, samples were collected of forages at the site for delta C (δ13C) analysis. To increase the accuracy of the C3 calculation, these samples were also used for NIRS analysis to estimate the difference in digestibility between C3 and C4 species.

Representative 'grab' samples of the predominant forage species at the trial site were collected at disparate times of year i.e., peak wet-season (February 2020) and peak dry-season (November 2020). Grass forage species collected were Rhodes, black spear grass, urochloa, indian couch and buffel; legume species collected were wynn cassia, stylo and leucaena. These samples were oven dried at 60-65°C, course milled, and freezer stored.

Faecal samples were collected from second and third cohort animals on the dates listed in Table 8. In December 2020, samples collected to that time were submitted to UQ for NIRS analysis in conjunction with faecal samples. Corresponding forage samples were submitted to University of Western Australia (UWA), Biogeochemistry Centre (Dr. Greg Skrzypek) for δ13C analysis.

The UQ NIRS testing ceased operating in January 2021. Faecal samples collected in 2021 were submitted to UWA for δ13C analysis in October 2021 in expectation that NIRS analysis of corresponding samples could also be completed. However, NIRS analysis this did not become available again during the life of the project and samples have been freezer stored.

Dr. Maree Bowen (DAF, Rockhampton) calculated Cp, DMD and %C3 in diet from results of samples submitted for NIRS and δ13C analyses.

Table 8. Faecal samples collected at Pinnarendi and corresponding analyses (2019-2021).

Date	*Sample*	*Paddocks sampled*	*NIRS analysis*	*Delta C analysis*
5-Mar-19	Wondergraze Redlands	P6, P7 P5, P8	✓	✓
1-Apr-19	Wondergraze Redlands	P1, P3 P2, P4	✓	✓
13-May-19	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✓	✓
1-Jul-19	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✓	✓
29-Aug-19	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✓	✓
18-Oct-19	Wondergraze Redlands Improved pasture	P6 P5 P9	✓	✓
16-Dec-19	Wondergraze Redlands Improved pasture	P6 P5 P9	✓	✓
29-Jan-20	Wondergraze Redlands Improved pasture	P4 P3 P9	✓	✓
19-Mar-20	Wondergraze Redlands Improved pasture	P7 P2 P9	✓	✓
23-Apr-20	Wondergraze Redlands	P6 P5	✓	✓
19-Jun-20	Wondergraze Redlands Improved pasture	P7 P8 P9	✓	✓
31-Jul-20	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✓	✓
16-Sep-20	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✓	✓
29-Oct-20	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✓	✓
14-Jan-21	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✗	✓
22-Feb-21	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✗	✓
14-Apr-21	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5, P8 P9	✗	✓
17-Jun-21	Wondergraze Redlands Improved pasture	P1, P3 P2, P4 P9	✗	✓
2-Aug-21	Wondergraze Redlands Improved pasture	P1, P3, P6, P7 P2, P4, P5 P9	✗	✓

3.3 Site monitoring

3.3.1 Weather monitoring

A weather station (Davis Vantage Pro2 Plus) was installed at the site in May 2018. It was located adjacent to the portable yards (south-east corner of Paddock 6) and was mounted 1.5 m above ground level. The station monitored rainfall, air temperature, dew point temperature, wind speed and solar radiation at 5 minute intervals. The station was connected via the 3G mobile network allowing access to real time and archived data via website.

Prior to installation of the weather station, only rainfall data was recorded at the site. This was from a single rainfall gauge installed near the eastern end of Paddock 7 and later from an additional gauge sited on the main entrance road at the eastern end of Paddock 6.

The weather station malfunctioned in late December 2018 and was not recommissioned until May 2019. Only rainfall was recorded during this period – measured at the proprietor’s residence approximately 1 km east of the trial paddocks. Rainfall data is reported as monthly totals compared to historical data from nearby Meadowbank (Bureau of Meteorology Station No. 031175). An analysis of monthly air temperature data identified the average monthly temperature and the number of days each month when:

- daily average temperature was 13°C or less;
- the daily minimum temperature was 2°C or less (frost likely);
- the daily maximum temperature was 25°C or more (for maximum leucaena growth occurs);
- the daily maximum temperature was 38°C or more.

Other parameters monitored by the weather station were not analysed.

3.3.2 Soil testing and site soil survey

3.3.7.1 Background sampling

Prior to development of the site for leucaena, surface soil samples (0-10 cm) were collected for analysis. The summarised results are shown in Table 8. Soil pH was suitable, in the range of 6.2-6.8 (average 6.4). Phosphorus levels were low ranging from 3.6-9.0 mg/kg (average 5.1). Average sulphur was low at 2.6 mg/kg. Potassium and magnesium levels were adequate, but zinc and copper were low.

To address nutrient deficiencies (P and S) fertiliser applications were made to leucaena plant rows prior to leucaena planting and after establishment. Fertiliser applications were also made to the interrow pasture and the improved pasture paddock. Details of these applications are in the final report for Phase 1 of the project (Lemin, 2018).

Table 9. Soil analyses taken from surface samples (0-10 cm) across Pinnarendi trial site in 2016 (averaged).

Sample analyte	*Average of samples (n = 9)*
pH (1.5 Water)	6.4
Phosphorus (mg/kg)	5.1
Sulphur (mg/kg)	2.6
Potassium (cmol(+)/kg)	0.53
Magnesium (cmol(+)/kg)	1.3
Zinc (mg/kg)	0.33
Copper (mg/kg)	0.21

3.3.7.2 Soil sampling regime

Soil samples were collected across the site in November 2019 and in August 2021, according to a pattern of sampling across the site – two samples were collected from each of the eight leucaena paddocks and the improved pasture paddock (i.e., 18 samples in total). For the leucaena paddocks; one sample was a composite of three sub-samples taken from the middle of the inter-row pasture area adjacent to the three pasture exclosures in each paddock (refer 3.3.10.2); the other sample was a composite of three sub-samples taken adjacent to the first sample, but within 1 m of the next leucaena plant row immediately to the north of the pasture exclosures. For the improved pasture paddock; one sample was a composite of three sub-samples taken adjacent to the three pasture exclosures in the cleared (and fertilised) area of the paddock (refer 3.3.10.2); the other sample was from adjacent the single pasture exclosure in the regrowth (and unfertilised) area of the paddock. All samples were through the surface profile down to 10-12 cm (A horizon). All samples were sieved to remove course organic matter, rocks, and nodules. Samples analysed by Nutrient Advantage Laboratory Service, Werribee, Victoria.

In May 2019, two additional samples were taken from a location in Paddock 1 where there was a marked difference in leucaena growth within the same row. Large, healthy leucaena transitioned to undersized leucaena with poor growth within about 20 m of row (Fig. 8). As with other sampling, the top 0-12 cm of the profile was sampled.

Figure 8. Soils samples were taken in proximate areas with contrasting leucaena growth (photo March 2019).

3.3.7.3 Site soil survey

A 1:25 000 scale soil survey of the trial site was undertaken by officers of the Land Resource Assessment Division of the Queensland Department of Resources (QDR), Mareeba. Field work was undertaken in December 2021 after pruning of leucaena at the site. An Electromagnetic (EM) ground survey across the site was attempted in November 2021 but was not finished due to equipment failure. Only Paddock 1 and a portion of Paddock 2 were able to be EM surveyed.

The detailed methodology and results of the soil survey is attached as Appendix 9.3. In summary, a total of 12 representative core samples were collected and described. The core samples were from immediately adjacent leucaena plant rows. Samples from six of the sites were submitted to the Department of Environment and Science Chemistry Centre at Boggo Road, Dutton Park, Queensland for analysis. The laboratory analytical results allowed for calculations of plant available moisture content (PAWC) for the six sites submitted for detailed analysis. Additional surface samples (0-20 cm) were collected as a second observation from the middle of the adjacent inter-rows (i.e., between leucaena rows), for comparative fertility analysis away from the plant row.

3.3.3 Psyllid monitoring

Checks for psyllid occurrence and resulting damage were conducted during weekly to fortnightly visits to the site – particularly during high risk periods from about April to July each year. In the 15 months prior to grazing at the site, psyllid damage was assessed by inspecting 72 sentinel leucaena trees across the site (nine per paddock) and rating damage on each tree according to Table 9. A detailed description of this method is given in the final report for Phase 1 of the project (Lemin, 2018).

Routine assessments in this manner were conducted once it was judged that significant psyllid damage was being sustained at the site (damage rating 3 or more in paddocks at the site for at least two weeks) and maintained until psyllid incidence was no longer significant.

Table 10. Psyllid damage rating criteria.

Damage rating	*Criteria*
0	no psyllids present
1	psyllids observed but no noticeable damage
2	slight curling of leaves
3	tips and leaves curling and yellow
4	tips and leaves badly curled; yellowish and covered in sap
5	loss of up to 25% of young leaves
6	loss of up to 50% of young leaves
7	loss of up to 75% of young leaves
8	100% loss of young leaves and blackening of lower leaves
9	blackened stem with total leaf loss

3.3.4 Leucaena growth and characteristics

3.3.4.1 Growth

Observations of leucaena growth were made throughout the grazing period during regular visits to the site. In this way, the seasonal growth of leucaena at the site was characterised and issues were documented.

3.3.4.2 Yield

To estimate leucaena yield, grazing exclosures were erected across the site in December 2019. These were fixed mesh barriers (about 1.6 m high) enclosing a 3 m length of leucaena row to exclude cattle and prevent grazing leucaena growing within the exclosure. There were two exclosures installed in each paddock (16 in total), sited to achieve an estimate of 'average' yield in the paddock. In Paddocks 1,2 5 and 8; exclosures were both erected in areas with 'typical' leucaena. In Paddocks 3,5,6 and 7; one exclosure was erected in an area with larger leucaena (high yielding) and the other was erected in an area with smaller leucaena (low yielding).

Leucaena yield was measured by hand cutting all edible leaf, green (immature) pod and green stem (≤ 6 mm diameter) from all leucaena stems which originated from inside the exclosures. This material was oven dried at 65^{o}C to a constant weight. Dried material from respective exclosures was sieved (8 mm aperture) to separate leaf from stem (and any green pod) to determine the amount of each fraction. Material harvested from within the exclosure represented the yield from 30 m^2 of the paddock (at 10 m row spacing); this was converted to a 'paddock' dry matter yield (kg/ha).

At the outset, the intention was to harvest exclosures every four months; nominally at the end of the wet season (April); end of early dry season (August); and at the end of the late dry season (December). However, resource constraints meant that harvesting was only conducted twice per year during 2020 and 2021: at the end of the wet season (April-May); and prior to the wet season (October-December). This provided a coarse estimate of annual yield and for comparison between years. Prior to each harvest, photographs were taken of each exclosure to compare with the corresponding yield result.

With continuous stocking of all paddocks during 2021, a subjective estimate of 'pilferage' was made prior to harvesting each exclosure. Pilfered material was leaf and stem near the perimeter of the exclosures which had been eaten by cattle. The estimate was made by visually comparing partially grazed leucaena at the edges of the exclosure with ungrazed, 'intact' leucaena within the confines of the exclosure.

Prior to 2019, additional yield assessments had been conducted on an ad-hoc basis by hand cutting edible material from 10 m sections of leucaena row chosen to be representative of the respective paddock. These assessments were of 'presentation' yield since cattle had grazed leucaena in the areas assessed.

Timing of all leucaena harvests at Pinnarendi are summarised in Table 10.

The harvest conducted in April 2021 coincided with a leaf drop event at the site which occurred about 10 April. Paddock 8 was harvested 7 April, but Paddocks 1-7 were harvested during the period 14-29 April.

The harvest in November 2021 was after rainfall during October had re-invigorated leucaena growth. Delaying this harvest would have captured on-going growth but was undertaken in anticipation of leucaena pruning. All grazing exclosures at the site were removed on 2 December 2021, just prior to mechanical pruning which occurred the following day.

Table 11. Leucaena yield assessments at Pinnarendi, 2018-2021.

Harvest date	*Comment*
2018	*- 'presentation yields'; refer final report for Phase 1 of the project (Lemin, 2018)*
2019	
2 May	- grazed yield from exclosures; all paddocks; already grazed prior to erection of exclosures - ungrazed yield rom exclosures; all paddocks
1 Aug	- ungrazed from exclosures; all paddocks
16 Dec	- ungrazed from exclosures; all paddocks
2020	
14 May	- ungrazed from exclosures; all paddocks
6 Nov	- ungrazed yield from exclosures; all paddocks
2021	
7-29 Apr	- ungrazed yield from exclosures; all paddocks; yield reduced by leaf drop in early April
8 Nov	- ungrazed yield from exclosures; all paddocks; yield response from storm rain

3.3.4.3 Quality

Dietary quality of leucaena pasture at Pinnarendi was evaluated from sampling in mid-2018 with results presented in the final report for Phase 1 of the project (Lemin, 2018). Additional samples of dried material harvested from grazing exclosures were collected over the period 2019-21 comprising leaf, immature (green) pod, green stem (≤ 6 mm diameter) and samples of leucaena 'as grazed' which comprised the proportion by dry weight of leaf and stem and green pod that were present at time of yield assessments. Additionally, samples of 'yellow' and 'green' leucaena leaf were collected from Paddocks 1-6 in March 2019.

All samples were oven dried at 65°C to constant weight, milled to ≤2mm particle size and freezer stored prior to submission for feed value analysis in late 2021. Analysis was conducted by Dairy One (New York, USA) using wet chemistry procedures.

3.3.4.4 Leucaena yield at off-site locations

To allow a comparison of leucaena productivity in environments suited for leucaena adoption in north Queensland, exclosures to measure leucaena yields were also installed in commercial leucaena paddocks at a sub-coastal and inland site.

The sub-coastal site, (960 mm aar) had two-year old Redlands established on red-earth soils of low fertility (typically: P < 5 mg/kg; S = 5-8 mg/kg, pH = 6-6.5) which had superphosphate applied at establishment. The inland site (820 mm aar) had two-year old Wondergraze planted on moderately fertile alluvial soils (typically: P = 10-25 mg/kg; S 2-5 mg/kg; pH = 6.4-6.8) which had superphosphate and granulated sulphur applied during establishment. Both sites had double row leucaena planted at 10 m centres.

Grazing exclosures measuring 5 x 4 x 1.6 m (length x width x height) were erected within paddocks at each of these sites (eight in total at each site). Each exclosure represented 50 m^2 of the leucaena paddock (at 10 m row spacing). Both sites were 'set' (edible material stripped) in late December 2019 and subsequently harvested bi-annually in conjunction with harvests conducted at Pinnarendi (Table 11). Harvests were not able to be completed at the sub-coastal site in 2021 as high river levels prevented property access at key times of the year.

Table 12. Leucaena yield assessments at north Queensland sites (2019-2021).

Year	***Pinnarendi***		***Sub-coastal***		***Inland***	
	Mid-year harvest	***End-year harvest***	***Mid-year harvest***	***End-year harvest***	***Mid-year harvest***	***End-year harvest***
2019	n/a	16 Dec	n/a	27 Nov (strip)	n/a	17-18 Dec (strip)
2020	14 May	16 Nov	28 May	27 Oct	24 Jun	16 Nov
2021	7-29 Apr	8 Nov	none	none	2-3 Jun	16 Nov

3.3.5 Interrow pasture growth and composition

Annual inter-row pasture yield and composition was assessed from 2019-2021.

3.3.5.1 2019 assessment

A visual assessment of inter-row pasture was conducted for Paddocks 1-4 only in March 2019. Assessments were calibrated against three quadrat cuts taken from Paddock 4 at the same time. Visual assessments of residual pasture yields in all paddocks were made in mid-December 2019, before any significant rain had been received at the site.

3.3.5.2 Pasture exclosures and residual paddock yields (2020-21)

To estimate inter-row pasture productivity and composition, grazing exclosures were erected within all paddocks in September-October 2019 to exclude grazing by trial cattle. Three 1 m^2 exclosures were erected along the centre of the middle inter-row in each paddock, about 200 m apart (i.e., 3 x 8 = 24 in total) and four exclosures were erected in the improved pasture paddock; three in the improved pasture area and one in the end with native pasture and regrowth.

All pasture within exclosures was cut about 5 cm from the ground and removed. In subsequent years, all material from within exclosures was cut to 5 cm as per Table 12 to determine biomass yield and composition. For yield determination, the entire sample from each exclosure was dried at 65^{o}C to constant weight and dry matter yield determined. For composition analysis, samples were sorted into grass and legume species prior to drying. The principle species were noted and component samples were dried separately.

Visual estimates of residual biomass pasture in all paddocks at the end of the dry season were also made as per Table 12.

Table 13. Pasture assessments at Pinnarendi, 2020-2021.

Date	***Method***	***Comment***
1 April 2020 6 November 2020	Grazing exclosure cut – all paddocks Visual assessments – all paddocks	End of main growing season End of dry season
7 April 2021 August 2021	Grazing exclosures cut – all paddocks Visual assessment – all paddocks	Endo of main growing season Residual biomass after removal of third cohort

3.3.6 Key management activities

3.3.6.1 Weed control activities

Control of eucalyptus regrowth within trial paddocks was not warranted during the grazing phase of the trial. Herbicide control of regrowth was last conducted in December 2016.

Poison peach (*trema tomentosa*), is toxic to stock and occasional isolated plants up to about 1 m height occur in all paddocks at Pinnarendi. Plants were mechanically grubbed using hand tools whenever found.

A small, established outbreak of Parramatta grass (*Sporobolus africanus*) in Paddock 5, was manually dug out in mid-2021.

3.3.6.2 Leucaena monitoring and control

Monitoring of the site for occurrence of volunteer or escaped leucaena was conducted periodically in conjunction with routine site visits for cattle management and site measurements. Follow-up control was conducted in late 2021 and early 2022 which was during the time that paddocks were being spelled. Lack of grazing combined with favourable weather resulted in volunteer leucaena becoming more observable, when normally it would have been eaten by cattle.

Seedlings and small plants to about 0.6 m height were hand sprayed with Conquerer® (triclopyr @ 300 g/l and picloram @ 100 g/L) mixed at 375 mL per 100 L (plus wetter). Larger plants were hand sprayed with Access® (240 g/l triclopyr, 120 g/L picloram) mixed at 1 part per 60 parts diesel.

3.3.6.3 Pruning

Leucaena was pruned at the site in early December 2021, four months after removal of the third cohort animals. Pruning was carried out on 3 December by a commercial contractor using a Valtra T202 reverse steer tractor (approx. 200 HP) equipped with a PTO operated AHWI FM600 forestry mulcher fitted with chipping teeth (Fig. 9). The mulcher had to be operated within 10-25 cm of the ground to allow clearance for cut stems under the tractor. This equipment cut and mulched the 61 ha site (approx. 50 km of leucaena row) in a single pass taking about 12 hours. The single-row leucaena at the site was mostly in the range of 2.5-3.5 m high with some areas at 4.5 m.

Figure 9. Equipment contracted for cutting leucaena in December 2021.

3.4 Economic analyses

3.4.1 Redlands versus Wondergraze cost-benefit analysis

A basic analysis was undertaken to determine the productivity loss (liveweight gain) at which the extra cost of planting Redlands would be recouped in any one year. This would give an indication of the minimum anticipated productivity loss which would justify the planting of Redlands.

The only cost difference from planting Redlands arises from the higher cost of Redlands seed – $70/kg for Redlands versus $50/kg for Wondergraze (March 2021 commercial seed prices), with other aspects of planting and subsequent management being the same. In the absence of psyllids, preliminary results from the trial at Pinnarendi indicated there was no production penalty from using Redlands – it was well grazed by cattle and productivity (LWG) was the same as for Wondergraze. Furthermore, Redlands should demonstrate a relative benefit to Wondergraze in psyllid prone environments, as productivity losses from psyllid damage would be avoided or reduced.

The avoided productivity loss at which the extra cost of Redlands would be recouped was calculated based on two price scenarios and expectations of liveweight gain and stocking rates from Pinnarendi as follows:

- average daily liveweight gain (ADG) = 0.6 kg
- annual liveweight gain = 219 kg/yr
- stocking at 2.5 ha/AE (1 AE = 450 kg steer) i.e., annual productivity = 219/2.5 = 87.6 kg/ha
- price scenarios: $4.30/kg liveweight (January 2021) and $2.85/kg (6 year average of north Queensland Saleyards to January 2021)
- planting twin rows at 1 kg/ha/row i.e., 2 kg/ha overall

- cost premium for Redlands seed = 2 kg/ha x $(70-50)/kg = $40/ha

Calculations based on these assumptions are given in Table 13.

Table 14. Expressing cost of Redlands seed as an equivalent productivity loss.

Measure	***Price A*** ***$4.80/kg***	***Price B*** ***$2.85/kg***
Redlands cost as liveweight	($40/ha) / ($4.80/kg) = 8.33 kg/ha	($40/ha) / ($2.85/kg) = 14.04 kg/ha
Redlands cost as AE productivity	(2.5 ha/yr/AE) x (8.33 kg/ha) = 20.8 kg/yr	(2.5 ha/AE/yr) x (14.04 kg/ha) = 35.1 kg/yr
Redlands cost as productivity loss	**(20.8 kg/yr) / (219 kg/yr) x 100 = 9.5 %**	**(35.1 kg/yr) / (219 kg/yr) x 100 = 16.0 %**

3.4.2 Redlands versus Wondergraze Gross Margin comparison

3.4.2.1 Background

A gross margin analysis was done to compare the economic performance of Redlands and Wondergraze leucaena cultivars relative to an unfertilised native pasture on the same red-earth soil type. Red-earth soils are not well-suited to leucaena as they typically have low fertility and moisture holding capacity. Nonetheless, they represent a significant area in sub-coastal north Queensland available for leucaena adoption, having been previously cleared for cropping but converted to beef cattle grazing if cropping was not profitable.

Annual rainfall is in the range of 750-1,000 mm but highly seasonal which limits leucaena productivity in drier months, particularly as these soils dry out rapidly. Closer to the coast, showers are more frequent after the main wet season helping to prolong pasture (and leucaena) productivity. Conversely, these sites are usually elevated (700-850 m), and cold weather in winter with frosts in some years can set-back leucaena productivity.

3.4.2.2 Method

The gross margins calculated were based on modelled forage and cattle management using data measured at the Pinnarendi trial and knowledge of local production systems. The gross margins were determined as an annual gross margin per hectare. The analysis included variable costs, cattle trading costs and the cost of establishing both cultivars of leucaena amortised over the expected life of the crop (as an annualised variable cost). The gross margins were calculated as the gross income received from the sale of cattle less the variable costs. Detail on this methodology is given in Appendix 9.4.1.

The analysis was based on a site area of 500 ha. The growing costs of the leucaena were based on a mixture of chemical and mechanical weed control methods. This broadly matches current industry practice in the north (for red-earth soils). As in the cost-benefit analysis (3.4.1), the only cost difference that arises when planting Redlands compared to Wondergraze leucaena, is due to the seed price for Redlands being $20/kg more. All other aspects of planting and subsequent management during establishment are the same.

Cattle production at each site was based on steers entering at 180 kg liveweight and finished to 400 kg liveweight for Redlands and 379 kg liveweight for Wondergraze. The 21 kg liveweight difference arises from the expected damage by psyllids to Wondergraze leucaena (refer 3.4.2.3). The grazing days, stocking rate and daily liveweight gain for pasture at each site were based on an assessment of measured values in both unpublished and published reports and the considered judgement of experienced DAF beef research and extension staff. The economic analysis was done by a Charters Towers based, DAF agricultural economist.

3.4.2.3 Redlands versus Wondergraze productivity difference – effect of damage by psyllids

The gross margin comparison between Redlands and Wondergraze leucaena cultivars was premised on higher productivity of Redlands in psyllid prone environments. At Pinnarendi however, cattle performance (LWG) had been the same for Wondergraze and Redlands. There was no demonstrated productivity advantage from Redlands, as there has been no significant psyllid populations at the site during grazing trials.

As an alternative to measured performance differences, the gross margin analysis used a weighted risk matrix with the probability of psyllid incursion over a 10 year period and subsequent liveweight gain impact based on the considered opinion of project investigators as per Table 14. This yielded an expected annual weight gain of about 199 kg compared to 220 kg in the absence of psyllids.

Table 15. Psyllid impact probability of occurrence.

Probability of occurrence *(Years in 10, P)*	***Expected liveweight gain*** *(kg/day)*	***Value*** *(Px)*	***Annual liveweight gain*** *(kg per head)*
1 in 10 years	0.400	0.400	146
2 in 10 years	0.480	0.960	175
2 in 10 years	0.550	1.100	201
3 in 10 years	0.600	1.800	219
1 in 10 years	0.603	0.603	220
1 in 10 years	0.603	0.603	220
10 year average	***0.547***	***5.465***	
Expected value for annual weight gain = 0.547 kg/head/day			
Expected annual weight gain = 199.5 kg/head			

3.4.3 Gross Margin Analysis of Redlands adoption on the Wet Tropical Coast

3.4.3.1 Background

An economic analysis based on beef enterprises on the north Queensland. Wet Tropical Coast (WTC) adopting leucaena (Redlands) was done. The WTC is a 250 km coastal strip from about Ingham in the south to Cairns in the north. It spreads inland from the coast about 10-15 km to the base of the eastern escarpment but extends further inland along river valleys (notably the Herbert, Tully, North and South Johnstone). Annual rainfall is high to extreme with greater than 2,500 mm typical during December to April. May to August is drier, but coastal stream showers from south-east trade winds usually result in semi-regular rainfall. From October to December rainfall is less reliable, and dry periods of 6-10 weeks can cause significant pasture stress.

Beef cattle grazing enterprises on the WTC are relatively intensive operations characterised by high stocking rates and high productivity (with fertiliser). For these operations, store cattle are typically sourced from further inland – either from saleyards or producers' own breeding properties. Historically and even today, high stocking rates are adopted, with a focus on productivity (kg/ha) rather than maximising liveweight gain. This is driven by competition from horticulture and sugarcane resulting in high land values, with the best soils dominated by banana production.

The WTC offers significant potential for the new Redlands cultivar since previous leucaena adoption has been virtually non-existent in-part due to the psyllid threat. In the few years prior to 2021, about 500 ha of Redlands has been established in this area, although there is local government concern about the weed threat posed by leucaena plantings.

An economic analysis of leucaena on the Dry Tropical Coast (Bowen to Townsville) was not conducted. This is also an area with potential for Redlands adoption although leucaena pasture systems in this drier environment will be inherently less productive without irrigation. Irrigated leucaena has been established by a few producers in this region, but detailed knowledge of these systems (costs and productivity) is insufficient for an economic analysis.

3.4.3.2 Method

The typical beef operation on the WTC is based on Signal grass (*Urochloa decumbens* formerly *Brachiaria decumbens*) with Tully grass (*Urochloa humidicola* formerly *Brachiaria humidicola*) used in areas with poor drainage. Legumes are not often sown into these systems as they seldom persist. For the study, gross margins were calculated for each of four pasture systems to allow comparison of the economic performance of leucaena over a grass pasture system in this environment. For leucaena it was assumed that the Redlands cultivar would be adopted based on its psyllid tolerance.

The four data sets are summarised in Table 15. They are based on two scenarios, i) an existing grass pasture system and ii) establishment on land previously used for sugarcane cropping. These scenarios were chosen since they represented two common situations facing producers considering leucaena establishment.

Table 16. Wet Tropical Coast production scenarios used in gross margin analysis.

Scenario	*Comment*
1. Pre-existing grass pasture	Baseline case (pre-existing)
2. Grass pasture including initial establishment costs (ex-sugarcane)	Baseline case if costs of establishment from previous cane farming are factored in
3. Grass-leucaena pasture including establishment costs of leucaena into pre-existing grass pasture	Baseline case with leucaena established later (leucaena as twin rows at 10 m centres)
4. Grass-leucaena pasture including establishment costs of grass and leucaena concurrently (ex-sugarcane)	Comparison case where a grass-leucaena system is established from previous cane farming (leucaena as twin rows at 10 m centres)

The gross margins calculated were based on modelled forage and cattle management using data measured at Pinnarendi and knowledge of local production systems. The gross margins were determined as an annual gross margin per hectare. The analysis included variable costs, cattle trading costs and the cost of establishing both cultivars of leucaena amortised over the expected life of the crop (as an annualised variable cost). The gross margins were calculated as the gross income received from the sale of cattle less the variable costs. Detail on this methodology is given in Appendix 9.4.2.

The analysis was based on a site area of 250 ha. The growing costs of the leucaena were based on a mixture of chemical and mechanical weed control methods. This was done to match current industry practice. Cattle production at each site was based on steers entering at 250 kg liveweight and taken to >400 kg (depending on system) over 365 days. Stocking rate and daily liveweight gain for pasture at each site were based on an assessment of measured values in both unpublished and published reports and the considered judgement of experienced DAF beef research and extension staff. The economic analysis was done by a Charters Towers based, DAF agricultural economist.

3.4.3.3 Productivity assumptions

WTC grass pasture productivity for the grass systems in Table 17 are based on a Queensland Department of Primary Industries (QDPI) grazing trial conducted at Utchee Creek Research Station over eight years (1976-85). This 40 ha trial had 30 ha of guinea grass (*Megathyrus maximus*) with some legume (*Centrosema sp.*), and 10 ha of Signal grass (*Urochloa decumbens*) pasture. Steers were introduced at 230-290 kg and removed at 380-440 kg liveweight. They were rotated within the site at intervals depending on pasture condition. Each year, 150 kg/ha of superphosphate was applied to the entire site with an additional 390 kg/ha of urea applied to the Signal grass. Average productivity over eight years was as follows:

- Annual liveweight gain = 155 kg/hd/yr (0.42 kg/day)
- Stocking rate = 2.35 AE/ha (AE – 450 kg steer)

This was a high stocking rate in comparison to the Pinnarendi trial where stocking was about 0.5 AE/ha. This stocking rate is considered to be too high to maintain pasture vigour and land condition, and in the context of increased focus on the contribution of agricultural runoff in Great Barrier Reef catchments. Nonetheless, no current reliable productivity data was available from producers and reports of earlier productivity studies were based on similarly high stocking rates. Therefore, the same stocking rate was adopted for the study, and this remains broadly in line with current practice.

The same stocking rate was also applied to the grass-leucaena pasture system in Table 15. In the absence of any productivity data from newly established grass-leucaena pastures on the WTC, an average daily liveweight gain (ADG) of 0.6 kg was attributed. Table 16 shows the main parameters for grass and grass-leucaena systems with inferred diet quality and intake.

Table 17. Basis for WTC production systems used in gross margin analysis (with inferred diet intake and quality).

Parameter	*Utchee Creek Grazing Demonstration 1976-1985 (QDPI)*	*Redlands leucaena (model)*
Pasture system	**Grass:** (30 ha guinea grass with some legume + 10 ha Signal grass	**Grass-Leucaena:** Twin row leucaena at 10 m centres
Fertiliser	• Superphosphate (P,S) 150 kg/ha/year • Potash 50 kg/ha at establishment • Sodium Molybdate 0.5 kg/ha at establishment and every 3 years guinea only • Urea 390 kg/ha/year on brachy	• CK55 (N,P,K) 250 kg/ha at establishment • Superphosphate (P,S) 200 kg/ha if leucaena established into existing grass pasture • DAP (N,P) 150 kg/ha/year after establishment
Stocking (AE/ha)	2.35	2.35
Liveweight Gain (kg/yr) **Average Daily Gain (kg)**	155 0.42	219 0.60
Estimated diet (400 kg steer) intake (% bodyweight) DM intake (kg/day) **Inferred diet quality** Dry matter digestibility (%) Energy (MJME/kg) Protein (%) **Resultant average intake** Energy (MJ/day) Crude protein (g/day)	 *2.3* *9.2* *69* *6.8* *7.5* *63* *690*	 *2.6* *10.4* *75* *7.2* *8.0* *75* *800*
Comments	Very high stocking rates and high rates of fertiliser applied. Prioritised productivity (kg/ha) over liveweight gain (kg/head).	Unknown liveweight gain on WTC as no producer data available. Annual ADG of 0.6 kg assumed and diet quality inferred. Leucaena should increase DMD and DM intake.

3.5 Extension and adoption

3.5.1 Field days and workshops/training

Field days and training events conducted or contributed to during the project are summarised in Table 17. Field days or visits were held annually at Pinnarendi except in 2020 when a field day scheduled for 31 March was cancelled two weeks beforehand due to COVID-19 restrictions.

Table 18. Field days, workshops and seminars associated with the project (2019-2022)

Event and date	***Target region***	***Focus / Topics***	***Attendees***
Pinnarendi Field Day and Redlands launch May 2019	North Queensland	Pinnarendi trial background, establishment, liveweight data; leucaena establishment costs in north Qld.; Redlands launch; rumen bug	75 producers and industry participants
Northern Territory Field Day and Seminar October 2019	Douglas Daly	Leucaena establishment and management; Pinnarendi trial; Leucaena CoP; grazing management systems	15 producers and industry participants
Starbrite Field Day and Seminar November 2019	Charters Towers district	Leucaena establishment, management and economics; producer experience;	50 producers and industry participants
Leucaena Network Conference Seminar September 2020	Northern Australia	Leucaena establishment in north Qld.	>80 producers and industry participants
Introduction to Leucaena Workshop October 2020	Wet Tropical Coast	Introduction to leucaena and establishment; local producer experiences; Leucaena CoP	23 producers
Pinnarendi-Whitewater Field day and Industry Update March 2021	North Queensland	Pinnarendi trial cattle liveweight and soil fertility; leucaena Code of Practice; e-beef smart farming; Whitewater pasture trial; producer experiences with leucaena; economics of drought management strategies; climate forecasting	20 producers and industry participants
Leucaena Field Day Pinnarendi -Whitewater field day March 2022	North Queensland	Pinnarendi trial update; leucaena under trees; Goshen leucaena liveweight data; climate update; climate update; beef business resilience, advancing beef leaders	20 producers and industry participants
Pinnarendi-Whitewater Industry Information Day June 2022	North Queensland	Introduction to leucaena; adoption in Qld.; requirements, establishment and management; cattle performance; Code of Practice; grass-legume pasture trial	9 industry participants

Particulars of events in Table 17 are given in the following.

3.5.1.1 2019 Pinnarendi field day and Redlands launch

An annual field day was held at Pinnarendi on 22 May 2019. In conjunction with the field day, MLA and UQ staged an official ‘launch’ of the Redlands variety.

The field day component was held the site yards where trial cattle were penned according to treatment along with documented liveweight gains (Fig.10). Presentations were made as follows:

- ***Craig Lemin (DAF, Mareeba):*** overview of the trial; liveweight performance of cattle; psyllid activity; comparative performance of the Redlands and Wondergraze varieties;
- ***Joe Rolfe (DAF, Mareeba):*** requirements for establishing leucaena on north Queensland land types (red-earths and northern frontage); assumptions made for costs of establishment on different land types;
- ***Vivian Finlay (DAF, Charters Towers):*** establishment costs and economics of leucaena on both red earth and northern frontage country;
- ***Bron Christensen (The Leucaena Network):*** background and rationale for 'The Leucaena Network' and recent activities; outline and importance of the Leucaena Code of Practice;
- **Greg Brown (producer and leucaena grower):** tribute to the late Jim Kernot (formerly DAF) for his contribution to the development of leucaena.

Afterwards, attendees reconvened at the Pinnarendi cafe where the Redlands variety was officially 'launched' by James Strong, Chief Executive Officer, MLA. UQ representatives Max Shelton and Chris Lambrides, as well as Scott Dalziel (formerly UQ) spoke about the development of Redlands and the opportunity it affords. Licensed Redlands producers Bruce Mayne (Mayne Seeds) and Peter Larsen (Leucseeds Pty. Ltd.), spoke about their personal experiences with establishing and growing leucaena.

There were about 75 attendees at the field day of which 45 were producers representing about 30 extensive and intensive beef businesses. The balance of attendees comprised representatives from local and state government agencies, agribusiness merchants, seed producers, natural resource management groups and MLA. The beef producers who attended were mostly from the Atherton Tablelands and the north Queensland coast (Innisfail to Mackay). The information booklet provided to attendees is attached as Appendix 9.5.

Figure 10. Attendees at the 2019 Pinnarendi field day and Redlands launch.

3.5.1.2 2019 Northern Territory field day and seminar

A 'Pathways to Potential' field day and seminar was held at Douglas Daly Research Station in the Northern Territory on 10 October 2019. The day included presentations on leucaena adoption in north Queensland and results from leucaena grazing trials at Pinnarendi and Douglas Daly. There was a field visit to leucaena demonstration site at nearby Bindaroo Pastures which had been fire damaged.

3.5.1.3 2019 Starbrite field day and seminar

A field day and workshop was held at Starbrite (Charters Towers district) on 13 November 2019. It included a field inspection of established irrigated leucaena and discussion of its management. This was followed by a seminar which included a presentation on leucaena establishment (DAF) and producer perspectives on leucaena planting and management (Darcy O'Brien, The Brook and Bruce Mayne, Fairview).

3.5.1.4 2020 Leucaena Network conference

The 2020 Leucaena Network Conference 'New Territories New Vision' was held in Townsville on 8 September 2020 with a theme of leucaena in new regions aiming to attract new growers to the conference. There were over 80 attendees at the conference.

In line with the theme, an opening presentation was made on 'Leucaena establishment – in Northern Queensland' (Craig Lemin, DAF). This was aimed at educating new or potential growers on principles for reliable leucaena establishment and initial management with particular reference to north Queensland environments.

