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Assessing productivity gains for cattle grazing "Redlands" (R12) leucaena in northern Queensland

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Abstract

Productive leucaena based grazing systems can double annual live-weight gains and increase carrying capacity for beef enterprises. However, there has been very little adoption of leucaena in northern Queensland. One major reason for this is the reduction in productivity from attacks by psyllid insects.

‘Redlands’ is a psyllid resistant leucaena arising from a breeding program undertaken by the University of Queensland and supported by Meat and Livestock Australia. It has potential to open up large areas for leucaena based beef grazing systems in northern Australia but its performance under commercial scale grazing conditions has not been tested. This project established a large-scale grazing trial in north Queensland to evaluate the liveweight gain performance of Redlands relative to the existing commercial Wondergraze variety.

A 62 ha site initially selected at ‘St Ronans’ was prepared and planted over the 2015-16 northern wet season. Unfortunately, establishment was unsuccessful, due to heavy rain after planting and soil drainage issues. An alternative, 61 ha site was selected at nearby ‘Pinnarendi’ and developed for the trial during 2016. Leucaena planting at the site occurred during January and February 2017. The leucaena was successfully established at Pinnarendi over the following 18 months.

The first cattle were introduced to the trial in April 2018 at a low and cautionary stocking rate using Brahman-cross steers from the commercial herd on the property. Some of these animals were replaced in June 2018 with Droughtmaster steers from the Department of Agriculture and Fisheries ‘Spyglass’ Beef Research Facility.

The average entry weight was 228 kg and individual liveweight of all animals was monitored on three occasions to November 2018, coinciding with rotation of animals between trial paddocks (within the same treatments). Liveweight gains averaged 0.33 kg/day over this period.

Data from the ongoing grazing trial will assess any relative productivity advantage from using Redlands and help confirm the economics of leucaena in north Queensland. The site will also improve industry understanding of leucaena establishment and management in northern environments. A productive and psyllid resistant leucaena variety would improve profitability and sustainability of northern beef businesses through increased feedbase productivity and enabling access to premium slaughter markets.

Executive summary

Attacks by psyllid insect in northern Australia reduce the productivity of leucaena pasture systems. This project addressed this significant constraint to leucaena adoption in north Australia. The psyllid resistant leucaena variety Redlands was developed by the University of Queensland and Meat and Livestock Australia.

Redlands was selected based on desirable production attributes and relative acceptability by cattle. However, there was no extensive grazing data to demonstrate the animal performance attributes of Redlands and this needed investigation. Whilst conferring psyllid resistance, there was some concern that the *L. pallida* component of Redlands might influence animal acceptance and subsequent liveweight gain. Conversely, the superior productivity of Redlands in psyllid prone environments was presumed to offer better liveweight gains relative to existing commercial varieties. This would justify its adoption and allow promotion of Redlands over other varieties.

This project was developed to set-up a large scale replicated grazing trial using Redlands and Wondergraze. Wondergraze is a conventional commercial leucaena variety which is susceptible to psyllid attack. Subsequent grazing trials would determine the relative liveweight gain performance between the two varieties and more generally provide productivity data on leucaena in northern environments. The project was conducted in two phases:

- Phase 1 - development and establishment of the trial site ready for the introduction of cattle. Establishment and management practices and inputs were recorded.
- Phase 2 - evaluation of liveweight gain performance of cattle grazing on the trial over consecutive grazing periods of 10-12 months. Related activities and aims included monitoring psyllid activity and damage; measuring carcass characteristics of cattle from the trial; collaboration with researchers investigating efficacy of the rumen inoculant for leucaena; and modelling economics of leucaena production systems and impact of future leucaena plantings on the Queensland beef industry.

Phase 1 – original trial site at St Ronans
A 62 ha site was originally selected at St Ronans and was prepared and planted with leucaena and inter-row pasture species over the 2015-16 northern wet season. The grass pasture established well, but heavy rainfall immediately after planting and poorly drained soils across some areas of the site resulted in an unsatisfactory establishment of leucaena and on-going poor performance. For these reasons, it was decided to relocate the trial to an alternate site at nearby Pinnarendi.

Phase 1 – establishment at Pinnarendi
Pinnarendi has relatively infertile, light, well-drained soils with low moisture holding capacity. The 61 ha site at Pinnarendi is relatively uniform and was already cleared. Site preparation was carried out during 2016 based on a trial design incorporating eight replicated paddocks. Rainfall allowed planting in January and February 2017. Subsequent germination of leucaena and initial establishment was satisfactory. Significant applications of phosphorus and sulphur were made due to low soil fertility. Rain in late May 2017 extended leucaena growth and development into the early dry season. A survey to determine establishment uniformity was conducted August 2017. Psyllids were active at the site from May to September 2017 and a monitoring program showed significantly

increased activity (damage) within Wondergraze plantings. Abnormally high rainfall was received during the last half of October 2017, ensuring survival of leucaena at the site and promoting renewed growth earlier in the season than would otherwise be expected. With leucaena and inter-row pasture well established, infrastructure for the grazing trials was installed, including internal fencing, water points and portable yard equipment.

Phase 2 – grazing at Pinnarendi
After successful establishment of the trial under Phase 1, a project to conduct the grazing phase over three years was developed. Animal ethics approval for grazing trials was obtained. Cattle were introduced to the trial for a pilot grazing period towards the end of the Phase 1 project in April 2018. The pilot grazing period is on-going and will inform refinement of the grazing methodology for future cohorts of cattle.

Cattle were initially introduced to the trial in April 2018 at a low and cautionary stocking rate. The first cattle on the trial were Brahman-cross steers from the commercial herd on the property. Some animals were replaced with Droughtmaster steers from the Department of Agriculture and Fisheries (DAF) ‘Spyglass’ Beef Research Facility in June 2018. From this time until early November 2018, a total of 28 steers were grazed continuously on the trial. These comprised 12 remaining steers from Pinnarendi with an average weight of 257 kg (sem. = 9 kg) and 14 smaller replacement steers from Spyglass with an average weight of 207 kg (sem. = 1 kg). Individual liveweight of all animals has been monitored on three occasions up to early November 2018. Preliminary liveweight gain of cattle averaged 0.33 kg/day over 133 days.

Psyllids were active at the site during 2017 and caused significant widespread damage to Wondergraze. Psyllids were present on Redlands in lower numbers and did not cause observable damage. Psyllid populations during 2018 were relatively low and short-lived with no perceived damage or reduction in yield of Wondergraze relative to Redlands.

Liveweight performance data from the trial has been measured during a period when leucaena productivity is seasonally constrained. Overall liveweight gains on the trial are superior to those which would be achieved on native pastures only. Full-year liveweight gains from the trial may provide compelling evidence for increasing leucaena adoption in northern environments. Animal performance data from the site will more generally inform the economics of leucaena systems. Experience and learnings from the site will improve industry understanding of leucaena establishment, management and productivity in northern environments. Leucaena adoption has the potential to improve profitability and sustainability of northern beef businesses through increased feedbase productivity and enabling access to premium slaughter markets.

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1 Background

1.1 Constraints to leucaena adoption in northern Queensland

Leucaena offers a pathway to dramatically improve productivity and 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 has been widely adopted in southern and central Queensland, enabling about approximately 50,000 tonnes of liveweight gain worth about $100M annually. However, there has been less than 2,500 ha established in north Queensland (Keating 2017).

Whilst most graziers are aware of the production benefits associated with leucaena, the low adoption rate is attributed to low producer confidence and experience in the technology; 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, the climate is more favourable for the proliferation of psyllids which can severely reduce productivity even if producers successfully establish leucaena.

1.2 Breeding program for psyllid resistant leucaena

The leucaena psyllid (*Heteropsylla cubana*) is a small insect that feeds by sucking sap from new leucaena shoots and young foliage. All previous commercial leucaena varieties were susceptible to psyllid attack and depending on seasonal conditions, such attacks can defoliate trees and limit plant growth (Dalzell 2006). Psyllid insect are more prevalent in humid, northern environments (during cooler weather) and their presence has constrained leucaena production systems to drier areas within the 600-800 mm rainfall zone.

Plant-based genetic resistance to psyllids is the most appropriate solution to 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 N.B.P.0791 UQ and MLA proceeded to commercialise the Redlands variety.

With Redlands psyllid resistant leucaena now available to beef producers, the next step was to investigate the relative productivity advantage from using Redlands and help confirm the economics of leucaena in north Queensland. This project has been designed to do this, and will also improve industry understanding of leucaena establishment and management in northern environments. A productive and psyllid resistant leucaena variety would improve profitability and sustainability of northern beef businesses through increased feedbase productivity and enabling access to premium slaughter markets.

2 Project objectives

2.1 Phase 1

Large scale replicated grazing trial
Develop a 62 ha (nominal) trial site incorporating the Redlands (R12) psyllid resistant leucaena variety and another current commercial variety (Wondergraze).

Producer Management Group
Establish a Producer Management Group (to include wider industry) to provide input to site preparation, planting and leucaena establishment in the north Queensland environment. The producer group will also provide advice throughout Phase 2.

2.2 Phase 2

Liveweight gain performance
Measure and compare the liveweight gain of weaners grazing Redlands and Wondergraze through to a commercial target weight.

Carcass characteristics
Document carcass characteristics for cattle finished on leucaena systems using the Redlands variety (assuming entry weights or grazing duration can be increased in later years of the trial).

Leucaena growth and yield
Measure vegetative growth and yield attributes of Redlands and Wondergraze at the trial site.

Economic modelling
Model the potential economic influence of future leucaena plantings on the Queensland beef industry.

Establishment and management of leucaena in north Queensland
Provide industry with data and information on refined establishment, on-going management and cost-benefit of leucaena production systems.

3 Trial site selection

3.1 St Ronans Station

A site at St Ronans was selected for the trial in November 2015. St Ronans is located 60 km south-west of Mt Garnet in north Queensland and is approximately 250 km from the coast. The property lies within the 600-900 mm average annual rainfall zone and had extensive areas of cleared country on basalt soils previously used for grain and forage cropping. Although 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.

A 62 ha site at St Ronans was prepared and planted over the 2015-16 northern wet season. At the end of March 2016, poor germination and growth of leucaena was principally attributed to heavy rain received soon after planting and possible attendant pre-emergent herbicide damage. Seedlings which had germinated and survived did not grow well, and whilst plant populations in some areas were bordering on acceptable, this was not sustained due to on-going plant death.

The project team became concerned about the long-term suitability of the site for the trial. It was apparent that about 40% of the site had poor drainage probably due to underlying clay and soils at the site were more variable than originally assessed. St Ronans received near average rainfall over the 2015-16 wet-season. Having experienced issues at the site under such relatively benign conditions, large areas of the site would be incompatible with leucaena in wetter years. By late April 2016, the project team was convinced that the site selected on St Ronans was not suited for establishment of the grazing trial and an alternate site for the trial would need to be selected.

A summary of the activities conducted at St Ronans is given in Appendix 1.

3.2 Selecting an alternative trial site

The requirements for an alternative trial site included:

- suitable soils
- a sufficient area of cleared land
- suitable climate i.e. sufficient rainfall and conducive to psyllid pressure
- a willing co-operator
- access to trial animals and yard infrastructure
- proximity for access by DAF staff and producers

After consideration, Pinnarendi was proposed as a possible site. Although less than 10 km from the original trial site, the soils at Pinnarendi are red-brown earths of granitic origin with very different characteristics. On assessing Pinnarendi for the trial, the owners offered the use of paddocks that had previously been used for cropping.

3.3 Pinnarendi Station

The paddocks at Pinnarendi had previously been cropped during the 1980's and 1990's and were cleared, relatively flat and rock-free. Since being cropped, this area had been used for grazing and had a good cover of pasture species comprising mainly Indian couch (*Bothriochloa pertusa*), Wynn cassia *(Chamaecrista rotundifolia)*, Sabi grass (*Urochloa mosambicensis*), Black Spear grass (*Heteropogon contortus*) and *Stylosanthes* spp. Initial field surveys with GPS showed there would be sufficient area to conduct the replicated grazing trial if some small areas of re-growth could be cleared and existing fences removed/realigned.

Advantages of the site included climatic conditions conducive to psyllid pressure; access to cattle for grazing trials; some access to machinery for site development and leucaena establishment; highway frontage and reasonable proximity to DAF facilities on the Atherton Tablelands.

4 Methodology

4.1 Trial site layout and establishment

Leucaena was established at Pinnarendi using strip cultivation to remove grass competition and cultivate a seed bed. By adopting this technique, about half the pastured area across the site (between the leucaena plant rows) was preserved. This method had been successfully employed at ‘Blanncourt’ in the Georgetown district and was preferred by the landowner. It reduced erosion risk from heavy rain which was likely during the preparation and establishment phase and reduced the time and cost for preparation. Plant rows were not deep ripped due to the additional cost of this operation and uncertainty of any benefit in the soils at Pinnarendi.

The opportunities for cultivation depended on storm rain leading up to the wet-season when conditions were best for sowing leucaena. The model scenario at Pinnarendi was:

- storm rainfall in November/early December to provide sufficient moisture for discing;
- follow-up rainfall to promote germination of weeds;
- rainfall around Christmas/New Year to allow cultivation using a tined implement to kill first generation of weeds and allow moisture infiltration;
- follow-up rainfall by late January for sowing, after first applying herbicide to control second generation weeds – soil disturbance would be minimised to conserve soil moisture;
- application of a pre-emergent herbicide immediately after sowing for mid-term weed control (grasses and broad leaf weeds);
- follow-up rainfall with cultivation at least 2 m either side of the plant row for weed control until leucaena sufficiently well-established (0.5-1 m high).

4.1.1 Trial design and layout

Configuration of the trial site at Pinnarendi was based on replicated treatments (Wondergraze and Redlands) across eight paddocks, i.e. four paddocks planted to Wondergraze and four planted to Redlands. The extent of the site was initially defined using a handheld Global Positioning System (GPS) device. Using the data collected, a Geographic Information Systems (GIS) consultant determined the overall area of the site and developed the detailed layout, including paddock boundaries and leucaena rows. The final layout (Fig. 1.) also adhered to the Leucaena Code of Practice (http://www.leucaena.net/codeofconduct.pdf or admin@leucaena.net).

The trial was split into two sections which were north and south of the main access road into the property and a paddock of Buffel grass (*Cenchrus ciliaris*). Based on the area in each of these sections, the northern section was split into six paddocks of 7.4 ha each (Paddocks 1-6) and the southern section into two paddocks of 8.3 ha each (Paddocks 7 and 8). Since Paddocks 7 and 8 were larger than Paddocks 1-6, a randomised, paired block design was adopted rather than fully randomise the treatment allocation.

The requirement for a paired analysis was supported by lighter soils at the eastern ends of paddocks 1-4, the inclusion of virgin country at the eastern ends of Paddocks 5-8 and the northern side of Paddocks 1 and 2. The paddock boundaries were adjusted so that the overall area and total length

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

of planted leucaena row in each paired sequence was the same. The layout of Paddock 4 was also constrained by a powerline easement running east-west through the paddock. Leucaena rows in Paddock 4 were aligned parallel to the powerline rather than parallel with the paddock boundary.

The site layout also determined the placement of future dividing fences and holding paddocks at the eastern ends of each treatment paddock and a laneway for moving animals to yards located between the main farm access road and the south-eastern side of Paddock 6.

The site is shown in Fig. 2, prior to any development activities for the trial.

a. b.

Fig. 2 Site of grazing trial at Pinnarendi in June 2016, prior to site development; a. view north-west, b. view south (Kennedy Highway frontage).

4.1.2 Soil testing

Soils sampling was conducted across the site in 2016, prior to site development. Samples were collected from the top 10 cm of the soil and submitted to Incitec-Pivot (Tolga branch) for analysis of pH, P, S, K, Mg, Zn and Cu (Table 1). The Soil pH range was 6.2-6.8 (average 6.4). Phosphorus levels were low ranging from 3.6-9.0 mg/kg (average 5.1) and average sulphur was 2.6 mg/kg. Potassium and magnesium levels were adequate but zinc and copper were low.

Table 1 Soil test results across trial site paddocks at Pinnarendi in 2016.

Pinnarendi soil analyses – 0-10 cm, cleared front paddocks, 2016										
Sample identifier	078	080	081	082	083	084	085	086	087	***Avg.***
pH *(1.5 Water)*	6.2	6.3	6.6	6.6	6.3	6.3	6.4	6.8	6.4	***6.4***
Phosphorus *(mg/kg)*	4.9	4.4	3.6	6.0	4.2	<5	4.6	9.0	4.2	***5.1***
Sulphur *(mg/kg)*	2	2	3	3	3	3	3	3	2	***2.6***
Potassium *(cmol(+)/kg)*	0.39	0.18	0.82	0.83	0.39	0.31	0.45	1.0	0.37	***0.53***
Magnesium *(cmol(+)/kg)*	1.4	1.1	1.1	1.5	1.0	0.8	1.2	1.8	2.0	***1.3***
Zinc *(mg/kg)*	0.15	0.16	0.28	0.57	0.28	0.19	0.25	0.97	0.15	***0.33***
Copper *(mg/kg)*	0.15	0.14	0.19	0.24	0.28	0.25	0.22	0.2	0.19	***0.21***

4.2 Pre-planting site preparation and management

4.2.1 Site clean-up

Existing internal fences were removed (August 2016) and a bulldozer pushed termite mounds and removed regrowth which had re-established sparsely across the site since it was last cropped. Thicker regrowth was also cleared from the eastern ends of Paddocks 4-8, along the northern boundary of Paddock 1 and the southern boundary of Paddock 8. Material along the northern end of Paddock 1 had to be pushed into piles for burning.