3.5.1.5 Introduction to leucaena workshop

An 'Introduction to Leucaena' workshop was held at Innisfail on 20 October 2020 hosted by DAF and The Leucaena Network. The workshop was originally scheduled for 24 March 2020 but was called-off because of COVID restrictions. Due to on-going demand, the workshop was re-scheduled. The workshop aimed at educating potential or new leucaena growers who had limited or no knowledge of the crop and its establishment.

The main presentation (DAF) covered the benefits of leucaena, site selection, principles of planting and establishment and initial management. Two local producers also gave presentations on their experience establishing leucaena for the first time at small and large scales. The Leucaena Code of Practice was covered and there was a presentation on climate tools to assist management decision making.

Figure 11. Innisfail leucaena workshop, 20 October 2020.

3.5.1.6 2021 Pinnarendi-Whitewater field day and industry update

In conjunction with Northern Gulf Natural Resource Management Group (NGNRM) and The Leucaena Network (TLN), DAF led a field day held 30 March 2020. The theme of the day was "Research to improve feed volume and quality during the dry season".

The day included field talks at both Pinnarendi and Whitewater and concluded with formal presentations at Undara Resort by DAF officers and leucaena producers (Figure 2). The main presentations on the day were:

- Yard talk updating performance of steers in the Pinnarendi trial and site soil fertility status/management.
- Leucaena Code of Practice and results from the Fairview Redlands Leucaena Demonstration (Rockhampton).
- Field talk on e-beef smart farming at Pinnarendi walk-over-weigh (WOW) site.
- Trial site walk and commentary demonstrating combinations of legumes and grasses for basalt provinces (targeting weaner nutrition).
- Producer presentations on experience with Redlands leucaena at Goshen (north Queensland) and Fairview (central Queensland).
- Formal presentation on economics of management strategies to improve profit and drought resilience.
- Practical presentation on climate cycles and interpretation of climate and weather forecast.

The day was attended by 18 producers representing about 12 beef businesses and two industry consultants.

3.5.1.7 2022 Pinnarendi-Whitewater field day and industry update

A field day and seminar was held at Pinnarendi and Whitewater on 31 March 2022 facilitated by TLN, DAF and the NGNRMG. The day commenced with a yard talk at Pinnarendi updating the latest cattle results and challenges of the site (soil limitations and sub-optimal leucaena growth during wet season). Attendees then moved to Whitewater for discussion on leucaena under trees and drought adaptation strategies and concluded with a field walk through the sown pasture trial site.

3.5.1.8 2022 industry information day - Pinnarendi-Whitewater

A field day targeting industry participants (rather than producers) was held on 21 June 2022 (postponed from 10 May due to rain). The day started at the Pinnarendi trial site with a presentation and question session on leucaena generally with emphasis on potential, adoption, establishment, and management in north Queensland. The Pinnarendi trial results were presented followed by a field walk to inspect grazed leucaena. Participants then re-located to Whitewater to inspect established grass-legume trial plots on red basalt. Participants comprised, rural merchants, pasture seed producers/merchants, natural resource management representatives, agricultural consultants, JCU and CSIRO representatives.

3.5.2 Media

3.5.2.1 Print and on-line media

An article on the Pinnarendi trial was written for the Northern Muster and was published in the “North Queensland Register” on 25 June 2020 (Appendix 9.7.1).

Information on the project has also been maintained on the FutureBeef website since 23 March 2017 (refer *https://futurebeef.com.au/resources/assessing-productivity-gains-for-cattle-grazing-redlands-r12-leucaena-in-northern-queensland/*).

The seminar “New legumes for grass-fed beef production in northern Australia” at Beef 2021 included a session on leucaena and the Pinnarendi trial results. The seminar was covered by Beef Central with a follow-up on-line article published 12 May 2021 (*Beef 2021: Stylo stayers show promise in pasture legume field - Beef Central*).

Recording for a FutureBeef podcast ‘Making your pasture make money’ was conducted in late December 2021 and published 3 May 2022. The podcast included interviews with DAF pasture researchers Craig Lemin and Kendrick Cox and DAF beef extension officers Bernie English and Joe Rolfe. The podcast focussed on establishing and managing improved pastures with an emphasis on legumes including leucaena (refer *https://futurebeef.com.au/resources/futurebeef-podcast-episode-3-making-your-pasture-make-money/*).

3.5.2.2 ABC radio

ABC Radio Far North recorded live interviews from leucaena paddocks at Goshen on 28 May 2020. Brett Blennerhasset (Goshen) and Craig Lemin (DAF) discussed cattle performance and benefits regarding the new Redlands cultivar. This was broadcast on the “Queensland Country Hour” the same day.

ABC Radio Far North conducted an interview with the Craig Lemin at Pinnarendi on 24 April 21 covering animal performance at Pinnarendi, leucaena adoption in north Queensland and the Redlands cultivar (Appendix 9.7.2). This was broadcast 28 April during the morning “Rural Report” and also played on the “Queensland Country Hour”, 29 April 2021.

3.5.3 Presentations and papers

Papers and formal presentations specifically relating to the project are summarised in Table 18.

The presentation made at Beef 2021 was at one of five Queensland Government seminars held during the event. The seminar titled "New legumes for grass-fed beef production in northern Australia" was presented by DAF officers Gavin Peck, Kendrick Cox and Craig Lemin. It focussed on the use of legumes to overcome dry-season deficits in feed energy and protein linked to recent DAF-MLA research to develop, test, and commercialise new legumes; particularly stylos, leucaena and desmanthus. The seminar was sold out with about 120 participants who were mostly graziers and beef industry professionals.

Table 19. Presentation and poster papers associated with the project.

Event	*Title*	*Authors*	*Content*
Northern Beef Research Update Conference 19-22 August 2019, Brisbane	Poster paper: *Animal performance from psyllid resistant leucaena (Redlands)*	C Lemin, J Rolfe, B English, K Cox, L Perry, S Dayes, A Larard, R & N Atkinson	Pinnarendi trial site details and design; preliminary liveweight data from first cohort
The Leucaena Network Conference 8 September 2020, Townsville	Presentation: *Pinnarendi Redlands Liveweight Gain Trial*	C Lemin, B English, J Rolfe	Pinnarendi site characteristics; trial design, establishment and set-up; grazing methodology; leucaena growth issues; psyllid occurrence; liveweight data of first and second cohorts; improved pasture comparison; Redlands versus Wondergraze comparison; preliminary liveweight data of third cohort
Beef 2021 5 May 2021, Rockhampton	Seminar presentation: *New legumes for grass-fed beef production in northern Australia*	G. Peck, C. Lemin, K. Cox	use of legumes to overcome dry-season deficits in diet energy and protein; testing, development and commercialisation of new legumes (stylos, leucaena and desmanthus)
Australian Association of Animal Sciences Conference 6 July 2022, Cairns	e-Poster and presentation: *Liveweight performance of cattle grazing Redlands and Wondergraze leucaena in north Queensland*	C. Lemin, B. English, J. Rolfe	Pinnarendi site characteristics; trial design, establishment and set-up; grazing methodology; liveweight performance of all three cohorts; Redlands versus Wondergraze comparison

3.5.4 CSIRO ADOPT modelling

The Adoption and Diffusion Outcome Prediction Tool (ADOPT) developed by CSIRO is designed to predict the extent and timing of adoption for an innovation or technology within an agricultural context. The analysis is specific to the identified technology or management practice and the target population of farmers (producers).

GR Consulting (Gerry and Lenore Roberts, Longreach) were engaged to facilitate two ADOPT analyses during the project. GR had a license to access and use the ADOPT software and previous experience with the process. The first session was in November 2019 at Mareeba, and the second was at Rockhampton in May 2021 at the same time as Beef21.

The project milestone schedule specified revised ADOPT modelling for achieving practice change at the end of the project (June 2022). This was not done due to the difficulty in engaging a diversity of participants and the prospect that that the outcomes would be little different from the 2021 exercise.

3.5.4.1 Mareeba session

For the initial ADOPT session, participants included seven north Queensland based DAF personnel engaged in beef extension and pasture research, a producer (who had established leucaena) and three staff from natural resource management groups (Northern Gulf and Desert Channels Queensland).

After group discussion the proposition for the ADOPT analysis was as follows:

The innovation: *leucaena to boost profitability – comparing the Redlands cultivar that is suited to the north.*

Target population: *landholders with cleared country and free draining fertile soils – coastal or inland with greater than 700 mm aar.*

For the ADOPT process, participants formed three groups with each group coming to a consensus response to each of the 22 questions (factor assessment) in the ADOPT model. Each group gave a short explanation of the reasoning for their response. In most cases, the response of all three groups was the same. Where two groups agreed and one group differed, the response of the two agreeing groups was used. When all three groups had a different response, a common response was negotiated.

With some questions, there was stark divergence in responses from the groups. This was due to differing interpretation of the ADOPT questions. Whilst groups came to the same judgement, ambiguity in the proposition resulted in possible responses which were at opposite ends of the scale.

3.5.4.2 Rockhampton session

The second session was planned to run in conjunction with Beef21 as there was an expectation that it would be easier to attract a diversity of participants including producers, agricultural consultants, and MLA representatives. This was not the case, with only a few officers from DAF, and TLN members in attendance.

Nonetheless, the participants had a good knowledge of leucaena and the beef industry. Additionally, Gerry Roberts (GR Consulting) had already prepared a base scenario from reading of recent published papers on leucaena work; listening to the long version of an ABC radio interview (refer 3.5.2.2) and experience of extension delivery to the beef and sheep industry. Using this scenario as a starting point, the ADOPT process was conducted with four variations to the modelling. The main propositions for the ADOPT modelling were as follows:

The innovation: *Establishing and growing leucaena for the first time requiring decision making to choose land type, variety and time of planting; and requiring farming activities for land preparation, planting and weed control.*

Target population: *Beef producers who had never planted leucaena before; most without experience farming crops but prepared to change practices on at least a test planting site.*

Variations to the target population were identified based on geographic location and associated annual average rainfall (aar). These variations were:

- north Queensland coastal (700 mm aar or greater)
- north Queensland sub-coastal (minimum 600 mm aar)
- north Queensland inland (minimum 600 mm aar)
- central Queensland inland (600-700 mm aar)

For the ADOPT process, participants came to a consensus response to each of the 22 questions (factor assessment) in the ADOPT model. Ambiguity in the proposition of some questions did not emerge as an issue during the Rockhampton session, whereas this had been a difficulty with the Mareeba session.

3.5.5 Leucaena plantings in north Queensland

Annual plantings of leucaena (all cultivars) were documented from 2020 to 2022. Data was gathered by DAF officers, mostly through direct contact with producers in the planning and post-planting phases of adoption. Sometimes, information was second-hand, typically through producers with knowledge of leucaena plantings in other regions.

Plantings were attributed to five broad regions:

1. Basalt provinces (north of Charters Towers to Mt Surprise)
2. Northern Gulf (Georgetown district)
3. Dry Tropical Coast – (Ayr district including Burdekin alluvials)
4. Wet Tropical Coast (Ingham, Tully, Innisfail districts)
5. Sub-coastal (Atherton Tablelands and red-earth soils)

4 Results

4.1 Animal performance and Redlands-Wondergraze comparison

4.1.1 First cohort

4.1.1.1 Liveweight performance

Liveweight performance data for the first cohort on Wondergraze and Redlands is given in Table 19. The table shows the average weights and ADG's of Pinnarendi and Spyglass steers as well as the combined results for each weigh date and for the overall period of grazing.

The ADG (± s.e.) over 368 days from 28 June 2018 to 1 July 2019 for all steers (regardless of source) was 0.681 ± 0.02 kg and 0.651 ± 0.02 kg for Wondergraze and Redlands respectively, which is an annualised weight gain of 247 kg and 238 kg respectively. These results include the introductory period for the Spyglass steers which had a been off water and feed for 4-6 hours prior to weighing 28 June. Weight loss during this time (and subsequent compensatory gain) will have had the effect of increasing apparent ADG over the period. The results for all steers using the next weighing as a start point are also given. The ADG over 387 days from 7 August 2018 to 29 August 2019 was 0.550 ± 0.02 kg and 0.523 ± 0.01 kg for Wondergraze and Redlands respectively. Results were reduced by weight losses recorded at the end of this period (1 July to 29 August 2019). For the Pinnarendi steers, the

ADG over 427 days from 28 June 2018 to 29 August 2019 were 0.541 ± 0.02 kg and 0.534 ± 0.03 kg for Wondergraze and Redlands respectively (which exclude their introductory period).

Table 20. Average weights and ADG's of first cohort steers grazing Redlands and Wondergraze leucaena at Pinnarendi.

Period 2018-19	*Source*	*No. head*	*Average weight (kg ± s.e.)*				*ADG (kg ± s.e.)*	
			Wondergraze		*Redlands*		*W'graze*	*Redlands*
			Start	*Finish*	*Start*	*Finish*		
28 Jun	Pin	12	264 ± 15	293 ± 15	251 ± 10	277 ± 9	0.68 ± 0.02	0.66 ± 0.05
7 Aug[A]	Spy	16	207 ± 2	223 ± 2	206 ± 2	219 ± 3	0.64 ± 0.07	0.32 ± 0.04
40 days	*All*	*28*	*232 ± 10*	*253 ± 11*	*226 ± 7*	*244 ± 9*	*0.53 ± 0.05*	*0.47 ± 0.06*
7 Aug	Pin	12	293 ± 15	313 ± 15	277 ± 9	293 ± 10	0.43 ± 0.04	0.35 ± 0.07
20 Sep	Spy	16	223 ± 2	241 ± 4	219 ± 3	232 ± 4	0.42 ± 0.06	0.30 ± 0.08
44 days	*All*	*28*	*253 ± 11*	*272 ± 12*	*244 ± 9*	*258 ± 9*	*0.43 ± 0.04*	*0.32 ± 0.05*
20 Sep	Pin	12	313 ± 15	312 ± 14	293 ± 10	294 ± 10	-0.01 ± 0.05	0.02 ± 0.09
8 Nov	Spy	16	241 ± 4	252 ± 4	232 ± 4	247 ± 4	0.22 ± 0.05	0.30 ± 0.02
49 days	*All*	*28*	*272 ± 12*	*278 ± 10*	*258 ± 9*	*267 ± 8*	*0.12 ± 0.05*	*0.18 ± 0.06*
8 Nov	Pin	12	312 ± 14	332 ± 12	294 ± 10	309 ± 11	0.48 ± 0.09	0.39 ± 0.117
19 Dec	Spy	16	252 ± 4	269 ± 5	247 ± 4	261 ± 4	0.42 ± 0.05	0.33 ± 0.06
41 days	*All*	*28*	*278 ± 10*	*296 ± 10*	*267 ± 8*	*282 ± 8*	*0.44 ± 0.05*	*0.35 ± 0.06*
19 Dec	Pin	12	332 ± 12	437 ± 14	309 ± 11	422 ± 13	1.39 ± 0.05	1.48 ± 0.08
5 Mar	Spy	16	269 ± 5	384 ± 7	261 ± 4	384 ± 6	1.51 ± 0.07	1.62 ± 0.04
76 days	*All*	*28*	*296 ± 10*	*407 ± 10*	*282 ± 80*	*400 ± 8*	*1.46 ± 0.05*	*1.56 ± 0.05*
5 Mar	Pin	12	437 ± 14	462 ± 14	422 ± 13	442 ± 11	0.93 ± 0.07	0.75 ± 0.14
1 Apr	Spy	16	384 ± 7	402 ± 7	384 ± 6	401 ± 6	0.66 ± 0.10	0.64 ± 0.06
27 days	*All*	*28*	*407 ± 10*	*428 ± 11*	*400 ± 8*	*418 ± 8*	*0.78 ± 0.07*	*0.69 ± 0.07*
1 Apr	Pin	12	462 ± 14	491 ± 13	442 ± 11	471 ± 13	0.67 ± 0.08	0.68 ± 0.08
13 May	Spy	16	402 ± 7	432 ± 10	401 ± 6	422 ± 5	0.73 ± 0.07	0.51 ± 0.06
42 days	*All*	*28*	*428 ± 11*	*457 ± 11*	*418 ± 8*	*443 ± 9*	*0.70 ± 0.05*	*0.58 ± 0.05*
13 May	Pin	12	491 ± 13	514 ± 11	471± 13	494 ± 12	0.49 ± 0.10	0.48 ± 0.03
1 Jul	Spy	16	432 ± 10	458 ± 10	422 ± 5	443 ± 6	0.53 ± 0.06	0.44 ± 0.06
49 days	*All*	*28*	*457 ± 11*	*482 ± 11*	*443 ± 9*	*465 ± 9*	*0.51 ± 0.05*	*0.45 ± 0.03*
1 Jul	Pin	12	514 ± 11	495 ±14	494 ± 12	479 ± 12	-0.29 ± 0.04	-0.32 ± 0.03
29 Aug	Spy	16	458 ± 10	441 ± 10	443 ± 6	422 ± 5	-0.28 ± 0.03	-0.26 ± 0.04
59 days	*All*	*28*	*482 ± 11*	*462 ± 11*	*465 ± 9*	*446 ± 9*	*-0.29 ± 0.04*	*-0.32 ± 0.03*
28 Jun	*Pin*	*26*	***264 ± 15***	***514 ± 11***	***251 ± 10***	***494 ± 12***	**0.680 ± 0.02**	**0.660 ± 0.03**
1 Jul[B]	*Spy*	*16*	***207 ± 2***	***458 ± 10***	***206 ± 2***	***443 ± 6***	**0.681 ± 0.03**	**0.644 ± 0.02**
368 days	*All*	*42*	**232 ± 10**	**482 ± 11**	**226 ± 7**	**465 ± 9**	**0.681 ± 0.02**	**0.651 ± 0.02**
7 Aug	*Pin*	*26*	***293 ± 15***	***514 ± 11***	***277 ± 9***	***494 ± 12***	**0.527 ± 0.02**	**0.521 ± 0.09**
29 Aug	*Spy*	*16*	***223 ± 2***	***458 ± 10***	***219 ± 3***	***443 ± 6***	**0.564 ± 0.03**	**0.525 ± 0.02**
387 days	*All*	*42*	**253 ± 11**	**462 ± 11**	**244 ± 9**	**446 ± 9**	**0.550 ± 0.02**	**0.523 ± 0.01**
28 Jun	*Pin*	*26*	***264 ± 15***	***514 ± 11***	***251 ± 10***	***494 ± 12***	***0.541 ± 0.02***	***0.534 ± 0.03***
29 Aug	*Spy***	*16*	*207 ± 2*	*458 ± 10*	*206 ± 2*	*443 ± 6*	*0.547 ± 0.03*	*0.505 ± 0.02*
427 days	*All***	*42*	*232 ± 11*	*462 ± 11*	*226 ± 7*	*446 ± 9*	*0.545 ± 0.02*	*0.517 ± 0.01*

[A] introductory period for Spyglass steers
[B] includes the introductory period for the Spyglass steers

Fig. 12 shows the growth curves for first cohort steers grazing Wondergraze and Redlands treatments. Fig. 13 shows the growth curves for first cohort steers grazing leucaena according to source (Pinnarendi or Spyglass). A summary of liveweight performance and stocking for first cohort steers is given in Table 20.

Figure 12. Growth curves for first cohort steers grazing Wondergraze and Redlands leucaena at Pinnarendi (2018-2019).

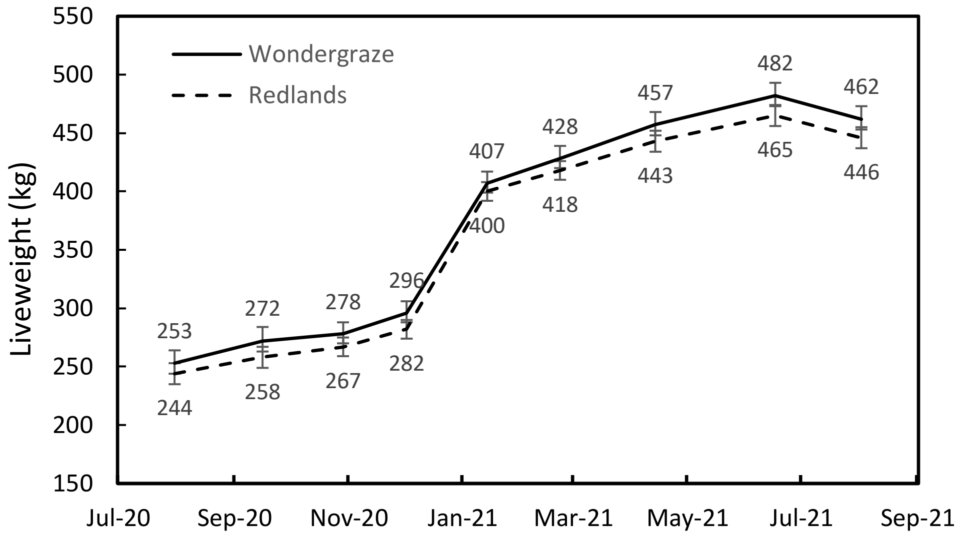


Figure 13. Growth curves for first cohort steers (according to source) grazing leucaena at Pinnarendi (2018-2019).

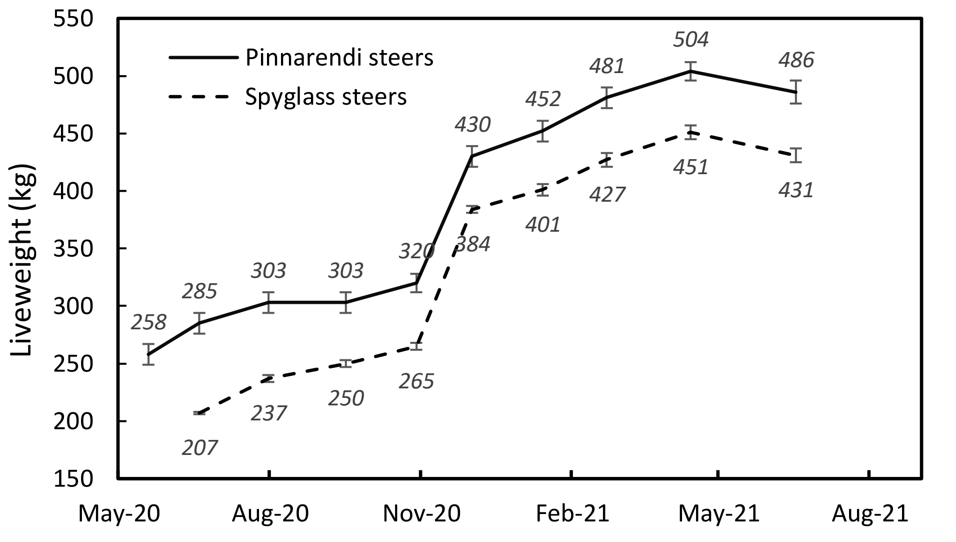


Table 21. Summarised liveweight performance and stocking for first cohort steers grazing Redlands and Wondergraze leucaena at Pinnarendi.

Time	***Period***	***ADG (kg ± s.e.)***	
		Wondergraze	***Redlands***
368 days	**28 June 2018 to 1 July 2019**	**0.681 ± 0.02**	**0.651 ± 0.02**
427 days	28 June 2018 to 29 August 2019	0.545 ± 0.02	0.517 ± 0.01
	Annualised weight gain (kg)	***247***	***238***
	Overall stocking rate (AE[A]/ha)	*0.40*	*0.39*

[A] AE = Adult Equivalent (450 kg steer at maintenance)

4.1.1.2 Commentary

Reported annual weight gains over 368 days to 1 July 2019 include the introductory period for the Spyglass steers. Although there would have been some subsequent compensatory gain, this was considered to be negligible in the context of annual performance. In fact, Spyglass steers had similar or lower liveweight gains than the Pinnarendi steers during this introductory phase.

For the final period of grazing (59 days, 1 July to 29 August), almost all first cohort steers lost weight with an average loss of about 18 kg/head. At the same time, smaller second cohort steers in the same Redlands and Wondergraze paddocks had average weight gains of 3 kg/head and second cohort Pinnarendi steers in the improved pasture paddock had average gains of 9 kg/head. Leucaena paddocks were overstocked at this time; leucaena productivity was low due to cool weather and dry conditions.

4.1.1.3 Statistical analysis

Variety effect

There was no significant difference between the two varieties for the ADG over 368 days (ADG368) (P-value=0.343) or actual weight (P-value=0.332) (Table 21). There was still no difference (P-value=0.532) when weight at 31 July 2020 was included as covariate.

Table 22. Mean values for analysis with Variety only in the treatment structure.

Variety	***ADG368 (kg/day)***	***Weight at 1 Jul 2019 (kg)***	***Weight at 1 Jul 2019 with weight at 28 Jun 2019 as a covariate***
Redlands	0.65	465	468
Wondergraze	0.68	482	479
P-Value: Treatment	0.343	0.332	0.532
sed	0.023	10.4	10.9

4.1.2 Second cohort

4.1.2.1 Liveweight performance

Liveweight performance data for the second cohort on Wondergraze and Redlands is given in Table 22. The table shows the average weights and ADG's for each weigh date and for the overall period of grazing.

The ADG (± s.e.) over 372 days from 13 May 2019 to 19 May 2020 was 0.546 ± 0.02 kg and 0.554 ± 0.02 kg for Wondergraze and Redlands respectively, which is an annualised weight gain of 199 kg and 202 kg respectively. Additionally, the ADG (± s.e.) over 403 days from 13 May 2020 to 19 May 2020 was 0.547± 0.02 kg and 0.569 ± 0.02 kg for Wondergraze and Redlands, respectively. All of these figures exclude an introductory period from steers entering the trial and the subsequent weigh date.

Table 23. Average weights and ADG's of second cohort steers grazing Redlands and Wondergraze leucaena at Pinnarendi.

Period 2019-20	***No. head***	***Average weight (kg ± s.e.)***				***ADG (kg ± s.e.)***	
		W'graze		***Redlands***		***W'graze***	***Redlands***
		Start	***Finish***	***Start***	***Finish***		
1 Apr13 May[A] 42 days	14	220 ± 18	267 ± 20	206 ± 17	257 ± 21	1.13 ± 0.07	1.21 ± 0.11
13 May-1 Jul 49 days	14	267 ± 20	299 ± 20	257 ± 21	290 ± 23	0.65 ± 0.03	0.68 ± 0.05
1 Jul-29 Aug 59 days	14	299 ± 20	303 ± 20	290 ± 23	291 ± 23	0.07 ± 0.02	0.02 ± 0.04
29 Aug-18 Oct 50 days	14	303 ± 20	312 ± 19	291 ± 2	298 ± 23	0.17 ± 0.04	0.15 ± 0.03
18 Oct-16 Dec 59 days	14	312 ± 19	328 ± 17	298 ± 23	312 ± 23	0.27 ± 0.04	0.23 ± 0.02
16 Dec-29 Jan 44 days	14	328 ± 17	341 ± 15	312 ± 23	309 ± 20	0.31 ± 0.06	-0.06 ± 0.09
29 Jan-19 Mar 50 days	14	341 ± 15	410 ± 18	309 ± 20	395 ± 23	1.38 ± 0.07	1.72 ± 0.13
19 Mar-23 Apr 35 days	14	410 ± 18	448 ± 18	395 ± 23	442 ± 26	1.07 ± 0.07	1.32 ± 0.11
23 Apr-19 May 26 days	14	448 ± 18	470 ± 20	442 ± 26	463 ± 26	0.88 ± 0.12	0.81 ± 0.16
19 May-19 Jun 31 days	14	470 ± 20	488 ± 20	463 ± 26	486 ± 25	0.56 ± 0.07	0.76 ± 0.09
13 May-19 May *372 days*	*14*	***267 ± 20***	***470 ± 20***	***257 ± 21***	***463 ± 26***	***0.546 ± 0.02***	***0.554 ± 0.02***
13 May-19 Jun *403 days*	*14*	*267 ± 20*	*488 ± 20*	*257 ± 21*	*486 ± 25*	*0.547 ± 0.02*	*0.569 ± 0.02*

[A] introductory period

Fig. 14 shows the growth curves of second cohort steers grazing Wondergraze and Redlands treatments. A summary of liveweight performance and stocking for second cohort steers grazing Wondergraze and Redlands is given in Table 23.

Figure 14. Growth curves for second cohort steers grazing Wondergraze and Redlands leucaena at Pinnarendi (2019-2020).

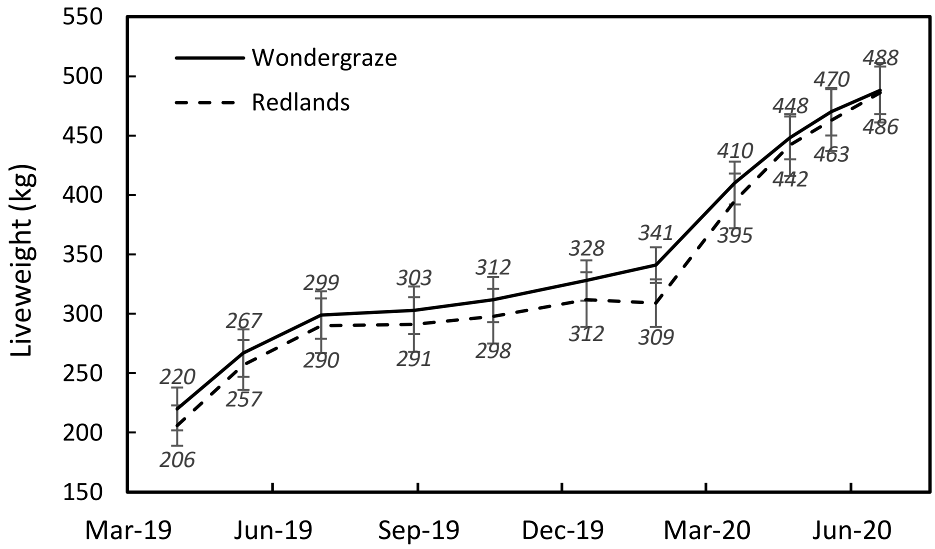


Table 24. Summarised liveweight performance and stocking for second cohort steers grazing Wondergraze and Redlands leucaena at Pinnarendi.

Time	*Dates*	*ADG (kg ± s.e.)*	
		Wondergraze	*Redlands*
372 days	**13 May 2019 to 19 May 2020**	**0.546 ± 0.02**	**0.554 ± 0.02**
440 days	13 May 2019 to 19 June 2020	0.547± 0.02	0.569 ± 0.02
	Annualised weight gain (kg)	***199***	***202***
	Overall stocking rate (AE^A/ha)	*0.34*	*0.33*

^A AE = Adult Equivalent (450 kg steer at maintenance)

4.1.2.2 Improved pasture comparison

Liveweight performance data for the second cohort steers in the improved pasture paddock and the aggregate of second cohort Pinnarendi and Spyglass steers in leucaena is given in Table 24. The table shows the average weights and ADG's for each weigh date and for the overall period of grazing.

The ADG (± s.e.) over 372 days from 13 May 2019 to 19 May 2020 was 0.542 ± 0.02 kg and 0.550 ± 0.02 kg for the improved pasture and leucaena respectively, which is an annualised weight gain of 198 kg and 201 kg respectively. Additionally, the ADG (± s.e.) over 403 days from 13 May 2020 to 19 May 2020 was 0.541± 0.02 kg and 0.548 ± 0.02 kg for the improved pasture and leucaena respectively. All of these figures exclude an introductory period from steers entering the trial and the subsequent weigh date.

Table 25. Average weights and ADG's of second cohort steers grazing improved pasture and leucaena at Pinnarendi.

Period 2019-20	*No. Head*	*Average Weight (kg ± s.e.)*				*ADG (kg ± s.e.)*	
		Improved pasture		*Leucaena*		*Pasture*	*Leucaena*
		Start	*Finish*	*Start*	*Finish*		
1 Apr-13 May[A] 42 days	12, 14	213 ± 13	269 ± 14	213 ± 12	262 ± 14	1.36 ± 0.08	1.17 ± 0.06
13 May-1 Jul 49 days	12, 14	269 ± 14	307 ± 14	262 ± 14	295 ± 14	0.77 ± 0.02	0.66 ± 0.03
1 Jul-29 Aug 59 days	12, 14	307 ± 14	316 ± 14	295 ± 14	297 ± 15	0.16 ± 0.03	0.05 ± 0.02
29 Aug-18 Oct 50 days	12, 14	316 ± 14	330 ± 14	297 ± 15	305 ± 15	0.28 ± 0.03	0.16 ± 0.03
18 Oct-16 Dec 59 days	12, 14	330 ± 14	343 ± 13	305 ± 15	320 ± 14	0.23 ± 0.02	0.25 ± 0.02
16 Dec-29 Jan 44 days	12, 14	343 ± 13	338 ± 12	320 ± 14	325 ± 13	-0.13 ± 0.06	0.20 ± 0.07
29 Jan-19 Mar 50 days	12, 14	338 ± 12	412 ± 13	325 ± 13	403 ± 13	1.48 ± 0.07	1.55 ± 0.09
19 Mar-23 Apr 35 days	12, 14	412 ± 13	455 ± 13	403 ± 14	445 ± 15	1.23 ± 0.10	1.19 ± 0.07
23 Apr-19 May 26 days	12, 14	455 ± 13	471 ± 14	445 ± 15	467 ± 16	0.64 ± 0.15	0.85 ± 0.10
19 May-19 Jun 31 days	12, 14	471 ± 14	487 ± 14	467 ± 16	487 ± 15	0.51 ± 0.05	0.66 ± 0.06
13 May-19 May *372 days*	*12, 14*	***269 ± 14***	***471 ± 14***	***262 ± 14***	***467 ± 16***	***0.542 ± 0.02***	***0.550 ± 0.02***
13 May-19 Jun *403 days*	*12, 14*	*269 ± 14*	*487 ± 14*	*262 ± 14*	*487 ± 15*	*0.541 ± 0.02*	*0.558 ± 0.01*

[A] introductory period

Fig. 15 show the growth curves of second cohort steers grazing the improved pasture paddock and leucaena. A summary of liveweight performance and stocking for the second cohort steers grazing in the improved pasture compared to the concurrent cohort in leucaena is given in Table 25.

Figure 15. Growth curves for second cohort steers grazing improved pasture and leucaena at Pinnarendi (2019-2020).

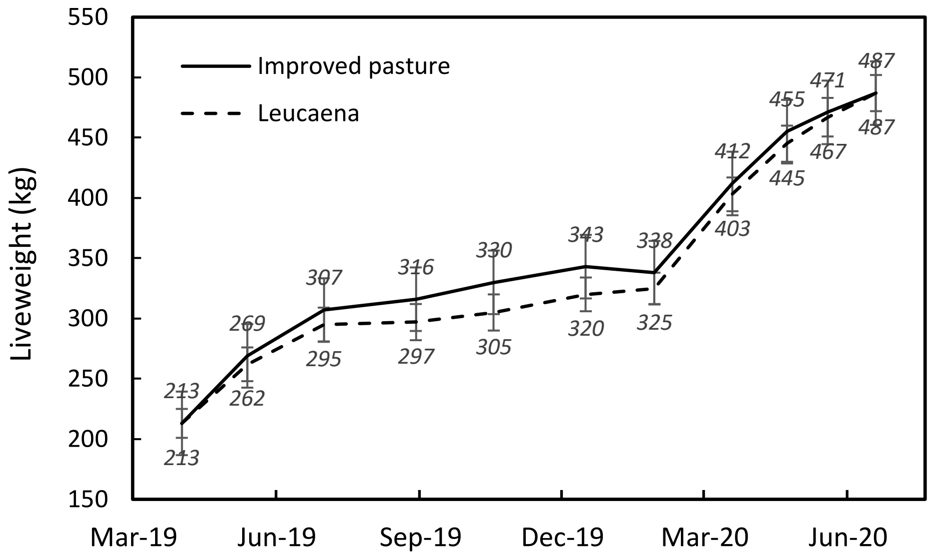


Table 26. Summarised liveweight performance and stocking for second cohort steers grazing the improved pasture and leucaena (Wondergraze and Redlands aggregated) at Pinnarendi.

Time	*Dates*	*ADG (kg ± s.e.)*	
		Improved pasture	*Leucaena*
372 days	**13 May 2019 to 19 May 2020**	**0.542 ± 0.02**	**0.550 ± 0.02**
403 days	13 May 2019 to 19 June 2020	0.541± 0.02	0.558 ± 0.01
	Annualised weight gain (kg)	***198***	***201***
	Overall stocking rate (AE^A/ha)	*0.40*	*0.34*

^{A} AE = Adult Equivalent (450 kg steer at maintenance)

4.1.2.3 Supplementation

Consumption of supplements and molasses by the second cohort steers is shown in Table 26 which includes animals in the improved pasture paddock.

Over the 150 days that urea blocks were supplied; steers consumed a crude protein equivalent of 111 and 129 g/day/head for the leucaena and improved pasture paddocks, respectively. This was a significant proportion (30-40%) of their overall requirement over this time.

For the period February 2020 to when steers were removed from the trial in mid-June 2020, leucaena and improved pasture steers consumed about 3.4 and 2.5 g/day supplemented P. It is considered that P would not have limited animal performance over this time.

For molasses feeding, leucaena steers were fed an equivalent of 3.1 and 6.6 MJ/day during the drier and wetter periods of the year, respectively. This was 6% and 7% of their respective estimated total energy requirement over these periods. For the improved pasture steers, the respective quantities were 2.3 and 4.9 MJ/day, which was about 4% and 6% of estimated total energy requirement.

Table 27. Supplementation of second cohort steers in leucaena and improved pasture paddocks at Pinnarendi.