4.2.2 Layout and fencing

With the site clear, the corners of paddocks and position of fences were identified using pre-determined GPS waypoints which verified the practicality of the preliminary layout. A final layout which identified the lengths and end points of all fences and plant rows as well as the areas of each trial paddock was agreed with the landowner. Plant rows were temporarily marked using steel posts to enable cultivation. This was completed at the start of October 2016.

Vermin-proof fencing was erected around the perimeter of the trial site to exclude rabbits and wallabies. The risk to young leucaena seedlings from pests was significant at Pinnarendi. Construction of this fencing was more elaborate than would otherwise have been required for stock containment alone.

Perimeter fencing was erected around the two sections containing Paddocks 1-6 and Paddocks 7 and 8. The style of fence built is shown in Fig. 3. Wire netting 1.2 m high with an aperture of 40 mm was erected and clipped to pre-tensioned plain wires to a height of 900 mm with a 300 mm apron folded onto the ground surface. The netting was placed on the outside of the fence relative to the leucaena planting. Two runs of barbed-wire were placed above the netting. After erection, a grader was used to push soil over the ground apron to prevent rabbits and wallabies getting under the fence.

Fencing commenced in early September 2016, with erection of end stays and straining posts. Fencing was completed by mid-November and soil pushed over the netting apron before New Year.

Fig. 3 Vermin-proof perimeter fencing used at Pinnarendi.

4.2.3 Re-growth control

By December 2016 significant sucker regrowth from lignotubers had occurred. This was mostly confined to areas where denser regrowth had been pushed a few months earlier (eastern ends of Paddocks 4, 5 and 6 and the northern side of Paddock 1).

Garlon™ herbicide (active constituent 600 g/L triclopyr) was used for control and was applied by hand spraying individual suckers in late 2016. The mixing rate was 4 ml/L, and a surfactant and marking dye was used. Being non-residual, the active ingredient in Garlon™ would not risk future damage to young leucaena seedlings.

4.2.4 Cultivation in preparation for sowing

While the timing of rainfall did not allow the scenario outlined in Section 4.1 to be implemented, the season was reasonable and allowed a compromised approach.

1. An initial discing of the plant rows was carried out in mid-October (Fig. 4). Conditions were dry so there was minimal ground engagement. This operation broke up the hayed-off pasture cover and disturbed the soil surface to allow better rainfall infiltration. Each plant row was cultivated by driving towards sighting posts placed at the end of rows.
2. The storm season was disappointing; with one fall of 5 mm at the site on 29 November. Isolated falls of 8 mm and 35 mm on 16 and 17 December respectively, provided sufficient moisture for a primary cultivation. This occurred over 3 days from 20-22 December. Each plant row was disced to a width of 5-6 m with 1-2 m overlap in the middle ensuring that the plant line received a double working.
3. Paddocks 7 and 8 and most of Paddock 1 received a secondary discing in the week between Christmas and New Year.

Good rainfall was received over an 11 day period from 29 December until 8 January, totalling 236 mm. This provided an excellent soil moisture profile. With a deteriorating seasonal outlook, it was decided to plant on this rainfall rather than cultivate and wait for follow-up rainfall. Whilst further cultivation would have resulted in a better prepared seedbed, it would also have meant additional moisture loss from the seed-bed zone and delayed sowing. Despite the relatively high amount of rainfall received and additional light falls over 12-14 January, the light textured soils at Pinnarendi allowed sowing to start on 14 January.

4.2.5 Weed control

The rainfall in early January resulted in germination and growth of weeds along the cultivated rows. In the week prior to sowing, Roundup Ultra®Max herbicide (active constituent 570 g/L glyphosate) was applied using a tractor mounted boom spray. The application rate was nominally 2 kg/ha across a 6 m swath centred on the plant rows. This application was made over three days from 12-14 January starting in Paddock 8 and finishing in Paddock 1 (as per Table 2). Some rows in Paddocks 7 and 8 had to be sprayed twice because of rain soon after spraying.

a.

b.

c.

d.

Fig. 4 Cultivation activities in preparation for sowing; a. marking rows for primary cultivation, b. primary cultivation in mid-October 2016 prior to storm season, c. and d. secondary cultivation after first storms (late December 2016).

4.2.6 Fertiliser application

A pre-plant application of SuPerfect® (9%P, 11%S) was made along the centre line of the cultivated strips. This occurred over the period 20-22 December 2016 about three weeks prior to the first leucaena sowing. The effective application rate to a 1 m strip along the plant row was 300 kg/ha.

Fertiliser was applied using a Vicon 3-point linkage mounted, pendulum spreader with the diffuser removed to limit broadcast to about a 1 m width.

4.2.7 Seed sourcing and testing

Redlands seed was sourced from a seed block at Walkamin Research Station. Seed from this site was approved for use based on DNA profiling in 2015. Testing confirmed that the samples of Walkamin grown Redlands seed were highly related with a degree of relatedness > 95% to Redlands (Lambrides 2016). Redlands genotypes were also genetically distinct from all other genotypes tested, particularly the commercial cultivars of Wondergraze and Cunningham.

Mature seed pods were hand-harvested throughout 2016. Pods were dried and hulled at Walkamin. Cleaned seed was stored as separate batches in a cool store at 18^{o}C for short periods (2-3 months). For longer term storage, seed was held in a cold store at 10^{o}C.

Prior to sowing at Pinnarendi in January 2017, 60 kg of Redlands seed was available, having been collected and cleaned at Walkamin during 2016. At a sowing rate of 1.5 kg/ha, this was sufficient for a total area of 40 ha which was more than the planned area of about 30 ha (half the trial site). More than sufficient Wondergraze seed for sowing the trial was purchased from Leucseeds Pty. Ltd. in late 2016.

4.3 Leucaena sowing

4.3.1 Seed preparation

Five to ten days before sowing, leucaena seed batches were removed from storage, combined and thoroughly mixed. Germination tests were conducted on samples of the aggregated seed. For testing, 50-100 seeds were wet-up and placed on moist filter paper and germination monitored over the following 5-7 days. Based on these tests, Redlands seed was mechanically scarified to improve germination. Commercially sourced Wondergraze seed did not need to be scarified.

Immediately prior to sowing, all seed batches were inoculated with a slurry of commercial rhizobia (strain CB3126) and commercial sticker by hand mixing in a bucket as per label instructions. Inoculated seed was ambient air dried on shade-cloth in the shade before being used in the planter.

4.3.2 Sowing equipment and method

There were two main sowing events (Section 5.1.2). For the initial sowing, a simple three-point linkage mounted single row unit, with disc openers and a press wheel driven seed plate was used (Fig. 5a). During sowing of the Wondergraze, limitations with the gearing and plate size meant that seed was planted at a high sowing rate of about 2 kg/ha. There was also seed leakage between the plate and the seed box when the unit was first used, resulting in seed spillage onto the soil surface. Prior to sowing Redlands, a new plate was manufactured which reduced the planting rate to 1-1.5 kg/ha and stopped seed wastage. The sowing rate for Redlands was significantly lower than for Wondergraze to ensure sufficient seed would be left over for follow-up sowings if required.

Just before sowing, plant rows were cultivated to a width of about 3 m using a 3-point linkage mounted toolbar. This resulted in some loss of soil moisture but was carried out due to residual unevenness in the seedbed from earlier discing operations. A heavy steel beam was dragged at an angle behind this unit to help even out the soil surface (Fig. 6).

For the second sowing, the heavy-duty, tined, ‘basalt’ planter was used (Fig. 5b). This was to overcome issues experienced with the planter used for the initial sowing (Section 5.1.2). Being a towed machine with wheels, it better tracked the uneven soil surface and maintained a more consistent sowing depth compared to the three-point linkage mounted planter.

a. b.

Fig. 5 Planters used for the first and second rounds sowing at Pinnarendi; a. three-point linkage mounted disc opener (first round sowing), b. heavy-duty towed basalt planter (second round sowing).

a. b.

Fig. 6 First sowing at Pinnarendi (January 2017); a. plant rows, b. pre-sowing cultivation and seedbed levelling.

4.3.3 Pre-emergent herbicide

Immediately after sowing of paddocks and on the same day, an application of pre-emergent herbicide was made across a 6 m swath centred on the plant rows using a tractor mounted boom spray. The herbicide used was Vezir® 700 (active ingredient 700 g/kg Imazethapyr) applied at an effective rate of 100 g/ha. The rate adopted was lower than the recommended maximum application rate of about 140 g/ha to avoid any herbicide damage to emerging leucaena.

4.3.4 Timing

Rainfall received in early January provided an excellent opportunity for sowing. Sowing commenced on 14 January as soon as glyphosate applications were completed. With a limited quantity of Redlands seed available, it was decided to sow Wondergraze paddocks first so that any issues with the planter could be resolved. Dates for events and activities associated with the first round sowing are shown in Table 2.

Table 2 Round 1 sowing at Pinnarendi – dates of events and activities.

Date	***Event/Activity***	***Comments/Issues***
31 Dec-8 Jan	236 mm rain	
Thu 12 Jan	Glyphosate application	Paddocks 7 and 8 – some rows sprayed twice due to showers
Fri 13 Jan	Glyphosate application	Paddocks 6, 5, 4 and 3
Sat 14 Jan	Glyphosate application	Paddocks 2 and 1
Sat 14 Jan	Sowing Wondergraze and Vezir® 700 application	Paddock 7
Sun 15 Jan	Sowing Wondergraze and Vezir® 700 application	Paddock 6 and most of 3 (southern side)
Sun 15 Jan	30 mm rain in afternoon	
Mon 16 Jan	Sowing Wondergraze and Vezir® 700 application	Paddock 1 and balance of 3 (northern side)
Mon 16 Jan	Planter plate mods.	New planter plate manufactured
Tue 17 Jan	Sowing Redlands and Vezir® 700 application	Paddocks 8, 5, 4 and 2
Tue 24 Jan	5 mm rain	
Thu 2 Feb	7 mm rain	
Sat 4 Feb	5 mm rain	
Mon 6 Feb	5 mm rain	

Due to variable emergence from sowing in mid-January it was decided to re-sow where required in an effort to improve the level of establishment and ensure the integrity of the trial. With spare seed and sufficient time remaining for establishment (assuming on-going wet season conditions) re-sowing commenced on 17 February. Soil moisture was good due to 50 mm being received the previous day in a storm. To avoid cultivating and killing leucaena which had emerged from the first round sowing, the planter was moved on the tractor toolbar so that the plant line was offset about 200-250 mm from the original plant line (Fig. 7).

Fig. 7 Second round sowing using heavy duty towed planter offset from first round plant line.

In some rows a third sowing was conducted, resulting in re-sowing on both sides of the original plant row. This was only done when a blockage occurred in the planter. Subsequent cultivation operations sacrificed one of the outside lines in instances where ‘triple-row’ sowing had occurred.

Whilst not every row in each paddock was re-sown, the majority of the site was ‘double-sowed’ in this fashion (Paddocks 1 and 7 excepted), since there was abundant spare Wondergraze seed and just sufficient leftover Redlands seed.

To conserve Redlands seed, some hand sowing was also carried out, mainly in Paddock 8. Later, other Redlands paddocks were also hand sown along gaps to the original centre row. By the time this occurred, germination from the second round sowing with the basalt planter was occurring which limited the amount of hand sowing required to fill-in gaps.

Dates for events and activities associated with the second round sowing are shown in Table 3.

Table 3 Round 2 sowing at Pinnarendi – dates of events and activities.

Date	***Event/Activity***	***Comments/Issues***
Thu 16 Feb	Hand sowing Redlands	Only to gaps in half of Paddock 8
Thu 16 Feb	50 mm rain	40 mm in heavy storm followed by 10 mm steady rain in evening
Fri 17 Feb	Sowing Redlands	2/3 Paddock 8 with basalt planter
Fri 17 Feb	11 mm rain	
Sat 18 Feb	Sowing Wondergraze	Paddocks 6, 3 and end of 1 row in Paddock 7 with basalt planter
Sun 19 Feb	Sowing Redlands	Paddocks 2,4 and 5 with basalt planter
Mon 20 Feb	Sowing Redlands	Back over some rows in Paddock 8 with basalt planter
Mon 20 Feb	6 mm rain	
Tue 21 Feb	47 mm rain	Some heavy rain but mostly fairly steady over a few hours
Mon 1 Mar	Hand sowing Redlands	Finished Paddock 8, filled gaps in Paddocks 2 and 4
Mon 1 Mar	Sowing Wondergraze Paddock 1	A few rows in Paddock 1 with basalt planter
Sat 4 Mar	9 mm rain	
Sun 5 Mar	30 mm rain	
Mon 6 Mar	35 mm rain	
Wed 8 Mar	Hand sowing Redlands	Paddock 5 only (very little planted)
Wed 8 Mar	Commenced cultivation of weeds	Paddocks 6-4
Wed 8 Mar	5 mm rain	
15-22 Mar	52 mm rain in 5 falls over 8 days	

4.4 Post-sowing site management

4.4.1 Grasshopper control

Project investigators visited the site on 23 January 2017 to inspect germination and progress of seedlings. Substantial numbers of grasshoppers were observed within the grass strips in the leucaena paddocks and neighbouring grass paddocks. This was 7-10 days after sowing and there was no evidence of damage to young seedlings.

As a precautionary measure an aerial application of pesticide was made on the following day. Albatross® (active constituent 200 g/L fipronil) was applied on the morning of 24 January at a rate of 100 ml/ha. The application was made across all the leucaena paddocks as well as the boundaries with neighbouring grass paddocks (northern side of Paddock 7 and eastern ends of Paddocks 1-3).

4.4.2 Weed and re-growth control

By early March, weed growth in the cultivated planting strips required control to reduce competition to young leucaena plants. In order of decreasing importance most of the weed competition was from Wynn cassia (*Chamaecrista rotundiflia*), Whiteye (*Mitracarpus hirtus*), Hairy Indigo (*Indigofera hirsute*), Gambia pea (*Crotalaria goreensis*), Star burr (*Acanthospermum hispidum*), Sabi grass (*Urochloa mosambicensis*) and Crowsfoot grass (*Eleusine indica*). Broadleaf weeds were more widespread and a bigger problem than grasses. Heavy grass growth only affected relatively small areas at the eastern ends of Paddocks 4 and 5. With no herbicide option available, a tined cultivator was used to cultivate an area about 1.5 m either side of the plant line leaving an uncultivated gap along the leucaena plant line itself.

In Paddock 7 with good emergence and establishment from a single row sowing, the uncultivated gap was minimised to about 300 mm. In the balance of paddocks which predominantly had a double row planting as a result of the second round sowing, tines had to be positioned further apart on the toolbar to leave a wider gap for the leucaena (Fig. 8a and b).

An initial cultivation was done in this manner across all Paddocks on 8, 14 and 16 March. By the end of March a follow-up cultivation was required due to on-going weed growth across all paddocks. This was done over two days, 20 March and 3 April. (Fig. 8c). A third cultivation was done across all paddocks at the end of April (Fig. 8d).

A fourth cultivation was done in late May following the useful fall of rain on 18 May. Whilst not strictly necessary, this provided longer term weed control since conditions were no longer favourable for on-going weed germination and growth. This cultivation also provided an exemplar for the importance of weed control for a field day held at the site on 24 May. No further cultivation for weed control was conducted.

A few areas at the eastern end of Paddocks 3 and 4 had heavy grass growth which was not effectively controlled by cultivation. These areas (in the cultivation zone) were blanket sprayed with Verdict™ (active constituent 520 g/L haloxyfop) mixed at a rate of 1 mL/L using a hand lance on 22 March 2017. Spot spraying was also required in all rows of Paddock 2, the southern two rows of Paddock 1 and eastern ends of rows in Paddocks 5 and 6.

a. b. c. d.

Fig. 8 Cultivation for weed control; a. cultivation in mid-March with single plant row, b. cultivation in mid-March with double plant row, c. second cultivation in late March, d. third cultivation in late April/early May.

There were isolated occurrences of Gamba grass (*Andropogon gayanus*) in Paddocks 2, 3, 4 and 5. It had spread from an established stand in a neighbouring paddock immediately east (and upwind) of these trial paddocks. Gamba is highly productive and palatable to cattle when green but is also a restricted invasive plant under the Biosecurity Act 2014 (Queensland). While its presence is insignificant relative to the rest of the inter-row pasture, control spraying was carried out to limit its future spread whilst still easily managed, with the long-term aim of eradicating it from the trial.

All observed occurrences of Gamba grass in the trial paddocks were spot sprayed with Roundup Ultra®Max (active constituent 570 g/L glyphosate) on 23 January 2018 mixed at 10 mL/L.

A follow-up treatment to control lignotuber regrowth was carried out on 8 March 2017. Garlon™ was again used, employing the same method and application rate as described in 4.2.3, but without using a surfactant. Only the known problem areas were treated which was mainly the eastern ends of Paddocks 4-8. Care was taken not to overspray leucaena seedlings in areas where regrowth was occurring directly on or near the plant line. A mop-up treatment using the same herbicide but with surfactant added was carried out on 6 April.