Product	*Target ingredient*	*Period*	*Amount fed*		
			Redlands	*Wondergraze*	*Improved pasture*
LNT Uramol®	Nitrogen - crude protein equivalent (g/day)	3 Sep 19-31 Jan 20 150 days	111	111	129
Olsson's Supaphos 8%	Phosphorus (g/day)	12 Feb 20-19 Jun 20 128 days	3.4	3.4	2.5
Molasses	Energy (MJ/day)	1 Apr 19-16 Dec 19 259 days	3.1	3.1	2.3
		17 Dec 19-19 Jun 20 185 days	6.6	6.6	4.9

4.1.2.4 Commentary

No statistical analysis was conducted on the second cohort as there was no replication due to drought conditions which constrained stocking of the trial during 2019.

Overall weight gains over the grazing period were slightly higher for the Redlands steers compared to Wondergraze. Initially, Wondergraze steers outperformed steers on Redlands but a period of compensatory growth saw Redlands steers outperform during the second half of the grazing period (mid-December 2019 to mid-June 2020). Overall stocking and productivity of Wondergraze and Redlands paddocks was almost the same (Table 23).

For the improved pasture comparison, overall weight gains over the grazing period were slightly higher for the leucaena steers (Wondergraze and Redlands aggregated) compared to the concurrent group in the improved pasture. Initially however, the improved pasture steers outperformed the leucaena steers. This was attributed to the improved pasture having had three years spelling prior to animals entering. Stocking rates were conservative, so that there was always a reserve of pasture which included a significant amount of *Stylosanthes sp*. In contrast, the inter-row pasture in the leucaena paddocks had no wet-season spelling and productivity declined progressively as drought conditions intensified in the second half of 2019. Once leucaena became productive from about mid-January 2020, leucaena steers outperformed steers on the improved pasture for the rest of the grazing period.

From Figs. 14 and 15, the Redlands and improved pasture steers had negative weight gains during January 2020, likely associated with a reduction in gut retention when transitioning to a higher quality diet.

Despite slightly higher weight gains for the leucaena steers, overall productivity was higher in the improved pasture paddock due to a higher stocking rate (Table 25). Again, this was a consequence of the improved pasture paddock having been spelled, and dry conditions limiting leucaena growth during most of 2019.

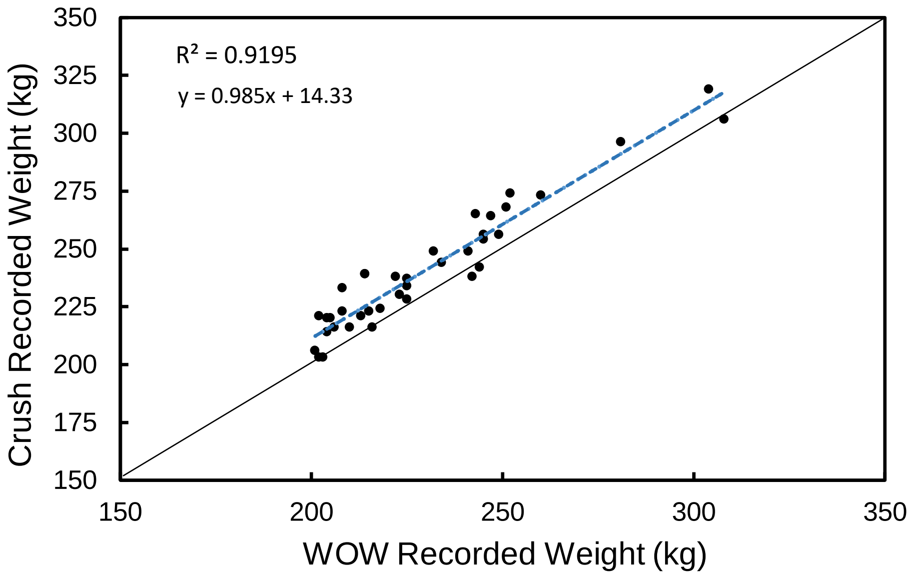
4.1.2.5 Walk over weigh unit

There were no issues experienced training second (and third) cohort cattle to use the WOW. The WOW weighs cattle automatically in real-time, but uses a proprietary algorithm to determine animal weight based on recorded weights over the few days prior, taking into account weights before and after animals water.

For comparison, individual steer weights recorded by the WOW for second cohort animals, were compared to weights manually recorded at various weigh days. An exact correlation was not expected since the WOW weights are archived weekly and do not necessarily correspond with weigh days. Also, weights recorded on weigh days are variably affected by gut fill and water intake. Nonetheless, there should be a good correlation over time (as animals weight increases).

Weights recorded by the WOW versus weights recorded in the yards for a selection of animals and dates for which data was comparable are shown in Fig. 16 (with a 1:1 correlation line for reference). There was good correlation between the two methods over the recorded weight range. Recorded manual weights were about 14 kg heavier than the WOW weights.

Figure 16. Correlation between recorded yard weights and WOW weights for a selection of second cohort animals based on comparable data.



4.1.3 Third cohort

4.1.3.1 Liveweight performance

Liveweight performance data for the third cohort steers on Wondergraze and Redlands is given in Table 27. The table shows the average weights and ADG's of Pinnarendi and Spyglass steers as well as the combined results for each weigh date and for the overall period of grazing.

The ADG (± s.e.) over 367 days from 31 July 2020 to 2 August 2021 for all steers (regardless of source) was 0.64 ± 0.02 kg and 0.59 ± 0.03 kg for Wondergraze and Redlands respectively, which is an annualised weight gain of 234 kg and 214 kg respectively. Additionally, for the Pinnarendi steers, the ADG (± s.e.) over 440 days from 19 May 2020 to 2 August 2021 was 0.67 ± 0.02 kg and 0.63 ± 0.03 kg for Wondergraze and Redlands respectively. All of these figures exclude an introductory period from when steers entered the trial and their subsequent weigh date.

Table 28. Average weights and ADG's of third cohort steers grazing Redlands and Wondergraze leucaena at Pinnarendi at respective weigh dates.

Period 2020-21	*Source*	*No. head*	*Average weight (kg ± s.e.)*				*ADG (kg ± s.e.)*	
			Wondergraze		*Redlands*		*W'graze*	*Redlands*
			Start	*Finish*	*Start*	*Finish*		
23 Apr **19 May**[A] 26 days	Pin	27	196 ± 7	230 ± 7	197 ± 6	231 ± 6	1.31 ± 0.05	1.31 ± 0.06
19 May **19 Jun** 31 days	Pin	27	230 ± 7	262 ± 7	231 ± 6	262 ± 7	1.04 ± 0.06	1.00 ± 0.05
19 Jun **31 Jul** 42 days	Pin	26	262 ± 7	297 ± 7	262 ± 7	295 ± 8	0.79 ± 0.06	0.80 ± 0.05
23 Jun **31 Jul**[B] 38 days	Spy	16	194 ± 3	212 ± 3	195 ± 3	210 ± 1	0.49 ± 0.08	0.40 ± 0.06
31 Jul **16 Sep** 47 days	Pin Spy *All*	26 16 *42*	292 ± 7 212 ± 3 *265 ± 10*	320 ± 7 231 ± 4 *286 ± 11*	295 ± 8 210 ± 1 *263 ± 10*	315 ± 8 223 ± 4 *280 ± 11*	0.49 ± 0.04 0.40 ± 0.03 *0.46 ± 0.03*	0.42 ± 0.04 0.29 ± 0.05 *0.36 ± 0.03*
16 Sep **29 Oct** 43 days	Pin Spy *All*	26 16 *42*	320 ± 7 231 ± 4 *286 ± 11*	324 ± 7 238 ± 5 *291 ± 10*	315 ± 8 223 ± 4 *280 ± 11*	319 ± 7 228 ± 6 *284 ± 11*	0.09 ± 0.03 0.15 ± 0.07 *0.11 ± 0.03*	0.09 ± 0.04 0.11 ± 0.08 *0.10 ± 0.04*
29 Oct **2 Dec** 34 days	Pin Spy *All*	26 16 *42*	324 ± 7 238 ± 5 *291 ± 10*	341 ± 6 254 ± 6 *308 ± 11*	319 ± 7 228 ± 6 *284 ± 11*	334 ± 8 241 ± 7 *299 ± 11*	0.51 ± 0.06 0.47 ± 0.06 *0.49 ± 0.04*	0.45 ± 0.05 0.40 ± 0.06 *0.43 ± 0.04*
2 Dec **14 Jan** 43 days	Pin Spy *All*	26 16 *42*	341 ± 6 254 ± 6 *308 ± 11*	360 ± 6 285 ± 6 *331 ± 9*	334 ± 8 241 ± 7 *299 ± 11*	348 ± 8 267 ± 7 *318 ± 10*	0.43 ± 0.06 0.72 ± 0.06 *0.54 ± 0.05*	0.33 ± 0.07 0.61 ± 0.05 *0.43 ± 0.05*
14 Jan **22 Feb** 39 days	Pin Spy *All*	26 16 *42*	360 ± 6 285 ± 6 *331 ± 9*	412 ± 7 342 ± 8 *386 ± 9*	348 ± 8 267 ± 7 *318 ± 10*	405 ± 7 328 ± 7 *376 ± 10*	1.35 ± 0.06 1.47 ± 0.05 *1.40 ± 0.04*	1.46 ± 0.06 1.56 ± 0.08 *1.50 ± 0.05*
22 Feb **14 Apr** 51 days	Pin Spy *All*	26 16 *42*	412 ± 7 342 ± 8 *386 ± 9*	473 ± 8 402 ± 9 *446 ± 10*	405 ± 7 328 ± 7 *376 ± 10*	464 ± 12 392 ± 8 *436 ± 11*	1.19 ± 0.06 1.18 ± 0.05 *1.18 ± 0.04*	1.15 ± 0.06 1.24 ± 0.07 *1.19 ± 0.05*
14 Apr **17 Jun** 64 days	Pin Spy *All*	26 16 *42*	473 ± 8 402 ± 9 *446 ± 10*	509 ± 8 442 ± 11 *483 ± 10*	464 ± 12 392 ± 8 *436 ± 11*	497 ± 15 420 ± 12 *468 ± 13*	0.56 ± 0.05 0.63 ± 0.08 *0.59 ± 0.04*	0.52 ± 0.05 0.44 ± 0.10 *0.49 ± 0.06*
17 Jun **2 Aug** 47 days	Pin Spy *All*	26 16 *42*	509 ± 8 442 ± 11 *483 ± 10*	525 ± 9 461 ± 12 *501 ± 10*	497 ± 15 420 ± 12 *468 ± 13*	508 ± 18 430 ± 14 *478 ± 15*	0.36 ± 0.05 0.41 ± 0.09 *0.39 ± 0.05*	0.24 ± 0.06 0.21 ± 0.07 *0.23 ± 0.05*
31 Jul ***2 Aug*** *367 days*	*Pin* *Spy* *All*	*26* *16* *42*	***297 ± 7*** ***212 ± 3*** **265 ± 10**	***525 ± 9*** ***461 ± 12*** **501 ± 10**	***295 ± 8*** ***210 ± 1*** **263 ± 10**	***508 ± 18*** ***430 ± 14*** **478 ± 15**	**0.621 ± 0.02** **0.677 ± 0.03** **0.642 ± 0.02**	**0.580 ± 0.03** **0.599 ± 0.04** **0.587 ± 0.03**
19 May **2 Aug** 440 days	Pin	27 (26)	*230 ± 7*	525 ± 9	231 ± 6	508 ± 18	0.668 ± 0.02	0.630 ± 0.03

[A] introductory period for Pinnarendi group
[B] introductory period for Spyglass group

Fig. 17 show the growth curves for third cohort steers grazing Wondergraze and Redlands treatments. Fig. 18 shows the growth curves for third cohort steers grazing leucaena according to source (Pinnarendi or Spyglass). A summary of liveweight performance and stocking for third cohort animals is given in Table 28.

Figure 17. Growth curves for third cohort steers grazing Wondergraze and Redlands leucaena at Pinnarendi (2020-2021).

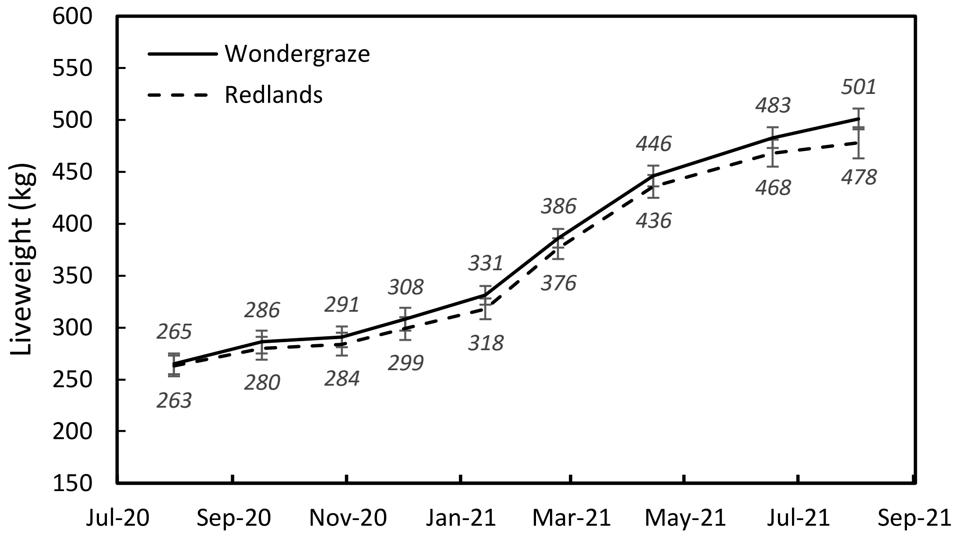


Figure 18. Growth curves for third cohort steers (according to source) grazing leucaena at Pinnarendi (2020-2021).

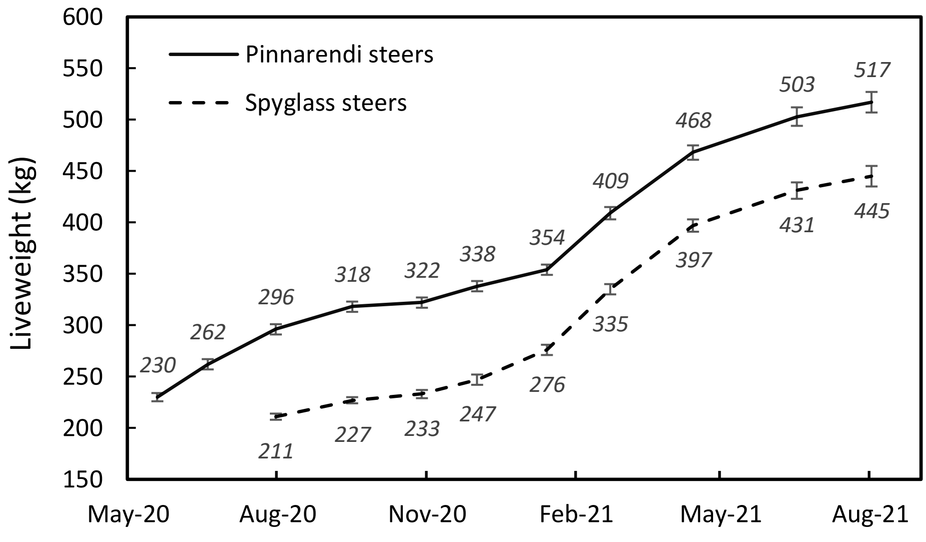


Table 29. Summarised liveweight performance and stocking for third cohort steers grazing Redlands and Wondergraze leucaena at Pinnarendi.

Time	*Dates*	*ADG (kg ± s.e.)*	
		Wondergraze	*Redlands*
367 days	**31 July 2020 to 2 August 2021**	**0.642 ± 0.02**	**0.587 ± 0.03**
440 days	19 May 2020 to 2 August 2021	0.668 ± 0.02	0.630 ± 0.03
	Annualised weight gain (kg)	***234***	***214***
	Overall stocking rate (AE[A]/ha)	*0.60*	*0.58*

[A] AE = Adult Equivalent (450 kg steer at maintenance)

4.1.3.2 Improved pasture comparison

Liveweight performance data for third cohort steers in the improved pasture paddock and the aggregate of animals in leucaena is given in Table 29. The table shows the average weights and ADG's for each weigh date and for the overall period of grazing. Table data excludes the introductory period for the Spyglass steers, i.e., from entry to the trial on 23 June 2019 to subsequent weighing on 31 July. For the improved pasture steers the data also excludes one Spyglass steer which escaped the trial in January 2021 and was subsequently replaced with a Pinnarendi steer on 14 April which was considerably heavier (refer 3.2.6.4).

The ADG (± s.e.) over 367 days from 31 July 2020 August 2021 was 0.610 ± 0.02 kg and 0.615 ± 0.02 kg for the improved pasture and leucaena steers respectively, which is an annualised weight gain of 222.5 kg and 224.5 kg respectively.

Table 30. Average weights and ADG's of third cohort steers grazing improved pasture and leucaena at Pinnarendi at respective weigh dates.

Period 2020-21	*No. head*	*Average weight (kg ± s.e.)*				*ADG (kg ± s.e.)*	
		Improved pasture		*Leucaena*		*Pasture*	*Leucaena*
		Start	*Finish*	*Start*	*Finish*		
31 Jul-16 Sep 47 days	9, 42	219 ± 7	236 ± 8	264 ± 7	283 ± 8	0.37 ± 0.05	0.41 ± 0.02
16 Sep-29 Oct 43 days	9, 42	236 ± 8	249 ± 8	283 ± 8	288 ± 8	0.30 ± 0.04	0.10 ± 0.02
29 Oct-2 Dec 34 days	9, 42	249 ± 8	262 ± 9	288 ± 8	303 ± 8	0.36 ± 0.07	0.46 ± 0.03
2 Dec-14 Jan 43 days	9, 42	262 ± 9	284 ± 6	303 ± 8	324 ± 7	0.53 ± 0.07	0.49 ± 0.04
14 Jan-22 Feb 39 days	9, 42	284 ± 6	344 ± 6	324 ± 7	381 ± 7	1.52 ± 0.09	1.45 ± 0.03
22 Feb-14 Apr 51 days	9, 42	344 ± 6	391 ± 7	381 ± 7	441 ± 7	0.93 ± 0.06	1.18 ± 0.03
14 Apr-17 Jun 64 days	9, 42	391 ± 7	430 ± 7	441 ± 7	476 ± 8	0.61 ± 0.03	0.54 ± 0.04
17 Jun-2 Aug 46 days	9, 42	430 ± 7	443 ± 8	476 ± 8	490 ± 9	0.28 ± 0.05	0.31 ± 0.04
31 Jul-2 Aug *367 days*	*10, 42*	***219 ± 7***	***443 ± 8***	***264 ± 7***	***490 ± 9***	***0.610 ± 0.02***	***0.615 ± 0.02***

Fig. 19 shows the growth curves of third cohort steers grazing the improved pasture paddock and leucaena. The curves are offset as the leucaena group comprised more than 60% Pinnarendi steers which had a higher average weight when the Spyglass steers entered the trial. For a better comparison, Fig. 20 shows the growth curves of third cohort steers grazing the improved pasture paddock with just the third cohort Spyglass steers grazing leucaena. The improved pasture group was 90% comprised of third cohort Spyglass steers.

A summary of liveweight performance and stocking for third cohort steers grazing the improved pasture and leucaena is given in Table 30. Productivity of just the Spyglass steers on leucaena is also included as a better comparison with the improved pasture.

Figure 19. Growth curves for third cohort steers grazing improved pasture and leucaena at Pinnarendi (2020-2021).

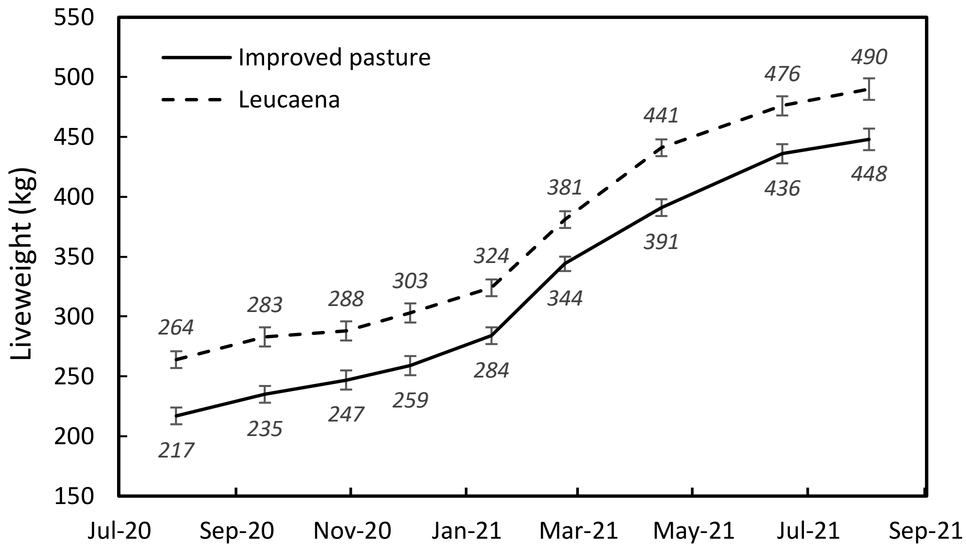


Figure 20. Growth curves for third cohort steers grazing improved pasture and leucaena (Spyglass steers only) at Pinnarendi (2020-2021).

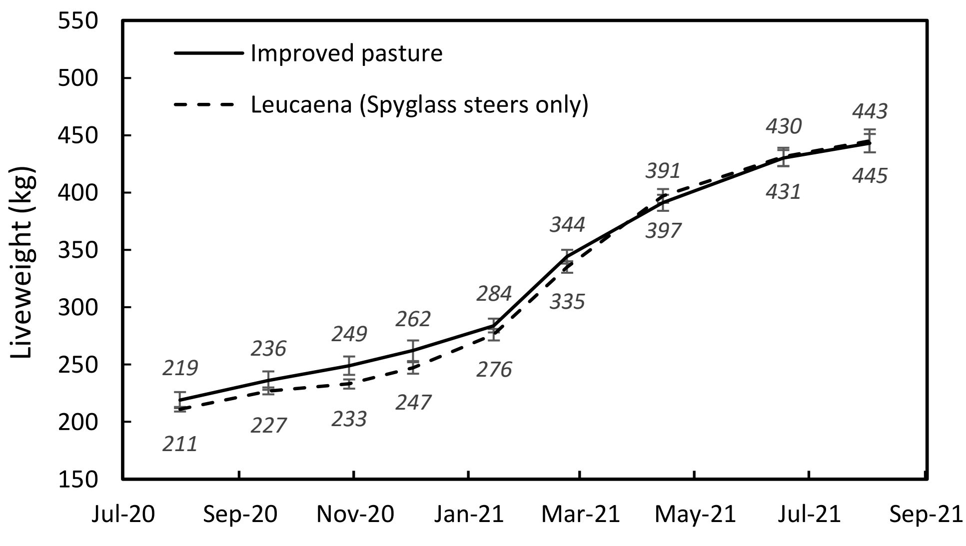


Table 31. Summarised liveweight performance and stocking for third cohort animals grazing the improved pasture and leucaena (Wondergraze and Redlands aggregated) at Pinnarendi.

Time	*Dates*	*ADG (kg ± s.e.)*		
		Improved pasture	*Leucaena*	*Leucaena Spyglass steers only*
367 days	**31 Jul 2020 to 2 Aug 2021**	**0.610 ± 0.02**	**0.615 ± 0.02**	**0.638 ± 0.03**
	Annualised weight gain (kg)	***223***	***224***	***233***
	Overall stocking rate (AE[A]/ha)	*0.28*	*0.59*	*0.59*

[A] AE = Adult Equivalent (450 kg steer at maintenance)

4.1.3.3 Supplementation

Consumption of supplements and molasses by third cohort steers is shown in Table 31 which includes animals in the improved pasture paddock.

Over the 86 days that urea blocks were supplied animals consumed a crude protein equivalent of 76 and 81 g/day/head for the leucaena and improved pasture paddocks respectively.

For the period January 2021 to when animals were removed from the trial in early August, leucaena and improved pasture animals consumed about 1.5 and 1.4 g/day supplemented P. These were low intakes (particularly for the wet season months), but P should not have significantly limited animal performance over this time considering previous applications of fertiliser (containing P) to the leucaena and improved pasture paddocks

For molasses feeding, leucaena animals were fed an equivalent of 1.9 and 1.4 MJ/day for the leucaena and improved pasture paddocks respectively.

Table 32. Supplementation of third cohort animals in leucaena and improved pasture paddocks at Pinnarendi.

Product	*Target ingredient*	*Period*	*Amount fed*		
			Redlands	*W'graze*	*Improved pasture*
LNT Uramol® **NT Uraphos**	Nitrogen - crude protein equivalent (g/day)	6 Aug 20-31 Oct 20 86 days	76	76	81
Olsson's Superphos **LNT® Phosrite**	Phosphorus (g/day)	7 Jan 21-2 Aug 21 207 days	1.5	1.5	1.4
Molasses	Energy (MJ/day)	31 Jul 20-2 Aug 21 367 days	1.9	1.9	1.4

4.1.3.4 Commentary

Weight gains for third cohort steers grazing Wondergraze and Redlands showed a similar pattern (Fig. 17) although there was a small cumulative outperformance of Wondergraze. This is attributed to poor leucaena growth in Redlands Paddocks 2 and 8 which resulted in underperformance of Redlands relative to Wondergraze, particularly during the 2021 winter period (although this was not investigated for statistical significance). This is believed to be a legacy issue from establishment, which became more apparent with on-going grazing of the third cohort and heavier stocking rates.

From Table 27 and Fig. 18, overall weight gains over the grazing period were marginally higher for Spyglass steers than the Pinnarendi steers. Initially, Spyglass steers underperformed the Pinnarendi group, and this could be attributed to the Spyglass group adjusting to a new environment. However, Spyglass steers then had compensatory weight gains over the late spring and summer period and subsequently performed on-par with Pinnarendi steers from about March 2021.

From Table 29 and Fig. 19, overall weight gains over the grazing period were slightly higher for the leucaena steers (Wondergraze and Redlands aggregated) compared to the group in the improved pasture Table 29). This difference is starker when comparing the improved pasture steers with just the Spyglass steers in the leucaena (Fig. 20). In this case the leucaena steers had an additional annual liveweight gain of 10 kg/head compared to the improved pasture steers (Table 31).

Overall productivity of leucaena was significantly more than the improved pasture paddock due to a combination of the higher weight gains and the stocking rate being more than double that of the improved pasture (Table 31). Nonetheless, it is likely that the improved pasture paddock could have sustained a heavier stocking rate, as utilisation was conservative.

4.1.3.5 Statistical analysis

Variety effect

There was no significant difference between the two varieties for the ADG over 367 days (ADG367) (P-value=0.371) or actual weight (P-value=0.416) (Table 32). There was still no difference (P-value=0.376) when weight at 31 July 2020 was included as covariate.

Table 33. Mean values for analysis with Variety only in the treatment structure.

Variety	*ADG367 (kg/day)*	*Weight at 2 Aug 2021 (kg)*	*Weight at 2 Aug 2021 with weight at 31 Jul 2020 as a covariate*
Redlands	0.59	478	483
Wondergraze	0.64	501	496
P-Value: Treatment	0.371	0.416	0.376
Covariate	-	-	0.08
sed	0.053	23.6	11.6

Source effect

The interaction of Cultivar and Source was not significant for ADG367, weight on 2 August 2021 or for weight on 2 August 2021 with weight on 31 July 2020 as covariate (P-value=0.323, 0.438, 0.354 respectively. When the Treatment-Source term was dropped from the model, the main effect for Source was not significant for ADG367 or for weight on 2 August 2021 with weight on 31 July 2020 as covariate (P-value=0.193 and 0.227 respectively). The main effect of Source was significant in the analysis of Weight on 2 August 2021 (Pinnarendi mean = 518 kg, Spyglass mean = 444 kg; sed = 11.1 kg; P-value <0.001).

4.1.4 Fourth cohort

4.1.4.1 Liveweight performance

Liveweight performance results for the fourth cohort steers are given in Table 33. The ADG (± s.e.) over 138 days to 17 July for all 30 head was 0.75 ± 0.03 kg based on the calculated liveweights on 1 March. This was an average weight gain of 103 kg/head. If the 'known' (recorded) liveweights from 12 April are used as starting weights, the ADG was 0.77 ± 0.03 kg over 96 days.

For the six head which remained on the trial for an additional 50 days, the ADG over this period (17 July to 5 September) was 0.47 ± 0.10 kg. As a discrete group they had and ADG over 188 days to 5 September of 0.70 ± 0.05 kg, based on the calculated liveweights on 1 March. This was an average weight gain of 122 kg/head. If the 'known' (recorded) liveweights from 12 April are used as starting weights, the ADG was 0.72 ± 0.06 kg over 146 days.

Table 34. Average weights and ADG's of fourth cohort steers at respective weigh dates.

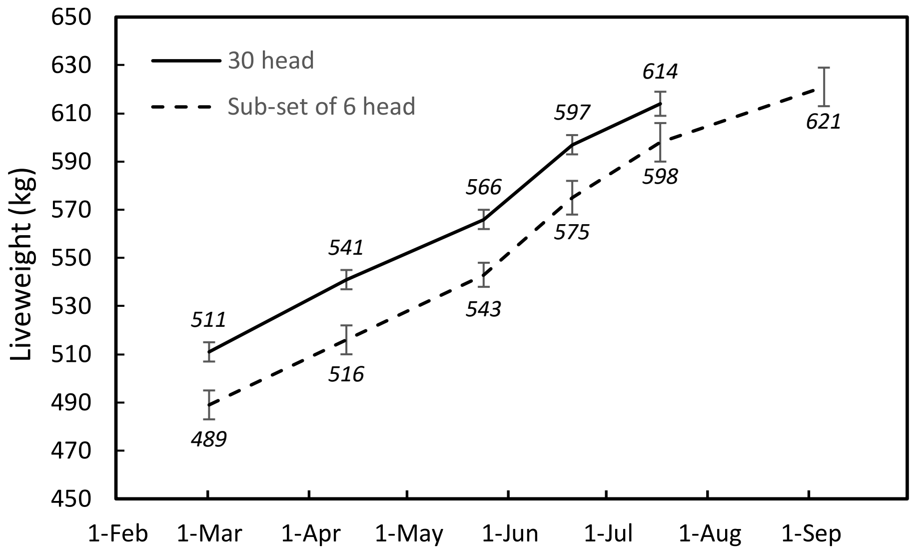
Period	***No. head***	***Average weight (kg ± s.e.)***		***ADG (kg ± s.e.)***
		Start	***Finish***	
1 Mar-12 Apr 42 days	30	460^{A} ± 3 *511^{B} ± 4*	541 ± 4	1.93* ± 0.04 *0.72** ± 0.04*
12 Apr-24 May 42 days	30	541 ± 4	566 ± 4	0.61 ± 0.05
24 May-20 Jun 27 days	30	566 ± 4	597 ± 4	1.15 ± 0.05
20 Jun-17 Jul 27 days	30	597 ± 4	614 ± 5	0.62 ± 0.07
17 Jul-5 Sep 50 days	6	598 ± 8	621 ± 8	0.47 ± 0.10
1 Mar-17 Jul 138 days	30	*511^{B} ± 4*	614 ± 5	***0.75** ± 0.03***
12 Apr-17 Jul 96 days	30	*541 ± 4*	614 ± 5	***0.77 ± 0.03***
1 Mar-5 Sep 188 days	6	*489^{B} ± 4*	621 ± 9	**0.70** ± 0.05**
12 Apr-5 Sep 146 days	6	*516 ± 6*	621 ± 9	**0.72 ± 0.06**

^{A} based on curfew weight

^{B} based on 10% loss of liveweight on 1 March

Fig. 21 shows the growth curves for all 30 head in the fourth cohort over 138 days from 1 March to 17 July; and for the sub-set of 6 head which were on the trial for 188 days to 5 September.

Figure 21. Growth curves for fourth cohort steers grazing leucaena at Pinnarendi (March-September 2022).



Commentary

When the 30 head of fourth heavyweight steers were introduced on 1 March, pasture and leucaena productivity at the site was still high. After low rainfall in March, there was well-above average rainfall in April, May and July which sustained leucaena growth. Leucaena usually becomes less productive at the site from about late May due to cooler weather and drier conditions, but this was not the case in 2022. As such, leucaena intake by fourth cohort animals was not significantly restricted by leucaena productivity until about early July when growth was checked by cold weather. New growth resumed with warmer conditions in mid-July, about the time most animals were removed for slaughter.

After 17 July 2022, the six head remaining were rotated to a fresh Wondergraze paddock (Paddock 1) and were rotated to Redlands Paddock 5 on 24 August by which time Paddock 1 had little remaining leaf due to grazing and increasing psyllid damage. At this time psyllids were heavily affecting Wondergraze paddocks at the site. Fig. 22 shows some of the remaining six head on 30 August 2022 in good condition and one week prior to slaughter (average weight about 620 kg).

Figure 22. Final fourth cohort steers on 30 August 2022, one week prior to slaughter.

Supplementation and stocking

Over 138 days from 1 March to 17 July 2022 fourth cohort animals consumed an average of about 2.5 g/day/head of supplemented P (from commercial blocks). From molasses feeding, these animals consumed an equivalent of 0.58 MJ/day/head.

The six head which remained on the trial for an additional 50 days consumed negligible supplemented P but were fed molasses equivalent to 0.37 MJ/day/head during this period.

Over 138 days from 1 March to 17 July 2022 the stocking rate for the 30 steers in the fourth cohort was 0.61 AE/ha. After 17 July, the stocking rate for the six head which remained on the trial for an additional 50 days was 0.36 AE/ha.

4.1.4.2 Carcass data

Key carcass characteristics data (MSA grading) are given in Table 34 for the 24 head which were slaughtered 19 July. Five animals were ineligible for MSA grading as either the rib fat measurement was ≤ 2 mm, or pH was > 5.7 (body no.'s 283, 286, 282, 268, 273, Table 2). Nonetheless, an opportunity grading index was calculated for these carcasses. All but one carcass had a P8 fat measurement of 5-22 mm resulting in processor grading into the top box. All but two carcasses had a cold ossification score of 200 or less, and all carcass weights were over 300 kg except one.

Table 35. Key MSA grading data for 24 steers 'finished' on leucaena for 138 days at Pinnarendi.

Tag no.	*138 Day ADG (kg)*	*Body no.*	*P8 fat (mm)*	*Rib fat (mm)*	*Cold ossification score*	*MSA Marbling Score*	*Hump cold (mm)*	*pH*	*MSA index*
51	0.86	267	20	4	190	220	125	5.70	**50.08**
52	0.63	276	23	8	150	240	150	5.65	**52.76**
53	0.89	283	10	*2[A]*	140	290	100	5.65	*55.92**
54	0.59	266	20	9	180	220	105	5.64	**53.02**
55	0.82	286	12	4	190	320	115	*5.74[A]*	*52.04**
56	0.70	287	10	11	150	340	115	5.63	**55.62**
57	0.57	272	22	4	160	360	100	5.66	**55.93**
58	1.08	284	10	13	140	400	140	5.64	**56.53**
59	0.54	275	7	6	180	340	90	5.61	**56.09**
61	0.65	285	8	4	150	320	105	5.65	**54.78**
62	0.64	274	20	9	140	220	95	5.65	**56.6**
63	0.97	282	10	*2[A]*	140	380	115	5.64	*55.41**
64	0.81	289	10	7	160	300	150	5.69	**52.96**
66	0.75	277	13	10	130	340	125	5.63	**55.95**
68	0.67	279	20	5	200	330	85	5.63	**56.13**
70	0.64	288	10	15	150	370	130	5.67	**55.42**
71	0.61	269	13	3	140	370	155	5.64	**54.51**
74	1.06	280	20	3	150	350	110	5.59	**55.22**
76	1.02	268	10	*2[A]*	150	250	90	5.61	*55.82**
77	0.72	271	20	4	150	230	130	5.64	**51.92**
78	0.66	278	18	5	280	360	105	5.63	**53.35**
79	0.85	281	15	10	150	400	120	5.58	**55.74**
81	0.60	270	15	3	190	220	110	5.69	**51.26**
82	0.48	273	9	*1[A]*	300	310	100	5.68	*51.59**

[A] attribute disqualifies carcass from MSA grading (regrade opportunity index calculated)

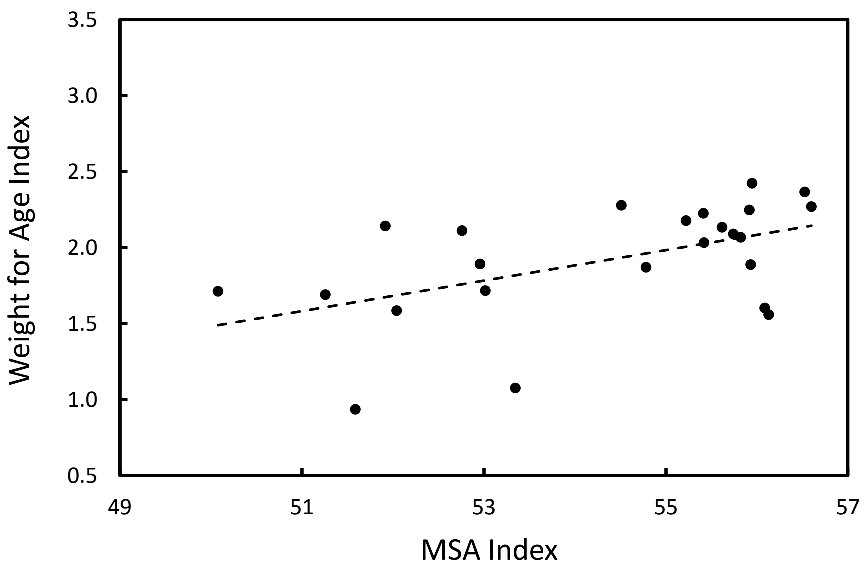
Carcass weight data is presented in Table 35. Average (± s.e.) carcass weight relative to liveweight prior to transport was 50.2 ± 0.3% (range 47.6-52.6%). There was no correlation between individual liveweight gain over the study period and MSA index. However, as a proxy for 'weight for age' an index was calculated by dividing the liveweight on 17 July by the ossification score (Table 35). As per Fig. 23, there was some correlation between these measures which is to be expected.

Table 36. Weight attributes for 24 steers 'finished' on leucaena for 138 days at Pinnarendi.

Tag No.	*Liveweight 17 July (kg)*	*Body No.*	*Carcass Weight (kg)*	*Carcass weight to liveweight ratio*	*Weight for age index[A]*
51	640	267	325	0.508	3.4
52	624	276	316.5	0.507	4.2
53	636	283	314.5	0.494	4.5
54	626	266	308.5	0.493	3.5
55	614	286	301	0.490	3.2
56	646	287	320	0.495	4.3
57	596	272	301.5	0.506	3.7
58	664	284	331	0.498	4.7
59	572	275	288.5	0.504	3.2
61	588	285	280	0.476	3.9
62	610	274	317.5	0.520	4.4
63	610	282	311.5	0.511	4.4
64	628	289	302.5	0.482	3.9
66	620	277	315	0.508	4.8
68	600	279	311	0.518	3.0
70	608	288	304.5	0.501	4.1
71	614	269	318.5	0.519	4.4
74	670	280	326.5	0.487	4.5
76	646	268	310	0.480	4.3
77	610	271	321	0.526	4.1
78	594	278	300.5	0.506	2.1
79	636	281	313.5	0.493	4.2
81	626	270	321	0.513	3.3
82	558	273	280	0.502	1.9

[A] 17 July liveweight divided by ossification score

Figure 23. Relationship between MSA carcass index and 'Weight for Age' index (liveweight divided by ossification score) for 24 steers 'finished' on leucaena for 138 days at Pinnarendi.



4.1.5 Cohort comparison

Figs. 24 and 25 compare the annual liveweight performance over the three cohorts of steers (2018-2021). Fig. 12 shows comparative liveweight gains of steers grazing Redlands and Wondergraze. Fig. 13 shows comparative liveweight gains for steers grazing leucaena (Redlands and Wondergraze combined) and improved pasture (there were no first cohort steers in the improved pasture).

Figure 24. Comparison of annual liveweight gains for Redlands and Wondergraze across three cohorts of steers grazed at Pinnarendi (2018-2021).

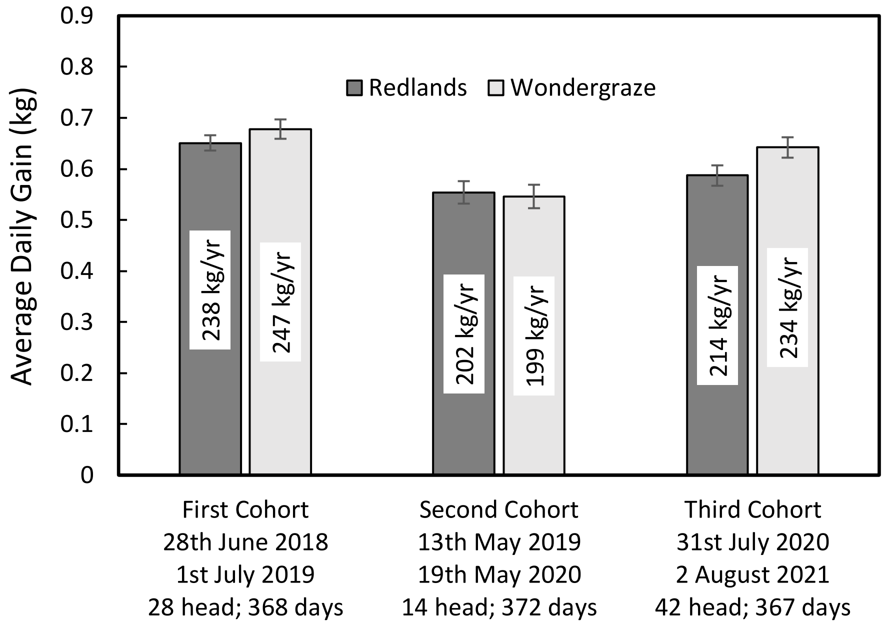


Figure 25. Comparison of annual liveweight gains for leucaena and improved pasture across three cohorts of steers grazed at Pinnarendi (2018-2021).

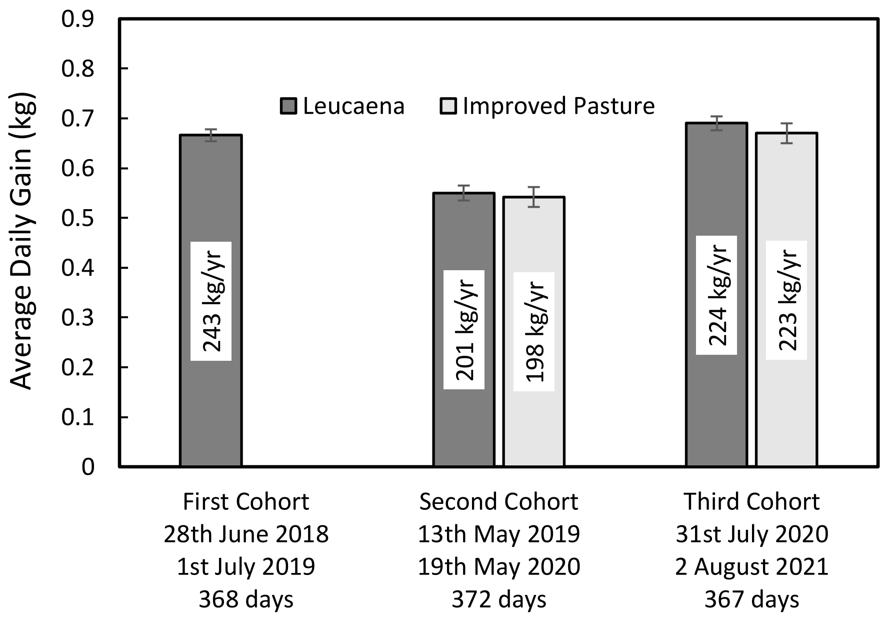
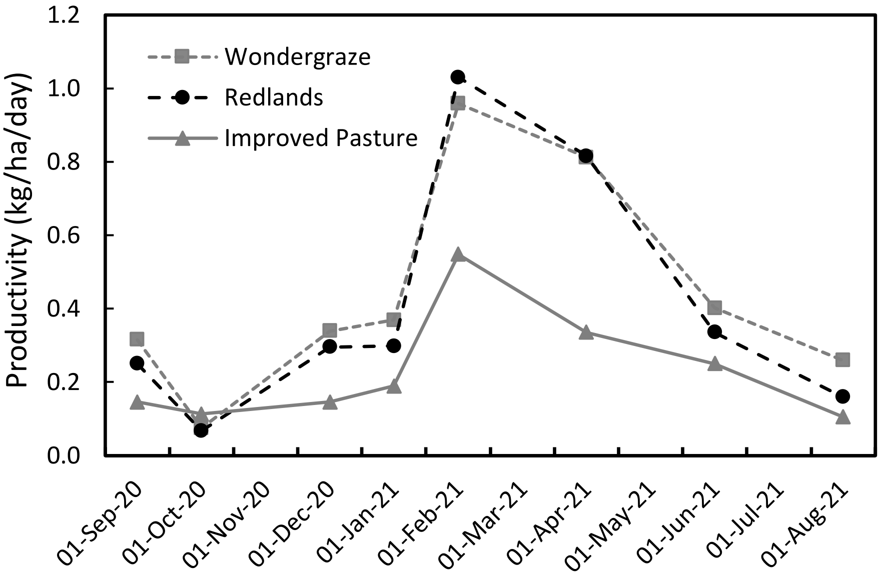


Fig. 26 compares the productivity (expressed as liveweight gain per unit area per day) for third cohort steers grazing Wondergraze, Redlands and the improved pasture. Although annual liveweight gains were similar for leucaena and improved pasture (Fig. 13), leucaena was more productive due to higher stocking.

Figure 26. Comparison of productivity for Redlands and Wondergraze leucaena against improved pasture for third cohort steers at Pinnarendi (2020-2021).



4.2 Faecal sampling

Levels of CP and DMD determined from NIRS analyses of forage samples collected at the site are shown in Figs. 27 and 28 respectively. Samples for leucaena were Redlands and Wondergraze combined.

Wet season CP levels were higher than dry season values for all grass species averaging 12.6% and 2.6% respectively. Similarly, legume species (excluding leucaena) had corresponding CP levels of 18.0% and 6.1% (both higher than grasses). Leucaena had similar CP for wet and dry season samples; 13.0% and 14.1% respectively. Notably the dry season CP was higher than the wet season value. Excluding leucaena, wynn cassia had the highest levels of CP for both wet and dry season samples.

For DMD, wet season levels were about 100% higher (i.e., 2x) than dry season values for all species except leucaena which had similar wet and dry season values. Notably the average DMD of leucaena was 47% which was considerably lower than an average of 63% recorded for 'edible' leucaena from work in central Queensland (Maree Bowen, pers. comm.).

Estimates of dietary CP, DMD and %C3 during 2019-20 for animals in the improved pasture, Redlands and Wondergraze paddocks are shown in Figs. 29-31. For both leucaena paddocks, diet CP and %C3 were more consistent than for the improved pasture paddock. In all paddocks, diet CP increase dramatically from late 2019 to early 2020. This was when rainfall was received after drought conditions at the site during 2019.

Figure 27. Seasonal crude protein levels for predominant C3 and C4 species sampled at the Pinnarendi trial site in 2020 (determined from NIRS analysis).

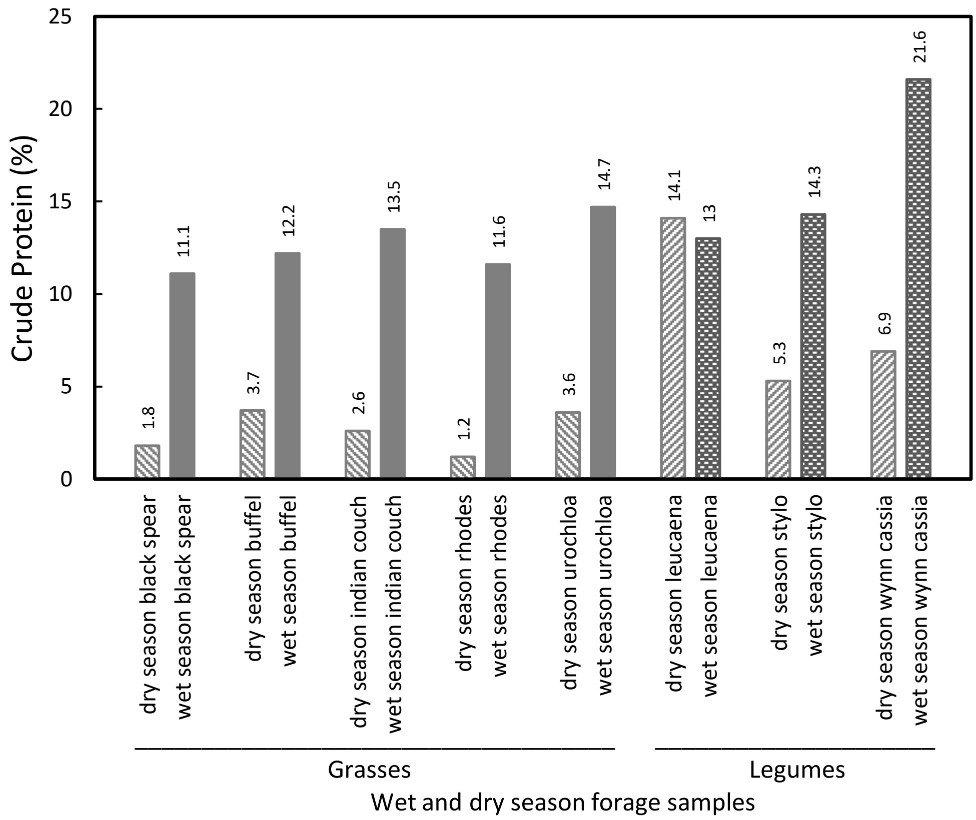


Figure 28. Seasonal dry matter digestibility for predominant C3 and C4 species sampled at the Pinnarendi trial site in 2020 (determined from NIRS analysis).

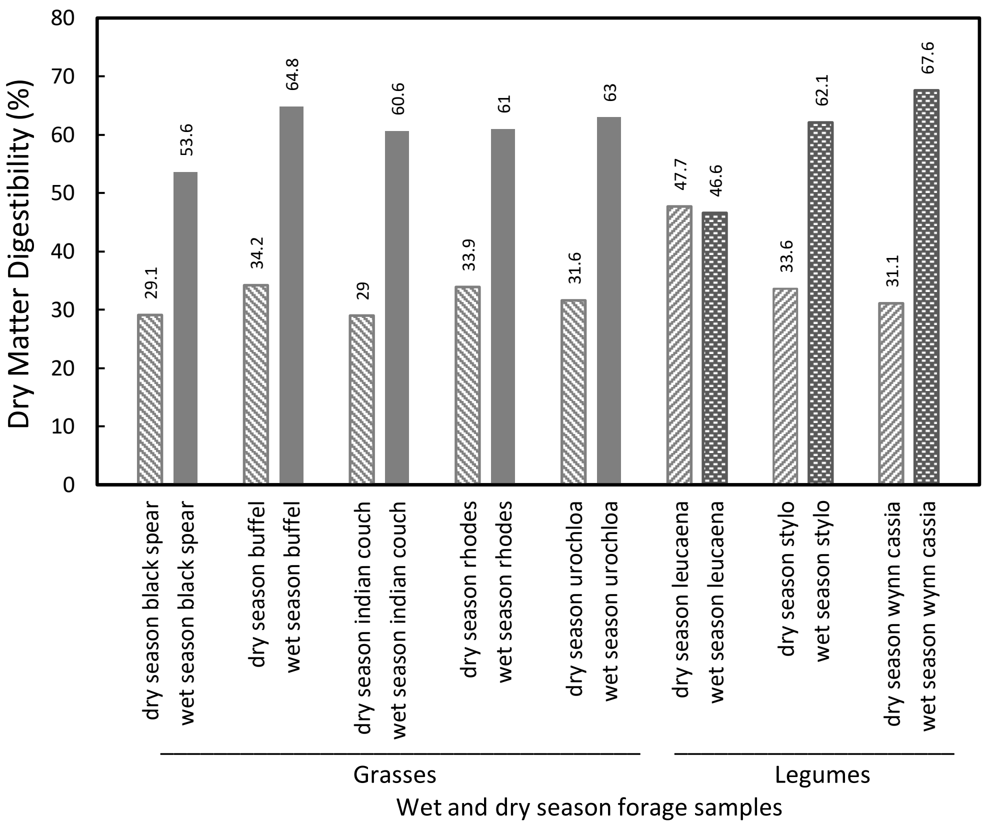


Figure 29 Estimated dietary CP, DMD and %C3 for improved pasture paddock at Pinnarendi (May 2019 - December 2020).

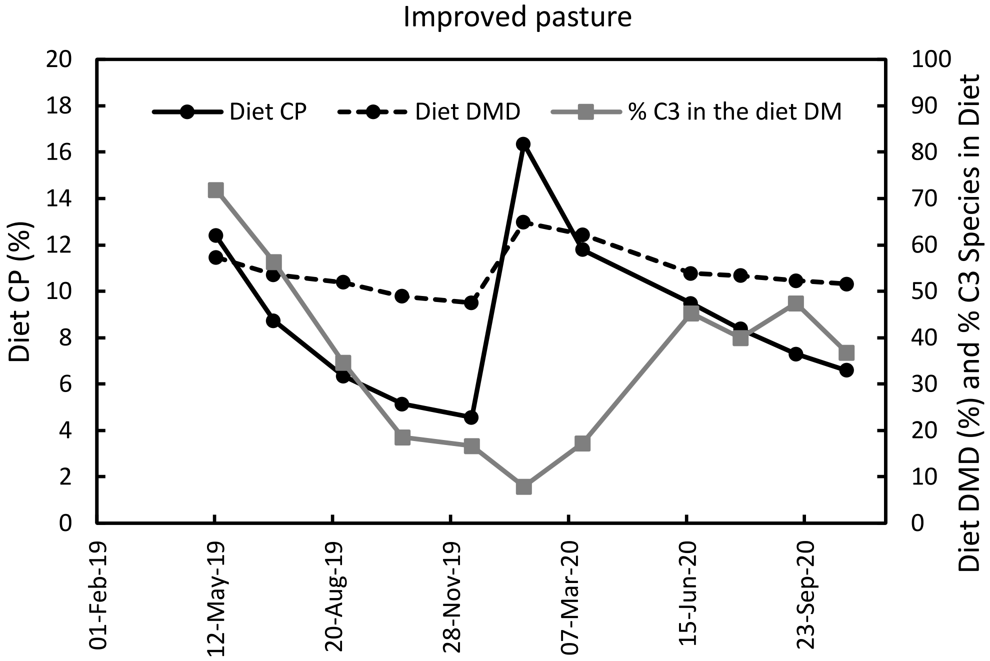


Figure 30. Estimated dietary CP, DMD and %C3 for Redlands leucaena at Pinnarendi (May 2019 - January 2021).

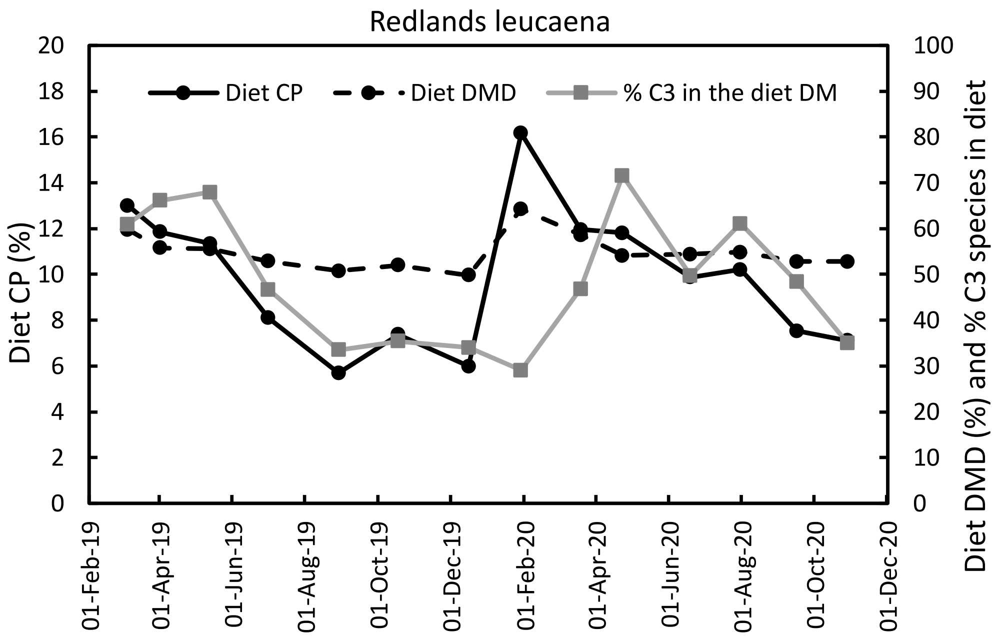
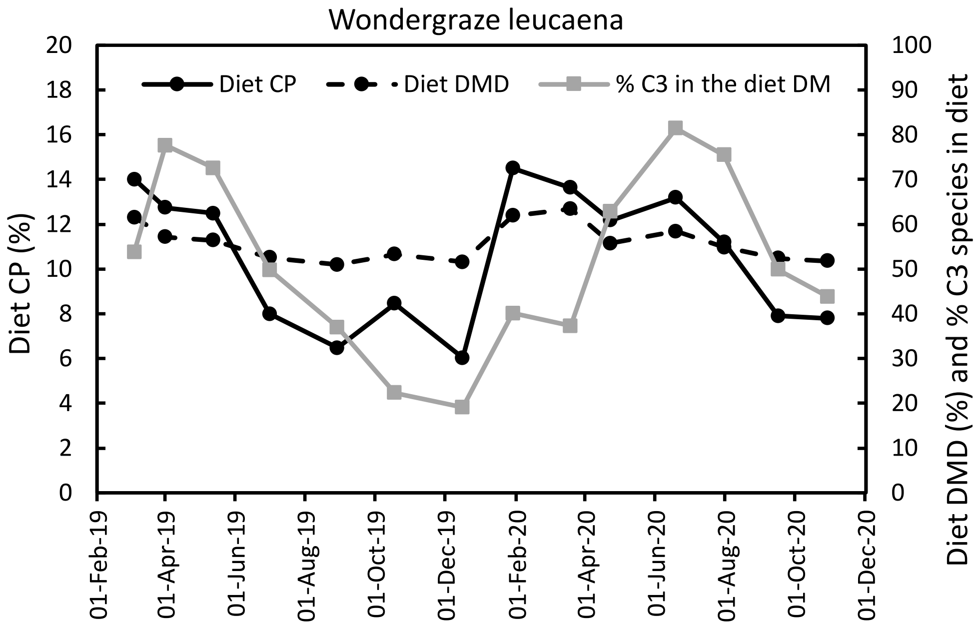


Figure 31. Estimated dietary CP, DMD and %C3 for Wondergraze leucaena at Pinnarendi (May 2019 - January 2021).



4.3 Site monitoring

4.3.1 Weather conditions

4.3.1.1 Rainfall

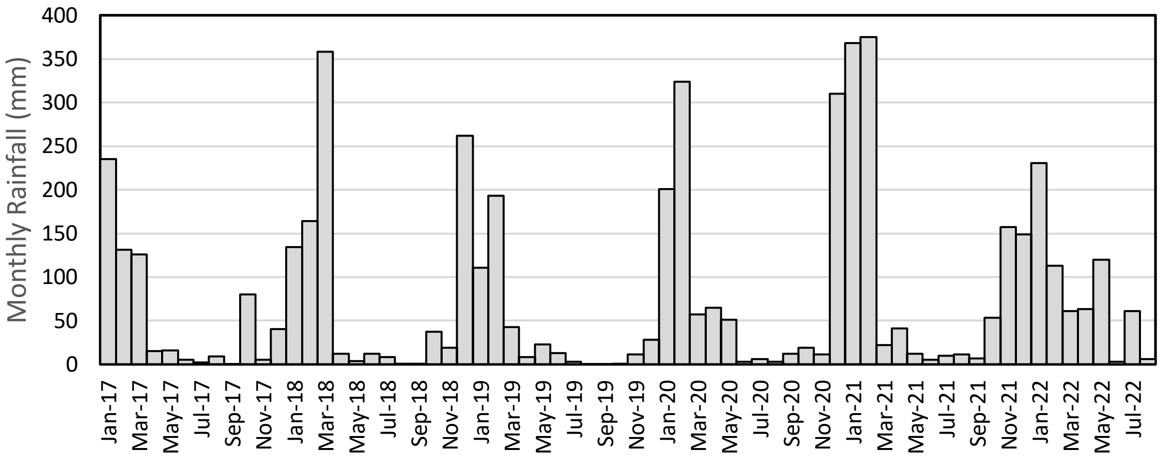
Monthly rainfall totals recorded at the site since establishment of the trial in January 2017 to August 2022 are given in Table 36 together with corresponding statistics for nearby Meadowbank Station (Bureau of Meteorology station #031175). Drought conditions were experienced at the site in 2019 with only 434 mm received. The recorded monthly totals are also shown in Fig. 32 which underscores the seasonal nature of rainfall in most years. The period from October 2021 to May 2022 has been an exception to this pattern, with more than 50 mm per month received for eight consecutive months and a further 61 mm in July 2022.

Table 37. Rainfall statistics for Meadowbank and monthly totals recorded at Pinnarendi (January 2017 to July 2022).

Rainfall	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
Meadowbank[A]													
average	*191*	*196*	*126*	*40*	*26*	*17*	*12*	*8*	*9*	*23*	*70*	*122*	***840***
median	*152*	*191*	*98*	*25*	*16*	*11*	*6*	*0*	*0*	*12*	*50*	*118*	***679***
Pinnarendi leucaena trial site													
2017	235	131	126	15	16	5	2	8.5	0	80	5	40	***663***
2018	134	164	358	12	4	12	8	1	1	37	19	262	***1012***
2019	111	193	43	8	23	13	3	0	0	1	11	28	***434***
2020	201	324	57	65	51	3	6	3	12	19	11	310	***1062***
2021	368	375	22	41	12	5	10	11	7	53	157	149	***1210***
2022	231	113	61	63	120	3	61	6	-	-	-	-	*658*

[A] Source: Australian Government, Bureau of Meteorology (Station #031175, Meadowbank)

Figure 32. Monthly rainfall totals recorded at Pinnarendi trial site (January 2017 - August 2022).



4.3.1.2 Temperature

Monthly average temperatures recorded at the site from May 2019 to August 2022 (40 months) are shown in Fig. 33. For the same period, the number of days per month when the maximum temperature was at least 25°C (for optimum leucaena growth) are shown in Fig. 34. This threshold was achieved on most days in most months, except June and July. Daily maximum temperatures of 38°C or greater were only recorded twice; December 2019 and 2020.

Over the 40-months of recording there were only 11 days when the daily average temperature was 13°C or less; two days in June 2019, three days in May 2020, one day in August 2021 and five days in June-July 2022. There were no occasions where the daily minimum temperature was 2°C or less. From Figs. 33 and 34, the winter period in 2021 was considerably milder than in other years.

Figure 33. Monthly average temperatures recorded at Pinnarendi trial site (May 2019 - August 2022).

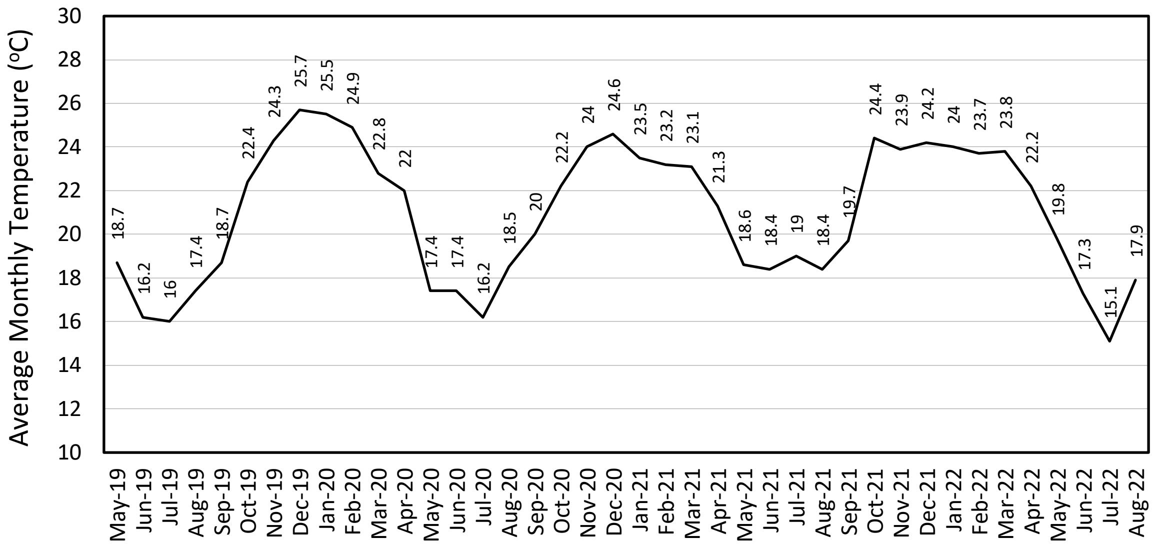
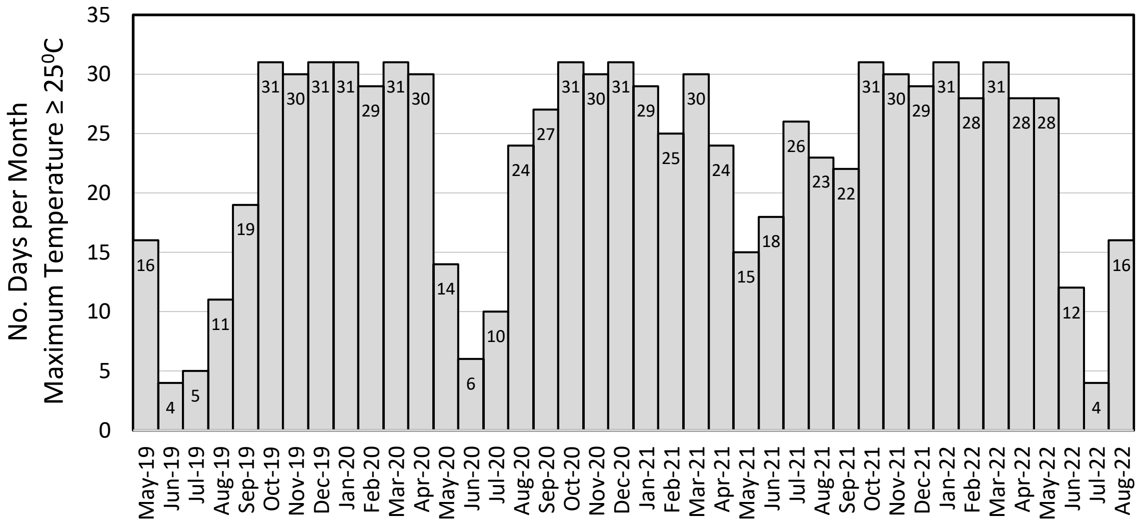


Figure 34. Number of days per month maximum daily temperature was at least 25°C recorded at Pinnarendi trial site (May 2019 - August 2022).



4.3.1.3 Annual weather conditions during grazing years

2018

The 2017-18 wet season started with below median rainfall in November and December and continued with about average rainfall in January-February 2018. There was 298 mm in March which was in the wettest decile for March rainfall. Rainfall over the April-September period was lower than median with just 32 mm received over six months. In October, 32 mm was received from one storm early in the month. November was drier than average, but December rainfall was well above average with 262 mm received. Overall, there was above average rainfall in 2018 totalling 1012 mm.

Temperatures at the site were not recorded prior to May 2018. Temperature data from May 2018 to December 2020 was not available for analysis. However, conditions were generally cold over the

2018 winter period. In June, the nights of 19 and 20 June each had minimum temperatures close to 4°C and there was some frost. For July, minimums were frequently less than 10°C but minimums were always above 5°C. There was cold weather in late August, with 2.8°C recorded on 21 August being the lowest temperature for the year, resulting in frost across low areas of the site.

2019

The 2018-19 wet-season was average overall with above median rainfall in December 2018, and near median rainfall in January and February 2019. Low rainfall in March developed into drought conditions during the remainder of 2019. There was little useful rainfall for 10 months from the end of February until the end of December. Totals of 23 mm in May and 13 mm in June were from drizzle only. Unusually, there was no storm activity during late spring and the first storm rain was received on 26 December (27 mm). Only 434 mm was received for 2019, which was well below the Meadowbank median.

Due to malfunction of the weather station, temperature data was only available from early May 2019. Cool to cold weather conditions were experienced from June to October intensified by dry conditions and low humidity. In June there were two days with average daily temperatures of 13°C or less including a remarkably cold day on 21 June with a maximum of 12°C. However, there was no frost at the site during 2019, and the lowest temperature for the year was 4.5°C on 18 July. There were only 20 days in the June-August period where the daily average temperature was 25°C or higher. September was also relatively cool, recording only 11 days with daily averages of at least 25°C. December was hot with an average monthly temperature of 24.6°C including eight days with daily maximums above 37°C. The highest temperature of the year was 38.2°C on 25 December.

2020

Above average rainfall totalling 1,062 mm was received at the site during 2020. There was a late start to the 2019-20 wet season, with no useful rain received in December 2019. However nearly 650 mm was recorded at the site during January-April 2020. Going into the dry season, the last useful rain was 34 mm on 23 May. There was some rainfall in all months to September, but it was light drizzle and of no benefit.

Falls of 7 mm (24 September), 13 mm (23 October) and 8 mm (13 November) were useful but insufficient to overcome seasonally dry conditions. Again, there was no 'early start' to the wet-season. The first significant storm rain was on 7-8 December (29 mm). Good rainfall was received from 18 December onwards. Total December 2020 rainfall was 310 mm which was well above average. This accorded with an active La Nina declared by the Bureau of Meteorology in late September 2020.

Overall, temperatures at the site during the cooler months were milder than the previous year, although there were three consecutive days in late May 2020 where the average daily temperature was less than 13°C. During the winter months, there were 40 days with daily average temperatures of 25°C or higher and no days where the average daily temperature was 13°C or less. During this time, cloudy conditions from persistent south-east trade winds resulted in mild overnight temperatures. There was no frost at the site during 2020. The lowest temperature was 3.4°C recorded on 17 July.

Periods of hot weather, which can occur during the October-December period, were not protracted. February was the hottest month of the year with an average temperature of 24.9°C. The highest temperature for the year was 39.2°C recorded on 6 December.

2021

Overall, 2021 was the wettest year at the site with 1,210 mm received. The 2020-21 wet season had well above average rainfall with 1,054 mm received during December-February 2020-21. Above median or near median rainfall was received in all months except for March when only 22 mm was received. During January and February, there was 368 mm and 375 mm respectively, each of which ranked within the wettest decile (90%) for median rainfall at Meadowbank.

Going into the dry season, the last useful fall of rain at the site was 32 mm received over 4 days on 21-25 April. As usual, rainfall received over the five months May to September was of little benefit (55 mm in total). Rainfall to break the dry season was received early with 48 mm in October. Storm activity in November resulted in more than double the average rainfall for the month (157 mm). Regular storms during the last third of December also resulted in above average rainfall for the month (149 mm).

Overall, temperatures at the site during 2021 were mild with no remarkable extremes and no prolonged periods of cold weather. Cloudy conditions and rain limited daytime maximums during the first quarter of the year. During the winter months, conditions were warmer than the previous two years at the site; there were 64 days with daily average temperatures of 25^{o}C or more and only one day (6 August) when the average daily temperature was 13^{o}C or less. The average July temperature was 19^{o}C which was 3^{o}C higher than in 2019 and 2020. Again, there was no frost at the site during 2021. The lowest temperature for the year was 7.0^{o}C on 7 July. The highest temperature for the year was 34.8°C recorded on 19 October.

2022

The 2021-22 wet season was characterised by above average rainfall in November-December 2021 and January 2022. This was followed by below average rainfall in February and well below average rainfall in March (113 and 61 mm respectively). However, a total of 246 mm was received in the April-July period with well above median falls in April, May and July. To the end of July 2022, 653 mm had been received which was more than the 2017 and 2019 annual totals.

Average temperatures during the 2022 summer and autumn period at the site were consistent with previous years although the May average was about 1-2°C warmer than 2020 and 2021, respectively. There was an outbreak of cold weather in early June with four consecutive days when daily average temperatures was less than 13^{o}C.

4.3.2 Soil analyses and classification

Previous applications of fertiliser at Pinnarendi supplied 80 kg/ha P and 233 kg/ha S to the leucaena plant rows. The inter-row pasture received 22 kg/ha P and 26 kg/ha of S. The improved pasture paddock received 27 kg/ha P and 33 kg/ha of S in January 2019.

4.3.2.1 2019 analyses

Analyses of samples collected in November 2019 are shown in Table 37.

Table 38. Soils sample analyses, Pinnarendi 2019.

Paddock no. and sample location	*pH (1:5 water)*	*Organic carbon (%)*	*Nitrate nitrogen (mg/kg)*	*Colwell phosphorus (mg/kg)*	*Phosphorus buffer index*	*Sulphur (mg/kg)*	*Calcium (cmol$^+$/kg)*	*Magnesium(cmol$^+$/kg)*	*Potassium(cmol$^+$/kg)*	*Zinc (mg/kg)*	*Copper (mg/kg)*
P1 leucaena row	6.0	1.0	6	11	33	6	2.3	0.7	0.42	0.54	0.29
P1 inter-row	6.2	1.2	3	<5	40	4	2.4	0.9	0.44	0.54	0.30
P2 leucaena row	6.3	1.3	10	12	42	5	3.4	0.7	0.63	0.40	0.36
P2 inter-row	6.4	1.5	10	<5	36	4	3.8	1.0	0.57	0.53	0.35
P3 leucaena row	6.0	1.2	10	11	30	5	3.2	0.7	0.39	0.39	0.36
P3 inter-row	6.3	1.0	9	7	20	5	2.9	0.8	0.37	0.32	0.33
P4 leucaena row	6.3	1.1	10	12	52	8	3.1	0.7	0.62	0.47	0.37
P4 inter-row	6.9	1.2	7	<5	29	13	3.7	1.0	0.97	0.36	0.35
P5 leucaena row	6.3	1.1	6	<5	48	4	3.2	0.9	0.43	0.31	0.34
P5 inter-row	6.3	1.2	6	6	47	6	3.6	0.9	0.41	0.28	0.29
P6 leucaena row	6.1	1.1	5	29	47	5	3.2	0.6	0.40	0.72	0.30
P6 inter-row	6.3	1.4	6	<5	45	4	3.5	1.0	0.41	0.36	0.30
P7 leucaena row	6.3	1.3	6	12	44	4	2.5	0.8	0.44	0.20	0.26
P7 inter-row	6.2	0.8	5	7	41	4	2.2	0.8	0.39	0.15	0.27
P8 leucaena row	6.3	1.1	6	12	34	7	2.9	0.7	0.37	0.22	0.26
P8 inter-row	6.4	1.2	4	10	38	4	3.0	0.9	0.30	0.17	0.25
P9 (buffel) unfertilised	8.0	1.2	3	<5	31	1	5.5	1.1	0.20	0.17	0.15
P9 fertilised	6.4	0.9	3	6	33	3	2.4	0.7	0.34	0.17	0.30

From Table 37, the average of P levels for leucaena Paddocks 1-8 were 13 mg/kg and 6 mg/kg for the leucaena plant row and inter-row pasture area, respectively. This accords with the higher application of P to the leucaena plant rows. The average S levels were the same for the leucaena plant rows and the inter-row pasture area at 6 mg/kg. This was despite ten times higher applications of S to leucaena plant rows.