Further control of re-growth suckers was carried out in late 2017. As per the previous treatments, Garlon™ was applied using a hand lance. Control in Paddocks 1, 2, 5 and 6 was completed on November 7 and 8. Only regrowth in the inter-row area was sprayed. Suckers growing in or immediately adjacent to the leucaena plant rows were not treated to avoid accidental damage to leucaena.

The balance of paddocks were treated on 7 December; Paddocks 3 and 4 were completed, Paddocks 7 and 8 were partially treated and then completed in late March 2018.

4.4.3 Fertiliser applications

The pre-sowing fertiliser application in December 2016 was made in a band along the centreline of the cultivated strip. While leucaena was generally sown within the fertilised band there was misalignment in some sections of row which meant there was a risk of leucaena seedlings emerging on the edge or outside of the fertilised band – particularly for the follow-up sowings made alongside the original planting line. For assurance that all seedlings had adequate fertiliser during early development, a second fertiliser application was made post sowing/emergence. SuPerfect® (9%P, 11%S) was again applied using the same Vicon spreader. This was done over all paddocks on 8 and 9 March 2017. The effective application rate to the strip along the plant row was 280 kg/ha.

A broadcast application of SuPerfect® was made to the inter-row pasture on 1 August 2017 at a rate of 240 kg/ha. The entire trial area received the application including the leucaena rows. Application was made by a contractor using a truck mounted-spreader with GPS guidance (Fig. 9).

a. b.

Fig. 9 Broadcast superphosphate application 1 August 2017; a. approx. 15 t of fertiliser delivered to site, b. application in progress (Paddock 4 – Redlands).

An application of granulated sulphur (90% S) was made to a 1 m strip along the leucaena plant rows in August 2017 at a rate of 160 kg/ha, again using the Vicon spreader. The tractor drove along and over the top of the leucaena rows, taller leucaena plants were bent over but not damaged.

In mid-March 2018, an aerial application of sodium molybdate (39 % Mo) was made to ensure adequate levels of molybdenum for nitrogen fixation. The application rate across the entire trial area was 300 g/ha of product. This was in response to observations from a small scale nutrient trial (Section 4.5.4) implemented in February 2018 to investigate sub-optimal leucaena growth at the site. The balance of a 20 L drum of trace element mix leftover from the nutrient trial was applied in conjunction. In addition, a contingency application of a custom fertiliser blend (12% N, 11% P, 10.5% S) was made about a week later. By this time, the height of leucaena prevented driving over the row, so the application was made by a contractor using a tractor-drawn spreader with side-throw capability. Fertiliser was applied to a band about 3-4 m either side of the plant row at a rate of 250 kg/ha.

Fertiliser applications to April 2018 are summarised in Table 4.

Table 4 Fertiliser applications at Pinnarendi leucaena trial site (November 2016 – April 2018)

Application date	***Reason***	***Product and application rate***	***Nutrient application rate***	***Method and basis of application***
November 2016	Pre-sowing P and S	SuPerfect® 300 kg/ha	P: 27 kg/ha S: 33 kg/ha	Tractor mounted spreader ~1 m strip along plant rows
March 2017	Post-sowing P and S	SuPerfect® 280 kg/ha	P: 25 kg/ha S: 31 kg/ha	Tractor mounted spreader ~1 m strip along plant rows
August 2017	Inter-row pasture	SuPerfect® 240 kg/ha	P: 22 kg/ha S: 26 kg/ha	Truck spreader Broadcast across whole site
August 2017	Post-sowing long term S	Granulated sulphur (NutriGold®) 160 kg/ha	S: 144 kg/ha	Tractor mounted spreader ~1 m strip along plant rows
March 2018	Promote leucaena N fixation *Balance of trace element (~19 L) added to tank*	sodium molybdate 300 g/ha *Complete Plus® ~0.32 L/ha*	Mo: 117 g/ha *N: 17 g/ha* *S: 5 g/ha* *Zn: 13 g/ha* *B: 5 g/ha* *Mn: 3 g/ha* *Fe: 3 g/ha* *Cu: 2 g/ha* *Mo: <1g/ha* *Co: <1g/ha*	Aerial (plane) Across whole site
March 2018	Correct suboptimal leucaena growth	Custom NPS blend 250 kg/ha	N: 30 kg/ha P: 27.5 kg/ha S: 25 kg/ha	Tractor towed side throw spreader ~3-4 m swath along plant rows

4.5 Post-planting monitoring and investigations

4.5.1 Establishment uniformity

Uniformity across leucaena treatments was dependent on consistent plant population across the site. Data from biomass measurements of leucaena (and inter-row pasture) will be used to determine quantities and quality of pasture available to cattle in the trial. A quantitative basis for assessing uniformity (success of establishment) was also used based on in-field measurement of leucaena populations within all replicates at the site.

The method was developed in consultation with a DAF biometrician and involved directly assessing 5% of the entire planting. The 5% level was selected based on it being practical timewise whilst also being sufficient for statistical integrity.

With the value for the total planned meterage of leucaena in each replicate known from the trial design ('R_t'), 5% of this value was calculated ('R_5'). A nominal plot length ('P_x') of 25 m was chosen, so that the number of samples ('n') in each replicate was determined by dividing R_5 by 25. To summarise:

$$n = R_5/P_x = (R_t \times 5/100)/P_x \qquad \text{where } P_x = 25$$

This calculation yielded a total of 98 sampling plots; 12 sampling plots for Paddocks 1-6 and 13 for the slightly larger Paddocks 7 and 8. The location of sampling plots within each replicate was determined by randomly selecting the sampling plot within pre-determined sampling blocks. A sampling block was determined by dividing R_t by n, which yielded a value close to 300 m for each replicate. There were 12 potential sampling plots within each sampling block (i.e. 300/25 = 12).

A 25 m grid was set-out over the trial site plan (perpendicular to the plant rows in each replicate). Each of the 300 m sampling blocks (12 for Paddocks 1-6 and 13 for Paddocks 7 and 8) was identified by starting from the north eastern corner of each replicate and progressing west along the first row to its end then starting again at the eastern end of the next row (and so-on). A sampling plot was then chosen at random within each sampling block. Where a sampling plot directly abutted a subsequent sampling plot (i.e. at the end of one block and start of the next) or was very close to another sampling plot in an adjacent row; an alternate sampling plot was selected. This method ensured a reasonable spread of sampling plots across each replicate and avoided clustering of sampling plots if a systematic or fully randomised sampling had been adopted.

The resultant sampling plot layout is shown in Fig. 10. These sampling plots were located in-field using GPS and were pegged for future reference. Plant population and typical height were recorded within each 25 m sampling plot as follows:

Population:
- 0 = no plants (fail)
- 1 to 5 plants/m = 1,000-5,000 plants/ha (low)
- 2 = 6 to 10 plants/m = 6,000-10,000 plants/ha (good)
- 3 = > 10 plants/m = > 10,000 plants/ha (high)

Typical height:
- 0 = no plants
- 1 = < 0.25 m
- 2 = 0.25 to < 0.5 m
- 3 = 0.5 to < 1.0 m
- 4 = 1.0 to < 1.5 m
- 5 = >= 1.5 m

This generated a total of 300 and 325 data points in Paddocks 1-6 and Paddocks 7 and 8 respectively. All leucaena plants within each meter of row were included in the assessment (plants from the original January sowing and the follow-up February sowing if applicable).

Fig. 10 Start locations of sampling plots (98 plots in total) for leucaena population and height survey based on row number with 25 m grid overlay.

4.5.2 Psyllid monitoring

A psyllid monitoring program was implemented at the site to record damage using a systematic method. In consultation with a DAF biometrician, the method developed was based on monitoring nine sentinel plants in each replicate (paddock) in a grid-type layout (i.e. 72 plants in total = 8 x replicates x 9 plants/replicate). Three rows in each replicate were selected, and three plants identified within each of these rows – one towards the eastern end, one towards the western end and one near the middle. The end plants were generally 50-100 m from the ends of rows. These plants were marked with flagging tape for identification and monitored for psyllid presence and damage about every two to four weeks (once psyllids become and remain active).

Damage was observed using the naked eye based on a previously developed rating scale (Wheeler 1988). A modification to the rating scale was adopted whereby a rating '1 = no damage observed' was changed to '1 = no damaged observed (psyllids present)' and an additional rating of '0 = no psyllids present' was added. The modified rating scale was as follows:

0 = no psyllids present
1 = no damage observed (psyllids present)
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 leaves and blackening of lower leaves
9 = blackened stem with total leaf loss

Monitoring in 2017 was conducted on nine occasions from the end of May until early November when psyllids were no longer active at the site. Monitoring recommenced at the site in early May 2018 and was conducted on four occasions up to the end of August when psyllids again became relatively inactive at the site. For monitoring in 2018, many trees had to be reselected as the original sentinel trees could not be identified. For the last monitoring event at the end of August, no data was collected in Paddocks 1-4 as there was very little leaf on leucaena as a result of sustained grazing by cattle and dry conditions.

4.5.3 Rainfall and weather monitoring

Prior to 2017, rainfall recordings at the site were reported by the landowners from a gauge approximately 0.5 km east of the trial site. A measuring cylinder rain gauge was installed on the perimeter fence at the eastern end of Paddock 7 in December 2016. This gauge was damaged mid-year during the dry-season. Two similar gauges were installed at the site in early December 2017 – one on the main entrance road at the eastern end of Paddock 6, and a replacement for the damaged gauge at Paddock 7.

A weather station (Davis Vantage Pro 2 Plus) was installed adjacent to the portable yards (south-east corner of Paddock 6) in early May 2018. The station is web connected via the 3G mobile network and monitors rainfall, air temperature, dew point temperature, wind speed and solar radiation. Readings can be accessed in real time and data is archived.

4.5.4 Soil/leaf testing and small-scale fertiliser trial

To investigate perceived poor growth of leucaena from about the start of February 2018, soil and leaf samples were collected during 2018 (Table 5). Leaf samples were submitted to Phosyn Analytical (Junction Road, Andrews, Qld. 4220). Soil analyses were conducted by Nutrient Advantage Laboratory Services (South Road, Werribee, Vic. 3030).

Table 5 Dates and detail of soil and leaf sampling, Pinnarendi 2018.

Date	*Type*	*Details*	*Comment*
21 Feb 18	Soil	3 samples of surface profile (0-10 cm)	Taken when sub-optimal leucaena growth/colour was observed.
27 Feb 18	Leaf	4 samples of fully formed fresh leaf	Taken to investigate cause/deficiency of suboptimal leucaena growth/colour; 3 samples from plants with poor colour, 1 sample from plants with good colour.
14 Mar 18	Soil	4 samples, each with 0-10, 10-20 and 20-50 cm sub-samples	Additional samples taken after mistake with requested analysis of samples taken 21 Feb.
14 Jun 18	Soil	2 samples, each with 0-10, 40-50 and 50-100 cm subsamples	One sample taken adjacent plants with poor colour; another sample taken adjacent plants with good colour.

A small scale nutrient trial was also implemented, based on replicated treatments across sections of rows in Paddocks 5-8. Various rates of a range of nutrients were applied on 21 February 2018 (Appendix 2).

In summary, 66S (13%N, 11%P, 15%K, 5%S), Muriate of Potash (50%K), Gran-Am® (20%N, 24%S) and SuPerfect® (9%N, 11%P, 19%S) were applied at 300 kg/ha to discrete 10 m sections of row. Additionally, a commercial trace element mix (5.2% N, 1.5% S, 4% Zn, 1.6% B, 1.1% Mn, 1% Fe, 0.5% Cu, 0.1% Mo, 0.1% C0) was also applied as a foliar spray at rates of 5 and 10 L/ha of product over additional 10 m sections of row in combination with the above fertiliser treatments. The trace element mixes were also applied over 10 m sections of row without the fertiliser treatments.

On 5 March 2018, Gran-Am® and 66S were applied separately to 20 m sections of row in Paddock 4 at rates of 300 kg/ha. The trace element mix was again applied over separate 20 m sections of row with the fertiliser treatments but at a higher rate of 25 L/ha. The high rate trace element mix was also applied over 20 m sections of row without the fertiliser treatments. The trace element was mixed in water applied at 200 L/ha and in all cases a wetting agent (Spreadwet, active constituent 600 g/L ethoxylated nonyl phenol and alkyl ether and fatty acids) was added at 40 mL/100 L water.

The sites of the small scale nutrient applications were observed and surface roots of selected vigorous leucaena plants were dug and inspected for the presence of nodules in May 2018. In June 2018, a backhoe was used to dig two inspection trenches about 1.2 m deep immediately beside leucaena rows. One trench was adjacent to leucaena with yellowish leaf and poor growth and the other was adjacent to healthy leucaena. Soils samples were taken from the top (0-10 cm), middle (40-50 cm) and bottom (90-100 cm) of each trench. Adjacent leucaena plants were also dug up and roots inspected for the presence of nodules.

4.6 Infrastructure for grazing trial

Following leucaena establishment in September 2017, installation of infrastructure for animal handling and weighing was completed by April 2018.

4.6.1 Fencing and yard facilities

Internal fencing to divide trial paddocks at the site and provide management lanes/capture paddocks was started in mid-September 2017 and completed by November. The original plan for a laneway with separate header/capture paddocks at the eastern end of the trial paddocks was altered in favour of combining the lane and capture paddocks. Internal fencing included 6.2 km of 4-strand barbed wire fence, with associated gateways and straining posts.

4.6.2 Water points

Watering points were located at the eastern end of the trial paddocks with adjacent paddocks sharing a common trough (i.e. four troughs in total). A 50 mm polythene supply line was laid in mid-August 2017 from a tank (27, 500 L capacity) located on a high point to the south of the trial site, running along the eastern end of the trial paddocks. A tank level monitor was installed in May 2018 which is web connected via the 3G mobile network. This enables remote monitoring of supply levels and delivers alerts via SMS when pre-set levels are reached.

Locally made concrete water troughs were delivered to the site in late December 2017. These were installed and connected to the supply line in February 2018. Trough floats were installed in April and the system tested prior to introduction of cattle. Cameras were installed adjacent to troughs in May 2018; each camera is web connected via the 3G mobile network. Images captured at pre-set intervals during daylight hours are can be remotely viewed to confirm water availability and animal welfare.

4.6.3 Yard and weighing facilities

Portable yards with a crush, load beams and loading ramp were installed in early 2018.

4.7 Animal ethics approval

An application for animal ethics approval was prepared and submitted to the DAF Animal Ethics Committee in December 2017. The application provided for up to 172 head of cattle to be utilised in the trial over the period from 1 February 2018 to 31 January 2021.

The application was approved 11 December 2017 (ref. SA 2017/12/628 – Appendix 3).

The approval also included collaborative work with Diane Ouwerkerk (Molecular Biologist, DAF Brisbane) to collect rumen fluid from animals in the trial for the purpose of evaluating and comparing efficacy of the leucaena rumen inoculum when grazing Redlands versus Wondergraze.

An amendment request regarding sourcing of trial animals from the DAF Spyglass Beef Research Facility and a proposal to change the grazing regime (refer Section 4.8.3) was lodged in June 2018 and approved.

4.8 First year grazing

The first year of grazing at the trial site was a learning phase to refine the grazing methodology adopted with subsequent cohorts of cattle over the following two to three years. The proposed methodology was to graze all paddocks concurrently for at least 10 months each year at the same stocking rate. The first year stocking rate would be reduced relative to the calculated theoretical stocking rate due to leucaena at the site not having attained full productivity. In the longer term, it was intended to spell all leucaena paddocks for about two months each year during the early wet season.

4.8.1 Theoretical stocking rate

Theoretical set stocking rates based on full productivity of leucaena are calculated as follows:

<u>Assumptions</u>

Average entry weight, $W_e = 200\ kg$

Anticipated annual liveweight gain on leucaena-grass pasture system, $ALWG = 220\ kg$

Adult equivalent animal at maintenance, $AE = 450\ kg$

Grazing period from March to mid-December = *10.5 months*

Hectares per *AE* on leucaena-grass pasture system (annual basis) = *1.6 ha per AE*

Therefore the theoretical exit weight, W_{ex} after 10.5 months:

$$W_{ex} = W_e + (10.5/12 \times ALWG) = 200 + (0.875 \times 220) = 392.5 \text{ kg}$$

The average weight, W_{avg} over the grazing period:

$$W_{avg} = (W_e + W_{ex})/2 = (200 + 392.5)/2 = 296 \text{ kg}$$

The average adult equivalent, AE_{avg} over the grazing period is therefore:

$$AE_{avg} = W_{avg}/450 = 296/450 = 0.66 \text{ AE}$$

So the area required per AE on a 10.5 month basis is:

$$1.6 \times AE_{avg} = 1.05 \text{ ha per } AE_{avg}$$

Therefore the stocking rate of paddocks 1-6 which have an area of 7.4 ha (average) each is:

$$7.4 \text{ ha}/1.05 \text{ ha per } AE_{avg} = 7.0\ AE_{avg}$$

For Paddocks 7 and 8 which have an area of 8.16 ha each, the stocking rate is:

$$8.3 \text{ ha}/1.05 \text{ ha per } AE_{v} = 7.9\ AE_{avg}$$

The maximum total number of animals in the trial over a 10.5 month grazing period would be:

$$6 \text{ paddocks x } 7.0\ AE_{avg} + 2 \text{ paddocks x } 7.9\ AE_{avg} = 58$$

4.8.2 Animal selection

The first cohort of animals used in the trial was sourced from commercial herds on Pinnarendi and Spyglass. Weaner steers were selected from a larger pool of similar class animals on the basis of apparent suitable temperament and liveweight in the range 160-230 kg. Animals which appeared atypical were excluded.