For the improved pasture paddock (P9), measured P and S levels were slightly higher for the fertilised area compared to the unfertilised area of eucalypt regrowth with native pasture.

For the leucaena paddocks, pH was consistently lower for the leucaena plant rows compared to the interrow pasture (average of 6.2 and 6.4 respectively). For the improved pasture paddock, pH was 8.0 for the unfertilised area of eucalypt regrowth and native pasture, versus 6.4 measured in the pastured and fertilised area. This was the same as the average for the leucaena interrow pasture.

Results from samples taken in May 2019 from a location in Paddock 1 with marked differences in leucaena growth within the same row are given in Table 38. The analysis of soil adjacent trees with excellent growth recorded higher levels of all macronutrients compared to results from the area with poor growth. However, levels of macronutrients from the area with poor growth were still adequate with the exception of nitrogen, which was lower than for the area with excellent growth (2 mg/kg versus 6 mg/kg).

Table 39. Soils sample results from same row with vigorous leucaena and underdeveloped leucaena, Paddock 1, Pinnarendi, May 2019.

Paddock 1 Same leucaena row May 2019	*pH (1:5 water)*	*Organic carbon (%)*	*Nitrate nitrogen (mg/kg)*	*Colwell phosphorus (mg/kg)*	*Phosphorus buffer index*	*Sulphur (mg/kg)*	*Calcium (cmol⁺/kg)*	*Magnesium(cmol⁺/kg)*	*Potassium(cmol⁺/kg)*	*Zinc (mg/kg)*	*Copper (mg/kg)*
Poor growth	6.0	1.5	2	38	60	13	2.9	0.7	0.45	0.49	0.35
Excellent growth	5.6	2.8	6	51	110	18	4.1	1.1	0.59	1.1	0.34

4.3.2.2 2021 analyses

Analyses of samples collected in November 2019 are shown in Table 39. The average P levels for leucaena Paddocks 1-8 were 6 mg/kg and 5 mg/kg for the leucaena plant row and inter-row pasture area, respectively. The average S levels were 3.6 and 3.4 mg/kg for the leucaena plant rows and inter-row pasture areas, respectively.

For the improved pasture paddock (P9), measured P levels were < 5 mg/kg for both the fertilised area and unfertilised area of eucalypt regrowth and native pasture. Respectively, S levels were 2.8 and 1.3 mg/kg.

For the leucaena paddocks, pH was similar for the leucaena plant rows compared to the interrow pasture (average of 6.1 and 6.2 respectively). For the improved pasture paddock, pH was 6.5 for the unfertilised area of eucalypt regrowth and native pasture, versus 6.3 measured in the pastured and fertilised area.

Table 40. Soil sample results, Pinnarendi 2021.

Paddock no. and sample location	*pH (1:5 water)*	*Organic carbon (%)*	*Nitrate nitrogen (mg/kg)*	*Colwell phosphorus (mg/kg)*	*Phosphorus buffer Index*	*Sulphur (mg/kg)*	*Calcium (cmol⁺/kg)*	*Magnesium(cmol⁺/kg)*	*Potassium(cmol⁺/kg)*	*Iron (mg/kg)*	*Copper (mg/kg)*
P1 leucaena row	6.0	0.86	9.1	8.5	50	4.6	1.7	0.6	0.33	36	0.43
P1 inter-row	6.3	1.02	1.2	<5	46	3.7	2.1	0.8	0.27	44	0.41
P2 leucaena row	6.3	1.03	3.4	6.8	23	3.3	2.8	0.7	0.46	32	0.48
P2 inter-row	6.2	1.25	3.9	5.3	48	3.2	2.9	0.8	0.37	35	0.49
P3 leucaena row	5.7	1.11	3.5	5.8	26	3.9	2.6	0.7	0.42	36	0.42
P3 inter-row	6.3	1.04	4.9	6.7	27	3.1	2.9	0.8	0.32	33	0.48
P4 leucaena row	6.2	1.17	3.4	<5	44	3.1	2.7	0.7	0.28	8	0.36
P4 inter-row	6.3	1.08	2.3	<5	47	3.1	3.3	0.7	0.29	26	0.34
P5 leucaena row	6.3	1.2	0.7	<5	46	3.4	3.3	0.9	0.33	29	0.40
P5 inter-row	6.2	1.29	1.0	<5	31	3.3	2.8	0.8	0.32	31	0.38
P6 leucaena row	6.2	1.16	2.8	12	39	4.5	2.7	0.8	0.35	36	0.43
P6 inter-row	6.2	1.22	3.0	<5	37	3.1	2.5	0.8	0.32	48	0.45
P7 leucaena row	6.3	0.93	4.2	<5	37	3.1	2.2	0.7	0.37	28	0.39
P7 inter-row	6.2	0.97	2.9	<5	25	2.9	2.4	0.9	0.45	38	0.36
P8 leucaena row	6.2	1.01	4.4	5.3	32	3.6	2.6	0.7	0.30	30	0.34
P8 inter-row	6.2	1.21	3.6	<5	31	3.5	2.8	0.9	0.22	37	0.31
P9 (buffel) unfertilised	6.5	0.73	2.6	<5	24	1.3	1.2	0.8	0.18	26	0.25
P9 fertilised	6.3	1.24	2.6	<5	55	2.8	2.8	0.8	0.33	48	0.43

Table 40 summarises changes in average soil pH, N, P and S from 2016 to 2021, for samples taken from the leucaena plant rows, interrow pasture area (leucaena Paddocks 1-8) and Paddock 9 (improved pasture paddock).

Soil pH measured in the leucaena inter-row pasture declined from 6.5 prior to site development to 6.3 in 2021. Soil pH in the leucaena plant rows was lower at 6.2 in both 2018 and 2021.

Prior to site development, S levels (inter-row pasture area) averaged 2.6 mg/kg, increasing to 5.5 mg/kg after fertiliser applications and falling to 3.4 mg/kg in 2021. In 2019, P measured in the leucaena interrow and improved pasture was 6 ppm, which was low considering earlier applications of superphosphate to these areas. In 2021, soil P was 5 ppm or less in these areas. For the leucaena rows, average P was 13 ppm (marginal) in 2019 due to concentrated applications of superphosphate. The average of 2021 analyses was 6 ppm which was sub-optimal.

Table 41. Average pH, N, P and S levels for Pinnarendi trial paddocks from 2019 and 2021 (mean ± standard error).

	2016[A]	2019	2021
Paddocks 1-8: leucaena rows			
pH (1:5 Water)	*n/a*	*6.2 ± 0.05*	*6.2 ± 0 .07*
Nitrate Nitrogen (mg/kg)	*n/a*	*7.4 ± 0.78*	*4.0 ± 0.84*
Phosphorus (Colwell, mg/kg)	*n/a*	*13 ± 2.4*	*6 ± 1.0*
Sulphur (MCP, mg/kg)	*n/a*	*5.5 ± 0.50*	*3.6 ± 0.17*
Paddocks 1-8: interrow pasture			
pH (1:5 Water)	*6.5 ± 0.06*	*6.4 ± 0.08*	*6.3 ± 0.03*
Nitrate Nitrogen (mg/kg)	*7.0 ± 1.1*	*6.3 ± 0.84*	*2.9 ± 0.47*
Phosphorus (Colwell, mg/kg)	*<5*	*6 ± 0.6*	*5 ± 0.2*
Sulphur (MCP, mg/kg)	*2.6 ± 0.16*	*5.5 ± 1.10*	*3.4 ± 0.18*
Paddock 9: pastured area			
pH (1:5 Water)	*n/a*	*6.4*	*6.3*
Nitrate Nitrogen (mg/kg)	*n/a*	*3.0*	*2.6*
Phosphorus (Colwell, mg/kg)	*n/a*	*6*	*<5*
Sulphur (MCP, mg/kg)	*n/a*	*3.0*	*2.8*

[A] Sampled from leucaena paddocks prior to development and fertiliser applications

4.3.2.3 Site soil survey

The full report for the site soil survey is attached as Appendix 9.3. The site soil map is shown in Fig. 35. The key findings from the soil survey were:

- The soils across the trial site are residual or colluvial deposits formed over Tertiary aged duricrust and are predominantly deep Red Chromosols (86% of the area). They are duplex soils with a texture contrast between their sandy-loamy topsoil (A horizons) and clayey red subsoil (B horizons).
- Soil depth is variable across the site. In some locations the top of the C horizon (weathered substrate) was encountered before 1.5 m.
- The analytical data show these soils are infertile or deficient in most key plant nutrients and are subject to leaching losses with a low capacity to retain nutrients.
- The soils are acidic to strongly acidic throughout. For most sampling locations pH was lower at the surface than through the subsoil, ranging between 5.3 to 6.1 at the surface, and 5.3 to 6.7 in the subsoils. Inter-row surface pH at the sample locations is consistently higher than the corresponding sites on the adjacent plant rows.
- There are locations throughout the trial site where pH is likely to be affecting leucaena growth, and the generally low pH throughout the site would also be affecting nutrient availability.
- Acidification is likely to be an issue at the site. In the undisturbed state, these soils typically have a higher surface pH, with a uniform to decreasing trend down the profile. The lower surface pH across the sampled locations is likely to be an effect of cropping practice, including history of fertiliser applications.
- The macronutrients—N, P, Calcium, Magnesium and Potassium, as well as measured micronutrients, except for Iron, are all found to be deficient (Shelton et al., 2021). Available sulphur (S) is deficient across all surface samples however, it exceeds 10 mg/kg in the subsoils, which is considered sufficient for leucaena.

- Concentrations of available N are more uniform between analysed locations than P and other nutrients. This is likely due to the influence of leucaena as a nitrogen fixing legume. Surface P levels vary considerably between the plant row and the inter-row at most sampling locations, likely due to the recent pattern of P fertiliser applications (higher rates of P applied to the plant rows).
- Electrical conductivity (EC) is found to be at moderate levels at the surface but is low or negligible throughout the subsoil.
- The reserves of both N and P (Total N and P) appear to be high, however available N and P are considered deficient due to limited availability from these reserves. Given the influence of leucaena as a nitrogen fixing legume, available N should not be a critically limiting element across the trial site. However, the availability of P will be a major fertility constraint.
- Addressing the low pH, and actions to avoid or reverse acidification of the trial site are critical to improving P availability.
- The phosphorus buffer index (PBI) indicates the P fixing or sorption capacity of the soil influencing P availability. PBI is low in the surface samples, with negligible effect on P availability. However, PBI increases to high levels in the subsoils, necessitating P applications of 2-3 times the ordinary rate to meet plant needs from the subsoil. It appears that stratification of applied P fertiliser is also occurring.

4.3.2.4 Soil moisture holding capacity

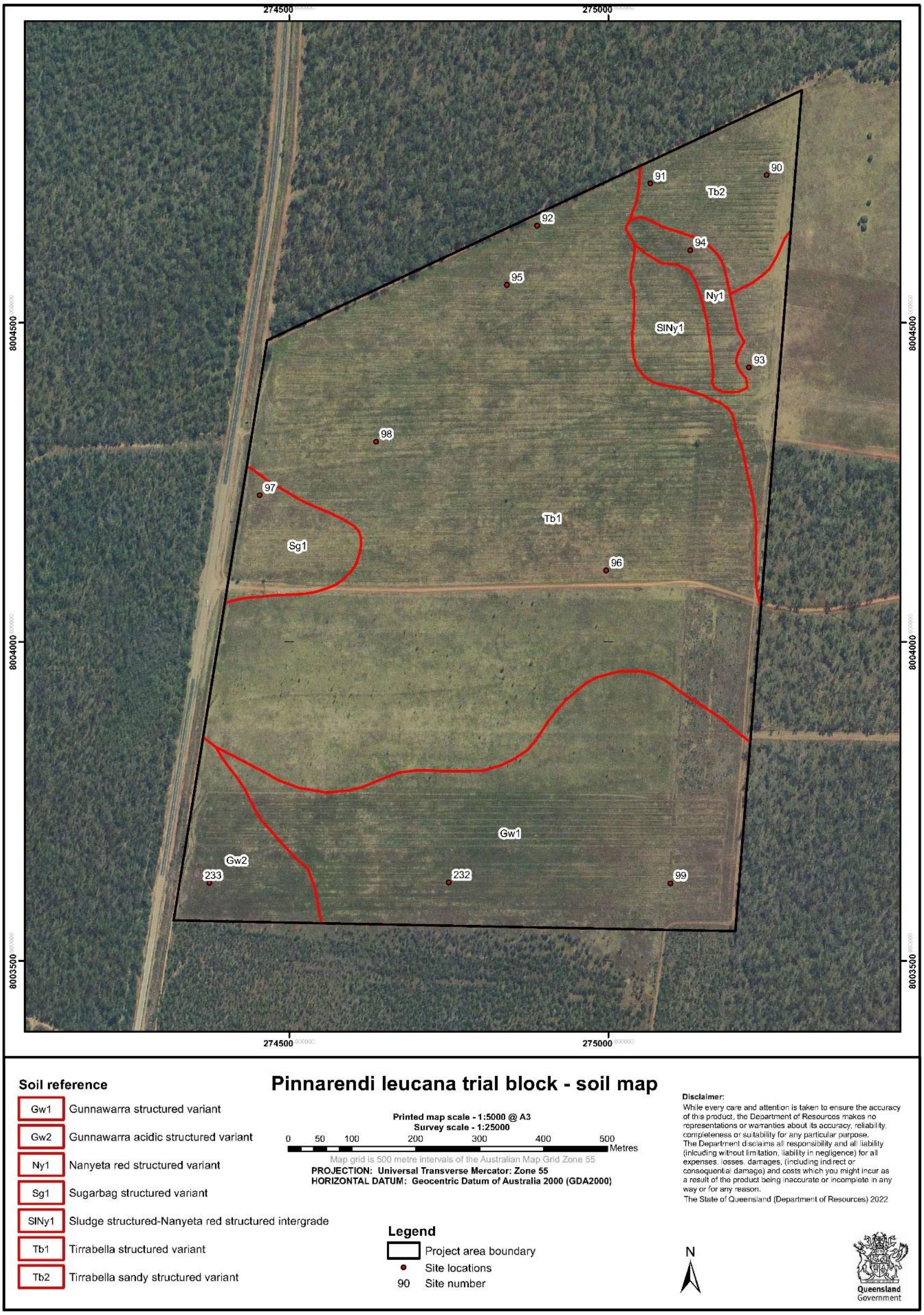
The laboratory analytical results allowed the calculation of plant available water content (PAWC) for the six analysed samples. The results of these calculations are in Table 41, which shows the PAWC at 0.6 m and 1.2 m for each site. For leucaena, soils should have a capacity to store at least 100 mm of soil moisture in the top 1 m of soil profile (Shelton et al., 2021). The results show this would be achieved across most of the trial site. However, the calculations do not take into account the gravel or nodular content of soils; the high Iron/Manganese nodule content of some sites are likely to have a lower PAWC than indicated.

The soils at the site do not have a high soil moisture holding capacity, will dry out reasonably quickly following rainfall inputs and will not sustain adequate moisture supply through the dry season. In hot conditions, typical evapotranspiration rates for this locality mean the indicated PAWCs would last only a few weeks, slightly longer during cool periods. While Leucaena can access soil moisture from deeper than the 1.2-1.6 m of described profile depth, observations suggest the overall depth of soils may not be much deeper. Depth of soil will be variable across the trial site however, the top of the C horizon (weathered substrate) was encountered at some sites before 1.5 m.

Table 42. Calculated plant available water capacities (PAWC) at Pinnarendi trial site.

Site No.	*Profile depth sampled (m)*	*PAWC to 0.6 m (mm)*	*PAWC to 1.2 m (mm)*
90	0 - 1.35	80	120
95	0 - 1.50	78	124
96	0 - 1.50	80	120
97	0 - 1.40	70	108
98	0 - 1.60	82	126
232	0 - 1.30	78	123

Figure 35. Pinnarendi trial site soil map.



4.3.3 Psyllid incidence

No psyllid activity or damage was observed at the site from November 2017 until early May 2018. With the 2018 infestation, psyllid populations and associated damage were low compared to the 2017 attack when leucaena was still in the establishment phase. Nonetheless, monitoring as per 3.3.3. was implemented with damage assessments conducted four times up to early September 2018 when psyllids became inactive at the site. The paddock average ratings by cultivar from monitoring in 2018 are presented in Table 42 which shows consistently higher psyllid damage and occurrence in Wondergraze compared to Redlands. Damage from this infestation peaked in June and there were no lasting effects from the infestation after psyllid numbers declined.

Table 43. Psyllid rating data from leucaena at Pinnarendi during 2018 (not analysed).

Date	*Average psyllid incidence/damage – damage ratings from Table 9 (Wheeler, 1988)*									
	P1 W'Grz	*P2 R'lands*	*P3 W'Grz*	*P4 R'lands*	*P5 R'lands*	*P6 W'Grz*	*P7 W'Grz*	*P8 R'lands*	*Overall W'Grz*	*Overall R'lands*
8/5/18	2.6	0.8	3.0	0.6	3.0	3.8	1.9	0.1	**2.8**	**0.4**
7/6/18	3.6	0.2	3.4	1.9	1.8	4.4	3.4	0.2	**3.7**	**1.5**
26/7/18	2.0	0.9	2.9	0.7	0.7	1.8	0.3	0.0	**1.8**	**0.6**
30/8/18	n/a	n/a	n/a	n/a	0.4	1.7	0.9	0.3	**1.3**	**0.4**

For the rest of the grazing period (up to August 2022) there was no significant or sustained psyllid activity at the site until June 2022. Whilst psyllids were observed in every year (particularly on Wondergraze), populations were low, damage was rarely significant and formal assessment of damage (as per 3.3.3) was not implemented. In 2022, psyllids were first observed in late May and populations slowly increased through to removal of fourth cohort cattle in early September. From late August, extensive psyllid damage to Wondergraze was clearly noticeable at the site but Redlands was untouched. Had replicated grazing been conducted at this time, it is expected that a significant difference in animal performance between Wondergraze and Redlands would have been measured. Timing of psyllid occurrences and associated effects at the site after September 2018 are summarised in Table 43.

Whilst there was no psyllid damage of consequence at Pinnarendi during replicated grazing at Pinnarendi, psyllids did cause substantial damage to Redlands plantings at sites in north Queensland during 2020 and 2021. These included sites on the WTC, and sub-coastal sites on the Atherton Tablelands and in the Herbert River valley. Infestations and damage were mainly from July to October. Whilst not formally assessed, damage (leaf loss/spoilage) in 2020 was estimated to be at least 50%, with some areas completely defoliated or spoiled. Notably, some paddocks had more heavily affected areas, typically on the south-east side (prevailing wind direction). Also, areas which were being actively grazed by cattle, had less damage (sometimes little) compared to areas which were being spelled (un-grazed). In 2021, there was also psyllid damage to Redlands at these sites, but to a lesser degree.

Table 44. Psyllid occurrence and damage at Pinnarendi (2018-2022); damage ratings from Table 9.

Date	*Occurrence*	*Comment*
2018		
8 May	Wondergraze Redlands	Minor damage (rating 2.8) Psyllids present but no noticeable damage (rating 0.4)
7 June	Wondergraze and Redlands	Significant damage (rating 3.7) Slight damage (rating 1.5)
26 June	Wondergraze and Redlands	Slight damage (rating 3.7) Psyllids present but no noticeable damage (rating 1.5)
30 July	Wondergraze and Redlands	Slight damage (rating 1.3) Psyllids present but no noticeable damage (rating 0.4)
2019		
May	Wondergraze only	Low populations, no significant damage (rating 1)
June	Wondergraze only	Low populations, no significant damage (rating 1)
2020		
May	Wondergraze only	Low populations, no significant damage (rating 1)
June	Wondergraze only	Low populations, no significant damage (rating 1)
2021		
Second week April	Wondergraze only	Slight damage (rating 2); psyllid populations declined by 14 April in conjunction with weather related leaf drop
2022		
Late May	Wondergraze Redlands	Slight damage (rating 2) Psyllids present but no noticeable damage (rating 1)
June	Wondergraze only	Minor damage (rating 3); reducing to slight damage (rating 2) by end of month
July	Wondergraze only	Minor damage (rating 3)
August	Wondergraze Redlands	Minor damage (rating 3) increasing to heavy damage to 25% of area (rating 7-8) and moderate damage to balance of area by end of the month (rating 5) Psyllids present but no noticeable damage (rating 1)
September	Wondergraze Redlands	Heavy to moderate damage affecting >75% of area by second week of September (rating 7-8). Psyllids present but no noticeable damage (rating 1)

4.3.4 Leucaena productivity

4.3.4.1 Seasonal growth observations

Leucaena growth at Pinnarendi is principally a result of weather conditions in each year. The typical pattern of productivity starts with a growth response from sustained rainfall during the wet-season months of December-March. Typically, this occurs in early January with at least 50 mm of rainfall received over a 3-day period occurring by 5 January in 70% of years ('green-day') at nearby Meadowbank. In about 30% of years, this occurs by the end of November from seasonal storms received before the wet-season monsoon. New growth during the wet-season is not all eaten by cattle and a significant forage 'bank' of leucaena develops (Fig. 36).

Once regular wet-season rainfall stops (usually by April), leucaena productivity progressively decreases even if weather conditions are mild. This occurs due to lower soil moisture levels. By June, leucaena productivity at the site is usually low due to cooler weather and drier conditions. In most years, cattle consumed most of the available yield by June-July with new leaf production checked. The August-October period is characterised by the lowest leucaena productivity at the site – particularly if there are periods of cold weather (with light frosts in some years).

Of note, in 2022 there was unseasonably high rainfall in May (120 mm) and July (61 mm). This extended the period during which soil moisture was not limiting and leucaena remained productive until early July whilst temperatures remained mild. Cold weather in early July eventually checked new leaf production (despite good soil moisture), but productivity resumed with warmer conditions later in the month.

Typically, warmer weather becomes sustained in September, becoming warm-hot in October. Even without useful rainfall, leucaena responds with a modest flush of new growth which provides valuable 'green pick' for cattle (Fig.37). However, without rainfall, this growth was not sustained and did not result in any excess forage (unless paddocks were spelled for 3-4 weeks). Without rainfall, cattle consume this material and leucaena returns to a dormant state.

However, new leaf production occurs in response to any useful rainfall (at least 10-15 mm) at this time of year – typically responding within a week of rain being received. This results in a higher production of new leaf compared to the September 'flush' but unless follow-up rainfall is received, soil moisture is depleted and leucaena growth is not sustained. Without follow-up rainfall – this pattern of new growth followed by low productivity is repeated 2-3 times with intermittent rainfall events.

Observations of leucaena growth at the site for each calendar year are given in detail in Appendix 9.6.

Figure 36. Leucaena growth during wet season exceeded consumption by cattle (photo taken early January).

Figure 37. Green leaf produced in September-October with warmer weather but no rain.

4.3.4.2 Yellow leaf and sub-optimal growth

Sub-optimal leucaena growth towards the end of the main growing season (by early March) was observed at Pinnarendi in all years from and including 2018. Typically, both Redlands and Wondergraze have good growth and colour at the beginning of the wet season but progressively exhibit poorer (yellow) colour as the season progresses, with some areas having relatively poor growth (Fig 38). Previously, this was attributed to poor or failed inoculation during initial establishment subsequently causing nitrogen deficiency (Lemin, 2018). This phenomenon has moderated each year (both in the extent and severity of area affected) but, was again observed in 2022. Section 4.3.6.5 (Table 46) presents results from leaf samples collected from 'green' and 'yellow' leucaena during 2020 and analysed in 2021 (Fig. 39).

Separate to the issue of generalised poor growth and colour, another consistent observation was contrasting growth (i.e., poor versus vigorous) within nearby areas. Surface soil testing (0-12 cm) conducted in May 2019 did not indicate a particular basis for contrasting growth (refer 4.3.4.1 and Table 38).

Figure 38. Typical area at Pinnarendi with poor wet season growth and yellow leaf.

Figure 39. Contrast between yellow leaf and leaf with good colour.

4.3.4.3 2022 and growth after cutting

After cutting on 3 December 2021, leucaena across the site was reshooting within 10 days. In early January 2022, one month after pruning, leucaena was 20-30 cm high (Fig. 40). By mid-February, 2.5 months after pruning), leucaena was up to 1.5 m high (Fig. 41). Shattering of stems during pruning was not harmful and promoted extra shooting which resulted in a higher number of stems re-developing from stumps than if they were cut cleanly.

Despite this, re-growth was slower than anticipated considering that weather conditions were ideal (wet and warm). This was attributed to soil fertility being limiting. By comparison, leucaena cut to 30 cm on an alluvial soil at Georgetown had regrown to about 1.5-1.8 m within six weeks (Fig. 42). There was also a subjective difference in regrowth between Redlands and Wondergraze paddocks at Pinnarendi, with Redlands recovery being patchy and slower.

Leucaena had re-grown sufficiently to allow introduction of fourth cohort heavyweight steers on 1 March 2022.

During grazing of the third cohort animals (with paddocks continuously stocked for over 12 months) observable differences emerged between some leucaena paddocks with regard to 'leafiness' and vigour. In particular, Wondergraze Paddocks (1 and 7) were superior to adjacent Redlands Paddocks 2 and 8. This was consistent with original differences in establishment success at the outset of the trial, with Paddocks 2 and 8 in particular having reduced plant density and smaller plants (Lemin, 2018). Set-stocking from fully replicated grazing exacerbated these differences and resulted in lower liveweight gains being recorded for these paddocks during the final phase of grazing third cohort animals.

Figure 40. Leucaena at Pinnarendi one month after cutting (Paddock 7, 6 January 2022).

Figure 41. Leucaena at Pinnarendi 2.5 months after cutting (Paddock 1, 15 February 2022).

Figure 42. Leucaena in Georgetown district six weeks after cutting (28 January 2022).

4.3.4.4 Leucaena yield 2019-21

Total average dry matter yields from leucaena exclosures at Pinnarendi are given in Table 44 for Redlands and Wondergraze paddocks from 2019-2021. The highest and lowest yields recorded in individual exclosures are also given.

Table 45. Average annual dry matter yields measured at Pinnarendi from 2019-2021; with highest and lowest individual exclosure yields.

Year	***Wondergraze***			***Redlands***		
	Average total yield (kg/ha ± se)	*High (kg/ha)*	*Low (kg/ha)*	***Average total yield (kg/ha ± se)***	*High (kg/ha)*	*Low (kg/ha)*
2019	**680 ± 183**	1,072[P7]	327[P3]	**263 ± 87**	495[P4]	49[P8]
2020	**1,418 ± 201**	1,946[P6]	993[P3]	**872 ± 168**	1,201[P4]	379[P8]
2021	**1,341 ± 181**	1,603[P6]	1,110[P3]	**786 ± 132**	1,205[P5]	376[P2]
2021 corrected for pilferage	***1,548 ± 183***	*1,811[P6]*	*1,198[P1]*	***1,002 ± 131***	*1,362[P5]*	*665[P2]*

[P#] indicates paddock in which yield was recorded

Over three years, the average yield of Redlands was about 55% lower than for Wondergraze reflecting paddock differences at the site. In particular, Redlands Paddock 8 consistently recorded the lowest yields (except in 2021), although yields recorded in Paddock 8 were likely an underestimate of actual paddock yield due to siting of the exclosures.

Yields were lowest in 2019, due to dry conditions. Despite high wet season rainfall in 2021, recorded yields were lower than 2020 due to leaf drop in early April 2021 after a period of relatively dry weather (Appendix 9.6.3).

The ratio of leaf to stem (by weight) was lower at the end of the wet season, with an increased proportion of leaf present at the end of the year. Typically the leaf to stem ratio at the end of the main growing season was about 50:50; with a corresponding ratio of 75:25 at the end of the dry season. This is associated with vigorous structural growth during the wet season.

Site comparisons

Total average dry matter yields from leucaena at Pinnarendi (Redlands and Wondergraze combined) are given in Table 45 in conjunction with corresponding yields recorded at northern Queensland. sites nearer the coast and further inland. The highest and lowest yields recorded in individual exclosures are also given for respective sites.

Yields at the sub-coastal site in 2020 were reduced due to cold weather and associated leaf drop. Yields at the inland site showed a remarkable increase from 2020 to 2021 due to good growing conditions in 2021 and recovery of leucaena from high grazing pressure prior to erection of the exclosures. A significant proportion of yield recorded in 2021 would have been beyond the reach of grazing cattle.

Table 46. Average annual dry matter yields measured at Pinnarendi compared to commercial plantings at sub-coastal (Redlands) and inland sites (Wondergraze) during 2020 and 2021; with highest and lowest individual exclosure yields.

Year	***Pinnarendi (Wondergraze and Redlands)***			***Sub-coastal site (Redlands)***			***Inland site (Wondergraze)***		
	Average total yield (kg/ha ± se)	*High (kg/ha)*	*Low (kg/ha)*	***Average totally yield (kg/ha ± se)***	*High (kg/ha)*	*Low (kg/ha)*	***Average total yield (kg/ha ± se)***	*High (kg/ha)*	*Low (kg/ha)*
2020	**1,145 ± 145**	1,946	379	**680 ± 183**	1,072^{P7}	327^{P3}	**597 ± 104**	1,053	208
2021	**1,064 ± 130**	1,603	376	**-**	-	-	**3,248 ± 476**	5,270	1,965

4.3.4.5 Leucaena quality

Results from quality analysis of 51 leucaena samples collected over the period 2019-21 are given in Appendix 9.8. Averaged values for selected groups of samples are discussed below.

Average results for samples of leaf exhibiting 'yellow' (poor) or 'green' (good) colour are in Table 46. Average crude protein was 18.5% in yellow leaf versus 15.5% for green leaf, whereas other dietary attributes were similar. These samples are a combination of Redlands and Wondergraze at the site.

Table 47. Dietary attributes of green and yellow leucaena leaf sampled at Pinnarendi in March 2019 (Redlands and Wondergraze).

Material analysed	***Crude protein (%)***	***Acid digestible fibre (%)***	***Neutral digestible fibre (%)***	***Lignin (%)***	***Non-fibre carbohydrate (%)***	***Total digestible nutrients (%)***	***Metabolisable energy (MJ/kg)***	***Relative feed value***
All green leaf	18.5	24.7	30.4	11.7	40.3	62.0	9.7	217
Std. error	0.4	0.8	1.7	0.6	1.5	1.1	0.2	13.9
All yellow leaf	15.5	26.0	30.2	13.2	43.6	60.5	9.5	218
Std. error	1.3	1.6	2.0	0.9	1.2	1.7	0.3	18.1

Average results for leaf, green stem (≤ 6 mm) and immature (green) pod are in Table 47. These are from the Pinnarendi trial site only and are for Redlands and Wondergraze combined. These samples were analysed for interest, since the leaf-stem fractions were separated anyway for determining the leaf stem ratio of harvested samples. There was only one sample only of green (immature) pod. Leaf samples had a higher dietary quality than stem samples. Immature pod had high protein levels (comparable with leaf) whereas other dietary parameters were about mid-way between leaf and stem.

The Relative Feed Value (RFV) is an index used to compare potential energy intake of forages and does not account for protein intake. Forage RFV's are ranked against the digestible dry matter intake of full bloom lucerne (with RFV = 100, acid digestible fibre (ADF) = 41 and neutral digestible fibre (NDF) = 53). Average RFV's measured for leucaena leaf, green stem and immature pod were 223, 78 and 107, respectively.

Table 48. Dietary attributes of forage fractions from leucaena at Pinnarendi (Redland and Wondergraze samples combined).

Pinnarendi (Redlands/Wondergraze)	***Crude protein (%)***	***Acid digestible fibre (%)***	***Neutral digestible fibre (%)***	***Lignin (%)***	***Non-fibre carbohydrate (%)***	***Total digestible nutrients (%)***	***Metabolisable energy (MJ/kg)***	***Relative feed value***
Leaf	17.2	23.6	29.9	11.1	42.1	62.3	9.8	223
Std. error	1.4	1.1	1.4	0.7	2.4	0.7	0.1	13.3
Green stem[A] only	7.0	51.0	60.2	15.1	21.9	47.2	6.2	78
Std. error	1.5	10.0	11.4	2.9	4.6	8.9	1.2	16.6
Immature (green) pod only	17.0	37.7	51.8	11.1	20.4	55.0	7.8	107
Std. error	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[A] ≤ 6 mm diameter

Average results for samples of 'as grazed' leucaena are given in Table 48 for both Redlands and Wondergraze at Pinnarendi and for samples taken from commercial leucaena at sub-coastal and inland sites in north Queensland (Redlands and Wondergraze respectively). The number of samples for each cultivar and site were too low to make conclusive distinctions. However, crude protein levels were lower at Pinnarendi compared to the other sites, and Redlands had lower dietary quality than Wondergraze (but still high). Non-Fibre Carbohydrate (NFC), a key measure of pasture quality, averaged 32% and 41% for Redlands and Wondergraze, respectively. For comparison, high quality dairy pastures grown on the Atherton Tablelands have NFC's around 40%. Table 49 compares key dietary parameters measured for Redlands and Wondergraze (average of all 'as grazed' samples from all sites), with the range typically measured for 'high' and 'low' quality Australia silages.

Table 49. Dietary attributes of Redlands and Wondergraze leucaena 'as grazed' at three sites in north Queensland.

'As grazed'	*Crude protein (%)*	*Acid digestible fibre (%)*	*Neutral digestible fibre (%)*	*Lignin (%)*	*Non-fibre carbohydrate (%)*	*Total digestible nutrients (%)*	*Metabolisable energy (MJ/kg)*	*Relative feed value*
Pinnarendi - Redlands	14.2	32.2	40.8	12.6	34.2	57.0	8.6	153
Std. error	0.6	3.7	5.4	0.6	5.7	2.6	0.6	28.6
Pinnarendi - Wondergraze	14.3	30.4	33.8	11.3	41.1	60.5	9.4	185
Std. error	0.0	5.1	4.4	2.1	4.3	3.5	0.7	34.5
Sub-coastal - Redlands	18.3	31.9	41.3	12.0	29.7	57.5	8.7	150
Std. error	1.0	5.0	6.3	0.2	5.3	2.5	0.6	32
Inland alluvial - Wondergraze	18.5	24.5	30.0	9.9	40.8	63.0	9.9	221
Std. error	1.8	3.3	3.1	0.9	1.3	2.0	0.4	31

Table 50. Range of dietary parameters in Australian silages compared with average values measured for Redlands and Wondergraze leucaena in north Queensland.

Quality measure	***Low quality silage[A]***	***High quality silage[A]***	***Redlands leucaena***	***Wondergraze leucaena***
Metabolisable Energy (MJ/kg DM)	6.7	11.3	8.6	9.7
Digestibility (%)	42	72	57	62
Neutral Detergent Fibre (%)	72	32	41	32
Acid detergent fibre (%)	47	25	32	27
Crude Protein (%)	8.5	10.8	16.3	16.4

[A] source: Futurebeef.com.au

4.3.5 Interrow pasture productivity

4.3.5.1 2019 assessments

Inter-row pasture biomass estimated from visual assessments of Paddocks 1-4 in March 2019 are given in Table 50. They ranged from 4,400 to 5,000 kg/ha DM a with an average of 4,650 kg/ha DM and comprised about 60% grasses, 35% legumes and 5% other species.

Table 51. Estimated yields (by visual assessment) of inter-row pasture for Paddocks 1-4 at Pinnarendi leucaena trial, 5 March 2019.

Visual estimate	*Paddock*			
	1	**2**	**3**	**4**
Yield (kg/ha DM)	**4,800**	**4,400**	**5,000**	**4,400**
Legume (%)	*40*	*30*	*36*	*35*
Grass (%)	*58.5*	*69*	*61*	*57*
Other (forbs, weeds etc.) (%)	*1.5*	*1*	*3*	*8*

A comparison of actual biomass from quadrats cut in Paddock 1 to estimated biomass from visual assessment of the same quadrats is given in Table 51. The data showed an underestimation of yield of around 15%. The large difference with quadrat 1 is anomalous. This quadrat contained a large component of stylo with woody stem which substantially increased the result for dry matter content.

Table 52. Comparison of estimated yield and composition (by visual assessment) and actual values from quadrat cuts: Paddock 1, Pinnarendi leucaena trial, 5 March 2019

Quadrat[A] no. (Paddock 1)	*Yield* (kg/ha DM)		*Difference from estimate* (%)	*Composition (%)* Grasses : Legumes	
	Estimate	***Actual***		***Estimate***	***Actual***
1	6,000	11,250	+ 87	20 : 80	23 : 77
2	4,500	5,080	+11	30 : 70	35 : 65
3	4,000	4,640	+16	60 : 40	66 : 34

[A] area of quadrat = 1 m^2

Results of visual assessments of residual pasture biomass across all paddocks in mid-December 2019 (before any significant rain had been received) are given in Table 52. Most species were hayed off and dormant. Residual standing pasture was 1,100-1,600 kg/ha DM. Assuming an overall start-of-season yield for all paddocks of 5,500 kg/ha DM (inferred from Table 50 and 51), and an end-of season yield for all paddocks of 1,450 kg/ha DM (averaged from Table 52); estimated pasture utilisation was 70-75%.

Table 53. Estimated yields (by visual assessment) of inter-row pasture at Pinnarendi leucaena trial, 16 December 2019.

Paddock	*Estimated yield (kg/ha DM)*	*Comment*
1	1,620	lots of spear grass remaining
2	1,600	lots of spear grass remaining
3	1,280	Seca with some leaf
4	1,420	Seca with some green leaf
5	1,550	cattle just removed
6	1,350	cattle just removed
7	1,100	Seca with green leaf
8	1,500	Seca with no leaf
1-8	n/a	***Species noted:*** Legumes: wynn cassia, stylo (Seca, Verano) Grasses: urochloa, black spear, kangaroo, Rhodes
9 (buffel)	1,450[A]	***2 quadrats cut:*** No. 1 actual = 1,248 kg/ha DM No. 2 actual = 1,552 kg/ha DM

[A] made with reference to photo standard

4.3.5.2 Pasture exclosures and residual paddock biomass yields 2020

Pasture assessment results for 2020 are shown in Table 53. Overall (averaged) dry matter yield at the end of the wet season was estimated at 4,300 kg/ha comprising about 65% grasses and 35% legumes (with weeds, forbs and herbage comprising < 1%). The overall (averaged) difference between Redlands and Wondergraze paddocks was not considered significant (within margin of error). The measured pasture yield in the improved pasture paddock was higher than for the leucaena paddocks and this was likely the actual case. However, the measured contribution of legumes in the improved pasture paddock was lower than for the leucaena paddocks (17% versus 35%) and this was considered to be an underestimate.

For the end of year-end assessment, all species were hayed off and/or dormant. Residual standing pasture was about 1,700 kg/ha DM (Table 53). Assuming an overall start-of-season yield for all paddocks of 4,300 kg/ha DM, indicative pasture utilisation was about 60% with some additional utilisation between the assessment date in early November and new-season pasture growth from rain in mid-December.

Table 54. Estimated dry matter yield and utilisation of leucaena inter-row pasture and improved pasture paddock at Pinnarendi leucaena trial over 2020.

Paddock	***End of wet season pasture yield from grazing exclosures (April 2020)*** *kg/ha DM*	***Composition Grasses : Legumes : Other*** *(% by weight)*	***End of dry season residual pasture yield from visual estimate (November 2020)*** *(kg/ha DM)*	***Indicative pasture utilisation*** *(%)*
P1 P3 P6 P7	4,107 3,711 3,674 4,924	90 : 10 : <1 65 : 35 : <1 60 : 40 : <1 35 : 65 : <1	1,700 1,700 1,800 1,600	
Wondergraze overall	***4,104 ± 304***	***63 : 37 : < 1***	***1,700***	***59***
P2 P4 P5 P8	4,235 4,250 4,710 4,483	90 : 10 : <1 90 : 10 : 0 40 : 55 : 5 60 : 40 : <1	1,600 1,800 1,850 1,500	
Redlands overall	***4,458 ± 252***	***70 : 29 : 1***	***1,688***	***62***
P9 - improved pasture	***4,710 ± 281***	***83 : 17 : 0***	***1,900***	***60***

4.3.5.3 Pasture exclosures and residual paddock biomass yields 2021

Pasture assessment results for 2021 are shown in Table 54. Overall (averaged) dry matter yield at the end of the wet season is estimated to have been 6,100 kg/ha comprising about 10% grasses, 80% legumes and 10% weeds. The overall (averaged) difference between Redlands (6,380 kg/ha) and Wondergraze (5,900 kg/ha) was not considered significant (within margin of error). However, the higher pasture yield measured in the improved pasture paddock (8,905 kg/ha DM) relative to the leucaena paddocks, accorded with observations on site.

After cattle were removed in August, residual standing pasture yield was about 1,750 and 2,500 kg/ha DM for the leucaena and improved pasture paddocks, respectively. Utilisation based on dry matter yields at the end of the wet season was about 70%. This was higher than for the previous year (estimated at about 60%) and was a consequence of higher pasture yield at the end of the wet season rather than higher grazing pressure.

Table 55. Estimated inter-row pasture dry matter yield and utilisation at Pinnarendi leucaena trial over 2021 (leucaena paddocks and inter-row pasture paddock).

Paddock	***End of wet season pasture yield from grazing exclosures (April 2021)*** *kg/ha DM*	***Composition Grasses : Legumes : Other*** *(% by weight)*	***End of dry season residual pasture yield from visual estimate (August 2021)*** *(kg/ha DM)*	***Indicative pasture utilisation*** *(%)*
P1 P3 P6 P7	6,093 5,100 6,317 6,100	71 : 17 : 12 92 : 0 : 8 79 : 6 : 15 83 : 17 : 0	1,400 1,950 1,800 1,950	
Wondergraze overall	***5,903 ± 388***	***81 : 10 : 9***	***1,775***	***70***
P2 P4 P5 P8	5,223 6,047 8,833 5,410	95 : 2 : 3 72 : 3 : 25 80 : 8 : 12 90 : 7 : 3	1,500 1,600 1,900 1,850	
Redlands overall	***6,378 ± 515***	***84 : 5 : 11***	***1715***	***73***
P9 - improved pasture	***8,905 ± 1,873***	***71 : 27 : 3***	***2,500***	***72***

4.3.5.4 Commentary

The overriding feature of the inter-row pasture at the site has been an observable increase in weeds and a decline in grass species. This was beginning to be obvious in January 2021, when purple top (*Verbena bonariensis*) was dominating some areas of the pasture to a greater extent than previously during the trial. Whilst this could have been a seasonal phenomenon it was more likely the result of grazing pressure. Grazing pressure had been constant, with no significant spelling of paddocks since cattle were introduced in April 2019.

This was confirmed by measurements from the pasture exclosures where average grass dry matter composition declined from about 65% in 2020 to less than 10% in 2021. This result is exaggerated because annual cutting within the pasture exclosures has resulted in regrowth of pasture species that were longer representative of the 'grazed' inter-row areas at the site. More realistically, grass composition across the site from visual estimations of residual pasture at the completion of grazing in August 2021 is likely closer to 35-40%. Nonetheless, this is still a significant decline and was attributed to continuous stocking at the site over almost three years. This resulted in grass species being supplanted by legumes – predominantly wynn cassia (*Chameacrista rotundifolia*) and weeds (*Hyptis suaveolens, Praxelis clematidea, Sida rhombifolia*), but also *Stylosanthes spp.*

The situation is similar but not as pronounced in the improved pasture paddock, where wynn cassia is becoming dominant. The principle cause here is likely a result of pasture dieback rather than grazing which has been less intensive than in the leucaena paddocks. Pasture dieback significantly afflicted buffel grass (cv. USA) in this paddock starting in 2019.

To encourage re-colonisation by grasses, the site was wet-season spelled in conjunction with leucaena pruning in December 2021. There were no cattle at the site for three months from December 2021 to March 2022.

4.3.6 Site management activities

4.3.6.1 December 2021 pruning

As planned, leucaena at the site was pruned after removal of the third cattle cohort. Pruning was conducted within a 12 hr period on 3 December 2021. Pruning was originally intended after completion of grazing of the third cohort once rain had promoted sustained leucaena growth. The grazing trial was completed 2 August and Spyglass animals were removed on the same day. Rainfall in October and early November promoted leucaena growth which would have allowed pruning by mid-November (regardless that the Pinnarendi steers remained in the trial paddocks). However, the contractor was unavailable. This forfeited 3-4 weeks of recovery growth during the main growing season prior to the planned re-introduction of cattle in March 2022.

For the site as a whole, the average pruning speed was 5 km/hr (5 ha/hr). In areas with leucaena >3 m high (about 40% of the site) travel speed was reduced to 2.5-3 km/hr. Maximum travel speed was about 6 km/hr for small leucaena. The overall cost of pruning on a wet-hire basis (fuel and operator) was $50/ha including GST but excluding transport and travel related costs. If leucaena had been uniformly large across the site, the cutting cost would have increased to $65-70/ha including GST.

The mulching machine used resulted in almost all leucaena stems being completely cut through with only a small amount of residual (un-mulched) material remaining adjacent to the leucaena rows. Leucaena was cutdown to about 10-20 cm with stems were shattered almost to ground level in most cases; particularly stems >30 mm in diameter (Fig. 43).

Figure 43. Leucaena cut at Pinnarendi, 3 December 2021.

4.4 Economic analyses

4.4.1 Redlands versus Wondergraze cost-benefit analysis

Modest anticipated productivity losses (liveweight gain) from psyllid damage would be sufficient to justify the higher cost of planting the psyllid tolerant Redlands cultivar (3.4.1, Table 13). At a sale price of $2.85 liveweight, avoiding a 16% productivity loss in any one year would offset the higher cost of planting Redlands (or two years with 8% losses). Similarly, at a price of $4.80, avoidance of a 10% productivity loss in a single year would be sufficient.

Although actual reductions in liveweight gain incurred from psyllids were not measured, it is usual for psyllids to defoliate Wondergraze in northern coastal and sub-coastal environments, resulting in damage to >50% of foliage. Liveweight gains would be reduced from such attacks. Notably, during 2020 (and to a lesser degree in 2021) coastal and sub-coastal Redlands plantings were significantly affected by psyllids with leaf damage and loss of plant productivity. Nonetheless, if Wondergraze had been planted instead, the magnitude and duration of losses would certainly have been greater. In August-September 2022, Wondergraze at Pinnarendi was significantly damaged by psyllids, whereas Redlands was unaffected. Had replicated grazing been conducted at this time, it is highly likely that Redlands would have recorded higher ADG's than Wondergraze over a 2-3 month period.

4.4.2 Redlands versus Wondergraze Gross Margin Analysis

The results from the Redlands versus Wondergraze Gross Margin Analysis are given in Table 55. As detailed in 3.4.2.3, for Wondergraze, the expected effect of psyllids is a $21 kg/head/year reduction in liveweight gain which translates to a $26 /ha/year reduction in gross margin. This is based on the probability of psyllid occurrence over a 10 year period, which expects the annual liveweight gain of steers on Wondergraze to be 199 kg, 21 kg less than for Redlands (220 kg) which is assumed to be unaffected by psyllids.

This translates to a significant difference in gross margin between Redlands and Wondergraze (Table 55). The gross margin for the base case native pasture was $25/ha. The gross margin for Wondergraze is $60/ha which is 140% higher; for Redlands it is $86/ha and 250% higher. This analysis is predicated on psyllid damage estimated by project investigators however, this assumption requires validation and should be viewed as an investigatory analysis, not a conclusion.

Table 56. Gross margin analysis of native pasture and leucaena on a red-earth soil in sub-coastal Queensland.

Steer cohort	***Native pasture (base case)***	***Redlands***	***Wondergraze***
Number purchased	161	279	279
Starting weight	180	180	180
Starting price	$3.02	$3.02	$3.02
Closing weight	300	400	379
Closing price	$2.85	$2.85	$2.85
Number of days	365	365	365
Weight gain per day	0.329	0.603	0.547
Livestock sales	**$127,996**	**$295,743**	**$280,579**
Livestock purchases	$87,557	$151,729	$151,729
Freight in	$2,635	$4,565	$4,565
Freight out	$3,375	$9,865	$9,865
Treatment expenses	$8,457	$10,861	$10,861
Selling expenses	$9,269	$19,759	$19,001
Forage growing costs	$0	$48,230	$46,929
Total expenses	***$111,293***	***$245,010***	***$242,951***
Gross margin	***$16,703***	***$50,733***	***$37,628***
- after interest	*$12,325*	*$43,147*	*$30,042*
- after interest ($/ha)	***$25***	***$86***	***$60***
Change gross margin (%)	-	*250%*	*144%*

4.4.3 Gross Margin Analysis of Redlands adoption on the Wet Tropical Coast

The gross margins for the four production scenarios for improved pasture and Redlands adoption on the WTC are given in Table 56. In the scenario where leucaena is established into an existing grass pasture system, gross margins under the assumptions used, increase from $97/ha to $491/ha. Likewise, when leucaena is established with grass (at the same time) into country previously cropped for sugarcane, the gross margin is $491/ha versus $35/ha if only grass was established.

With both scenarios, these are substantial extra returns producing an additional $400-450/ha in revenues. This is driven by the high stocking rates, whereby increases in liveweight gain result in large increases in kilograms of livestock sold. Considering that the analysis is based on an unsubstantiated ADG of 0.6 kg when leucaena is included, additional analyses were performed to determine the annual liveweight gain (and corresponding ADG) required to break even when establishing leucaena i.e., where the gross margin ($/ha) is $97 and $35 for the ‘existing improved pasture to Redlands’ and ‘sugarcane to improved pasture with Redlands’ respectively. This weight gain is close to 165 kg (ADG = 0.45) in both cases. This is a relatively modest increase from the baseline scenario (an existing grass pasture) which has published annual liveweight gains of about 155 kg.

Table 57. Gross margin analysis for grass and grass-leucaena (Redlands) pastures systems on the Wet Tropical Coast (250 ha).

Steer cohort	***Sugarcane to improved pasture***	***Existing improved pasture***	***Existing improved pasture to Redlands***	***Sugarcane to improved pasture with Redlands***
Number purchased	747	747	699	699
Starting weight (kg)	250	250	250	250
Starting price	$3.70	$3.70	$3.70	$3.70
Closing weight (kg)	405	405	469	469
Closing price	$3.25	$3.25	$3.25	$3.25
Number of days	365	365	365	365
Weight gain per day	0.425	0.425	0.600	0.600
Livestock sales	**$919,541**	**$919,541**	**$996,427**	**$996,427**
Livestock purchases	$691,641	$691,641	$647,198	$647,198
Freight in	$7,863	$5,897	$7,358	$7,358
Freight out	$15,927	$15,927	$17,388	$17,388
Treatment expenses	$20,244	$20,244	$18,943	$18,943
Selling expenses	$59,356	$59,356	$62,340	$62,340
Forage growing costs	$81,283	$67,738	$77,712	$87,986
Total expenses	**$876,313**	**$860,802**	**$830,938**	**$841,213**
Gross margin	***$43,228***	***$58,739***	***$165,489***	***$155,214***
- after interest	*$8,646*	*$24,157*	*$133,129*	*$122,854*
- after interest ($/ha)	***$35***	***$97***	***$533***	***$491***

Whilst these indicated additional returns from leucaena would appear to strongly support adoption, there are some cautionary points:

- The outcomes are based on high stocking rates which are likely not sustainable, and are not recommended.
- There is a diversity of soil types in the WTC area; liveweight gain results from QDPI trials were on good quality soils and would not be attained in soils with lower fertility or with less favourable characteristics.
- This analysis was based on 3-year prices (2019-2021) which have been well above long-term prices.
- Psyllids have caused damage to Redlands on the WTC in existing commercial plantings. Whilst not measured, productivity losses are likely to reduce annual liveweight gains compared to if there was no psyllid damage.
- Actual productivity of leucaena on the WTC is not documented; assumed ADG of 0.6 kg may be optimistic with regard to the high stocking rates used.
- Anecdotally, existing growers of Redlands have expressed some disappointment with cattle performance and issues with weed competition generally.

4.5 Extension and adoption

4.5.1 CSIRO ADOPT modelling

4.5.1.1. Mareeba session

Key measures from the initial ADOPT process in Mareeba where the 'innovation' was *leucaena to boost profitability in the north* and the 'target population' was *landholders with cleared country, free draining fertile soils and annual rainfall >700 mm (coastal or inland)*; were:

- 'time to peak adoption' (TPA) was 13.3 years (with 50% adoption in about six years);
- 'peak adoption level' (PAL) was predicted to be 88%, with 33% adoption after five years and 80% adoption in 10 years.

The most sensitive factor (question) to the PAL was the 'proportion of target farms where there is a major enterprise that could benefit from the innovation'. The group response was for a majority of target farms to have a major enterprise that could benefit. If only half the target farms are in this category, then adoption would fall by 13% to 75%. If almost all target farms were in this category, then adoption would increase by 6% to 94%.

The most sensitive factor (question) to the TPA was 'what proportion of the target population will need to develop substantial new skills and knowledge to use the innovation'. The group response was that a majority of the population will need new skills and knowledge'. If almost all of the population are in this category, then time to peak adoption increases by two years to 15.3 years. If only half the population are in this category, then time to peak adoption reduces by 1.8 years to 11.5 years.

Discussion

The consensus of the group was that the TPA and PAL predicted by the model were optimistic. Based on the history of leucaena adoption in central Queensland, it was felt that the PAL would likely be less than 50% and that the TPA would take decades (20-30 years). This resulted in some scepticism about the usefulness of the ADOPT tool in predicting outcomes for the northern beef industry.

As a result, Gerry Roberts followed up literature and contacted one of the developers of ADOPT at CSIRO. The following points were made about ADOPT:

- whilst first developed for mixed farming systems, it is based on adoption data from other farming types;
- it has been used successfully in extensive grazing systems;
- it can be used for both individual innovations and management practice change;
- with complex management practices, identify steps to achieve the outcome and use ADOPT with each step;
- need people who know the target producer population as a 'reality check';
- 'inertia' in adopting changes to management practice is often due to a lack of clear benefits in 'ease and convenience' for a producer.

In future, it was decided that more credible ADOPT outputs for leucaena adoption in north Queensland might be obtained by splitting the target population into 'coastal' and inland producers.

4.5.1.2 Rockhampton session

The principle predictions from the ADOPT process conducted in Rockhampton are given in Tables 57 and 58.

In north Queensland, the TPA for the three variations of target population was consistently about 20 years. The PAL was about 45% for coastal and inland areas reducing to 25% PAL for sub-coastal areas. These figures were viewed as more credible than results from the initial ADOPT process which predicted a TPA of 13 years and a PAL of 88%.

For north Queensland, some consistent factors emerged as more likely to be important in influencing PAL:

- profit motivation of producers;
- potential for extra mid-term and longer term profit;
- potential to reduce enterprise risk;
- potential for environmental advantage (or harm);
- additional management implications for the enterprise.

For the north Queensland target populations, the TPA of the innovation was also influenced by consistent factors all of which were around knowledge and experience i.e., skills and knowledge required, relative complexity, observability, and ability to be trialled. Generally however, TPA is not as sensitive to these factors as compared to factors which mostly influenced the PAL.

For the central Queensland target population, the TPA was considerably lower at 11 years and the PAL was considerably higher at 70% (compared to north Queensland target populations). This accords with substantial existing levels of leucaena adoption in the region and greater areas of suitable land. Nonetheless, the most important factors influencing PAL were again around profit, risk, environment, and ease/convenience. Similarly, important factors for the TPA were around knowledge and experience.

One caveat relates to the 'Environmental costs and benefits' (under 'Relative advantage of the Innovation'). Attributing leucaena as producing 'a small environmental advantage' rather than 'a moderate environmental disadvantage', has the effect of almost doubling peak adoption in the model. This factor warrants further investigation as leucaena has several potential environmental advantages, but it's weed potential is a significant environmental disadvantage.

Table 58. ADOPT predictions relating to 'peak adoption level' for establishing and growing leucaena amongst beef producers who have not previously planted leucaena in four sub-regions of Queensland (target populations).

Target population variant	*Peak adoption level (%)*	*Key adoption levels* *@ 5 years* *time to 50%* *@ 10 years*	*Peak adoption level: most sensitive factor* *(rating attributed)*	*Other important factors*
1 **Northern coastal**	48	8% 9 years 29%	**Profit benefit** *Large profit advantage*	Profit motivation Risk exposure Ease/convenience Environmental +/- Future profit
2 **Northern sub-coastal**	26	4% 9 years 16%	**Risk exposure** *Moderate risk reduction*	Profit benefit Ease/convenience Environment +/- Profit motivation
3 **Northern inland**	44	6% 9 years 24%	**Enterprise scale** *About 50% could benefit*	Profit benefit Risk exposure Profit motivation Ease/convenience
4 **Central inland**	71	36% 5 years 69%	**Profit benefit** *Large profit advantage*	Risk exposure Enterprise scale Profit orientation Environment +/- Ease/convenience

Table 59. ADOPT predictions relating to 'time to peak adoption' for establishing and growing leucaena amongst beef producers who have not previously planted leucaena in four sub-regions of Queensland (target populations).

Target population variant	*Time to peak adoption level (years)*	*Time to 50% adoption*	*Time to peak adoption: most sensitive factor* *(rating attributed)*	*Other important factors*
1 **Northern coastal**	20	9 years	**How easily trialled** *Difficult to trial*	Observability Existing skills and knowledge
2 **Northern sub-coastal**	20	9 years	**Existing skills/knowledge** *Majority will need new skills and knowledge*	How easily trialled Complexity
3 Northern inland	21	9 years	**How easily trialled** *Difficult to trial*	Complexity Existing skills and knowledge
4 **Central inland**	11	5 years	**Existing skills/knowledge** *Majority will need new skills and knowledge*	How easily trialled Complexity

4.5.2 Leucaena plantings in north Queensland

Successfully established leucaena plantings in north Queensland since 2020 up to and including the 2021-22 wet season are given in Table 59. Figures in Table 59 represent about 20 producers. Plantings in north Queensland have increased from a pre-2020 area of about 2,300 ha to over 4,300 ha in 2022.

New plantings on the WTC were undertaken by about six growers in the Innisfail and Tully districts. There were also significant new plantings in the Georgetown district (Northern Gulf) attributed to just two growers who are continuing to expand their leucaena plantings each year depending on seasonal conditions. Plantings in the Northern Gulf and basalt provinces are constrained to producers with pre-existing cleared country. Whilst plantings in lightly timbered basalt soils have occurred, this has only been by a few producers and the long-term productivity of this type of planting is not confirmed. A pioneering 1,000 ha planting in the 1990' is still productive but was established into timbered basalt country with standing timber poisoned in-situ. This practice is no longer an option.

There is considerable scope for additional plantings in the Dry Tropics (with irrigation) and the WTC (contingent on local government accord) as there exists large areas of cleared country.

Sub-coastal plantings are mostly attributed to just one producer in the upper Herbert River valley on red-earth soils. Despite poor fertility and low moisture holding capacity, the red-earths offer considerable scope for leucaena adoption (Redlands), particularly in the Herbert River catchment where there are existing areas of cleared land and motivated producers, and rainfall is better distributed through the year.

On the Atherton Tablelands, there must be sufficient value proposition relative to competing land uses and a high productivity from existing improved pastures where annual liveweight gains in the range of 230-280 kg have been recorded (Winks et al. 1970). The productivity of leucaena relative to these highly productive pastures is not known. This also applies to leucaena plantings on the WTC.

The planting on the Burdekin alluvials in 2021 was part of a larger 80 ha site at DAF's Spyglass Beef Research Facility. This site comprises replicated paddocks 50% strip sown into existing pasture (mainly black spear grass and Seca stylo) with i) improved grass pasture (species mix); ii) *Stylosanthes sp*.; iii) desmanthus; and iv) leucaena (Redlands). All paddocks received an application of superphosphate at 250 kg/ha. This site has been set-up as a grazing trial to compare options for pasture development.

Table 60. Historical and proposed leucaena development in north Queensland.

District	***North Queensland successfully established leucaena plantings (all cultivars)***				***Total (ha)***	***Comments***
	Pre 2020	***2020***	***2021***	***2022***	***By district***	
Basalt provinces	*1,065[A]*	*5*	*20*	*0*	***1,090***	*[A]excludes 400 ha area planted in 2019 with 95% failure*
Northern Gulf *(Gilbert alluvials)*	*190[B]*	*50[BB]*	*280*	*50*	***570***	*[B]235 ha planted; [BB]350 ha planted*
Burdekin alluvials	*30*	*0*	*20[C]*	*not known*	***50***	*[C]DAF Spyglass Beef Research Facility*
Dry Tropical Coast	*480*	*30*	*630[D]*	*90*	***1,230***	*[D]assumes 600ha out of 1200 ha expansion by one grower*
Wet Tropical Coast	*100[E]*	*120[EE]*	*140*	*0*	***360***	*All Redlands; [E]250 ha planted; [EE]320 ha planted*
Sub-coastal	*430*	*235*	*250*	*125*	***1,040***	*Predominantly Redlands*
TOTAL	***2,295***	***440***	***1,340***	***265***	***4,340***	

5 Conclusion

5.1 Key findings

5.1.1 Psyllid tolerant Redlands productivity

Liveweight gains for three successive cohorts of steers were equivalent for animals grazing Redlands and Wondergraze leucaena at Pinnarendi in north Queensland. Redlands was readily accepted and grazed by cattle which were previously naive to leucaena. Statistical analyses of results from the first and third cohorts determined that there was no significant difference in liveweight performance for cattle grazing the Redlands or Wondergraze cultivars over 12-months.

A productivity advantage (compared to Wondergraze) conferred by the psyllid tolerance of the Redlands cultivar was not demonstrated. This was because Wondergraze at the site was not significantly affected by psyllids during 3.5 years of replicated grazing and plant growth was similar to Redlands. However, economic modelling shows that the small extra cost of planting with Redlands would be recouped even if only minor productivity losses (approximately 10% in any year) from psyllid damage are avoided. There are no apparent extra costs associated with establishing and managing Redlands other than the initial higher cost of seed.

5.1.2 Animal performance on leucaena

Annual liveweight gains for three cohorts of weaner steers grazing leucaena (Redlands and Wondergraze) at Pinnarendi averaged 223 kg (ADG=0.610 kg) and ranged from 199 kg to 249 kg (ADG's of 0.681 and 0.546 kg respectively). These were achieved at an overall average stocking rate of 0.44 AE/ha (2.27 ha/AE).

Weight gains were measured at almost all weighing events over all years (for both Redlands and Wondergraze). This is in contrast to animals grazing native pastures on similar soils in the same environment where weight loss is usual during the mid-late dry season due to low quality pasture. Under such conditions, annual weight gains of 80-100 kg/head (ADG=0.22-0.27 kg) at stocking rates of 0.10-0.13 AE/ha are typical.

A cohort of 30 heavyweight steers which with an average liveweight of 511 kg were 'finished' to slaughter weight and had an ADG over 138 days of 0.75 kg (103.5 kg liveweight gain). A sub-set of six animals had an ADG over 188 days of 0.70 kg. Most of these animals met MSA grading standards and graded an average MSA index of 54.5. This performance was achieved during a time of the year which included the winter period (early dry season) when liveweight gains are normally low due to declining pasture quality.

Dietary quality of leucaena samples at Pinnarendi (as grazed by cattle) were similar to high quality silage but with higher crude protein and lower metabolisable energy. Redlands and Wondergraze samples from the site had similar dietary attributes. The best quality sample was from Wondergraze at an inland site taken after the wet season when leucaena was still growing abundantly.

All animals in the trial were naïve to leucaena, but only third cohort steers received leucaena rumen inoculant which was administered to every animal. Despite this, animals in other cohorts did not show any symptoms of mimosine toxicity – they remained healthy and gained weight as conditions allowed.

5.1.3 Comparative animal performance on improved pasture

Annual liveweight gains of weaner steers grazing an adjoining improved pasture paddock (previously fertilised) were measured for two cohorts in conjunction with similar animals grazing in the leucaena trial. Results were remarkably similar to the leucaena animals, although stocking rates were lower. The average annual liveweight gain achieved was 210 kg (ADG=0.58) at an average stocking rate of 0.34 AE/ha (2.94 ha/AE).

Generally, the ADG's measured for improved pasture animals throughout the year were similar the leucaena animals but were lower during the mid-late dry season.

5.1.4 Leucaena gross margins in north Queensland

Gross margin analyses of Redlands leucaena relative to alternate pasture options in two north Queensland environments showed favourable returns from establishing leucaena.

In a sub-coastal environment with red-earth soils, Redlands had an expected gross margin 2.5x higher than a base case native pasture. For the same environment, Redlands had 1.4x higher gross margins than Wondergraze (using an assumed probability of psyllid damage).

On the WTC, the additional returns (gross margins) from establishing Redlands leucaena into an existing improved pasture or land previously used for sugar cane appear to strongly support adoption. However, this was based on assumptions of high stocking rates using data from historical trials which were focussed on maximising productivity per unit area (not individual animal performance). These stocking rates were damaging to pastures, particularly during the wet season, and are not viewed as sustainable. Additionally, the productivity of Redlands on the WTC is not documented. Therefore, these assumptions require validation, and this analysis should be viewed as investigatory, not conclusive.

5.1.5 Limitations and opportunities for leucaena on red-earth soils

The red-earth soils at the Pinnarendi trial site, broadly represent a significant area of already cleared country in the region which could be used for leucaena adoption. In some cases, they are already being used for cropping and hay production.

Leucaena performance at Pinnarendi was principally constrained by the seasonality of rainfall combined with the low water holding capacity of the soils. The soils at the site dry out quickly following rainfall inputs and do not sustain adequate moisture supply for leucaena through the dry season. Whilst leucaena has the ability to extract water at depths beyond 1.5 m, the soils described at Pinnarendi are not much deeper (or are shallower). Low fertility and difficulty in raising fertility sustainably, are also an issue with these soils. The conclusion is that the site and soils are not well suited to leucaena.

Despite this, animal performance and indicated economic returns are much higher than for native pasture and appear to justify leucaena development. Even with the limitations described, the ability of leucaena to produce a modest amount of high quality leaf during warmer conditions following the winter months (despite usually dry conditions) has been a feature of the crop at the site. Additionally, leucaena was productive when out of season rainfall was received (during 2022 for example) and responded quickly to break of season rainfall, whereas inter-row pasture species remained mostly dormant until sustained rainfall was received.

5.1.6 Leucaena pruning and management

Leucaena at the Pinnarendi trial site required pruning five years after establishment. Pruning costs were $50/ha (contractor, wet basis and excluding mobilisation costs). It is likely that without constraints imposed by trial aims, pruning could have been delayed another 1-3 years with strategic grazing with larger cattle and high short term stocking.

Leucaena at the site was established and managed according to the Leucaena Network Code of Practice. There was minimal requirement for control of volunteer (or weedy) leucaena. Cattle grazed off new seedlings which emerged in the vicinity of plant rows after the wet season. Control of some volunteer plants along fence lines and around water points was required in the sixth year after planting.

5.2 Benefits to industry

5.2.1 Leucaena productivity in the north

The project has demonstrated that productivity of Redlands is at least equivalent to Wondergraze and producers can be confident in using Redlands for leucaena adoption. More broadly, the project has demonstrated high liveweight gains from leucaena in a sub-coastal north Queensland environment. This performance underpins the economic case for leucaena adoption in the region by producers. Leucaena can improve business profitability, increase resilience to drought and reduce the intensity of greenhouse gas emissions from livestock production.

Heavyweight steers were successfully finished to slaughter weight on leucaena at Pinnarendi in the final year of the project. They gained over 100 kg in 5.5 months at a time of year when native pastures could not have sustained this animal performance. Although this was assisted by unseasonal rainfall in 2022, interrow pasture at the site did not respond significantly to this rainfall whereas leucaena remained productive. Leucaena opens up marketing and production opportunities for northern producers previously only available through supplementary feeding or moving cattle to properties on the coast, Atherton Tablelands or further south.

Whilst no production benefit was able to be demonstrated from using Redlands compared to Wondergraze (in the absence of psyllids), at the completion of grazing trials in July-September 2022 psyllids caused extensive damage to Wondergraze at the site. Had replicated grazing been conducted at this time, it is highly likely Redlands would have had higher weight gains as it was unaffected by psyllids and was productive due to rainfall received during the 2022 'dry season' (when dry conditions normally limit leucaena productivity at the site).

5.2.2 Leucaena establishment and adoption in north Queensland

Knowledge and experience have been gained from establishing and managing leucaena at the Pinnarendi site and from engagement with producers planting leucaena. This includes innovative practices developed by producers themselves. This increased knowledge will reduce establishment risks and costs associated with leucaena adoption in the north. In particular, this relates to seedbed preparation, timing of planting and weed control.

During the project, an estimated 2,000 ha of leucaena has been established in north Queensland (mostly Redlands). Conservatively assuming an *increase* in annual ADG of 0.25 kg and an *increase* in stocking rate of 0.2 AE/ha, these plantings should be producing an additional 110-120 t of liveweight gain/year (valued at $0.5M at current prices). Although exact areas suitable for leucaena adoption are not known, there is scope for an additional 5,000-10,000 ha of plantings on country already cleared and with reasonably suitable soils and pro-active producers.

Much of this country has red-earth soils closer to the coast. The case for leucaena on these soils is improved moving closer to the coast as rainfall is less seasonal, and leucaena should be more productive throughout the year. Countering this will be higher psyllid pressure and increased occurrence of frost and cold weather.

Elsewhere in northern Queensland, alluvial frontage soils are being developed for leucaena by a small number of growers. Rainfall seasonality is the principle constraint to productivity and available cleared land is the principle constraint to adoption. Nonetheless, these land types represent a significant opportunity for leucaena adoption. Soil P, is usually adequate and water holding capacity of these soils is higher than the red earths.

On the Atherton Tablelands and the WTC, there have been Redlands plantings by a few producers. There is considerable scope for more adoption, particularly on the WTC, with areas of suitable soils and cleared land. There are also more months in the year with adequate rainfall to maintain productivity. However, there are concerns about psyllids (refer 6.1) and difficulty controlling weeds, even in established plantings.

5.2.3 Improved pasture productivity

Liveweight gain of steers in the improved pasture paddock at Pinnarendi was almost the same as for leucaena, although stocking rates were lower. This performance was better than expected, and is an indication to industry of the productive potential of improved pastures in northern environments. Important factors for this productivity at Pinnarendi, were the contribution of legumes (mainly Seca stylo), applied superphosphate fertiliser, and conservative stocking.

Promoting adoption of improved pastures and measuring resulting animal performance is the principle focus of proposed pasture resilience projects in northern Queensland over the next several years.

6 Future research and recommendations

6.1 Psyllid damage to Redlands

No reliable, long-term animal performance data is available from Redlands plantings on the WTC relative to existing highly productive improved (predominantly grass) pastures in the region. This data is needed to more thoroughly assess the economics of leucaena adoption in this region. Likewise, such data is also needed to justify leucaena on the Atherton Tablelands, where annual liveweight gains of 250 kg are already achieved with productive pastures, and there are competing land uses. To date, plantings on the Atherton Tablelands have been limited.

Commercial plantings of Redlands on the WTC and hinterland have been significantly affected by psyllids. These are environments which are apparently more prone to psyllids than Pinnarendi. On the WTC, damage and productivity losses has led to doubts by some producers as to the worth of leucaena in these environments. Data is required to provide additional assurance for producers considering leucaena adoption.

Additionally, the timing and extent of psyllid damage should be quantified, and management strategies explored which may reduce their impact. Anecdotally, psyllid damage appears to be reduced if high grazing pressure can be maintained in leucaena blocks. Infestations are not always uniform, often affecting parts of paddocks (typically the windward side) more severely than others. However, the scope for realising worthwhile strategies is probably limited.

In hinterland regions, psyllid damage to Redlands has been significant but less than on the coast. Producers here remain convinced of the worth of Redlands, citing they would not consider other varieties which have historically been seasonally decimated by psyllids in these environments.

Finally, there is the question as to whether the psyllid resistance of commercially available Redlands matches the originally selected line. Redlands seed used for planting at Pinnarendi was sourced from a DAF-grown block at Walkamin Research Facility, planted with the original “R12” line and subsequently heavily rogued for psyllid occurrence. Redlands at Pinnarendi has demonstrated good psyllid resistance to date which may be by virtue of the environment or the original seed line.

6.2 Grazing management under seasonal productivity

At Pinnarendi, leucaena and inter-row pasture are most productive at the same time of year (January-March), but with leucaena maintaining good growth into April-May if conditions remain mild. Cattle preferentially graze the inter-row grasses during the wet-season, grazing more leucaena as the season progresses. To limit excessive leucaena growth and take advantage of high leucaena yields at this time, high stocking rates are required. However, this conflicts with the need for conservative management of inter-row species.

There was an alarming decline in desirable inter-row pasture species during 3.5 years of grazing at Pinnarendi – with an increase in weeds and dominance of wynn cassia in particular. This is largely attributable to set stocking and a lack of wet-season spelling. Introducing a regime of wet-season spelling should assist in the retention of desirable inter-row species but coincides with the time that leucaena also needs to be exploited. Wet-season spelling will allow leucaena to grow beyond the reach of cattle and will require earlier pruning intervention.

There is a need to investigate strategies which seek to simultaneously arrest the decline of desirable inter-row species whilst optimally utilising leucaena at the site. One option is timing wet-season spelling with leucaena pruning. Another option is to graze different classes of cattle at different times of the year. The economics and practicalities of pasture regeneration (re-sowing and species mix) could also be investigated.

Such studies will have wider implications for leucaena in northern environments, where it will typically be grown in areas with highly seasonal rainfall and productivity due to the low water holding capacity of soils. This is in contrast to central Queensland, where rainfall is more evenly distributed and soils often have high water holding capacity.

6.3 Managing soil fertility

Economically maintaining adequate soil fertility for leucaena at Pinnarendi and other sites with low fertility in northern environments, is likely to be challenging. Repeat soil testing at the site showed overall levels of P and S in leucaena paddocks to be lower than expected considering the history of fertiliser applications made. Soil fertility is likely constraining leucaena productivity during the wet-season in particular.