4.8.3 Grazing regime

A lower set stocking rate was adopted than the theoretical stocking rate set-out in Section 4.8.1. Only three animals were initially assigned to each paddock (replicate) when cattle were first introduced to the trial in April 2018. This was less than half the theoretical stocking rate. The intention was to leave these animals in each of their respective paddocks for the duration of the first year grazing (nominally 10.5 months).

Using such small groups of animals was not practical. Animals did not display ‘mob behaviour’ and some animals were flighty and difficult to handle. Rather than persist, it was decided to combine animals into two larger groups and rotate them (or sub-groups) between paddocks. Groups of animals would remain within the same treatments and be grazed for a minimum of 12 months.

Cattle were rotated between trial paddocks principally on the basis of leucaena availability with concurrent spelling of unoccupied paddocks (Table 6).

4.8.4 Cattle introduction and management

Cattle were first introduced to the trial in April 2018. An initial cohort of 24 steers was sourced from the commercial herd at Pinnarendi. As there was only a pool of about 30 animals to select from the opportunity to eliminate animals judged as unsuitable was limited. After selection, rumen sampling, weighing and drafting in the yards at Pinnarendi, animals were moved to the trial paddocks on the same day, however seven animals escaped back to the main herd within the first 18 hours. No attempt was made to return these animals to the trial. A further five animals were also removed from the trial at the first weigh event (28 June) on the basis of unsuitable temperament.

With no more animals to select from at Pinnarendi, replacement steers were sourced from DAF’s ‘Spyglass’ Beef Research Facility (about 250 km south of Pinnarendi). Sixteen steers were selected from 40 animals yarded at Spyglass on 26 June. After weighing and rumen sampling, these animals were transported to Pinnarendi by truck on 28 June and subsequently integrated with the steers already in the trial at Pinnarendi. After this time all animals in the trial had suitable temperament and could be handled with relative ease. For habituation to routine handling all animals were intermittently fed molasses (equating to about 2.5 MJ ME/head/day).

On the same day as being initially weighed and selected animals received management ear tags, vaccination for Bovine ephemeral fever (diluent Batch 185668 Exp. 04/01/18, vaccine Batch 196619 Exp. 18/08/18) and were treated for external/internal parasites (if not recently done) using industry standard commercial products. Animals were re-vaccinated for Bovine ephemeral fever on 8 November 2018 (diluent Batch 269225 Exp. 03/01/19; vaccine Batch 252667 Exp. 25/05/19).

4.8.4.1 Cattle characteristics and treatment allocation

There was a significant difference in the mean weight of animals based on source (Pinnarendi or Spyglass) at 28 June. The Pinnarendi animals were slightly older and heavier having already been on the trial for 70 days. The 12 steers sourced from Pinnarendi had a mean weight (28 June) of 257 kg (sem. = 9 kg). They were Brahman cross steers (*Bos indicus*) from the commercial herd at Pinnarendi and were approximately 12 months old when introduced to the trial on 19 April. The 16 steers sourced from Spyglass introduced to the trial on 28 June had a mean entry weight (28 June) of 207 kg (sem. = 1 kg). These animals were approximately 12 month old Droughtmaster cross steers (*Bos indicus x Bos taurus*) from the commercial herd at Spyglass.

For allocation to the Redlands or Wondergraze treatments steers were first blocked by source and weight then randomly allocated between treatments from each block. Allocation by this method resulted in the same number of animals by source in each replicate and no significant difference in the mean liveweight for treatments. The mean (± sem) weight of animals was 225 ± 7.0 kg and 232 ± 10.0 kg for the Redlands and Wondergraze treatments, respectively.

4.8.4.2 Rumen sampling and inoculation

To be able to utilise leucaena efficiently it has been necessary to inoculate cattle with bacteria, *Synergistes jonesii*. In conjunction with the DAF-MLA preliminary project B.GBP.0026 'Feeding leucaena to manage the rumen for maximum beef profit', rumen fluid was collected *per os.* from trial animals. The Animal Ethics application included the procedure for rumen fluid sampling. There were plans for five rumen sampling events including entry and exit samples as well as seasonal sampling (based on pasture condition) as follows:

1. naïve sample immediately before animals were introduced to the trial
2. 2nd naïve sample after animals have been grazing leucaena for 7-14 days (prior to inoculation with rumen inoculum)
3. sample during wet season (lush grazing)
4. sample near end of dry season (lower quality)
5. sample on removal from trial

Only the naïve rumen fluid samples were collected during 2018 (from both Pinnarendi and Spyglass animals). Additional sampling and inoculation was not carried out as planned because of the low productivity of leucaena during the dry-season and perceived low level (< 30%) of leucaena in the diet of cattle grazing in the trial.

4.8.5 Weight measurements and rotation of animals in trial

There were four complete grazing periods up until early November 2018 with cattle weighed at the beginning and end of each period (coinciding with rotations to new paddocks). Individual animal weights are recorded manually and electronically and cross referenced to each animals electronic and management tags. Animals are typically weighed within one to two hours of being mustered from paddocks and yarded.

Cattle groupings, rotations and grazing periods are summarised in Table 6. For the first grazing period commencing 19 April, 17 steers from Pinnarendi were grazed in Paddock 5 and 6. There were 11 steers in the Wondergraze treatment and six steers in the Redlands treatment. On 28 June, five of these animals were removed (unsuitable temperament) leaving a balance of 12 Pinnarendi steers which were combined with the 16 steers sourced from Spyglass. The combined group was split evenly based on weight and origin/breed and allocated to the Wondergraze or Redlands treatments (this required reallocation of some Pinnarendi animals). These animals were moved to Paddocks 7 and 8 (14 animals per paddock) for the second grazing period.

After 40 days grazing, each treatment group of 14 animals were split into two even groups of seven, again based on weight and origin/breed. These animals were moved into Paddocks 1-4 for the third grazing period (remaining within the same treatments). After 44 days grazing, each treatment group of seven animals was recombined into two groups of 14 and moved into Paddocks 5 and 6. This was the start of the fourth grazing period and animals again remained within the same treatments. After 49 days grazing, each treatment of group of 14 animals were again split into their former groups of seven and moved back into back into Paddocks 1-4 for the fifth grazing period. Each group went into the same paddocks (treatment and replicate) as for the third grazing period.

Table 6 Rotation of steers in leucaena treatments at Pinnarendi during 2018.

<table>
<tr><th>Date</th><th>Paddock 1 W'graze</th><th>Paddock 2 Redlands</th><th>Paddock 3 W'graze</th><th>Paddock 4 Redlands</th><th>Paddock 5 Redlands</th><th>Paddock 6 W'graze</th><th>Paddock 7 W'graze</th><th>Paddock 8 Redlands</th></tr>
<tr><td>1st rotation
19 Apr to 26 Jun (70 days)</td><td></td><td></td><td></td><td></td><td>Group 1
11 x B'mn</td><td>Group 2
6 x B'mn</td><td></td><td></td></tr>
<tr><td>2nd rotation
26 Jun to 7 Aug (40 days)</td><td></td><td></td><td></td><td></td><td rowspan="2">spell
88 days</td><td rowspan="2">spell
88 days</td><td>Group A+B
6 x B'mn
8 x D'mtr</td><td>Group C+D
6 x B'mn
8 x D'mtr</td></tr>
<tr><td>3rd rotation
7 Aug to 20 Sep (44 days)</td><td>Group A
3 x B'mn
4 x D'mtrr</td><td>Group C
3 x B'mn
4 x D'mtr</td><td>Group B
3 x B'mn
4 x D'mtr</td><td>Group D
3 x B'mn
4 x D'mtr</td><td rowspan="3">spell
100+ days</td><td rowspan="3">spell
100+ days</td></tr>
<tr><td>4th rotation
20 Sep to 8 Nov (49 days)</td><td>spell
49 days</td><td>spell
49 days</td><td>spell
49 days</td><td>spell
49 days</td><td>Group C+D
6 x B'mn
8 x D'mtr</td><td>Group A+B
6 x B'mn
8 x D'mtr</td></tr>
<tr><td>5th rotation
8 Nov</td><td>Group A
3 x B'mn
4 x D'mtrr</td><td>Group C
3 x B'mn
4 x D'mtr</td><td>Group B
3 x B'mn
4 x D'mtr</td><td>Group D
3 x B'mn
4 x D'mtr</td><td>spell
40+ days</td><td>spell
40+ days</td></tr>
</table>

W'graze = Wondergraze, B'mn = Brahman, D'mtr = Droughtmaster

4.8.6 Leucaena and inter-row pasture yield measurement

Ad hoc leucaena and pasture yield measurements were made during the first year of grazing (2018). Leucaena yield was assessed at the beginning and end of the third grazing period (Paddocks 1-4) and at the beginning of the fourth grazing period (Paddocks 5 and 6). An assessment of inter-row pasture yield was made in August across Paddocks 1-4.

Leucaena yield assessments were made by collecting all leaf and stem (≤ 5 mm diameter) from four randomly selected 10 m sections of row in each paddock. This material was oven dried at 60°C to constant weight. Leaf and stem from each sample were separated and weighed. The average weight of the four samples was used as an estimate of the dry matter yield for the respective leucaena paddock. These samples were collected in mid-August and early September 2018 for the third grazing period, and mid-September 2018 for the start of the fourth grazing period.

For nutrient composition and dietary parameters, the combined samples of leaf and stem collected in mid-August from within each of Paddock 1-4 were separately ground and 100 g sub-samples submitted for analysis to Dairy One Inc. (Forage Testing Laboratory, Ithaca, New York USA 14850).

Inter-row pasture yield assessment was made in late July 2018 by cutting pasture from within 1 m^2 quadrats at six randomly selected locations within each paddock (GPS coordinates recorded). Pasture was cut 50-75 mm from the ground and quadrats were positioned in the middle of the inter-row area (with respect to adjacent leucaena rows). This material was oven dried at 60°C to constant weight. Legumes and grasses from each quadrat were segregated by hand, weighed separately, and the principal species present were recorded. The average weight of the six samples was used as an estimate of the pasture dry matter yield for each paddock.

5 Results

5.1 Leucaena sowing and early establishment

5.1.1 Germination tests

Germination tests on Redlands seed sourced from the Walkamin pilot block typically showed germination of about 30-45%, with 35-50% hard seed and 20% dead or abnormal seed. Due to relatively high levels of hard seed, all Redlands seed was mechanically scarified. This increased germination to 60-70% (with 10-20% hard seed and 20% dead or abnormal).

The commercially sourced Wondergraze seed had germination of 80-90%. Redlands seed was more variable in size and smaller overall compared to Wondergraze seed. The viability of Redlands seed harvested through 2016 was less than for seed harvested in 2015 due to higher levels of damage by bruchid beetles (*Callosobruchus maculatus*).

5.1.2 Sowing

5.1.2.1 Round 1 sowing

By mid-February emergence and development of leucaena from the first sowing in mid-January could be evaluated. All of the leucaena which had emerged was looking healthy and was growing well. Paddocks 1, 7 and 8 had very good or satisfactory emergence. There had also been no damage from pests. However, emergence in the balance of paddocks was variable, with some acceptable areas but also many areas with very few or no seedlings.

This was attributed to unevenness in the seedbed at sowing – particularly for Paddocks 2-6 which only had a single discing. The cultivation operation carried out just before sowing worked well in paddocks with few weeds and little residual plant material. In many areas the seedbed was uneven and there was poor control of sowing depth using the three-point linkage mounted planter.

Emergence was related to seedbed conditions at the time of sowing and to a lesser extent the timing of rainfall. Overall, soil moisture was not considered a substantially limiting factor for germination. There was some crusting of the soil surface in paddocks sown prior to the 30 mm of rain received 15 January and this inhibited or prevented emergence where seed was sown deeply. There was also variation in soil types across trial paddocks which affected planter performance and germination. A summary of the conditions and corresponding emergence in each paddock is given in Table 7.

By early March (after the second round sowing) it was evident that there had been on-going germination from the first round sowing – particularly for Redlands paddocks. Continued germination so long after sowing is unusual and was attributed to high levels of hard seed (particularly Redlands) and consistently wetter conditions. Prolonged germination improved the level of establishment across the site.

Table 7 Round 1 sowing – summary of paddock conditions and emergence.

Paddock and treatment	***Comments***
1 – Wondergraze	Planted into good moisture; good seedbed; generally good emergence
2 – Redlands	Planted into reasonable moisture, lumpy seedbed, variable emergence
3 – Wondergraze	30 mm same day as planting, lumpy seedbed, variable soils, variable emergence
4 – Redlands	Planted into reasonable moisture, lumpy seedbed, variable soils, variable emergence
5 – Redlands	Planted into reasonable moisture, lumpy seedbed, variable soils, variable emergence
6 - Wondergraze	30 mm same day as planting, lumpy seedbed, variable emergence
7 - Wondergraze	First paddock planted, into good moisture, good seedbed, very good emergence in all except one end of one row (seed ran out), 30 mm rain day after planting
8 - Redlands	Planted into reasonable moisture, good seedbed, satisfactory emergence

5.1.2.2 Round 2 sowing

There was good rainfall immediately before and on several days following the second round sowing. Although no rainfall was received for an 11 day period up to 4 March, soil moisture was conserved due to mild weather conditions. Therefore, on-going germination and emergence was not limited by moisture availability.

The basalt planter was better able to maintain a consistent planting depth. The only issue was that the planting tine left a furrow as a result of moist soil displaced by the tine not slumping back. Whilst this had the potential to reduce emergence if heavy rain washed soil back into the furrow, it only occurred in a few areas after receiving 47 mm rainfall on 21 February (Fig. 11).

Emergence from the second round of sowing was good and resulted in a more consistent population of leucaena seedlings across the trial paddocks. Where germination and emergence from the first round sowing had been poor, there was usually good germination and emergence from the second round sowing to compensate (Fig. 12). On-going germination from the first round sowing also improved the overall seedling population.

Notwithstanding the above, germination failed or was relatively poor in some sections of row and this led to suboptimal or unsatisfactory plant populations in some areas. This was most evident at the eastern ends of Paddocks 2-4 which had lighter soils.

a. b.

Fig 11. Second round emergence after sowing with basalt planter; a. furrow left along plant line; b. furrow after 47mm rainfall received 21 February.

Fig 12. Typical emergence after second round sowing using tined basalt planter.

5.1.3 Weed control

Regular cultivation either side of the plant row for weed control during the second quarter of 2017 was reasonably effective at limiting competition from weeds and the inter-row pasture. The final cultivation was carried out after a rainfall event on 18 May 2017. This ensured long-term weed control as dry conditions after that time were far less favourable for on-going weed germination and growth.

The best weed control was achieved in Paddock 7 where the single row planting allowed control of weeds in close proximity to leucaena. In all other paddocks, with closely spaced twin rows, weed control was compromised from the cultivating tines being further apart. Intra-row weeds could not be cultivated and significantly competed with leucaena seedlings.

Rainfall in October reinvigorated leucaena growth whereas weeds were much slower to respond and cultivation was not required. Weeds which did develop quickly became moisture stressed in the ensuing hot and dry weather. This was particularly apparent in the previously cultivated area either side of leucaena rows, due to increased moisture loss from the bare surface.

Grass control using Verdict™ over some areas in March 2017 was effective. By early April grass which received this treatment was mostly dead (individual tussocks) or significantly set-back in areas with heavy growth. However, leucaena seedling populations in areas which previously had heavy grass growth were lower, either because of poor emergence or subsequent competition from the grass.

Gamba grass control in January 2018 was effective although new plants established in some areas, usually in close proximity to previous outbreaks.

5.1.4 Pest control

The January 2017 application of Albatross® to control grasshoppers was deemed effective. Despite grasshoppers remaining in high populations in neighbouring grassed paddocks, they did not appear to migrate into the leucaena paddocks over the following weeks. Small numbers of grasshoppers were observed in the trial area by mid-March however leucaena seedlings had developed to a stage where damage from grasshoppers was not considered to be a risk.

5.1.5 Re-growth control

For all spraying events, wilting of suckers was evident within one to two days of Garlon® application and death occurred over the following one to two weeks in most cases. Good control was progressively achieved with follow-up treatments. Best control was achieved during the wet-season when suckers had a flush of new growth.

For the November 2017 treatment, some herbicide damage occurred to small sections of leucaena row about a week after spraying. This was due to spray drift, even though wind conditions at the time of treatment were light. Leucaena leaves turned yellow, but there was no mortality and affected plants recovered within two to three weeks.

5.1.6 Weather

Rainfall recorded at Pinnarendi over 2017 and 2018 is presented in Table 8 together with monthly rainfall statistics for nearby Meadowbank Station (source Bureau of Meteorology). The 2017 wet season started later than usual, with below median rainfall in the previous November-December period (2016). Good rainfall from January to April provided generally favourable conditions for sowing and early leucaena establishment. April and May had below average rainfall but the 16 mm recorded in May (equal to the May median) was mostly received in a single day providing a significant late boost to soil moisture.

Conditions from June to October were dry. Storm rain received in mid-October totalling 80 mm was in the wettest decile for October rainfall. Rain during November and December 2017 was lower than normal. Close to average rainfall was received in January and February 2018. In March 2018 298 mm was received which was in the wettest decile for March rainfall. Rainfall over the April-September period was lower than median (totalling 32 mm over 6 months). There was a good break to the season in October 2018 with 32 mm recorded.

No temperature data was recorded at the site during 2017 and up until late May 2018. Anecdotally, temperatures during 2017 were close to normal except for higher than average maximums in December and January 2017-18. The 2017 'winter' was mild. There was no frost at the site. Colder conditions occurred during the 2018 winter period and this did supress leucaena growth. In June, there were 15 nights when the air temperature was < 10°C (measured 1.5 m above the ground) including nine consecutive nights. The nights of 19 and 20 June each had several hours of temperatures < 10°C with a minimum close to 4°C. For July, there were 11 nights with air temperature < 10°C but minimums were always above 5°C. Late August had nine nights with temperatures < 10°C and the minimum temperature for the year of 2.8°C on 21 August. Probable light frost damage resulted from consecutive nights of low minimums in June. After another cold night on 21 August, leucaena was frost affected in lower areas of Paddocks 1-6. The effects were short lived, as leucaena responded to warmer temperatures (September) with a flush of new shoots and leaf.

Table 8 Historical monthly rainfall statistics for Meadowbank and monthly totals recorded at Pinnarendi - January 2017 to October 2018.

	Monthly rainfall statistics for Meadowbank **(Pinnarendi actuals Jan 2017 to Feb 2018)**												
	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	***Total***
Meadowbank average	*191*	*196*	*126*	*40*	*26*	*17*	*12*	*8*	*9*	*23*	*70*	*122*	***840***
Meadowbank median	*152*	*191*	*98*	*25*	*16*	*11*	*6*	*0*	*0*	*12*	*50*	*118*	***679***
Pinnarendi 2017 actual	**235**	**131**	**126**	**15**	**16**	**5**	**2**	**8.5**	**0**	**80**	**5**	**40**	***663***
Pinnarendi 2018 actual	**175**	**122**	**298**	**12**	**4**	**12**	**8**	**1**	**1**	**32**	**-**	**-**	***666***

Source: Australian Government, Bureau of Meteorology (Station #031175, Meadowbank).

5.2 Leucaena development

5.2.1 Activities in 2017

In May 2017 there was still good soil moisture at the trial site and leucaena seedlings were growing well. Weeds growing within the uncultivated area of plant rows competed significantly with leucaena in some areas.

At the start of May 2017, there was a noticeable difference in height between plants from the two sowings with first cohort plants mostly in the range 0.5-1.0 m (up to 1.3 m) and second cohort plants in the range 0.15-0.25 m. There were smaller plants in areas with the heaviest weed competition. The difference in height between planting cohorts was most evident where there was good emergence from both planting rounds; with first round plants out-competing the younger second round plants. From observation there was also a difference in growth between Redlands and Wondergraze at this time, with Wondergraze being more vigorous and uniform. Notwithstanding differences attributed to planting conditions, Wondergraze paddocks appeared to be better established, more uniform and more advanced than Redlands across both planting cohorts.

Establishment status of leucaena at the trial site as at April 2017 is summarised in Table 9.

Table 9 Status of leucaena plantings at Pinnarendi (April 2016).

Paddock and treatment	***Overall status at April 2016***	***Comments***
1 - Wondergraze	Good to excellent	Good initial strike and on-going growth
2 - Redlands	Good	Not as good strike as paddock 1 but has grown well
3 - Wondergraze	Average to good	Variable initial strike but good fill-in and growth
4 - Redlands	Average to good	Variable initial strike but good fill-in and growth – significant poor areas at eastern end
5 - Redlands	Average to good	Ok initial strike and good-fill-in and growth – some poor areas at eastern end
6 - Wondergraze	Good	Reasonably good from outset and good fill-in
7 - Wondergraze	Excellent	Best paddock from outset
8 - Redlands	Average to good	Good strike and early growth but growth significantly supressed by weeds

By August 2017 reduced soil moisture levels had stalled growth of smaller plants from the second round sowing. Larger plants from the first round sowing were accessing moisture deeper in the profile and were still growing. First cohort plants were mostly 0.5-1.0 m in height with the best plants 1.5 m or more. Second cohort plants were 250-500 mm in height, with smaller plants in areas which previously had the heaviest weed competition. At this time annual weeds had mostly hayed off or died and were no longer competing significantly with leucaena.

The perceived outperformance (growth) of Wondergraze relative to Redlands across the site towards the end of the wet season was no longer apparent. Psyllid attacks on Wondergraze across all paddocks from late May (Section 5.5) caused substantial leaf damage. Continued growth of Redlands without psyllid damage and attendant leaf loss meant that it was more advanced than Wondergraze (albeit less uniform). The perceived status of paddocks in August 2017 is summarised (Table 10).

Table 10 Status of leucaena plantings at Pinnarendi (August 2017).

Paddock and Treatment	***Updated status at August 2017***	***Comments***
1 - Wondergraze	Very good	Good from outset, less psyllid affected than other Wondergraze paddocks
2 - Redlands	Good to very good	Continued good growth
3 - Wondergraze	Good	Some poor areas in lighter soils
4 - Redlands	Good	Some poor areas in lighter soils
5 - Redlands	Excellent	Best paddock, some poorer rows at north-eastern corner
6 - Wondergraze	Very good to excellent	2nd best paddock but mostly heavily psyllid affected
7 - Wondergraze	Very good	Uniform except for north-west corner, no longer best paddock due to psyllid damage
8 - Redlands	Poor to average	Poorest paddock, good population but small plants, weed competition along plant row

Through August and September 2017 growth of most leucaena at the site was limited by moisture availability. Smaller plants stopped growing and lost leaf due to the dry conditions. Only the largest plants in the heaviest soils continued growing and producing new leaf. Notably, when psyllid populations decreased from about mid-September, affected Wondergraze plants responded with a flush of new leaf which remain largely undamaged.

Higher than usual rain was received in October 2017. This resulted in renewed growth across the site and ensured survival of smaller leucaena plants. All leucaena at the site had a growth response within a few days of this rain which continued until about mid-December. Whilst rainfall in November was below average, occasional storm rain was sufficient to maintain leucaena growth. December rainfall was light and leucaena on lighter soils stopped growing by the middle of the month due to a lack of moisture. Moisture stress had limited leucaena growth across the entire site by New Year (2018).

Typical leucaena development at the site is chronicled in Fig. 13 (a-d).

a(i). April 2017, typical growth of Wondergraze (Paddock 1 – Wondergraze)

a(ii). April 2017, typical growth of Redland (Paddock 2 – Redlands)

b(i). August 2017, typical growth of Wondergraze (Paddock 3 – Wondergraze)

b(ii). August 2017, typical growth of Redlands (Paddock 4 – Redlands)

c. June 2017, beginning of dry-season (Paddock 7 – Wondergraze)

d. November 2017, growth response to rain in October (Paddock 7 – Wondergraze)

Fig. 13 Typical development of leucaena at site during 2017.

5.2.2 Activities in 2018

Rainfall in early January 2018 produced another growth response in leucaena across the site. With no psyllids active, new growth on Wondergraze compensated for previous damage. Near the end of

January there had been no significant rainfall for three weeks. Leucaena on lighter soils became water stressed and stopped growing. Leucaena on heavier soils (about 75% of the site) continued to grow despite conditions progressively drying out. Overall, rainfall to February 2018 was irregular and leucaena growth was inhibited.

During February, regular rainfall was received at the site providing ideal conditions for sustained leucaena growth (Fig. 16a.). However, leucaena growth was not vigorous and this was concerning considering the significant amount of fertiliser applied before and after sowing (targeting phosphorus and sulphur deficiencies). Most of the leucaena at Pinnarendi had a yellow-green colour (Fig. 14a.). This was the case for both Redlands and Wondergraze across all trial paddocks with the exception of Paddock 7 (which had reasonably good growth and colour – Fig. 14b.). Soil and leaf samples were taken and a small-scale nutrient trial was implemented (Section 4.5.4). An observed response to nitrogen application from this trial (Fig. 15), was the basis for the additional application of a custom fertiliser blend which included nitrogen (Section 4.4.3).


a.


b.

Fig. 14 Leucaena in February 2018 with; a. poor colour and vigour; b. good colour and vigour.

Fig. 15 Observed response to nitrogen in the small-scale nutrient trial implemented in February 2018 (nitrogen treatment to left).

Almost 300 mm of rainfall was received at the site during March, falling before and after the application of the custom blended fertiliser. Colour and vigour of leucaena did appear to improve as a result, however little useful rainfall was received after March. Conditions dried out quickly and leucaena growth was checked earlier than in 2017.

When cattle were introduced to Paddocks 5 and 6 in April 2018 there was a moderate yield of leucaena available for grazing (Fig. 16b.). As discussed in Section 5.1.6, there were mild frosts in June. The cool weather and dry conditions resulted in some leaf loss and yield decline by early August 2018, when cattle were rotated into Paddocks 1-4 (Fig 16c.). The most significant frost of the year occurred in late August and resulted noticeable leaf blackening and loss in some areas, mostly in lower lying parts of Paddocks 3-6. Warming temperatures in September encouraged new growth despite dry conditions.

About 35 mm of rain was received during September. The heaviest fall was about 16 mm and this was sufficient to stimulate new growth and leaf production across all paddocks (Fig. 16e.). During this period, cattle grazing in Paddocks 5 and 6 continually browsed this material so that leucaena growth did not exceed the grazing pressure. When cattle were removed from these paddocks in early November, there was little leaf remaining and cattle had pushed down much of the larger stems to access leaf higher in the canopy (Fig. 16d).

a. February 2018, mid wet-season (Paddock 7 - Wondergraze).

b. First cohort of cattle introduced to Paddocks 5 and 6 (April 2018).

c. Yield decline by August 2018 due to dry and cool conditions.

d. Leucaena in Paddock 5 in early November 2018 (after seven weeks grazing).

e. New leaf production in November 2018 after 35 mm of rainfall in previous month.

Fig. 16 Leucaena at Pinnarendi over 2018.

5.3 Leucaena yield and quality measurements

Mean (± SD) leucaena dry matter yields at the start and end of the third grazing interval across Paddocks 1-4 were only 64 ± 33.0 kg/ha and 15 ± 9.0 kg/ha, respectively. The overall dry matter yield at the start of the fourth grazing period across Paddocks 5 and 6 increased to 158 ± 51.0 kg/ha due to the flush of growth during September. Paddock yields and leaf/stem ratios are summarised in Table 11. Dietary and nutrient analyses of leucaena leaf and stem (≤ 5 mm diameter) collected for yield assessment at the start of the third grazing interval are reported in Tables 12 and 13.

Table 11. Leucaena dry matter yields and leaf to stem ratios sampled at Pinnarendi before and after grazing (August-September 2018).

Treatment	***Before 3rd grazing period*** *(sampled 16, 17 August 2018)*			***After 3rd grazing period*** *(sampled 28 September 2018)*		
	Yield (DM kg/ha)	***Standard deviation (DM kg/ha)***	***Ratio of leaf : stem****	***Yield (DM kg/ha)***	***Standard deviation (DM kg/ha)***	***Ratio of leaf : stem****
Paddock 1	84	51	0.6 : 1	16	9	1.3 : 1
Paddock 2	40	27	1.1 : 1	8	4	1.5 : 1
Paddock 3	54	15	1.5 : 1	22	11	1.1 : 1
Paddock 4	77	15	1.1 : 1	17	5	1.6 : 1
Wondergraze overall (P1, P3)	***69***	***38***	-	***19***	***10***	-
Redlands overall (P2, P4)	***58***	***28***	-	***12***	***6***	-
	Before 4th grazing period *(sampled 12, 20 September 2018)*			***After 4th grazing period*** *(no data collected)*		
	Yield (DM kg/ha)	***Standard deviation (DM kg/ha)***	***Ratio of leaf : stem****	***Yield (DM kg/ha)***	***Standard deviation (DM kg/ha)***	***Ratio of leaf : stem****
Paddock 5 (Wondergraze)	168	49	1.4 : 1	-	-	-
Paddock 6 (Redlands)	148	59	1.8 : 1	-	-	-

** ≤ 5 mm diameter*

Table 12. Dietary attributes of leucaena leaf and stem (≤ 5 mm diameter) sampled at Pinnarendi in August 2018.

Paddock	***Material***	***Crude protein (%)***	***Soluble protein (%)***	***Acid digestible fibre (%)***	***Neutral digestible fibre (%)***	***Lignin (%)***	***Non-fibre carbohydrate (%)***	***Total digestible nutrients (%)***	***Metabolisable energy (MJ DE/kg DM)***	***Relative feed value****
1	stem	6.2	38	57.8	68.8	17.4	14.2	42	4.9	59
	leaf	20	60	26.8	32.4	12.6	36.8	61	9.4	195
2	stem	8	43	58.5	64.5	18.8	16.6	42	5.2	63
	leaf	21.5	69	28.3	31.2	13.5	36.5	61	9.5	199
3	stem	9.5	46	54.8	61.7	16.6	18	45	5.9	70
	leaf	19.7	55	30	32.3	13.3	37.2	60	9.4	189
4	stem	7.6	41	53.1	60.9	17.8	20.7	44	5.8	73
	leaf	22	56	26.1	28.4	12.4	38.8	63	9.8	224

*100 = lucerne hay (leaf and stem) cut at early flowering stage

Table 13. Nutrient composition of leucaena leaf and stem (≤ 5 mm diameter) sampled at Pinnarendi in August 2018.

Paddock	***Material***	***Calcium (%)***	***Phosphorous (%)***	***Magnesium (%)***	***Potassium (%)***	***Sodium (%)***	***Sulphur (%)***	***Iron (ppm)***	***Zinc (ppm)***	***Copper (ppm)***	***Manganese (ppm)***	***Molybdenum (ppm)***
1	stem	0.45	0.25	0.16	1.79	0.026	0.27	189	20	5	19	6
	leaf	1.34	0.27	0.75	2.22	0.066	0.63	1120	27	9	44	3.7
2	stem	0.59	0.20	0.23	1.82	0.122	0.29	323	24	5	22	7.4
	leaf	1.51	0.26	1.11	2.31	0.033	0.6	1970	27	11	73	3
3	stem	0.61	0.28	0.27	2.29	0.043	0.37	435	22	6	28	7.6
	leaf	1.39	0.26	0.63	2.23	0.055	0.59	729	27	10	47	2.8
4	stem	0.71	0.23	0.24	1.9	0.091	0.32	283	24	6	28	4.9
	leaf	1.24	0.27	0.91	2.42	0.027	0.68	911	30	13	75	3

5.4 Assessment of initial plant population and height differences

The data from the plant density and height survey is represented in Figures 17 and 18, respectively. For each paddock all sampling plots are represented with each metre of plot colour coded according to its corresponding rating category for plant density and height. Darker shades are used for higher plant density and height, lighter shades are for lower.

For the plant density representation there appears to be a difference between Wondergraze and Redlands treatments. Wondergraze Paddocks 1 and 3 in particular are generally darker in appearance than Redlands Paddocks 4 and 8 which are lighter. Paddocks 2, 5, 6 and 7 appear to be similar. For the height data the representation was more uniform with the exception of Paddock 1 (Wondergraze); darkest overall (tallest trees) and Paddock 8 (Redlands); lightest (smaller trees).

5.4.1 Plant population and density analysis

A formal analysis of plant population was conducted. Counts for each rating category (plant population and height) were analysed using a generalised linear mixed model (Fig. 19).

For plant population, there was a significant interaction of rating with variety ($p < 0.001$). For Redlands the majority of ratings were in the categories of ‘low’ and ‘good’ corresponding to 1,000-5,000 plants/ha and 6,000-10,000 plants/ha (equivalent to 1-5 and 6-10 plants/m of row). For Wondergraze the majority of ratings were in the categories of ‘good’ and ‘high’ corresponding to 6,000-10,000 plants/ha, and > 10,000 plants/ha (equivalent to 6-10, and > 10 plants/m of row).