The analytical data show these soils are infertile or deficient in most key plant nutrients and are subject to leaching losses with a low capacity to retain nutrients. There are locations throughout the trial site where pH is likely to be affecting leucaena productivity. The generally low pH throughout the site would also be affecting nutrient availability and acidification is likely to be an issue. Applications of agricultural lime may need to be factored into long-term management of leucaena on these soils. The phosphorus buffer index (PBI) influences P availability, PBI is low in the surface samples but increase to high levels in the subsoils.

Any future work at the site should investigate timing, type, and methods of fertiliser applications with regard to leucaena response, cost and long-term effects on soil chemistry. This work should also include the effect of agricultural lime applications.

6.4 Adoption

The principal constraints influencing the timing and level of adoption of leucaena in the north by target producers (producers with suitable land and climate for leucaena) are likely to be related to their skills and knowledge; the relative ease at which leucaena could be trialled at a smaller scale; the profit incentive; the degree to which leucaena may reduce enterprise risk and the number and scale of target enterprises. Future activities that attempt to support leucaena adoption in the north should consider these factors when engaging with target producers.

Adoption of leucaena on fertile (high P), often rocky, basalt soils ‘under trees’ presents a large opportunity for leucaena expansion in the north. Definitive, long-term productivity in these situations is not known but could be similar to results achieved at Pinnarendi. This would provide a compelling case for adoption, but requires resolution of practices for pruning, fertilising and control of volunteer leucaena, all of which present management challenges.

6.5 Effect of seedling vigour

There were differences in in paddock productivity at Pinnarendi related to the original establishment success. These differences became more apparent under sustained grazing pressure during 2021. After establishment, Redlands paddocks at the site were less uniform, had lower plant populations and smaller plants than Wondergraze. One possible cause was reduced seedling vigour during establishment. Redlands seed used for planting at Pinnarendi was in short-supply at the time, and was sourced exclusively from a DAF-grown block at the Walkamin Research Facility on the Atherton Tablelands. Seed was hand harvested but not graded in order to obtain as much seed as possible. Wondergraze used for the trial was purchased commercially, and was a more consistent seed-line with larger sized seed.

Whether smaller seed size and subsequent vigour was the cause of inferior Redlands establishment at Pinnarendi is a possibility. If so, the effect of leucaena seed size and vigour on establishment success generally requires investigation. This aspect may have implications for reducing establishment risk and increased long-term productivity.

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- Nigel Tomkins, formerly MLA.
- John McLaughlin, formerly Northern Gulf Natural Resource Management Group, Georgetown.

9 Appendix

9.1 Weigh dates – all cohorts

Table A1. Weigh dates of all cattle in the trial according to cohort (2018-2022).

Weigh Date	*Cohort 1*		*Cohort 2*		*Cohort 3*			*Cohort 4*
	Pin leucaena	*Spy leucaena*	*Pin pasture*	*Pin leucaena*	*Pin leucaena*	*Spy leucaena*	*Pin/Spy pasture*	*Wom leucaena*
2018								
19 April	•							
28 June	•	•						
7 August	•	•						
20 September	•	•						
8 November	•	•						
19 December	•	•						
2019								
5 March	•	•						
1 April	•	•	•	•				
13 May	•	•	•	•				
1 July	•	•	•	•				
29 August	•	•	•	•				
18 October			•	•				
16 December			•	•				
2020								
2 January			•	•				
29 January			•	•				
19 March			•	•				
23 April			•	•	•			
19 May			•	•	•			
19 June			•	•	•			
23 June					•	•	•	
31 July					•	•	•	
16 September					•	•	•	
29 October					•	•	•	
2 December					•	•	•	
2021								
14 January					•	•	•	
22 February					•	•	•	
14 April					•	•	•	
17 June					•	•	•	
2 August					•	•	•	
2022								
1 March								•
12 April								•
24 May								•
20 June								•
17 July								•
5 September								•

9.2 Animal health treatments

9.2.1 First cohort

Table A2. Animal health treatments administered to first cohort steers at Pinnarendi.

Date	*Applicable animals*	*Treatment*	*Comment*
26 June 2018	Cohort 1 Spyglass only	3-day vaccine	2 x diluent Batch 185668 Exp 04/01/18 2 x vaccine Batch 196619 Exp 18/08/18
8 November 2018	Cohort 1 All animals	3-day vaccine	4 x diluent Batch 269225 Exp 03/01/19 4 x vaccine Batch 252667 Exp 25/05/19
19 December 2018	Cohort 1 All animals	Fly tags	Details not recorded
5 March 2019	Cohort 1 All animals	3-day vaccine	5 x diluent Batch 315565 Exp 12/01/20 5 x vaccine Batch 252667 Exp 25/05/19

9.2.2 Second cohort

Table A3. Animal health treatments administered to second cohort steers at Pinnarendi.

Date	*Treatment*	*Comment*
23 April 2020	Botulism vaccine	1 x vaccine Batch 199507A04 Exp. 22/03/21
29 October 2020	3-day vaccine Fly tags	7 x diluent Batch 428231 Exp. 31/10/21 7 x vaccine Batch 403203 Exp. 24/07/21 Bayer Patriot® Batch AHR7014T Exp. Mar 2021
2 December 2020	3-day vaccine Tick pour-on	5 x diluent Batch 428231 Exp. 31/10/21 7 x vaccine Batch 403203 Exp. 24/07/21 Cattlemax™ Batch V15449/2 Exp. Jun 2021
17 June 2021	Tick pour-on	Tik Bos Batch 26718 Exp. Nov 2023

9.2.3 Third cohort

Table A4. Animal health treatments administered to third cohort steers at Pinnarendi.

Date	*Treatment*	*Comment*
23 April 2020	Botulism vaccine	1 x vaccine Batch 199507A04 Exp. 22/03/21
29 October 2020	3-day vaccine Fly tags	7 x diluent Batch 428231 Exp. 31/10/21 7 x vaccine Batch 403203 Exp. 24/07/21 Bayer Patriot® Batch AHR7014T Exp. Mar 2021
2 December 2020	3-day vaccine Tick pour-on	5 x diluent Batch 428231 Exp. 31/10/21 7 x vaccine Batch 403203 Exp. 24/07/21 Cattlemax™ Batch V15449/2 Exp. Jun 2021
17 June 2021	Tick pour-on	Tik Bos Batch 26718 Exp. Nov 2023

9.3 Soil survey report

Neil Enderlin and David Morrison
Land Resource Assessment, Department of Resources, Mareeba
August, 2022

A 1:25 000 scale soil survey was undertaken by Land Resources Officers of the Department of Resources, Mareeba Office on 93 ha of land on Pinnarendi Station (Lot 8/GU42), North Queensland. The area is a trial site established by Beef Research and Extension Officers, from the Department of Agriculture and Fisheries, Mareeba.

The trial site is used assess leucaena suitability for beef production in the Dry Tropics. Significant yield variations have been encountered which cannot be explained by pest pressure or fertiliser management. The survey was undertaken to map and characterise soil variability to help identify any soil related factors that may be responsible for these variations. Subsoil moisture is believed to be a significant underlying factor.

Initially this survey comprised an electro-magnetic induction (EMI) survey. The aim was to identify variability in soils across the trial site to guide the location of sites for sampling and characterise the soils present. The EMI meter aids in identifying and mapping soil variability by measuring apparent electrical conductivity which is influenced by soil properties such as moisture, chemistry, and texture. Unexpected damage to the EMI equipment due to rough terrain the survey to the north-eastern portion of the trial site. For the remainder of the site, mapping and site selection depended upon air photo interpretation, observable variation throughout the trial site, and variability in leucaena growth and production.

A total of 12 representative soil profile description and sampling sites were collected. These descriptions and associated laboratory analytical results are provided in Attachments 1 and 2. Profiles were described from relatively undisturbed cores retrieved using a 50mm sampling tube pushed into the ground by a utility mounted hydraulic soil rig. Sites were taken from the leucaena plant row, sampled to a depth between 1.2 and 1.6m.

If additional EMI work can be undertaken across the trial site, more detailed mapping between 1:5000 to 1:10 000 scale can be achieved with minimal additional soil sites.

Profiles were described in accordance with NCST (2009), photographed, and sampled for laboratory analysis. The location of each profile site is shown on the accompanying soil map (Attachment 3). Samples from six sites were submitted to the Department of Environment and Science Chemistry Centre at Boggo Road, Dutton Park for analysis. Additional surface 0-0.2m samples were collected as a second observation from the middle of the inter-row, for comparative fertility analysis away from the plant row. These results are included in Attachment 1.

The soils found across the trial site are residual or colluvial deposits formed over Tertiary aged duricrust. Four soil types or soil profile classes (SPC) (Powell 2008) and an intergrade have been identified and delineated into seven mapping units (Attachment 3). These have been correlated with existing SPCs established by Heiner and Grundy (1994) when mapping the soils of the nearby 1:100 000 Ravenshoe map sheet.

Soils across bulk of the trial site (86%) are predominantly very deep Red Chromosols (Isbell & NCST, 2021). They are duplex soils with a texture contrast between their sandy-loamy topsoil (A horizons) and clayey red subsoil (B horizons). These are identified as the Tirrabella and the Gunnawarra structured variants. Gunnawarra structured variant is differentiated from Tirrabella by a thick and pale A2 horizon and a greater abundance of ferro-manganiferous or manganiferous nodules in the subsoil. The Gunnawarra acid structured variant is a Kurosol rather than a Chromosol. Kurosols are texture contrast soils which are strongly acidic (pH

Soils across bulk of the trial site (86%) are predominantly very deep Red Chromosols (Isbell & NCST, 2021). They are duplex soils with a texture contrast between their sandy-loamy topsoil (A horizons) and clayey red subsoil (B horizons). These are identified as the Tirrabella and the Gunnawarra structured variants. Gunnawarra structured variant is differentiated from Tirrabella by a thick and pale A2 horizon and a greater abundance of ferro-manganiferous or manganiferous nodules in the subsoil. The Gunnawarra acid structured variant is a Kurosol rather than a Chromosol. Kurosols are texture contrast soils which are strongly acidic (pH < 5.5) in the major part of the B horizon (see site 233).

Minor extents of Red Dermosols occur within the Tirrabella mapping units, these are represented by site 92 and 90, which the laboratory particle size analysis show this is technically a Dermosol. A Dermosol is a structured soil that does not have a texture contrast between the A and B horizons. Red Kandosols were described in a paddock to the east of the trial site back in the late 1980's for an earlier cropping trial. These earlier sites differ to the present sites only in terms of their subsoil structure. It was not possible to determine the extent of the Dermosols. Additional EMI survey may be able to delineate these, and perhaps other soils, if their properties such as texture differ sufficiently from the Red Chromosols.

It is expected the Dermosols at sites 90 and 92 would behave similarly to the Chromosol sites in the same mapping unit. The difference is simply these have a more gradual change from the A into the B horizon rather than a clearer or sharper change found in the Chromosols.

The narrow elongate mapping unit found toward the north-western corner of the trial site has been identified as Nanyeta red structured variant (see site 94) which is a Red Chromosol. This differs from the Gunnawarra and Tirrabella units by a high ferruginous or ferro-manganiferous nodule content throughout the profile, mottles, and a lighter clay texture in the subsoil. Depth is also limited by underlying duricrust.

Adjoining the Nanyeta mapping unit is an area identified as a Sludge structured variant-Nanyeta red structured variant intergrade. The representative site (site 93) is a Dermosol which comprises soil properties attributable to both SPCs. Sludge is a mottled brown soil with a medium to thick pale A2 and a few nodules throughout. Nodules at site 90 increase with depth to an abundance like Nanyeta.

Along the western boundary at the main driveway into the property is a small area identified as Sugarbag structured variant. Representative site 97 is a mottled, nodular Yellow Chromosol with a thin pale A2 horizon. It has similarities to Sludge, but with lighter textured yellower upper B horizons grading into a heavier greyish medium clay with depth. The field pH for this profile was strongly acidic (pH <5.5) throughout, resulting in this site originally being classified a Kurosol. Laboratory pH results for the B2 horizons was between 5.7 - 6.4, meaning it is a Chromosol. The deeper, greyish medium clay B3 horizon was pH 5.4, and its poor drainage will be an issue for this area.

The analytical data show these soils are infertile or deficient in most key plant nutrients and are subject to leaching losses with a low capacity to retain nutrients.

The trial site soils are found to be acidic to strongly acidic throughout. For most sites pH was lower at the surface than through the subsoils, ranging between 5.3 to 6.1 at the surface, and 5.3 to 6.7 in the subsoils. Inter-row surface pH at the measured sites is consistently higher than the corresponding site on the plant row.

According to Shelton et al. (2021), leucaena growth is limited on strongly acidic (pH < 5.5) soils. There are locations throughout the trial site where pH is likely to be affecting leucaena growth and production. The generally low pH throughout the site would also be affecting nutrient availability, however it is not presently low enough for aluminium toxicity to be an issue here. The subsoil sample at site 97 with a pH of 5.4 had a very low concentration of aluminium (<0.03 mg/kg).

Acidification appears to be an important issue at this trial site. In the undisturbed state, these soils typically have a higher surface pH, with a uniform to decreasing trend down the profile. The lower surface pH across the sampled sites is likely to be an effect of cropping practice, including fertiliser application. Issues such as aluminium toxicity will emerge, and nutrient availability will continue to decrease, if acidification is not addressed. Regular doses of agricultural lime will need to be factored into long-term management of Leucaena on these soils.

The macronutrients—nitrogen (N), phosphorus (P), calcium (Ca), magnesium (Mg) and potassium (K)—along with measured micronutrients, except for Iron (Fe), are all found to be deficient (see Shelton et al., 2021). Available sulphur (S) is deficient across all surface samples, however it exceeds 10 mg/kg in the subsoils, which is considered sufficient for leucaena. Concentrations of available N are more uniform between analysed sites than P and other nutrients, reflecting the influence of Leucaena as a nitrogen fixing legume. Surface P levels vary considerably between the plant row and the inter-row at most sites, likely due to P fertiliser application practice.

Available N and P and the cations Ca and K are concentrated at the surface, decreasing considerably in the subsoils. This corresponds with electrical conductivity (EC) measurements and estimates of the soil's cation exchange capacity (CEC) across all sites. The CEC for the analysed sites is estimated as the sum of the measured cations.

EC is found to be at moderate levels (DERM, 2011) at the surface, but is low or negligible throughout the subsoil. Cl and sodium (Na) levels were too low to be measured in the laboratory, other than the anomalous surface Cl measurement of 105 mg/kg at site 233.

In the undisturbed state, the soils found across the trial site have naturally very low or extremely low levels of EC. The salts that contribute to this measurement (Cl and Na) are also negligible, other salts such as calcium carbonate ($CaCO3$) are not present (Baker and Eldershaw, 1993). This is a result of a combination of the endemic soil forming processes, landform, and the high leaching conditions that are present.

Low EC, along with low estimates of the soil cation exchange capacity (CEC) indicate these soils have little capacity to retain applied nutrients. Soluble applied nutrients will be subject to losses through processes such as leaching before the plant can make full use of them.

The cation magnesium (Mg) was also found to be deficient in topsoils, but is increasing in concentration with depth. It has become the dominant cation in the subsoil at sites 90, 96 and 97, where the Ca/Mg ratio is <0.6. Fertiliser and soil conditioner applications addressing deficiencies need to consider such imbalances. Achieving a desired balance of critical nutrients at the surface may worsen an imbalance in the subsoil.

While available N and P are considered deficient, the reserves of both nutrients (Total N and P) appear to be high. Not a lot of these nutrients are being made available from these reserves. As leucaena is a nitrogen fixing legume, available N would not be a critically limiting element across the trial site. However, the availability of P will be a major fertility constraint.

The availability of P in the soil will be highest at about pH 6.5 (Bailey 2011, Sandrai 2022), and a variability in low pH across the trial site may explain the variability in available P. Addressing the low pH, and actions to avoid or reverse acidification of the trial site are critical to improving P availability.

The phosphorus buffer index (PBI) has also been measured for all analysed sites. PBI indicates the P fixing or sorption capacity of the soil influencing P availability. PBI is low in the surface samples (38- 55), which corresponds to higher surface available P concentrations. However, PBI increases to levels as high as 291 in the subsoils. While effects on topsoil P availability is negligible, higher subsoil PBI necessitates P applications of 2 to 3 times the ordinary rate to meet plant needs from the subsoil.

It appears that stratification of applied P fertiliser is also occurring. This has been observed in cropping soils in southern Australia (see for example Ma, Rengel & Rose 2009 and Sandrai 2022) where P is only being applied on or within the soil surface. Phosphorus applied at the surface is not accumulating in the deeper subsoil where it would be more beneficial to the plant. It is not as readily soluble in water as other nutrients (e.g., N & Ca) which are subject to leaching losses or migration down the soil profile. The low levels of P found at the surface across the trial site might be explained in part by plant uptake, however other forms of losses are also likely occurring. This could include losses in runoff during rain events, and perhaps animal uptake of fertiliser broadcast over the surface.

Ma, Rengel and Rose (2009) discuss the benefit from directly applying P deeper into the soil profile, with crop positive yield responses in texture contrast soils experiencing seasonally dry conditions. Responses will depend upon other factors such as timing of application, crop type and root development, climatic and soil moisture conditions, in addition to the depth of application.

The laboratory analytical results allowed for calculations of plant available moisture content (PAWC) to be made for the six sampled sites using the model PAWCER (Littleboy & Glanville, 1995). This model provides pedo-transfer functions using inputs from the soil particle size and soil moisture analyses undertaken. The results of these calculations are provided in Table 1, which identify the cumulative PAWC throughout the profile, as well as a PAWC at 0.6m and 1.2m for each site.

Shelton et al. (2021) state soils should have a capacity to store at least 100mm of soil moisture in the top 1m of soil profile for leucaena. The PAWCER calculations show this would be achieved across most of the trial site. However, the model does not take into account the gravel or nodular content of soils. The high Fe/Mn nodule content of sites such as 97 are likely to have a lower PAWC than indicated.

The soils at this trial site do not have a high soil moisture holding capacity and will dry out reasonably quickly following rainfall inputs. The PAWC of these trial site soils will be much lower than found in more favourable soils such as very deep Red Ferrosols on local basalt landscapes. The PAWCER results indicate the soils will not sustain adequate moisture supply through the dry season. In hot conditions, typical evapotranspiration rates for this locality mean the indicated PAWCs would last only a few weeks, slightly longer during cool periods. While Leucaena can access soil moisture from deeper than the 1.2-1.6m of described profile depth, observations suggest the overall depth of soils may not be much deeper. Depth of soil will be variable across the trial site, however the top of the C horizon (weathered substrate) was encountered at some sites before 1.5m.

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Table A5. Calculations of plant water availability (PAWC) using the PAWCER model (Littleboy and Glanville, 1995).

Site	*Upper depth (m)*	*Lower depth (m)*	*Bulk density (g/m3)*	*Lower limit (mm)*	*Drained upper limit (mm)*	*PAWC (mm)*	*Cumulative PAWC (mm)*	*PAWC to 0.6 m (mm)*	*PAWC to 1.2 m (mm)*
90	0	0.11	1.54	15	33	18	18		
	0.11	0.25	1.54	25	44	20	37		
	0.25	0.88	1.48	126	180	55	92	80	
	0.88	1.15	1.57	105	130	26	118		
	1.15	1.35	1.62	51	61	10	128		120
95	0	0.15	1.57	20	43	23	23		
	0.15	0.45	1.55	59	97	37	60		
	0.45	0.7	1.53	61	89	28	88	76	
	0.7	1	1.53	80	104	24	112		
	1	1.3	1.54	86	104	19	131		
	1.3	1.5	1.64	32	37	6	139		124
96	0	0.2	2.08	15	33	18	18		
	0.2	0.5	1.83	25	44	20	37		
	0.5	0.8	1.63	161	224	63	101	80	
	0.8	1.2	1.60	71	88	17	117		
	1.2	1.5	1.61	51	61	10	127		120
97	0	0.2	1.64	23	51	28	28		
	0.2	0.4	1.57	38	62	23	51		
	0.4	0.65	1.60	54	77	23	74	70	
	0.65	0.9	1.60	60	78	18	91		
	0.9	1.28	1.61	96	118	21	112		
	1.28	1.4	1.63	30	36	6	118		108
98	0	0.25	1.60	35	70	35	35		
	0.25	0.65	1.53	90	142	52	87		
	0.65	1	1.60	86	114	27	114	82	
	1	1.45	1.62	118	142	24	138		
	1.45	1.6	1.58	42	48	7	145		126
232	0	0.2	1.55	31	59	29	29		
	0.2	0.52	1.50	72	113	41	70	78	
	0.53	1	1.55	122	163	40	110		
	1	1.3	1.54	85	103	18	128		123

9.4 Methodology for Gross Margin Analysis

9.4.1 Redlands versus Wondergraze comparison on red-earth soils

The method used a typical gross margin approach based on the allocation of variable costs to enterprises or activities but also included a pseudo 'contract' rate to cost machinery operations. The contract rate apportions overhead, operating and labour costs on a per hectare basis for the use of the machines or combinations of machines with an allowance for contractor profit and minor travel costs added. The final figure is a conservative estimate and approximates what might be charged between farmers. The contract rate does not represent what should be charged by a contracting business to undertake the same activity as that form of business would incur different costs. conservative estimate.

Cattle were valued in and out of the leucaena paddock regardless of whether they were already owned by the property initially or retained on-property after grazing at the site. The purchase and selling prices are derived from a six year and one month average for north Queensland saleyard prices (January 2015 – January 2021). The livestock value into the paddock, for stock purchased immediately prior to grazing, was calculated as the landed purchase cost, accounting for transport and buying costs. Total livestock costs included purchase cost, animal health expenses, sale levies, freight, and the opportunity cost of livestock capital. Labour costs of handling the livestock were excluded on the basis that such livestock costs are unlikely to differ significantly between the leucaena types on an annual basis. The opportunity cost involved in owning the cattle was accounted for by calculating the amount of interest that could have been received on the livestock capital if the leucaena enterprise had not been undertaken (interest rate of 5% assumed) and subtracting this amount from the gross margin.

Forage systems such as leucaena-grass have a productive life of more than one year and/or have establishment costs that contribute to production over several years. Therefore, the establishment costs were amortised (added as an average annual cost) in the calculation of the gross margin. The amortisation process includes the opportunity cost of the capital applied in the pasture establishment process in the calculation of the gross margin plus an allowance for the value of any grazing foregone during the establishment period of the perennial forage. This method allows a broad comparison of the gross margins received from annual forage crops with forages that have longer production periods.

9.4.2 Redlands adoption on the Wet Tropical Coast

The method used a typical gross margin approach based on the allocation of variable costs to enterprises or activities but also included a pseudo 'contract' rate to cost machinery operations (refer 8.5.1).

Cattle were valued in and out of the leucaena paddock regardless of whether they were already owned by the producer initially or retained on-property after grazing finished at the site. The purchase and selling prices are derived from a three year average for north Queensland saleyard prices (December 2018 – December 2021). Otherwise, calculation of livestock costs was the same as described in 8.5.1.

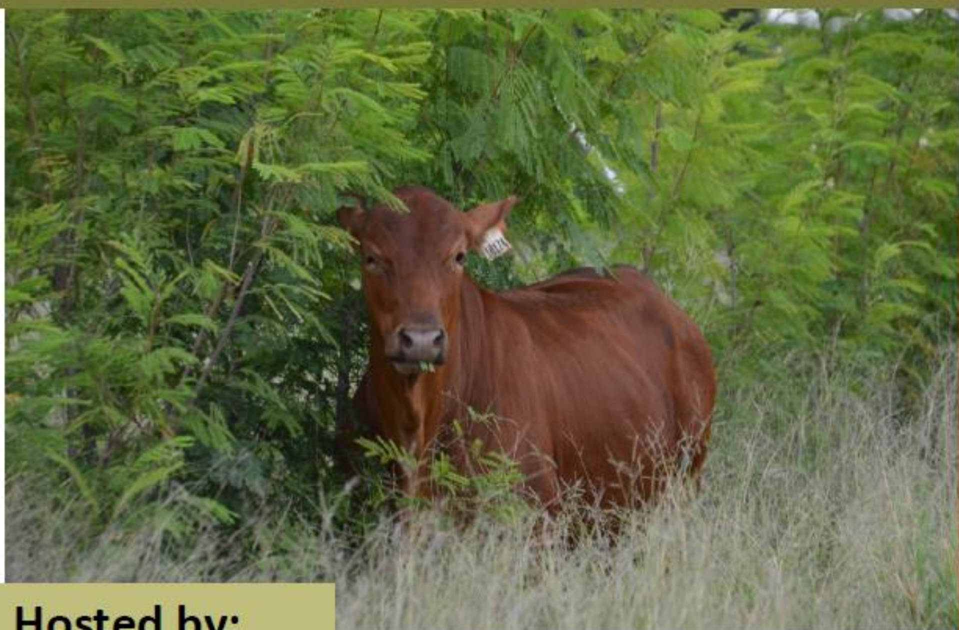
Also, as per 8.5.1, establishment costs were amortised (added as an average annual cost) in the calculation of the gross margin.

9.5 Field day and Redlands launch booklet

the leucaena network

Pinnarendi Field Day 2019

Leucaena liveweight trials and Redlands variety launch



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FutureBeef

QUEENSLAND GOVERNMENT

Department of Agriculture and Fisheries

Drought and Climate Adaptation Program

GrazingFutures Project

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Compiled by Jessica Gorman

(DAF Northern Beef and Feedbase Team)

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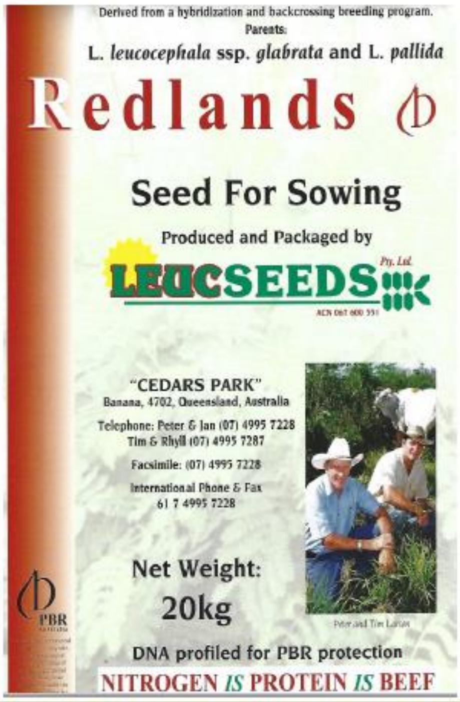
LEUCSEEDS Pty. Ltd.
ACN 067 600 551

When we discovered leucaena over 25 years ago we realised its magnificent potential as a high quality cattle feed and soil fertility builder. It has performed beyond our expectations and indeed is too good to keep to ourselves. My family and I are most happy to host you on a guided tour of our property (by prior arrangement) to inspect **Wondergraze, Tarramba** and the new **Redlands** so that you also may catch a vision of how this wonderful plant can improve the quality and profitability of your cattle operation.

Peter Larson, Leucseeds



Peter and Tim Larsen of LeucSeeds

You can contact Peter at

leucseeds@outlook.com

Remembering Jim Kernot

(DPI 1990-2009)

Jim joined the Department of Primary Industries (DPI) in Mareeba in 1990 as a pasture agronomist. As with any aspect of his life Jim put in 100 percent into his work with the DPI team and northern beef producers. Jim led the Local Best Practice project (LBP) engaging 250 beef producers from Charters Towers, the northern Gulf, Mitchell Grass Downs and Cape York to document typical land types, grazing practices, herd management, supplementation and marketing across 20 districts in north Queensland. This LBP project helped DPI teams broaden their producer networks and better understand the key industry issues to improve beef extension programs.

Jim then led the Meat Research Corporation-DPI live export Smart Manager benchmarking project to maximise land, herd and business performance. Smart Manager included many long and dangerous missions with Bernie English around north Queensland and up into the Asian live export markets. Jim recognised the significant impact native timber thickening has on carrying capacity. In close partnership with CSIRO, Jim led the Northern Fire trials across 9 properties in the Queensland Gulf. These trials identified the fire susceptibility of key native thickening species and produced recommendations and rules of thumb in relation to required fuel loads and post fire grazing management.

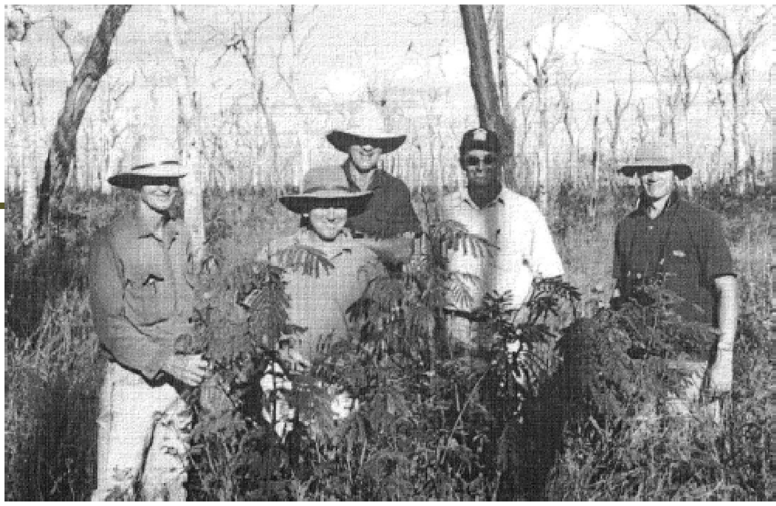
Jim Kernot inspecting leucaena in Central Queensland

Remembering Jim Kernot

(DPI 1990-2009)

Jim was also a leading expert on sown pastures in north Queensland. Greg Brown (Meadowbank), Bernie English and Jim participated in several study tours around central Queensland in the 1990's when leucaena was emerging as an important pasture legume in Queensland. Greg Brown pioneered the first large scale leucaena plantings on rocky basalt soils in far north Queensland. Jim Kernot was a keen observer of this development offering plenty of advice and recommendations (some which was heeded and some not) including importance of sulphur for these leucaena production systems.

Jim was a keen advocate for the development of a psyllid resistant leucaena variety, now known as Redlands. Jim also kept a close eye on 'big picture' industry matters serving as secretary of the North Queensland Beef Industry Committee for a decade. Jim was a passionate beef extension officer with a real vision for feedbase improvements as a way forward for many northern beef producers.



Bernie English, Jim Kernot, Greg Brown, Max Shelton and Scott Dalzell discussing the need for a psyllid resistant leucaena (Meadowbank 2000)

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the leucaena network

DAF and MLA have partnered with The Leucaena Network for the leucaena grazing trial at Pinnarendi. The Leucaena Network was formed by graziers to progress the leucaena industry with the aim "to promote the responsible development of leucaena in productive and sustainable ecosystems to build stronger rural communities". The Network has been providing graziers with education and agronomy support on growing leucaena for more than 20 years. The producer based network welcomes members from grazing industries, research and extension and service industries.

The Network has a successful history of project management including MLA Producer Demonstration Sites (PDS) and MLA Donor Company (MDC) projects including the Redlands for Regions MDC in collaboration with DAF, which was finalised in April 2019.

The Redlands for Regions project facilitated six best practice graziers, located in north Queensland from Nebo to Mount Garnett to establish 40ha of Redland trial sites. The project included extension support provided by DAF, a schedule of farm visits and public field days; and attendance at leucaena and enterprise improvement workshops.

Code of Practice

The Leucaena Code of Practice was developed in 2001 by The Leucaena Network for all producers to follow to maximise the productivity of leucaena while minimising the environmental impact. The current Code of Practice was developed for Queensland requirements and is currently undergoing review to allow adoption across Northern Australia. Adherence to the Code is self-regulatory however several Queensland Councils have adopted it as policy for leucaena establishment in their areas.

For more information about the Code of Practice, visit www.leucaena.net

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Background to development of cultivar Redlands

The leucaena psyllid (*Heteropsylla cubana*) is a serious insect pest of commercial leucaena (*Leucaena leucocephala* ssp. *glabrata*) in Australia especially in areas with average annual rainfall > 800 mm. Availability of a psyllid-resistant variety would increase the range of adaptation of leucaena by 30%, from 4.4 M ha to 5.7 M ha.

An MLA-supported breeding program was initiated in 2002 to develop a psyllid-resistant variety developed from inter-specific hybrids between the susceptible species *L. leucocephala* and the resistant species *L. pallida*. Forty breeding lines of the psyllid-resistant leucaena were produced following three generations of mass selection, two generations of backcrossing to *L. leucocephala*, and two generations of self-pollination, progeny testing and selection among backcrossed breeding lines. Selection for psyllid resistance was carried out at each stage of the breeding program.

Four of these breeding lines were then selected for possible release to industry. The lines were chosen for their psyllid resistance, moderate seed production and high *in vitro* digestibility comparable to that of the existing commercial cultivars. To move to commercialisation, it was necessary to gain Plant Breeders Rights (PBR) for these varieties, bulk up seed, and conduct a final assessment of psyllid resistance and forage yield, and test palatability to animals.

Fieldwork required to achieve PBR, required selection of one or more lines to be commercially released based on a final comparison of psyllid resistance, forage yield and forage quality. The field trial gathered data to prove the distinctness, uniformity and stability of the new variety. Part 1 documentation for QPBR was obtained giving provisional protection for two lines (#12 and #39) in 2014.

Selecting elite breeding lines grown in glasshouse (11 November 2013)

Redlands field being prepared for PBR trial and seed orchards

Seedlings transplanted into field at Redlands (21 November 2013)

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Background to development of cultivar Redlands

In parallel, additional work in conjunction with QDAF, a grazing preference trial was established at Whitewater Station in north Queensland to compare the grazing preference of the 4 breeding lines with commercial cultivars *L. leucocephala* cvv Cunningham and Wondergraze. Overall, there were no major differences in preference among the breeding lines. Although animals displayed a preference for commercial cultivars under light grazing when not psyllid damaged, all entries were well eaten with approximately 10% of leaf remaining at the end of the grazing period. Psyllid damage reduced the palatability of the commercial cultivars compared to the psyllid resistant breeding lines.

Breeding line #12 was ultimately selected for advancement to Stage 2 of the PBR application and has now been approved by IP Australia (reference 2014/112) (28/9/2017) and given the name cultivar Redlands.

Prior to final selection of #12 for release, seed orchards of each of the four selected lines were established at 3 locations in order to obtain breeder's seed for distribution to the commercial companies chosen to multiply and market the new variety. Seed of all of the non-selected breeding lines has been retained and placed into cold storage at the University of Queensland. Field plots of non-selected breeding lines have been destroyed, or are in the process of being destroyed.

About 40 kg of breeding line #12 was provided to Leuc Seeds PTY LTD as the first successful licensee to grow and distribute the new psyllid-resistant leucaena. In November 2015, 5 kg of seed was given to the second licensee, Bandana Station Carnarvon Pastoral with an additional 35 kg supplied in June 2016.

Commercial seed of cv. Redlands has now been harvested and is available for purchase by graziers.

Max Shelton

Seed pods forming on seed orchard at Redland Research Station (11 April 2014)

Redlands being readily consumed at Whtewater station (above and below)

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Pinnarendi:

Redlands vs Wondergraze

liveweight gain trial

Introduction:

Adoption of leucaena in the northern Australian beef industry has been slow, partly due to the prevalence of the sap-sucking leucaena psyllid (*Hetreropsylla cubana*). Recent efforts to develop new psyllid-resistant varieties have resulted in release of the Redlands cultivar which has the potential to increase leucaena productivity in northern environments. A large scale trial has been established at Pinnarendi to measure weight gain (LWG) of cattle grazing Redlands compared to the psyllid susceptible conventional Wondergraze variety.

Site selection:

A 62ha site at nearby St Ronans was originally selected for the trial and planted with leucaena over the 2015-16 wet season. However heavy rainfall and drainage issues on basalt soils caused poor establishment and the project was relocated to Pinnarendi. Preparation of the 61 ha site at Pinnarendi occurred over the second half of 2016 with planting during February 2017. The site at Pinnarendi had previously been used for cropping and had lighter soils with lower fertility and moisture holding capacity – they are not soils which would usually be selected for leucaena.

Trial design and land preparation:

There are eight paddocks with four 'paired-replicates' of Wondergraze and Redlands. Each pair of paddocks is the same size and has the same length of leucaena row. The site was cleaned, strip cultivated, perimeter fenced and fertilised before Christmas 2016. Netting fence was used to exclude rabbits and wallabies.

Before and after leucaena establishment at Pinnarendi

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Redlands vs Wondergraze liveweight gain trial

Planting and management:

Sowing occurred in mid-January 2017 with a follow-up planting in mid-February. A 10m row spacing was adopted to provide enough inter-row pasture during dry-season conditions. Germination and establishment was satisfactory. Management operations in the year after planting included an application of pesticide for grasshopper control, cultivation beside the leucaena to limit weed growth, additional fertiliser applications (leucaena and pasture) and control of re-growth.

Introduction of cattle:

Weaner steers (avg. wt. 208 kg) sourced from Pinnarendi were first introduced to the trial in mid-April 2018. Additional steers (avg. wt. 207 kg) from Spyglass (DAF) were added in late June. In total, 28 head (2 evenly split groups of 14) have been grazed within the same treatments (Redlands or Wondergraze) from 28th June 20 18 to 13th May 2019. The stocking rate was low and animals were rotated between paddocks. Cattle were weighed in August, September, November and December 2018; and in March, April and May 2019. On 1st April 2019 and extra 26 steers from Pinnarendi were added. Of these, 14 head (avg. wt. 213 kg) were allocated to the leucaena trial and 12 head were introduced to a neighbouring buffel grass paddock (fertilised) for comparison. All paddocks will now be grazed at the same time (no rotation) and the groups of animals will stay in the same paddocks.

New technology:

Cameras have been installed adjacent to water points to help ensure animal welfare. Images are taken every few hours. There is also a tank level monitor. A weather station records rainfall, temperature, wind speed and solar radiation. All this information can be accessed remotely on-line in real time. A Walk over Weighing unit will also be installed in the next six months for routine weighing of cattle in the buffel grass paddock.

***Fig. 1** Trial layout at Pinnerendi*

8 R'lnds 8.4 ha Water	7 W'grz 8.4 ha Water	Station Access Road	Yards/ Scales	6 W'grz 7.3 ha Water	5 R'lnds 7.3 ha Water	4 R'lnds 7.3 ha Water	3 W'grz 7.3 ha Water	2 R'lnds 7.3 ha Water	1 W'grz 7.3 ha Water
Laneway				Laneway					

Land preparation at Pinnarendi

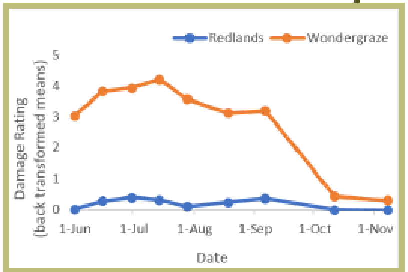
Redlands vs Wondergraze liveweight gain trial

Results:

Establishment:

Both Redlands and Wondergraze established well during 2017 across most of the site (8 paddocks). Despite good rainfall and extra fertiliser applications, leucaena growth over the 2017-18 wet season was sub-optimal. Potentially, this is attributed to nitrogen deficiency caused by poor root colonisation non-viable rhizobium inoculum (CB3126) applied to seed at sowing. This issue is gradually resolving but most areas continued to show yellowed-leaf and poor growth during the 2018-19 wet-season. Currently, Wondergraze paddocks are better established overall than Redlands. The reasons for this are not clear and may be due to soil characteristics or seed quality at sowing.

Fig.2 *Psyllid damage to leucaena at Pinnarenedi during 2017*



Psyllids:

Psyllids were active across the site from May to September 2017. Monitoring of incidence and damage (using a formal rating scale) showed that Wondergraze had significantly more damage than Redlands (which had no damage). Wondergraze recovered quickly once psyllid pressure declined after September. Psyllid activity was minimal during 2018.

Cattle performance:

Over 319 days to 13th May 2018, the Average Daily Gain (ADG) for all animals across both treatments (Redlands and Wondergraze) was 0.69 kg. There was no significant difference between treatments or the source of cattle (Pinnarendi and Spyglass).

Fig. 3 *Average daily liveweight gains at Pinnarendi leucaena trials (2018-2019)*

Grazing Period (2018-19)	*Average Daily Gain (kg liveweight)*		
	All	*Wondergraze*	*Redlands*
28 Jun to 7 Aug (40 days)	**0.50**	*0.53*	*0.47*
7 Aug to 20 Sep (44 days)	**0.38**	*0.43*	*0.32*
20 Sep to 8 Nov (49 days)	**0.15**	*0.12*	*0.18*
8 Nov to 19 Dec (41 days)	**0.40**	*0.44*	*0.35*
19 Dec to 5 Mar (76 days)	**1.51**	*1.46*	*1.56*
5 Mar to 1 Apr (27 days)	**0.73**	*0.78*	*0.69*
1 Apr to 13 May (42 days)	**0.64**	*0.70*	*0.58*
Overall (319 days)	**0.69**	*0.71*	*0.68*

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Redlands vs Wondergraze liveweight gain trial

Discussion:

Liveweight gain data from the first year of the trial is impressive and more than double what would be expected from animals grazing native pasture in the same environment. Animals continued to gain weight during dry season conditions when pasture quality was very low. Leucaena yield during this time was also low but, it continued to produce new leaf for animals to browse. So far, cattle have performed as well on Redlands as Wondergraze. With higher stocking rates now in place, future performance on Redlands may be affected by some inferior paddocks. However psyllid attacks may severely reduce the productivity of Wondergraze. The trial will continue for at least another two years. Future animal performance on leucaena can also be compared with animal performance from the neighbouring buffel grass paddock (improved pasture).

Experience and learnings from the site will improve industry understanding of leucaena establishment, management and productivity in northern environments. Animal performance data will inform the economics of leucaena systems. Full year liveweight gains from the trial can provide compelling evidence for increasing leucaena adoption in northern environments.

Craig Lemin, DAF

Joe Rolfe (DAF) and Craig Lemin (DAF)

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Economics of leucaena in north Queensland

Assumptions

- Running yearling steers on leucaena for 12 months
- Frontage country and red earth sites modelled
- Average turnoff weight 402kg and average sale price $965/head (or $2.40/kg)
- Fencing and water infrastructure costs included
- 5 years from sowing to full production (conservative)
- Increased establishment and ongoing fertiliser costs on red earth with lower fertility
- Leucaena seeding rate 2kg/ha to allow for 30% replant
- Frontage site has inter-row buffel pasture and red earth site has native and improved pastures (Urochloa, Seca, Verano and Wynn cassia)
- Red earth site required Redlands variety due to psyllid pressure ($60/ha seed cost increase)
- Economic analysis includes depreciation, interest, insurance, labour and contractor costs
- Cash flow analysis does not include the above costs

Soil Type	Plant Row Preparation			Seed		Herbicide/Pesticides						Fertiliser P & S Blend	
	Cutter-bar plant row	Deep rip plant row	Cultivate & plant	Wondergraze $50/kg	Redlands $80/kg	RoundUp	Spinnaker	Dictate	Verdict	Grasshopper	Ants/termites	200kg/ha	300kg/ha
Frontage Country	✓		✓	✓		✓	✓	x	✓	x	x	✓	
Red Earth Country		✓	✓		✓	✓	✓	x	✓	x	x		✓

	Economic Analysis*		Cash Flow Analysis	
	Cost ($/ha)	Payback (years)	Cost ($/ha)	Payback (years)
Frontage	281	9	225	8
Red Earth	372	10	316	10

* Based on Drought and Climate Adaptation Program (DCAP) options analysis (Bowen, Chudleigh, Rolfe & English, 2018)

If interested in analysing leucaena for your beef business contact the DAF Northern Beef and Feedbase Team

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Bruce Mayne Seeds

A Producer's tale

In 1954 my father bought Broken Plains, a scrub block in the Rolleston district. We had been successfully fattening steers on Buffel grass for 30 years however this had taken its toll on the soils. Leucaena was then established on Broken Plains where we saw firsthand the benefits as our land reverted back to a highly productive system once again.

In 1998 my wife Lucinda and I got the chance to purchase a property called Bandana in the Carnarvon Ranges. Leucaena had previously been established successfully nearby by the leucaena pioneer John O'Neil. The deep alluvial soils at Bandana were crammed full of phosphorus and just made for leucaena as the carrying capacity of our cattle doubled and weight gains increased to ~250kg and above per annum.

In 2015 we happened to be lucky enough to get one of the licenses to grow Redlands for seed. We bought a small property on the Calliope River called Fairview and it is here that the bulk of our seed production is taking place. While there has been a few bumps along the way, seed is now finally available in quantities that can establish commercial areas.

Growing leucaena is not without its share of problems. Anyone who has grown reasonable amounts have had their failures. Don't let this put you off, the increase of production will soon recover any establishment costs. With a few basic rules, you will eliminate a lot of the difficulties and once established, the rewards are there for years down the track.

Bruce Mayne, Mayne Seeds

Grandkids at Bandana within the Leucaena crop

Harvesting Redlands by hand at Fairview

You can contact Bruce via

M: 0437 6999942 or

E: brucemayne@outlook.com

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DAF and MLA Leucaena demonstration sites

Redlands for Regions

The Redlands for Regions project was developed to demonstrate the benefits and fast track the adoption and of the new psyllid resistant Redlands variety. With aid of the Department of Agriculture and Fisheries extension staff, local producers are evaluating Redlands across a range of soil types. Goshen Station and Quincan Springs have now become essential learning hubs for leacaean production systems in north Queensland.

Goshen Station

Brett and Theresa Blennerhassett planted Redlands on red earths at their Mt Garnet station between February and March 2018. 56ha was planted using a precision Norsemen leucaena planter. It was clearly demonstrated at this site that seed emergence was greatly dependent on planting depths. Seeds planted at a depth of 20-25mm had a higher emergence rate than seeds planted at >30mm. Overall establishment success of Redlands was 56% and Redlands plantings were expanded in the 2018/2019 growing season. Cattle were weighed on to this site in May 2019 to record liveweight gain.

Brett Blennerhassett at Goshen

Peter McLucas and Bernie English (DAF) at Quincan Springs

Quincan Springs

Peter and Colleen McLucas planted 32ha of Redlands at their Peeramon farm in February 2018. An adapted corn planter was used to sow Redlands on their fertile red basalt soils. Despite some early issues with seedbed preparation and weed control the Redlands establishment has been successful. Further leucaena evaluation will be carried out at this site in 2019 where annual live weight performance on grass/legume pasture will be compared to that of cattle grazing Redlands with grass and legume pastures.

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DAF and MLA Leucaena demonstration sites

Leucaena is known to thrive in fertile and free draining basalt soils however very little leucaena has actually been established by producers in this type of country. Demonstration sites at Whitewater and The Brook in Far North Queensland have increased the awareness surrounding leucaena benefits in timbered country.

Whitewater

Tom and Christine Saunders selected 33ha of well draining, high phosphorus and low sulphur red basalt soil to establish leucaena. Single rows were ripped in 2013 however due to low rainfall sowing was not carried out until 2014-2015 wet season. Low rainfall followed the sowing of Wondergraze and resulted in a low establishment success rate, therefore leucaena was resown in January 2016. Due to good planting conditions and follow up rain there was an establishment success rate of 75%. Grazing on the leucaena began 2017 dry season with a high stocking rate followed by a 6 month spell. Low weaner stocking rates were later introduced.

A liveweight gain trial is continuing to compare weaners on leucaena with weaners on native pasture. Preliminary results have already shown that over 65 days weaners on native pastures had an Average Daily Gain (ADG) of 0.06kg whilst the ADG of weaners on Wondergraze was 0.48kg from July to September 2018.

Tom Saunders at Whitewater

The Brook

Darcy and Lynda O'Brien's property consists of a mix of 85% red and 15% black basalt country. 400ha was ripped at ~15m row spacing in October 2017. Following good rain in December 2017, Redlands and Wondergraze was planted in double rows using a customised planter. Establishing leaucaena at The Brook was problematic due to pest animals (kangaroos and deer), planting depth and seedbed preparation issues. The O'Brien family fenced and replanted 100ha of Redlands in the 2018/2019 wet season.

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DAF and MLA Leucaena demonstration sites

Riverview and Blanncourt are two family run properties based in the Georgetown district. Leucaena was introduced to the alluvial soils adjacent to the Gilbert river on both properties. These demonstrations sites are key examples where motivated producers can develop leucaena on frontage country.

Riverview

Leucaena was established in the 2017-2018 wet season. In September 2017 160ha was cutter-barred to control suckers and nut grass. Sowing was delayed through to January 2018 due to hot and dry conditions. By the end of February 150ha of Wondergraze and 10ha of Redlands was planted. Pre-emergent herbicides were applied post-planting and Regent® was applied to control termites. Sempra® was used for nut grass control while Verdict™ controlled grass in the plant rows. Phosphorus and sulphur was applied over the plant rows pre and post planting. Overall there was a 65% leucaena establishment success rate at Riverview. Weaners were later introduced in August 2018. Steers running on leucaena and buffel pastures on Riverview from September to December 2018 (99 days) had an Average Daily Gain (ADG) of 0.18 kg/head. The ADG of these same steers on leucaena and buffel

Ronnie and Colleen Henry

Blanncourt

Leucaena was established at Blanncourt during the 2015-2016 wet season. Land preparation began in 2014 with the 10m plant rows across a 54ha site being cutter-barred and cultivated. A single row of Wondergraze was sown and then resown due to weeds and poor establishment. The site was then sprayed with pre-emergent herbicide post-sowing. Phosphorus and sulphur were added pre-planting and more sulphur was applied post-planting.

After the second leucaena planting, the establishment success at Blanncourt was 75%. Cattle were introduced when leucaena plants were 2m tall.

Glen and Cheryl Connolly

Both producers planted more leucaena during the 2018-2019 wet season, with very poor establishment results due to low rainfall and hot conditions post planting

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Other MLA-DAF Feedbase Research

The principal focus of the Promising and Progressing Pastures projects is to test and promote new pasture grasses and legumes suited to the seasonally dry areas of north and central Queensland. The aim is to identify best grass and legume options to improve the productivity and profitability of beef businesses. Sown-pasture systems are promoted through the development of plant evaluation sites and producer engagement across a range of land-types.

Promising Pastures

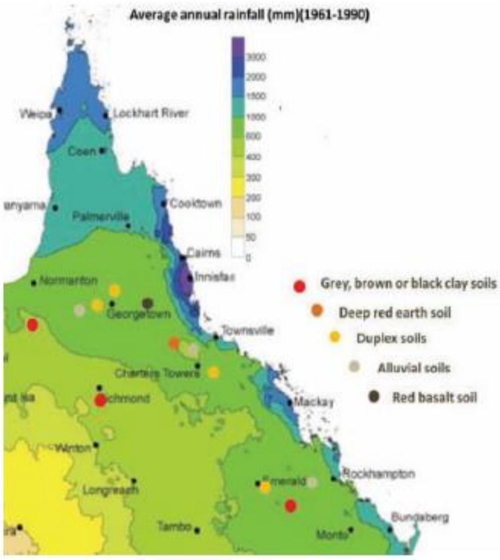
Replicated small plot assessments were completed across 12 research sites representing soils of moderate to high fertility. The sites were located in the Gulf of Carpentaria and sub-coastal central Queensland. Up to 29 legumes and 30 grasses developed over the last 20 years were compared with older varieties, where present Assessments were completed over 3-4 years and the evaluation sites managed as weaner paddocks.

Promising grasses included makarikari grass (*Pancium coloratum*), panic (*Panicum*) hybrids as well as brizantha (*Brachiaria brizantha*). The best performing legumes included desmanthus (*Desmanthus* spp.), stylos (*Stylosanthes* spp.) (particularly Primar and Unica stylos), butterfly pea (*Clitoria ternatea*) and newer varieties of atros (*Macroptilium atropurpureum*).

Progressing Pastures

The second phase of the program, 'Progressing Pastures', targets the testing of combinations of the best-performing lines from the small plot testing. The same land types will be targeted but the assessments will be conducted on a larger scale and managed as weaner paddocks. The sites will be used for demonstration. Seed increase is also being completed by DAF to ensure the availability of the superior varieties.

Whitewater promising pastures plot



Distribution of sites across Queensland

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MLA

Redlands: A game changer for Northern Beef

The launch of Australia's new psyllid-resistant leucaena variety marks a significant milestone for beef production in northern Australian. The potential to open up large areas for leucaena-based beef grazing systems in the north's high rainfall zones is now on our doorstep. Productive leucaena-based grazing systems have been shown to significantly increase annual live-weight gains and lift carrying capacity for beef enterprises. However, there has been very slow adoption of leucaena in northern Queensland to date and one major reason for this is the reduction in productivity from attacks by psyllid insects which favour northern climates. That's why Redlands is a game-changer for the high rainfall zone. Not only is it a palatable variety but it is not susceptible to attack from production-limiting psyllids.

Adoption of leucaena will increase carrying capacities in north and coastal Queensland, reduce age at turn-off, extend feedbase quality further into the dry-season and enable producers to target premium slaughter markets. It will also lift the potential for better rangeland management by reducing stocking rate pressure on native pasture systems and contribute to targets for a carbon neutral beef industry by 2030 through reduced methane emissions per unit of live weight production. Research conducted via the National Livestock Methane Project, managed by MLA, from 2010-15 demonstrated potential for leucaena to reduce greenhouse gas emissions by up to 20%.

It has taken almost 15 years to arrive at the commercial release of Redlands, which was developed with funding from Meat & Livestock Australia and bred by researchers at the University of Queensland. Of the $7.2 million invested in leucaena research and development across 26 projects to date, using both MLA Donor Company funds and levies, almost 12% has been dedicated to the development and assessment of psyllid-resistance leucaena for northern Australia.

Many producers have already been instrumental in demonstrating the potential of Redlands in northern Queensland. Our Producer Innovation Fast Track program called Redlands for Regions, has involved on-farm activities by producers and The Leucaena Network to showcase and document the establishment and assessment of Redlands in psyllid-susceptible areas. Given the premium price of Redlands' seed and costs of leucaena establishment, the information from this project will be critical in building producer confidence in planting Redlands in psyllid-prone areas. This information, combined with the experience from establishing and managing leucaena at the site, will directly contribute to better industry knowledge of the costs, benefits and opportunities for leucaena production systems in northern Australia. This work will be ongoing with MLA and the Department of Agriculture and Fisheries supporting Pinnarendi as a benchmark site generating productivity data for northern producers.

The commitment from the Department and individual producers who have been involved in on-farm trials provides confidence in Redlands playing a key role in supporting a productive, sustainable and profitable beef industry across northern Australia. I am delighted to join with the Department of Agriculture and Fisheries and the University of Queensland's commercialisation company, UniQuest, to celebrate the development and launch of Redlands today.

Jason Strong (Managing Director, Meat and Livestock Australia)

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Acknowledgements

We would like to thank the following for making this field day possible:

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Craig Lemin, Joe Rolfe, Bernie English, Alison Larard , Jessica Gorman and Emily Baretta

mla MEAT & LIVESTOCK AUSTRALIA

Jason Strong , Amanda McAlpine and Nigel Tomkins

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

LEUCSEEDS Pty. Ltd. ACN 067 600 551

Peter and Tim Larson

MAYNE SEEDS

Bruce Mayne

Max Shelton and Scott Dalzell

Pinnarendi Station Stay & Cafe

Ron and Nadine Atkinson

The DAF Beef and Feedbase Team greatly appreciate the assistance of:

- Ron and Nadine Atkinson for hosting this grazing trial and providing day to day support to the project team.
- Cameron and Sasha Burtenshaw (St Ronans) for hosting the initial trial site and supplying equipment for Pinnarendi
- Giles and Sally Atkinson for providing a bulldozer, machinery and wire roller for Pinnarendi
- Greg Brown for providing a tractor and assistance in setting up and establishing the Pinnarendi site

9.6 Annual observations of leucaena growth

9.6.1 2018

Rainfall in early January 2018 produced a growth response in leucaena across the site. With no psyllids active, new growth on Wondergraze compensated for previous damage by psyllids. Conditions then became dry and about a third of leucaena at the site became water stressed until regular rainfall in February. Despite this, leucaena did not grow vigorously, with Redlands and Wondergraze at the site having a yellow-green colour. There was little useful rainfall after March. Conditions dried out quickly and leucaena growth was checked earlier than in 2017.

When cattle were introduced in April 2018, there was a moderate yield of leucaena available for grazing. There were mild frosts in June. Cool weather and dry conditions resulted in some leaf loss and yield decline by early August 2018. The most significant frost of the year occurred in late August and resulted noticeable leaf blackening and loss in lower lying parts of the site.

Warmer temperatures in September encouraged new growth despite dry conditions. There was 37 mm rainfall at the site in October which stimulated new growth and leaf production across all paddocks. This was only sustained until early November and dry conditions progressively constrained growth. Plentiful rainfall in December promoted vigorous growth by the end of the year.

9.6.2 2019

Leucaena responded well to rainfall over the 2018-19 wet-season, particularly after heavier than normal rainfall in December 2018. However continued grazing by cattle limited overall plant height relative to the previous season when leucaena was ungrazed. Poor leaf colour ('yellowing') was evident towards the end of the wet-season but was judged not as prevalent as for the previous year.

Under set-stocking, leucaena productivity declined progressively from April onwards after poor March rainfall and continuing dry weather which developed in drought conditions. There were no frosts, but cool weather and dry conditions severely inhibited new leaf growth by mid-July. With a change to lighter stocking and rotational grazing in August, growth of new leaf during spell periods was sufficient for cattle to have fresh-pick for several days when rotated to a new paddock (with the exception of Paddock 8). Despite continued dry conditions, there was increased new leaf growth during October with increased temperatures, but this was less than in 2018. Leucaena response to a 10 mm fall of rain at the start of November was short-lived, hot and dry conditions prevailed, and leucaena productivity was very low.

9.6.3 2020

At the end of 2019, leucaena growth at the site was poor due to drought conditions. Rain in late December 2019 caused a growth response and good growth was maintained through the first five months of 2020 due to regular and above average rainfall, although 'yellowing' leaf was evident in the late wet season. As in previous years, productivity declined from about late April due to drier conditions and milder temperatures. By mid-August, all residual leaf had been effectively eaten by cattle (or had fallen off).

There were no frosts during 2020 although cold weather resulted in leaf loss and inhibited new leaf growth so that leucaena remained in a state of low productivity during the winter period. With warmer conditions in September and October, leucaena responded with modest new leaf growth despite progressively drier conditions. The ability of leucaena to produce a modest amount of new leaf during warmer weather (but otherwise dry conditions) has been a feature of the crop at the site. However, cattle ate new leaf as fast as it was produced. Small falls of rain during the spring months promoted new leaf production but only for 1-2 weeks each time. Overall, leucaena productivity was constrained until mid-December when good rain was received. By the end of December 2020, leucaena had produced a body of leaf that was 'ahead' of cattle in most paddocks (excepting Redlands Paddocks 2 and 8.

9.6.4 2021

Leucaena growth was good but not outstanding in response to above average rainfall received in December 2020 and to the end of February 2021. As for the previous year, leucaena showed generally good colour (dark green) in the early part of the wet-season trending to lighter green-yellow growth by late February. However, this phenomenon appeared less marked than in previous years, reducing in severity and in the extent of area affected.

Leucaena at the site dropped almost all leaf during April. This was despite high rainfall early in the year and warm temperatures prevailing. However, it was likely the result of moisture stress. Regular rainfall to the start of March was followed by 50 days of dry conditions during which only two small falls of rain were received (4 mm on 5 March and 6 mm on 25 March). Soils at Pinnarendi are well drained and dry rapidly. With a significant canopy, transpiration likely exceeded available soil moisture resulting in leaf abscission which occurred about 10 April. New leaf production resumed in May, as plant water demand was reduced, and useful rainfall was received 21-25 April.

There was no significant cold weather during the winter period in 2021, which allowed a modest level of productivity during this time but constrained by seasonally dry conditions. Cattle generally consumed new leaf growth as fast as it was produced particularly in Redlands Paddocks 2, 4 and 7 where are marked difference between neighbouring Wondergraze paddocks was apparent.

After Spyglass cattle were removed in early August, there were 28 head of Pinnarendi cattle remaining, which were mobbed and rotationally grazed at the site until mid-December on an ad-hoc basis. There was an early break to the dry season in 2021 with leucaena responding to good rain in early October. Follow-up rain in November allowed on-going active growth which combined with lower grazing pressure resulted in a surplus of growth at the time leucaena was pruned in early December.

Following pruning, existing soil moisture and further rainfall promoted re-shooting within a week, and there was good follow-up growth through December.

9.6.5 2022

Initial re-growth of leucaena after cutting in December 2021 was rapid but only modest in January-February 2022 despite warm, humid conditions and on-going rainfall. Growth during this time was likely constrained by sub-optimal soil fertility. Nonetheless, fourth cohort heavy weight steers introduced on 1 March had plenty of available forage. March had well-below average rainfall, which was concerning. Fortunately good (unseasonal) rainfall in April and May prevented leucaena becoming moisture stressed and leaf was retained.

At this time, cattle were rotated weekly between paddocks with each paddock being well-eaten by the time animals were rotated to a 'fresh' paddock. However, because of the out-of-season rainfall, leucaena remained productive. Remarkably, more unseasonal rainfall was received in July but associated cold weather checked leucaena growth. New growth resumed with warmer conditions in mid-July about the time most fourth cohort animals were removed for slaughter.

Psyllids significantly affected Wondergraze at the site from about mid-August with on-going damage through September. Additional unseasonal rainfall in early September (24 mm) sustained and promoted leucaena growth, particularly as temperatures warmed up with daytime maximums above 30°C.

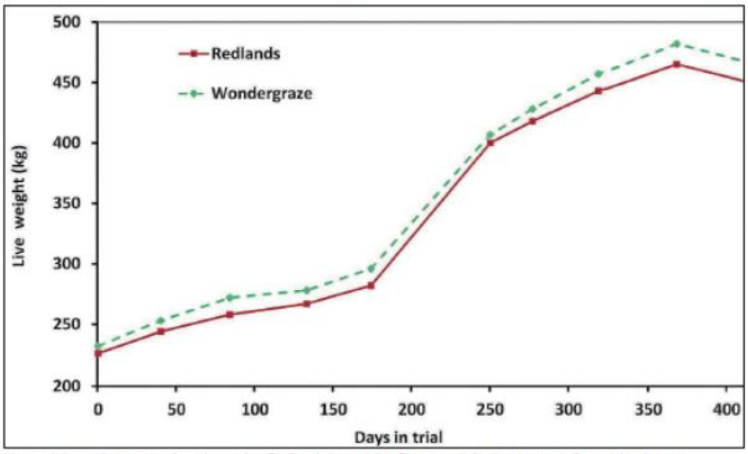
9.7 Media

9.7.1 Northern Muster article – 25 June 2020

northqueenslandregister.com.au Thursday June 25, 2020 NORTH QUEENSLAND REGISTER 15

FutureBeef NORTHERN MUSTER Information for rural business in North Queensland Queensland Government

Redlands up to the job



Live weight performance of cattle grazing Redlands in a trial at Pinnarendi Station in north Queensland, was equivalent to Wondergraze leucaena.

Psyllid-tolerant leucaena available

REDLANDS is the new psyllid-tolerant leucaena variety now available to the beef industry.

Bred by the University of Queensland and launched by Meat & Livestock Australia in 2019, it has the potential to open up new areas for leucaena development across northern Australia, but its performance under grazing was not known.

In a trial at Pinnarendi Station in north Queensland, the good news is that live weight performance of cattle grazing Redlands was equivalent to Wondergraze leucaena.

The Average Daily Gain (ADG) for cattle grazing Redlands over 368 days was 0.66 kilograms versus 0.68kg for Wondergraze.

This is an overall annual weight gain of 245kg/head (June 2018 to June 2019).

Whilst it is an impressive result, psyllids were not active during this time.

Live weight performance measurements are continuing at the site to try and demonstrate the productivity advantage from using Redlands leucaena.

Pinnarendi trial

Redlands is suited to extensive coastal and near-coastal sites with adequate rainfall (700 millimetres) where psyllid risk has previously constrained leucaena adoption.

A 60 hectare replicated trial site was planted in 2017 at Pinnarendi, near Mt Garnet, to compare live weight gains for cattle grazing Redlands or Wondergraze leucaena.

A cultivated strip method was used at 10 metre row spacing.

This retained the pre-existing pasture including urochloa, indian couch and black spear grass as well as substantial areas of the legumes wynn cassia and stylo.

The soils at Pinnarendi are relatively infertile red-earths and have required substantial phosphorus and sulphur applications to promote leucaena and pasture growth.

They are, however, prevalent across the region and this aspect combined with other favourable features made Pinnarendi an appropriate location for conducting the comparative grazing trial.

Pinnarendi is also in an area where psyllids are seasonally active and therefore test Redlands capacity for higher productivity during periods when Wondergraze was potentially affected by psyllids.

Cattle grazing

The grazing trial started in June 2018 with 28 Brahman cross and Droughtmaster weaner steers (averaging 229kg).

These steers were grazed for 14 months and removed at the start of September 2019.

A second and overlapping cohort of 14 Brahman cross steers (averaging 213kg) were introduced in April 2019 to the leucaena trial as well as 12 head to an adjacent 25ha fertilised pasture paddock with no leucaena.

Due to dry conditions, no extra animals were added to the trial for the rest of 2019, and stocking rates were low.

Results

The graph shows the growth curves for cattle grazing Redlands and Wondergraze over 427 days on the trial.

No supplements were fed during this period.

The steep part of the curve corresponds to ADGs of up to 1.6kg during the wet season.

During July and August 2019, cattle lost about 20kg/head before being removed from the trial.

Conditions were dry and cold with some frosts, so pasture quality was poor and leucaena productivity was low.

Unfortunately, there were no significant psyllid populations at the site during the grazing period to highlight any production advantages of Redlands over Wondergraze.

For the second cohort of cattle on the trial, a year of grazing is almost complete.

Due to drier than normal conditions during 2019, cattle performance has been less than recorded in the previous steer group.

ADG over 365 days is expected to be close to 0.56kg with no difference between Redlands and Wondergraze, however, psyllids were not active at the site for the second year running.

Remarkably, cattle in the improved pasture paddock, which is predominantly buffel grass, have shown equivalent live weight gains to the leucaena cattle.

This reflects the low productivity of leucaena during the second half of 2019.

It should also be noted this improved pasture paddock was ungrazed for four years prior to being incorporated in the trial.

All second cohort cattle were supplemented with urea blocks from September to the end of December and phosphorus blocks over the wet season.

Ongoing activities

Despite a late start, more than 600mm of rain has been received at Pinnarendi up to May 2020 and the second cohort of steers will be removed in late June.

A third cohort of steers were introduced during May with additional steers to be included at the same time as the older steers are removed.

This will see a return to complete stocking at the site with full replication.

Seasonal conditions appear more favourable for psyllids this year, so some productivity advantage from Redlands may be apparent.

It will be interesting to see if animal performance from the improved pasture paddock is also maintained.

For more information contact Craig Lemin, research officer, Department of Agriculture and Fisheries, Mareeba, 0467 804 870 or craig.lemin@daf.qld.gov.au.

Alternatively, you can visit futurebeef.com.au and then search for 'leucaena' or 'redlands'.

9.7.2 ABC Country Hour interview

ABC

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Queensland Country Hour
with Amy Phillips, Arlie Felton-Taylor

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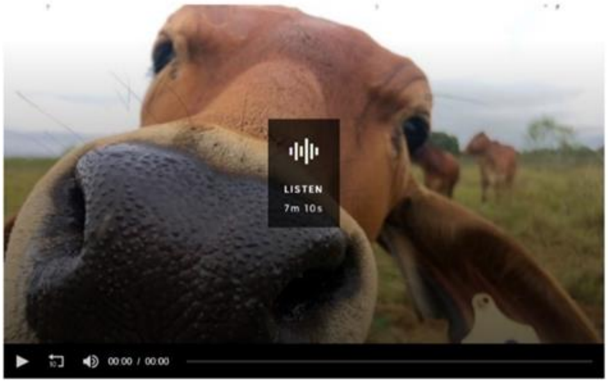

Image: ABC Rural: Charlie McKillop

Full episode • 1hr
Queensland Country Hour

7mins 10secs **Redlands leucaena trial yet to be tested by psyllids**

Leuceana researchers hoping wet weather puts fodder crop under psyllid pressure

On Queensland Country Hour with Arlie Felton-Taylor

Share

Download 3.29 MB

The new Redlands leucaena variety has been hailed as a 'game changer' for the northern cattle industry, touted to be palatable to cattle at the same time as being resistant to psyllids which have stymied efforts to establish the alternative fodder crop in the north. As the four-year trial on Pinnarendi enters its final stages, the Queensland department of Agriculture's Craig Lemin told Charlie McKillop the data confirms significant benefits to be gained but there's still more work to be done.

Duration: 7min 10sec
Broadcast: Thu 29 Apr 2021, 12:00pm

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9.8 Dairy-One detailed results

Table A6. Pasture quality analysis of leaf, stem and immature pod sampled at Pinnarendi 2019-21.

Cultivar	*Sample description*	*Date*	*Crude protein (%)*	*Acid digestible fibre (%)*	*Neutral digestible fibre (%)*	*Lignin (%)*	*Non-fibre carbohydrate (%)*	*Total digestible nutrients (%)*	*Metabolisable energy (MJ/kg)*	*Relative feed value*
Wondergraze	leaf + pod	5/19	13.5	36.2	45	13	30.7	55	8.08	126
Wondergraze	stem	5/19	6.2	58.6	64	16.1	19.1	45	5.62	63
Redlands	leaf + pod	5/19	12.7	35.7	45.4	13.6	31.1	54	7.93	125
Redlands	stem	5/19	6.2	58.8	69.7	17.8	13.3	41	4.61	57
Wondergraze	leaf + pod	5/19	14.1	24	29.9	8.9	45.2	64	10.09	218
Wondergraze	stem	12/19	6.2	50.1	58.4	14.9	24.6	48	6.49	79
Wondergraze	as grazed	12/19	14.3	25.3	29.4	9.2	45.4	64	10.09	219
Redlands	leaf	12/19	12.9	24.8	28.5	10.3	47.8	63	9.95	227
Redlands	stem	12/19	5.8	50.5	59.3	15.6	24.1	47	6.20	78
Redlands	as grazed	12/19	14.4	25.1	31	11.3	43.8	62	9.66	208
Wondergraze	leaf	5/19	16.4	23.4	29	12.5	43.8	62	9.66	226
Wondergraze	stem + pod	5/19	11.8	45.7	55.3	13.8	22.1	50	6.92	90
Wondergraze	as grazed	5/19	14.3	35.5	38.1	13.4	36.8	57	8.65	150
Redlands	leaf	5/19	15.1	25.8	30.4	13.2	43.7	60	9.52	211
Redlands	stem + pod	5/19	10.1	46.6	50.2	15.3	28.9	51	7.21	97
Redlands	as grazed	5/19	13	34.3	41.6	13.4	34.6	56	8.36	139
Combined	leaf	11/20	17.3	18.7	24.6	9.9	47.3	65	10.38	282
Combined	stem	11/20	10.8	37	49.8	11.2	28.6	55	7.93	112
Combined	as grazed	11/20	15.9	23.2	29.8	9.4	43.5	64	9.95	221
Wondergraze	leaf	4/21	22.6	23.7	33.3	8.9	33.3	63	9.81	197
Redlands	leaf	4/21	18.8	25.4	33.5	11.6	36.9	61	9.37	192
Redlands	stem + pod	4/21	13.4	43.8	54.4	13.9	21.4	51	7.07	94
Redlands	as grazed	4/21	15.1	37.3	49.8	13	24.2	53	7.64	112
Combined	pod	4/21	17	37.7	51.8	11.1	20.4	55	7.79	107
Redlands	leaf	5/20	18.8	29.3	38.4	12.2	32	58	8.94	160
Redlands	stem + pod	5/20	16.1	42.7	55.4	12	17.7	53	7.21	94
Redlands	as grazed	5/20	17.3	36.9	47.5	11.8	24.4	55	8.08	118
Redlands	leaf	10/20	21.5	21.7	28.2	10.7	39.5	64	10.09	238
Redlands	stem	10/20	11.7	43.7	51.5	15.3	26	50	7.21	99
Redlands	as grazed	10/20	19.3	26.8	35	12.2	34.9	60	9.23	181
Wondergraze	leaf	6/20	21.6	17.7	27.3	7.4	40.3	67	10.53	256
Wondergraze	stem + pod	6/20	8.7	50.3	60.6	14.8	19.9	47	6.20	76
Wondergraze	as grazed	6/20	17.7	26.7	30.8	9	40.7	64	9.95	205
Wondergraze	leaf	11/20	22.5	15.4	22.2	7.8	44.5	68	10.96	322
Wondergraze	stem + pod	11/20	13.3	35.9	47.4	11.4	28.5	56	8.08	120
Wondergraze	as grazed	11/20	20.2	21.2	26.9	9	42.1	65	10.38	251
Wondergraze	leaf	6/21	19.5	19.4	25.5	10.2	44.2	65	10.38	269
Wondergraze	stem + pod	6/21	10	45.2	55.6	14.5	23.6	49	6.78	90
Wondergraze	as grazed	6/21	16.7	27.8	33	10.7	39.5	61	9.52	190

Table A7. Pasture quality analysis of ''yellow' and 'green' leaf sampled at Pinnarendi March 2019.

Cultivar	*Sample description*	*Date*	*Crude protein (%)*	*Acid digestible fibre (%)*	*Neutral digestible fibre (%)*	*Lignin (%)*	*Non-fibre carbohydrate (%)*	*Total digestible nutrients (%)*	*Metabolisable energy (MJ/kg)*	*Relative feed value*
Redlands	yellow leaf	3/19	18.3	21.5	25.3	11.5	45.6	64	10.24	265
Redlands	green leaf	3/19	19.2	23.5	26.6	11.4	43.4	64	10.09	247
Wondergraze	yellow leaf	3/19	20	22.7	25.2	11.2	44	65	10.24	263
Wondergraze	green leaf	3/19	19.2	21.3	25.3	9.3	44.6	66	10.38	266
Wondergraze	yellow leaf	3/19	12.9	29	33.6	15.8	42.8	57	8.80	184
Wondergraze	green leaf	3/19	19	25.6	30.9	12.6	39.3	61	9.52	208
Redlands	yellow leaf	3/19	12.3	29.1	33	13.4	43.9	59	9.23	187
Redlands	green leaf	3/19	17.1	26.3	31.4	13.4	40.7	60	9.37	203
Wondergraze	yellow leaf	3/19	15.1	23	27.2	11.1	46.9	63	9.95	242
Wondergraze	green leaf	3/19	17.6	26.4	37.4	11.4	34.2	59	9.08	170
Redland	yellow leaf	3/19	14.1	30.6	37	16.1	38.1	55	8.51	164
Redlands	green leaf	3/19	18.8	25	30.7	11.9	39.7	62	9.66	210