	Plot Number	Plot Position																								
		0-1m	1-2m	2-3m	3-4m	4-5m	5-6m	6-7m	7-8m	8-9m	9-10m	10-11m	11-12m	12-13m	13-14m	14-15m	15-16m	16-17m	17-18m	18-19m	19-20m	20-21m	21-22m	22-23m	23-24m	24-25m
Paddock 1 Wondergraze	1	2	3	3	3	3	2	2	3	3	3	3	3	2	3	3	3	3	3	3	3	2	3	3	3	3
	2	3	3	3	2	2	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3
	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3
	5	2	3	3	3	2	3	3	2	3	3	3	2	1	1	2	3	2	2	2	3	2	3	2	2	3
	6	3	3	3	3	1	2	1	2	2	3	3	2	2	2	3	2	3	3	2	3	3	3	3	3	3
	7	1	2	2	3	3	0	1	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3
	8	3	3	3	3	2	2	3	2	3	2	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3
	9	3	1	2	3	3	3	3	3	3	2	1	3	2	2	3	1	2	3	2	1	3	3	3	1	2
	10	3	3	3	3	3	3	3	3	3	3	2	3	3	3	2	2	2	3	3	2	3	3	1	3	3
	11	2	3	3	3	2	3	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3
	12	3	3	3	3	3	3	3	3	2	3	3	2	2	3	3	2	3	3	3	3	3	3	3	3	3
Paddock 2 Redlands	1	2	2	1	1	2	1	2	1	2	1	1	1	1	1	2	2	2	1	2	1	1	1	1	1	2
	2	2	2	1	1	1	1	2	2	1	1	1	1	2	1	2	1	1	2	1	1	1	1	2	1	1
	3	2	2	0	1	2	2	2	2	2	3	2	2	1	2	1	1	3	2	2	1	1	1	1	1	1
	4	2	2	2	2	1	2	1	1	2	2	2	2	3	2	3	1	1	2	1	2	2	1	2	2	3
	5	0	1	2	1	1	2	1	1	1	1	1	1	2	2	1	1	1	1	1	2	2	1	1	1	1
	6	1	2	2	2	2	2	3	2	2	2	2	2	3	3	3	2	2	2	3	3	2	2	3	3	2
	7	2	1	2	2	1	2	2	1	1	1	2	1	2	2	1	1	1	1	1	2	1	1	2	2	1
	8	2	1	2	1	2	1	2	3	3	2	3	2	2	2	0	2	1	1	1	2	1	1	2	1	2
	9	1	1	2	2	2	1	2	2	2	2	2	2	2	3	2	2	2	2	2	3	3	2	2	2	3
	10	2	2	3	1	2	2	2	1	1	2	2	2	2	2	2	1	2	1	3	2	2	2	2	3	2
	11	3	2	1	2	1	2	2	0	1	1	1	1	1	0	2	2	1	0	1	1	3	1	1	1	0
	12	2	2	1	1	2	1	2	2	2	2	2	2	2	2	2	1	1	1	1	2	1	3	1	2	1
Paddock 3 Wondergraze	1	0	1	1	0	0	1	1	1	0	1	1	1	0	1	0	0	0	0	1	1	0	1	1	1	1
	2	2	2	2	2	2	3	3	3	1	2	2	2	2	2	2	2	2	1	2	2	2	2	2	3	3
	3	1	1	2	1	2	2	2	2	1	1	1	2	2	2	1	2	1	2	1	2	1	2	2	2	1
	4	3	3	2	3	2	3	2	3	2	3	3	3	2	3	1	3	3	3	3	1	1	2	2	3	3
	5	3	1	2	2	2	2	2	2	2	2	3	2	2	3	3	2	2	2	1	1	3	3	3	2	1
	6	3	3	2	3	1	2	2	2	1	2	1	1	2	2	3	2	2	1	2	2	1	1	1	2	2
	7	2	2	2	1	2	2	2	1	1	2	1	1	2	1	1	1	2	2	2	3	3	3	3	2	3
	8	3	3	2	3	3	2	3	3	3	3	3	3	3	3	2	3	3	2	3	2	3	3	3	3	3
	9	3	2	3	3	2	1	3	2	3	2	3	3	3	3	3	3	3	3	2	3	2	2	2	2	2
	10	2	3	2	2	2	2	3	2	1	2	2	1	2	1	1	1	1	2	2	2	2	1	1	1	1
	11	2	1	2	2	2	2	2	1	1	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3
	12	3	3	3	2	3	2	3	3	2	3	3	3	3	3	3	2	3	3	3	2	2	3	3	3	3
Paddock 4 Redlands	1	2	3	2	1	1	1	1	1	2	1	1	2	2	2	2	2	2	3	3	3	1	1	1	1	2
	2	1	2	2	2	1	2	3	2	2	2	1	3	1	1	1	1	2	2	2	3	2	2	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1
	4	1	2	2	3	3	1	2	1	2	2	2	3	1	1	2	1	0	0	2	1	0	1	1	1	1
	5	2	1	1	2	2	1	2	1	2	2	2	2	2	2	1	2	2	2	2	1	1	2	2	1	1
	6	1	2	1	1	2	3	2	2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
	7	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	1	1	2	1	1	1	0
	8	1	1	1	1	1	1	1	2	1	1	2	1	0	1	1	1	1	1	1	1	1	1	1	1	1
	9	1	2	2	2	2	1	1	1	2	2	2	2	2	1	2	1	2	1	2	1	1	1	1	2	2
	10	2	3	3	2	2	3	2	2	2	2	2	2	2	1	2	2	3	2	2	2	2	2	1	1	2
	11	2	1	2	1	2	2	1	2	3	3	2	2	2	1	2	1	2	2	1	1	1	2	2	1	1
	12	1	1	1	1	1	1	2	2	1	1	0	1	1	1	1	2	2	2	2	2	1	2	1	1	1
Paddock 5 Redlands	1	2	2	1	3	1	1	2	1	2	1	2	3	2	3	1	2	1	1	1	1	1	1	1	1	1
	2	3	2	3	3	3	2	2	2	1	1	2	3	2	3	3	3	3	3	3	2	2	3	2	3	3
	3	3	3	3	1	2	2	2	2	2	2	2	2	2	3	2	2	3	2	3	2	3	3	2	3	2
	4	2	2	2	2	1	1	1	1	1	1	2	1	3	2	1	1	1	2	2	2	3	1	2	1	2
	5	2	2	2	2	2	2	1	2	2	2	2	1	1	2	2	1	2	2	1	1	2	2	1	2	1
	6	2	2	2	1	1	1	2	2	2	3	3	3	3	2	3	3	2	3	3	3	3	3	3	3	3
	7	2	1	1	1	2	2	2	2	1	2	1	1	2	2	3	2	1	1	1	1	3	1	1	2	3
	8	3	2	3	3	2	3	3	2	1	1	2	2	2	2	2	1	2	2	3	2	3	3	3	2	3
	9	3	3	3	3	3	3	3	2	2	2	2	2	2	1	2	1	1	1	1	1	2	1	1	1	2
	10	2	1	1	2	1	2	1	2	2	1	3	2	2	2	2	2	1	2	2	3	3	1	1	1	1
	11	2	2	2	2	2	2	2	1	3	3	3	3	3	3	2	2	2	1	2	2	1	3	2	3	2
	12	1	1	2	2	2	2	1	2	2	2	2	1	2	3	3	2	2	1	1	3	2	2	2	1	1
Paddock 6 Wondergraze	1	2	3	2	1	2	2	2	2	2	2	3	2	2	2	2	2	2	3	3	3	2	2	1	1	1
	2	2	1	1	1	1	1	1	2	1	1	1	2	2	2	2	1	1	2	2	2	2	2	1	2	3
	3	2	2	3	1	3	3	3	2	1	1	1	3	2	2	3	2	2	1	3	2	3	2	2	3	3
	4	2	2	2	3	3	2	2	2	2	2	2	2	1	2	2	3	2	3	2	2	1	2	1	1	2
	5	1	1	2	1	2	2	2	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	2	2
	6	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	1	3	2	3	3	3	1	2	3
	7	1	1	0	1	1	1	1	0	1	0	1	1	1	1	1	1	1	2	1	2	2	1	1	1	1
	8	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	2
	9	1	2	2	3	3	2	2	3	3	2	2	2	2	3	2	3	3	1	2	1	3	3	2	3	3
	10	2	2	3	3	3	3	3	3	3	3	3	2	2	1	2	1	2	2	2	2	1	2	3	2	2
	11	2	2	2	1	3	2	3	2	1	1	2	1	1	1	2	1	1	1	2	1	1	0	1	0	1
	12	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3
Paddock 7 Wondergraze	1	3	2	3	3	3	2	2	3	3	3	3	3	3	3	1	1	3	2	2	3	3	3	2	3	2
	2	1	1	0	0	0	0	1	1	2	0	0	1	1	1	1	1	2	1	0	0	1	1	1	2	0
	3	2	3	3	2	2	2	3	3	3	3	3	3	3	2	3	3	3	3	3	3	2	2	3	3	2
	4	1	2	2	3	1	2	1	3	1	1	1	1	1	1	1	3	1	3	2	1	1	1	1	1	2
	5	1	2	3	3	2	3	1	3	3	3	2	3	2	3	1	1	2	1	1	3	2	2	1	1	3
	6	3	1	1	1	1	2	2	1	1	1	3	3	3	3	3	1	3	3	2	1	2	1	1	2	1
	7	3	2	1	3	1	1	3	2	2	2	1	1	2	1	3	1	2	1	1	1	1	3	3	3	3
	8	1	3	3	2	2	3	1	1	1	1	2	3	3	3	1	0	0	2	1	1	1	1	1	1	1
	9	1	1	1	3	2	2	1	1	3	1	2	1	3	2	2	1	3	3	3	2	2	3	3	3	3
	10	3	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	3	2
	11	3	3	3	3	2	2	3	2	0	3	2	2	3	3	1	1	2	2	3	3	2	3	3	3	3
	12	3	1	2	3	3	2	3	3	3	3	2	2	2	2	2	2	1	1	2	1	1	1	1	1	2
	13	1	1	1	1	0	0	1	1	1	1	1	1	1	2	3	2	1	2	1	1	2	1	2	1	0
Paddock 8 Wondergraze	1	1	1	1	1	1	1	0	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1	1	2	2
	2	2	2	1	2	3	3	3	3	2	1	2	1	2	1	1	2	1	2	2	2	2	2	3	2	2
	3	1	1	2	1	1	2	1	1	2	1	2	2	1	1	2	1	2	2	2	2	2	1	1	3	1
	4	1	1	1	1	1	1	1	2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
	5	1	2	1	2	1	1	1	2	1	1	1	1	1	2	0	1	0	1	1	1	2	3	1	1	1
	6	1	1	1	1	1	1	1	2	1	1	1	1	1	2	1	1	1	1	2	1	1	2	1	1	0
	7	2	1	1	1	1	1	1	1	2	1	1	1	1	1	0	0	1	1	2	1	1	0	1	1	1
	8	1	1	1	1	1	0	1	1	1	1	2	1	1	1	1	1	0	1	1	1	1	1	1	1	2
	9	3	2	2	2	1	2	2	2	2	1	2	1	1	1	2	2	2	1	2	2	1	1	2	1	1
	10	2	2	1	1	2	1	1	1	1	1	2	1	2	1	1	1	1	1	2	3	2	2	2	1	1
	11	2	2	1	1	2	2	1	1	2	1	1	1	1	2	2	1	1	1	2	2	1	1	1	1	1
	12	2	1	1	3	3	3	1	1	2	1	1	3	2	2	2	1	1	1	1	1	2	1	2	2	2
	13	0	1	1	1	2	1	1	2	0	1	0	0	1	1	0	2	1	2	2	2	1	2	3	2	1

0 = no plants (fail); 1 = 1-5 plants/m (low); 2 = 6-10 plants/m (good); 3 = > 10 plants/m (high)

Fig. 17 Pictorial representation of plant population survey at Pinnarendi leucaena trial, August 2017.

	Plot Number	Plot Position 0-1m	1-2m	2-3m	3-4m	4-5m	5-6m	6-7m	7-8m	8-9m	9-10m	10-11m	11-12m	12-13m	13-14m	14-15m	15-16m	16-17m	17-18m	18-19m	19-20m	20-21m	21-22m	22-23m	23-24m	24-25m
Paddock 1 Wondergraze	1	3	2	3	2	2	3	2	1	3	3	2	3	3	4	3	2	3	2	2	3	2	3	3	3	2
	2	1	2	2	1	2	3	3	2	2	2	3	2	2	3	1	1	2	2	2	3	2	1	2	2	2
	3	1	1	1	2	1	2	3	2	2	2	2	1	1	2	1	1	2	2	1	1	1	2	1	1	2
	4	3	3	3	3	2	2	3	3	4	3	3	3	2	3	3	2	2	3	3	3	3	3	3	2	3
	5	3	3	2	3	2	3	4	2	2	2	3	3	1	1	1	1	1	1	1	2	1	1	1	1	1
	6	1	1	1	3	5	4	1	1	2	2	3	1	2	3	3	2	3	3	3	3	4	2	2	1	3
	7	1	1	1	1	1	0	1	2	2	1	2	3	3	2	2	2	2	2	1	3	1	3	3	3	3
	8	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
	9	3	3	3	3	3	4	3	3	4	3	3	3	3	3	2	1	2	3	2	1	3	3	3	2	3
	10	2	3	2	2	1	2	2	2	2	3	4	3	4	4	3	3	3	3	3	1	3	3	2	2	2
	11	4	4	4	4	3	3	3	4	3	3	4	3	3	3	3	3	4	3	3	4	3	3	3	3	3
	12	3	2	3	2	3	2	3	3	2	3	3	3	3	3	2	1	1	3	4	3	3	2	1	1	1
Paddock 2 Redlands	1	3	3	2	3	3	2	2	4	3	3	3	3	2	2	2	3	3	2	3	2	1	2	1	1	2
	2	4	3	3	3	4	2	3	2	3	3	2	1	3	2	3	3	1	3	3	2	3	3	3	1	2
	3	3	3	0	3	3	3	4	3	2	2	3	3	3	3	3	2	2	2	3	2	1	2	3	3	3
	4	3	3	4	3	3	3	3	3	3	3	2	3	2	2	3	3	1	1	2	2	1	2	3	4	2
	5	0	1	1	1	1	2	2	2	1	1	1	1	1	2	1	1	2	1	2	1	2	1	1	3	1
	6	4	2	2	4	3	3	3	3	3	3	2	3	1	2	3	3	2	3	3	3	4	3	3	2	2
	7	2	1	3	2	2	3	2	1	2	4	3	2	3	4	2	3	3	2	3	3	2	3	2	3	3
	8	3	3	3	3	1	4	3	3	3	3	2	3	3	2	0	4	4	4	3	3	4	3	3	2	3
	9	3	3	3	3	3	2	4	3	3	2	2	3	3	3	2	3	3	3	2	3	3	3	3	3	3
	10	3	4	2	4	3	2	3	3	2	3	3	3	3	2	3	3	3	3	2	3	3	2	2	2	3
	11	4	2	2	3	2	2	2	0	2	3	2	2	3	0	3	3	3	0	1	1	1	2	2	1	0
	12	3	3	2	2	3	2	2	2	2	2	3	3	3	3	3	2	3	2	2	3	2	3	3	3	1
Paddock 3 Wondergraze	1	0	2	1	0	0	2	3	2	0	2	2	1	0	2	0	0	0	0	2	1	0	3	1	3	3
	2	2	3	2	2	3	2	3	2	1	3	3	3	3	3	2	3	2	2	2	3	1	1	2	2	2
	3	2	2	2	2	2	2	2	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2
	4	3	2	3	3	3	3	3	3	3	3	3	1	2	2	2	2	2	2	2	2	2	3	3	2	2
	5	3	3	3	3	3	2	3	2	2	1	2	2	3	3	4	2	2	1	1	2	2	2	2	2	1
	6	3	3	2	2	2	3	2	3	2	3	1	2	2	3	2	3	3	3	3	2	3	3	3	2	1
	7	3	4	2	3	4	2	2	2	2	3	3	3	2	3	1	1	2	3	2	2	3	3	3	2	2
	8	2	3	3	2	2	3	3	3	3	3	2	2	2	1	2	2	3	3	3	3	3	3	3	2	3
	9	3	3	3	3	3	2	3	3	4	4	3	3	3	3	4	4	3	3	3	3	3	2	2	1	1
	10	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2	2	2	3	3	3	2	3	3	2	3
	11	3	2	3	1	2	3	3	3	4	3	3	3	3	3	3	2	2	2	3	2	3	3	3	3	3
	12	3	3	2	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2
Paddock 4 Redlands	1	3	3	3	2	3	3	2	4	3	2	4	3	2	3	3	3	3	3	3	3	3	4	4	3	3
	2	3	2	2	2	3	3	3	2	3	2	2	3	2	2	2	2	3	3	3	3	3	3	4	3	3
	3	1	1	2	2	1	3	1	2	2	2	2	3	3	2	2	1	2	2	2	2	2	3	3	2	3
	4	3	3	3	3	3	2	3	4	3	3	3	3	3	3	3	3	0	0	3	1	0	3	3	3	4
	5	3	2	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	2	2	3	3	2	3	3	3
	6	3	3	3	3	4	4	3	3	4	2	3	3	3	3	3	3	3	4	2	3	3	3	4	3	4
	7	0	1	0	0	0	0	0	0	0	1	0	0	2	0	0	0	1	3	2	1	1	2	2	1	0
	8	1	1	2	2	2	1	3	2	1	1	3	1	0	4	1	2	3	3	1	1	2	3	2	3	2
	9	2	2	3	3	3	2	2	2	3	3	1	2	3	3	2	3	3	3	3	2	2	2	3	3	2
	10	3	3	3	3	3	3	3	2	3	3	4	3	3	3	3	2	3	3	2	3	3	3	2	3	4
	11	3	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	12	4	2	2	3	3	3	3	3	3	3	0	4	3	3	3	4	3	3	2	4	4	3	3	3	4
Paddock 5 Redlands	1	3	3	3	1	4	3	3	4	3	4	4	3	3	4	3	3	3	3	3	4	3	3	4	3	3
	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3
	3	3	3	2	2	3	3	3	3	2	3	3	4	3	3	3	3	3	3	3	3	4	3	3	3	3
	4	3	3	3	3	4	4	3	3	2	3	3	2	3	3	3	3	3	3	3	3	3	4	3	3	3
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	6	1	1	2	2	2	1	2	3	3	3	3	1	1	1	2	3	3	3	3	2	3	2	2	3	3
	7	2	3	1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
	8	3	4	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	9	3	3	3	3	3	3	4	3	3	2	3	3	3	3	3	3	2	3	1	2	3	3	3	3	3
	10	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	4	3	4	3
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	12	2	3	3	2	3	3	3	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3
Paddock 6 Wondergraze	1	3	3	2	1	2	2	2	3	2	1	3	1	3	3	2	1	2	2	3	2	2	3	2	1	2
	2	3	3	3	3	1	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
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	7	3	3	0	3	3	3	1	0	4	0	3	5	3	4	4	2	5	4	3	3	3	5	5	4	3
	8	3	1	3	3	2	3	3	2	3	4	2	3	1	3	1	1	1	1	2	1	4	0	3	3	3
	9	3	4	3	2	3	3	3	3	4	2	5	4	4	4	3	3	2	3	3	3	3	3	3	3	3
	10	3	2	3	3	3	2	2	2	3	2	1	2	3	2	1	1	2	3	3	3	3	3	3	3	3
	11	2	2	3	3	2	3	3	3	3	3	3	3	2	2	2	3	3	3	2	2	1	0	1	0	2
	12	3	2	2	2	2	3	3	3	2	2	2	3	3	2	2	2	2	3	3	3	2	2	2	2	2
Paddock 7 Wondergraze	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	3
	2	3	3	0	0	0	0	3	1	1	0	0	1	2	2	3	3	3	3	0	0	3	1	1	2	0
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	11	3	3	3	3	3	3	3	3	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	12	3	3	2	2	3	2	3	3	4	3	3	3	2	2	2	3	2	3	2	3	3	3	2	3	3
	13	3	3	2	1	0	0	3	2	1	2	3	3	2	3	3	4	4	3	3	3	3	4	4	3	0
Paddock 8 Wondergraze	1	1	1	3	2	3	2	0	2	2	2	1	1	1	1	2	1	1	1	3	3	3	2	3	2	2
	2	2	2	1	2	2	2	2	2	2	3	2	2	2	2	3	3	1	2	3	3	1	2	3	2	2
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	6	1	3	1	1	1	1	1	2	2	2	1	2	1	2	2	1	1	1	2	2	2	2	1	3	0
	7	3	4	3	3	2	1	1	2	2	2	2	2	1	1	0	0	1	1	1	2	1	0	1	1	2
	8	3	1	1	1	2	0	3	1	2	2	3	2	1	1	2	1	0	1	3	1	1	1	1	1	3
	9	3	2	3	2	2	1	1	2	1	1	1	1	1	1	2	1	1	2	2	1	1	1	2	2	1
	10	1	1	1	1	1	2	1	1	1	1	1	1	1	1	3	2	1	2	1	1	1	1	1	1	1
	11	3	3	1	2	3	2	1	1	3	2	2	2	2	2	1	2	2	1	1	1	2	2	1	2	1
	12	3	2	3	2	3	2	1	2	3	2	2	2	2	2	1	1	2	2	2	2	1	1	2	2	3
	13	0	2	2	2	3	3	1	2	0	2	0	0	2	1	0	1	3	2	3	3	3	2	2	2	3

0 = no plants (fail); 1 = < 0.25 m; 2 = 0.25 - < 0.5 m; 3 = 0.5 - < 1.0 m; 4 = 1.0 - < 1.5 m; 5 = >= 1.5 m

Fig. 18 Pictorial representation of plant height survey at Pinnarendi leucaena trial, August 2017.

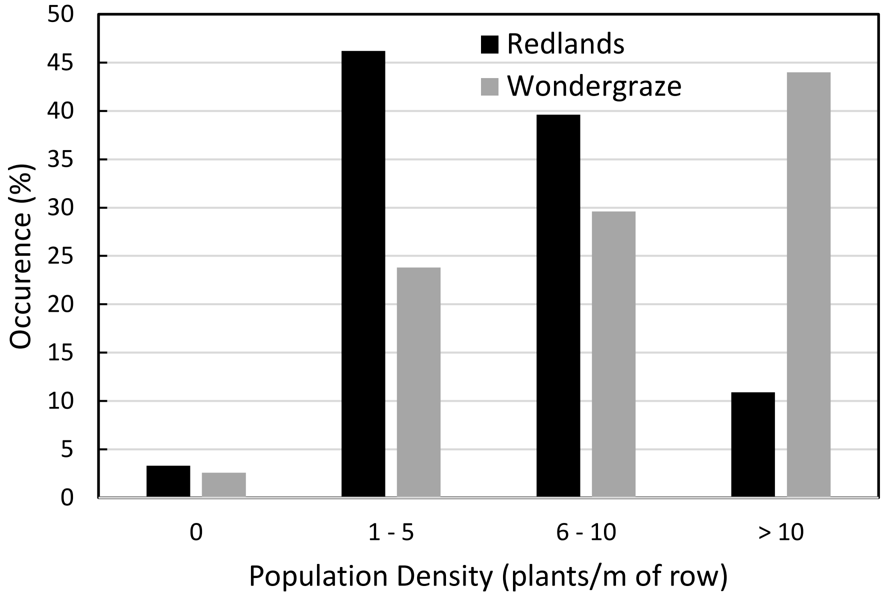


Fig. 19 Analysis of leucaena population survey (occurrence) at Pinnarendi, August 2017.

There was not a significant interaction between variety and height ($p = 0.123$). Plant heights for both Redlands and Wondergraze were both predominantly in the range of 0.25 - < 1.0 m. Fig. 20 shows the results of this analysis.

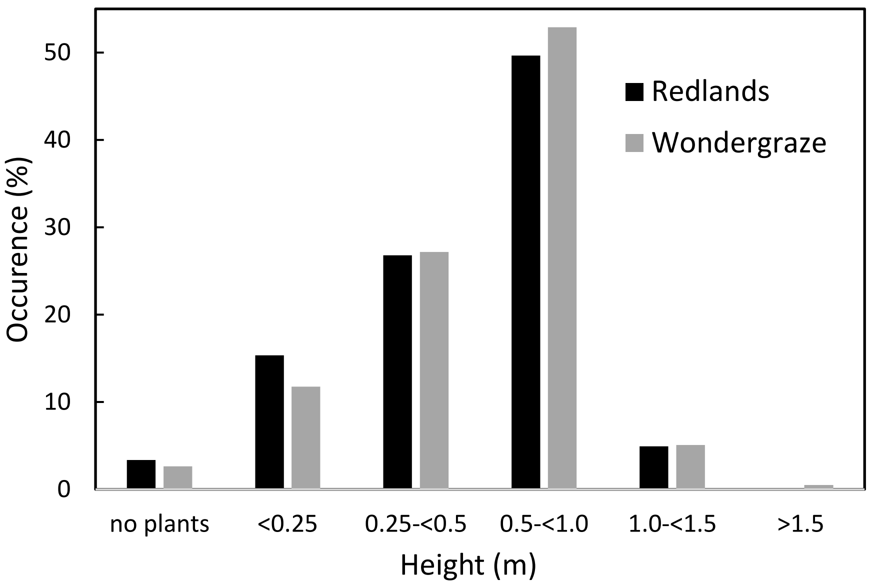


Fig. 20 Analysis of leucaena height survey at Pinnarendi, August 2017.

5.5 Psyllid damage monitoring

Psyllids were first observed at the site on 2 May 2017, but were only found on Wondergraze in low numbers and were not causing noticeable damage. By late May they were in higher numbers and beginning to cause noticeable damage to new growth on Wondergraze.

Raw data from nine assessments of psyllid activity conducted during 2017 and four assessments during 2018 appeared to show clear differences between Redlands and Wondergraze. All Wondergraze paddocks had psyllid damage at all five monitoring assessments up until the end of July 2017. None of the Redlands paddocks had apparent damage during this period although psyllids were present on some trees. Psyllid damage to a typical sample of Wondergraze leaf in June 2017 at Pinnarendi is shown in Fig. 21. alongside Redlands, which was unaffected.

a. Wondergraze sample, Paddock 6 b. Redland sample, Paddock 5

Fig. 21 Typical difference in psyllid damage between Wondergraze and Redlands at Pinnarendi, 2 June 2017.

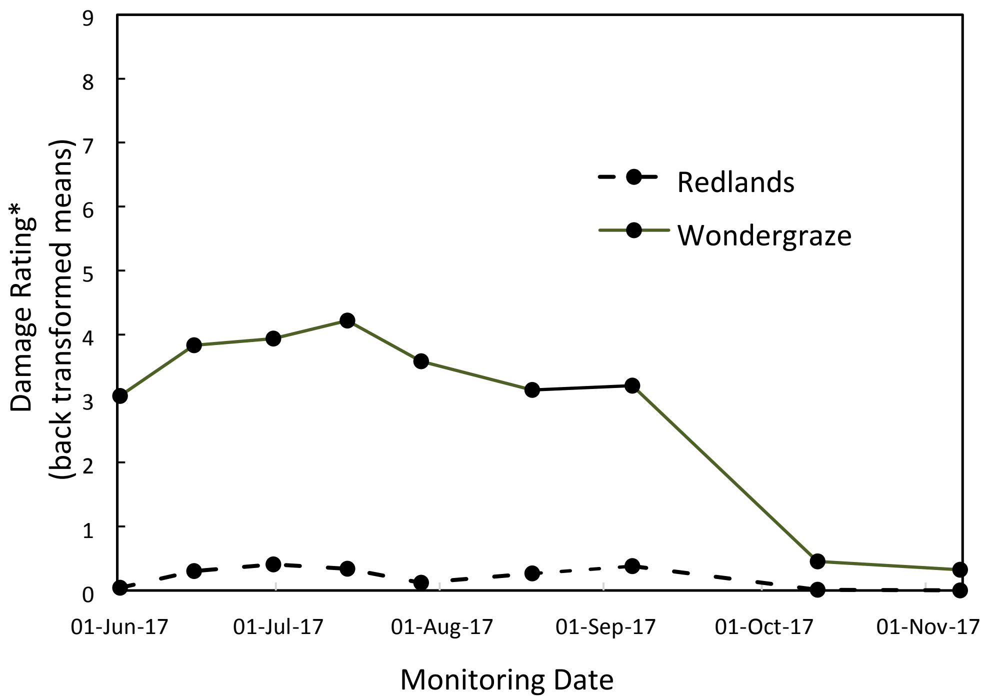
In early June 2017, Wondergraze paddocks were observed to have a yellow tinge to the upper canopy (when looking across the whole planting) and by mid-July it was apparent that Wondergraze at the site was being set-back relative to Redlands. By the end of July 2017, Wondergraze paddocks had been adversely affected by psyllids. Wondergraze was less developed and had less leaf cover overall compared with Redlands.

By early September, psyllid damage to Wondergraze had appreciably lessened. Presumably this was due to warming temperatures and decreased humidity. Whilst there were still psyllids present on Wondergraze, they were not causing obvious damage and Wondergraze paddocks progressively recovered from the cumulative damage received since May. Good rainfall in October caused Wondergraze to put on new growth which was not damaged by psyllids. This resulted in Wondergraze recovering relative to Redlands, to the extent that there was little apparent difference between it and Redlands by early December.

5.5.1 Psyllid activity during 2018 and damage analysis

Psyllid incidence and damage ratings were on a 10-point scale (0-9). For an initial analysis the ratings were averaged for the nine plants in each paddock and these averages considered as repeated measures in time. A Restricted Maximum Likelihood (REML) model was fitted to assess how the ratings differed over time for each variety. Whilst the residuals were relatively normal, applying a square root transformation to the average improved the normal probability plots. Pairwise comparisons were made using Fisher's protected Least Significant Difference (p = 0.05). Back transformed means are shown in Fig. 22.

The interaction of date and variety (Redlands or Wondergraze) was significant ($p < 0.001$). Psyllid ratings for Wondergraze were significantly higher than Redlands on all dates, however for the last two monitoring dates in October and November, they differed by less than 0.5 in the rating value. For Redlands, psyllid ratings did appear to differ over time ($p < 0.01$), but were always less than rating 1, indicating that psyllids were present but no damage was apparent. For Wondergraze, average psyllid ratings peaked in mid-July although this was not significantly different from ratings taken from mid-May to the end of July. During this period, average ratings ranged from 3.8-4.2.



* Based on modified damage rating scale (Wheeler 1988) where 0 = no psyllids present; 1 = no damage observed (psyllids present); 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 leaves and blackening of lower leaves; 9 = blackened stem with total leaf loss.

Fig. 22 Psyllid damage ratings for Wondergraze and Redlands leucaena at Pinnarendi during 2017.

5.5.2 Psyllid activity and monitoring during 2019

No psyllid activity or damage was observed at the site from November 2017 until early May 2018 at which time monitoring was again implemented. Psyllid populations and associated damage were comparatively low during 2018. There were four monitoring events up until early September 2018 (when psyllids became inactive at the site). The raw data from monitoring in 2018 (Table 14) indicated consistently higher psyllid damage/occurrence in Wondergraze compared with Redlands. Damage peaked in June and there was no noticeable effect from damage at the site before or after this time. Monitoring during 2018 ceased in September. The data were not analysed.

Table 14. Psyllid rating data from leucaena at Pinnarendi during 2018 (not analysed).

Date	*Average psyllid incidence/damage (based on rating scale by 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**

5.6 Soil and leaf test results

5.6.1 Soil tests

Soil test results in 2018 (after fertiliser applications in 2016-17) are shown in Table 15 with summarised results from 2016 testing shown as a baseline. Testing during 2018 showed increases in sulphur and phosphorus levels near the surface compared to samples taken in 2016 prior to fertiliser applications. Phosphorus in the top 10 cm of the profile increased from an average of 5 mg/kg to a corresponding average of 15 mg/kg. Likewise sulphur increased from 2.6 mg/kg to 7.1 mg/kg. Soil pH was similar. Sulphur levels increased markedly with depth whereas phosphorus declined. Since sulphur is easily leached in light soils with high rainfall, it is likely that surface applied sulphur moved deeper into the profile during the 2017-18 wet-season.

Table 15. Soil test results across trial site paddocks at Pinnarendi (2016 and 2018).

Sample date	***Comment/Details***	***pH** (1.5 ater)*	***Phosphorus** (mg/kg)*	***Sulphur** (mg/kg)*	***Potassium** (cmol(+)/kg)*	***Magnesium** (cmol(+)/kg)*	***Zinc** (mg/kg)*	***Copper** (mg/kg)*
2016	***Average of samples prior to site development***	*6.4*	*5.1*	*2.6*	*0.53*	*1.3*	*0.33*	*0.21*
21 Feb 2018	**Taken when sub-optimal leucaena growth / colour observed**							
	Paddock 5	6.0	15	8	0.21	0.6	0.42	0.31
	Paddock 6	5.8	18	11	0.14	0.6	0.36	0.31
	Paddock 7	6.4	23	4	0.17	0.6	0.20	0.15
14 Mar 2018	**Additional samples taken after mistake with requested analysis of samples taken 21 Feb**							
	Paddock 4 (0-10 cm)	6.4	17	6	-	-	-	-
	Paddock 4 (10-20 cm)	6.6	< 5	6	-	-	-	-
	Paddock 4 (20-50 cm)	6.6	< 5	14	-	-	-	-
	Paddock 6 (0-10 cm)	5.7	11	9	-	-	-	-
	Paddock 6 (10-20 cm)	6.0	< 5	6	-	-	-	-
	Paddock 6 (20-50 cm)	6.1	< 5	12	-	-	-	-
	Paddock 6 (0-10 cm)	6.1	< 5	4	-	-	-	-
	Paddock 6 (10-20 cm)	6.3	< 5	4	-	-	-	-
	Paddock 6 (20-50 cm)	6.3	< 5	13	-	-	-	-
	Paddock 7 (0-10 cm)	6.7	7	6	-	-	-	-
	Paddock 7 (10-20 cm)	6.5	< 5	4	-	-	-	-
	Paddock 7 (20-50 cm)	6.5	< 5	3	-	-	-	-
14 Jun 2018	**One sample taken adjacent plants with poor colour and another sample taken adjacent plants with good colour**							
	Paddock 2 upper (0-10 cm)	6.2	9	4	0.25	0.7	0.22	0.32
	Paddock 2 middle (40-50 cm)	6.9	< 5	13	0.28	0.9	0.03	0.10
	Paddock 2 lower (90-100 cm)	7.2	< 5	15	0.21	1.1	< 0.02	0.02
	Paddock 3 upper (0-10 cm)	5.0	28	12	0.25	0.9	0.36	0.33
	Paddock 3 middle (40-50 cm)	6.2	< 5	36	0.25	1.3	0.08	0.15
	Paddock 3 lower (90-100 cm)	6.3	< 5	22	0.08	1.4	0.06	0.03

5.6.2 Leaf tests

Results from leaf analysis of samples collected in March 2018 are given in Table 16. The sample of leaf with good colour had a higher level of nitrogen than any of the samples of leaf showing poor colour.

Table 16 Leaf analysis results from samples of leucaena collected at Pinnarendi in March 2018.

Sample	*Nitrogen (%)*	*Phosphorous (%)*	*Potassium (%)*	*Calcium (%)*	*Magnesium (%)*	*Sulphur (%)*	*Boron (ppm)*	*Copper (ppm)*	*Iron (ppm)*	*Manganese (ppm)*	*Molybdenum (ppm)*	*Zinc (ppm)*	*Sodium (%)*	*Chloride (%)*
P7 Wondergraze – good colour														
result	3.22	0.20	1.74	0.87	0.59	0.41	40	8.4	66	37	0.09	21	<0.05	0.68
interpretation	SL	SL	H	H	H	N	H	N	N	N	N	N	N	N
P1 Wondergraze – yellow colour														
result	2.85	0.20	1.74	0.99	0.55	0.45	46	9.9	73	49	0.14	21	<0.05	0.97
interpretation	L	SL	H	H	H	N	H	N	N	N	N	N	N	N
P2 Redlands – yellow colour														
result	2.56	0.20	1.66	1.10	0.51	0.44	42	9.1	83	48	0.10	19	<0.05	0.94
interpretation	L	SL	H	H	H	N	H	N	N	N	N	N	N	N
P8 Redlands – yellow colour														
result	2.56	0.17	1.66	0.92	0.57	0.37	39	8.5	58	47	0.14	18	<0.05	0.76
interpretation	L	L	H	H	H	N	N	N	N	N	N	N	N	N

SL = slightly low; L = low; N = normal; H = High (lab interpretation; not specific to leucaena)

5.6.3 Nodulation

Roots from leucaena unearthed in June 2018 were inspected for the presence of nodules. No nodules were observed on roots from a location where leucaena showed poor growth and colour (yellowing). However, a few (< 5 per plant) nodules were found on roots from a location where leucaena appeared healthier and had greener colour (Fig. 23). Nodules were dissected and viewed under a microscope (at 10 x magnification) and found to be active, having pink to brown colouration (Adjei et al. 2002).

a. Lack of nodulation on roots from leucaena with poor colour (yellow).

b. Small amount of nodulation on roots from leucaena with good colour (green).

Fig. 23 Leucaena roots unearthed in June 2018.

5.7 Inter-row pasture growth

The inter-row pasture species (particularly Seca, *Stylosanthes scabra*) grew well over the 2017-18 wet season (Fig. 24a.). This was attributed to spelling over two wet seasons combined with the application of superphosphate in August 2017. There was a heavy cover of mixed species within all the paddocks at the trial site leading into the dry-season at the end of April 2018. These included *Stylosanthes spp.*, Wynn cassia *(Chamaecrista rotundifolia)*, naturalised Indian couch (*Bothriochloa pertusa*), Sabi grass (*Urochloa mosambicensis*) and Black Spear grass (*Heteropogon contortus*). Quadrat cuts of inter-row pasture taken in Paddocks 1-4 in late July 2018 yielded dry matter biomass of about 6 t/ha (Fig. 24b. and Table 17).

a. Inter-row pasture – February 2018

b. Inter-row pasture yield assessment – late July 2018.

Fig. 24 Inter-row pasture at Pinnarendi trial site.

Table 17. Inter-row pasture dry matter yields in Paddocks 1-4 at Pinnarendi (July 2018).

Paddock	***Inter-row pasture yield***		***Inter-row pasture composition (% by weight)***		***Dominant species***
	Biomass (kg/ha DM)	***Standard deviation (kg/ha DM)***	***Legumes***	***Grasses***	
1	6,610	1,857	35	65	*Stylosanthes spp.* and Urochloa
2	5,920	1,553	44	56	*Stylosanthes spp.* and Urochloa
3	5,520	1,562	58	42	Wynn cassia and Urochloa
4	6,040	1,299	48	52	*Stylosanthes spp.* and Urochloa
Overall Average	***6,020***	-	***46***	***54***	

5.8 Preliminary weight gain data from pilot grazing phase

Grazing in the trial began in 2018 and is ongoing. The first year of grazing was a pilot exercise prior to a more formalised grazing trial being implemented in 2019. Stocking rates were conservative as leucaena was not fully established. Liveweight data has not yet been analysed.

5.8.1 First grazing period

The initial grazing period was over 70 days from 19 April to 26 June 2018 which covered the early part of the dry season. While only steers from Pinnarendi were used, the escape of some animals compromised the data since it resulted in different stocking rates for the Redlands and Wondergraze treatments and there was no replication. Leucaena yield was not assessed before or after grazing. Although animals were naïve to leucaena, both Wondergraze and Redlands treatments were immediately and readily eaten by cattle. Most leucaena in both treatments was consumed within the first month of grazing.

The average daily gain (ADG) for all animals and both treatments over 70 days was 0.67 kg (range of 0.37-0.89 kg). Despite having a higher stocking rate, the ADG measured for Wondergraze was higher than for Redlands (Table 18).

Table 18. Average daily liveweight gain for steers grazing Redlands and Wondergraze leucaena over 70 days at Pinnarendi from April to June 2018 (data not analysed).

19 April to 26 June 2018 (70 days)	***Average entry weight (kg)***	***ADG (kg)***		
		Average	High	Low
Overall (all 17 head)	***206***	***0.67***	**0.89**	**0.37**
Redlands - Paddock 5 (6 head)	*198*	*0.64*	0.89	0.37
Wondergraze – Paddock 6 (11 head)	*211*	*0.68*	0.77	0.57

5.8.2 Second grazing period

The second grazing period commenced with the addition of steers from Spyglass (Section 4.8.4). The grazing period was 40 days (26 June to 7 August), during mid dry-season. Animals were grazed in Paddocks 7 and 8 and leucaena yield was not assessed before or after grazing. Although the same number of animals were grazed in each paddock, data from this grazing period is qualified by the comparative poor establishment status of leucaena in Paddock 8 (Redlands) and the introduction of the Spyglass animals. By the end of this grazing period, very little leaf remained on the leucaena in either Paddock 7 or 8.

The ADG for all animals and both treatments over 40 days was 0.50 kg (range of 0.15-0.93 kg). The ADG for Wondergraze was slightly higher than for Redlands for both groups of animals (Fig. 25).

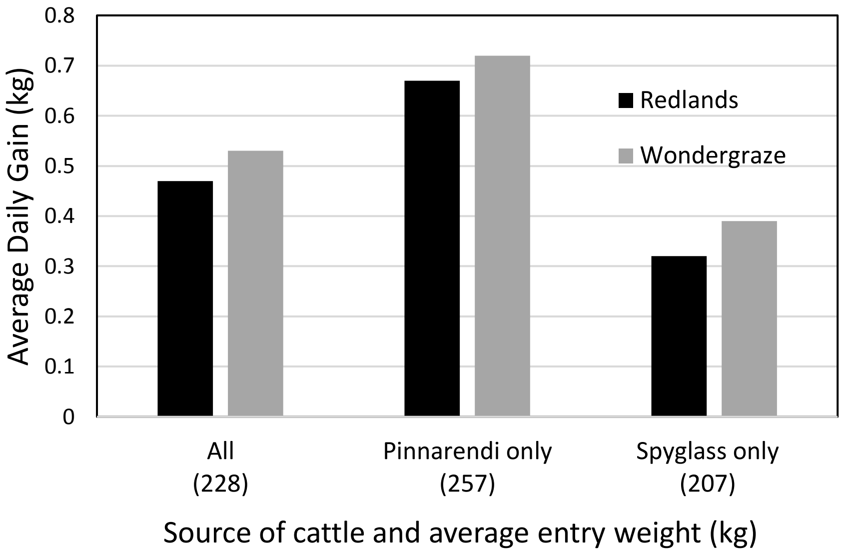


Fig. 25 Average daily liveweight gain for steers grazing Redlands and Wondergraze leucaena over 40 days at Pinnarendi from June to August 2018 (data not analysed).

5.8.3 Third grazing period

The third grazing period was the first time animals were evenly split across more than one replicate within treatments. The grazing period was 44 days (7 August to 20 September) during dry-season conditions with cool to cold nights. Paddocks 1-4 were used and leucaena yields were assessed at the beginning and end of the grazing period (Table 11). The inter-row pasture yield was also assessed at the start of grazing (Table 17). Leucaena yields were low due to the dry weather and cold overnight temperatures which slowed growth and resulted in some leaf drop. Most of the leucaena had been consumed by animals within the first few weeks of grazing.

The ADG for all animals and both treatments over 44 days was 0.38 kg (range of negative 0.02 kg to positive 0.64 kg). The ADG for Wondergraze was slightly higher than for Redlands for both groups of animals (Fig. 26).

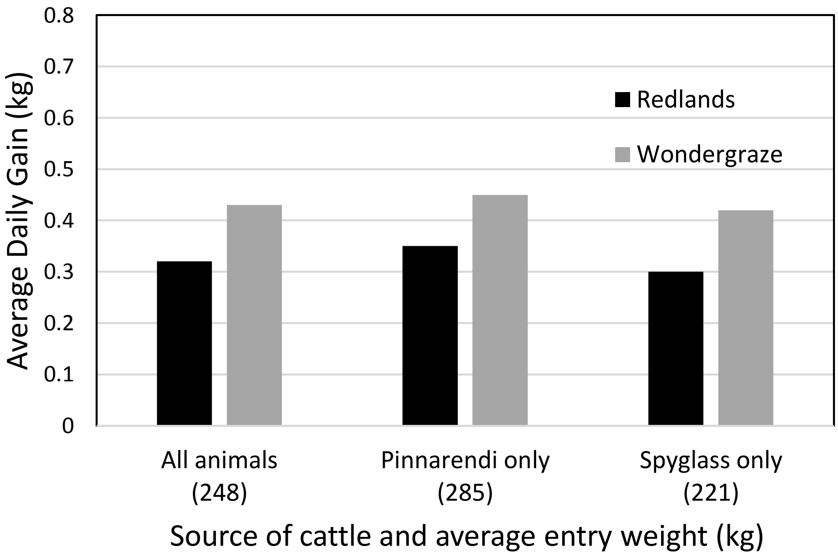


Fig. 26 Average daily liveweight gain for steers grazing Redlands and Wondergraze leucaena over 44 days at Pinnarendi from August to September 2018 (data not analysed).

5.8.4 Fourth grazing period

For the fourth grazing period, animals from Paddocks 1 and 3 (Wondergraze) were combined and moved to Paddock 6 (Wondergraze); animals from Paddocks 2 and 4 (Redlands) were moved to Paddock 5 (Redlands). There was no replication of the treatments for this grazing period. The grazing period was 49 days (20 September to 8 November), during late dry-season. Leucaena yield was assessed just prior to introduction of cattle. Despite dry conditions, the yield of leucaena had increased relative to the yield in Paddocks 1-4 assessed prior to the third grazing period in August (Table 17). This was due to production of new leaf in response to warming temperatures after some light frost damage in late August. The yield was still low however, and cattle consumed most of the leucaena by October. During October, 35 mm of rain was received which re-invigorated leaf production. This allowed cattle to continue consuming a low level of leucaena throughout the grazing period.

The ADG for all animals and both treatments over 49 days was 0.15 kg (range of negative 0.24 kg to positive 0.41 kg). For this grazing period, the ADG of Redlands was slightly higher than for Wondergraze (Fig. 27).

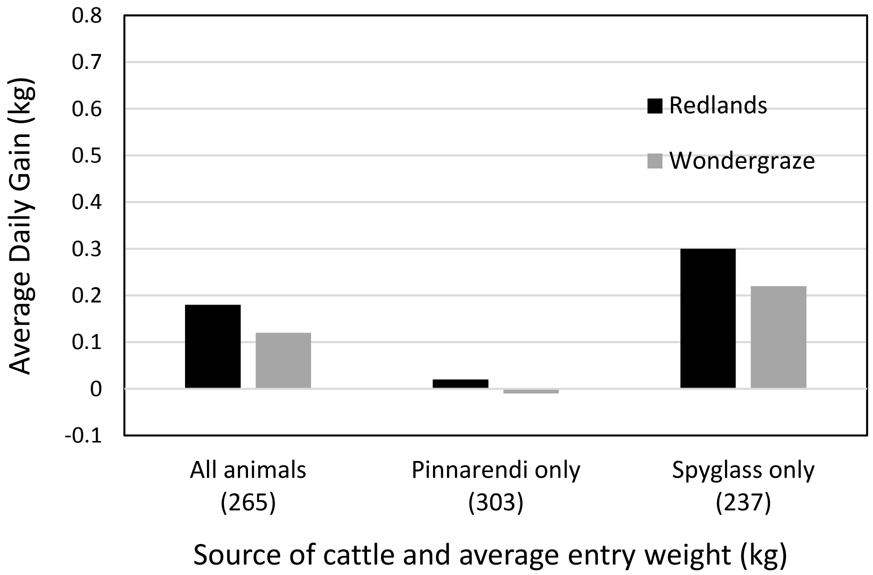


Fig. 27 Average daily liveweight gain for steers grazing Redlands and Wondergraze leucaena over 49 days at Pinnarendi from September to November 2018 (data not analysed).

6 Discussion

6.1 Establishment success and trial integrity

The establishment of Redlands and Wondergraze leucaena in replicated paddocks at Pinnarendi will allow valid comparison of productivity between the two varieties by monitoring liveweight performance of cattle grazing on each treatment.

Psyllid occurrence and damage at the site has been confirmed (particularly during 2017) and any productivity advantage conferred by the psyllid resistance of Redlands will be verified over the longer term. Psyllids are typically prevalent in the region from May to September which usually coincides with the time of year when leucaena is less productive due to the onset of drier conditions. This may supress any productivity difference between Redlands and Wondergraze at the site. Nonetheless, psyllids clearly affected productivity of Wondergraze at the site in 2017 and historically, psyllids severely damaged the commercial planting of leucaena at nearby Meadowbank. Psyllid attacks can also occur earlier in the year when leucaena is more likely to be growing vigorously.

During early establishment (2-3 months after sowing), it was observed that Wondergraze was generally more vigorous and uniform in comparison to Redlands. This was not attributed to planting conditions as Wondergraze paddocks appeared to be better established and more advanced than the Redlands treatments across both sowing events. The cause of this difference was speculated to be the lower quality, smaller and variably sized Redlands seed, compared to the commercially sourced Wondergraze seed.

By mid-2017, the observed difference between varieties (treatments) was less apparent with Redlands slightly more advanced than Wondergraze (though generally less uniform) due to psyllid damage in Wondergraze paddocks. Results from the population survey of leucaena across the site in August 2017 showed that there was still a difference between Redlands and Wondergraze. Wondergraze had higher plant populations and was more evenly established across the site compared to Redlands although there was not a significant difference in plant height between the two varieties.

Whilst paddock differences weren't formally compared in the study, Paddock 8 (Redlands) had notably poor establishment relative to other paddocks at the site, especially when compared to the neighbouring paddock of Wondergraze (Paddock 7) which was the best established paddock at the site. However, this is attributed to paddock specific conditions during establishment (weed competition/soils) rather than the Redlands variety. Paddocks 1-6 had more uniform establishment (when comparing neighbouring paddocks of paired-replicates). The generous 10 m row spacing at Pinnarendi may reduce differences between varieties over time, since there is little or no competition between neighbouring rows of leucaena. This may allow areas with lower populations of leucaena to compensate with increased plant growth.

6.1.1 Sub-optimal leucaena growth

Sub-optimal leucaena growth towards the end of the 2017-18 wet-season was concerning considering the significant amount of fertiliser applied before and after sowing, targeting phosphorus and sulphur deficiencies. Much of the leucaena at Pinnarendi had a 'yellow' colour and this was the case for both Redlands and Wondergraze at the site and across most trial paddocks.

The cause of sub-optimal leucaena growth has not been conclusively determined. It was speculated that the poor growth response may have been attributed to trace element deficiencies exacerbated by ready availability of macro nutrients (phosphorus and sulphur). Both zinc and copper levels from original soil tests were generally low across the site. Alternately, phosphorus and sulphur from fertiliser applications may not have been fully available in the soil with inter-row pasture also providing strong competition for phosphorus and sulphur.

Nitrogen deficiency was a likely explanation of the poor growth. In the small-scale nutrient trial carried out in February 2018, leucaena appeared to respond to nitrogen applications with improved colour and vigour whereas no response was observed to applications of other nutrients. Soil test results did not show any particular deficiencies of other macro nutrients.

The ground-based application of a custom blended fertiliser containing nitrogen (as well as contingency phosphorous and sulphur) and the aerial application of sodium molybdate (March 2017) was made to address the perceived issue of nitrogen deficiency. Whilst these applications were made towards the end of the wet-season, 90 mm of rain was received at the site in late March ensuring incorporation of these applications. Following this, a positive growth response was observed in the leucaena.

Analysis of leaf samples collected in March 2018 showed average levels of nitrogen in leaf with poor colour at 2.7% (interpreted as low), versus 3.2% (interpreted as slightly low) for the sample of leaf with good colour (Table 16). Phosphorus and sulphur analyses were similar for both leaf colour samples. Pasture quality of leaf samples taken in August 2018 across Paddocks 1-4 also showed good levels of phosphorus and sulphur in leaf with sulphur being particularly high. A lack of nodulation was observed on leucaena roots dug up at the site in June 2017, indicating failed or limited colonisation by rhizobia bacteria. This is likely attributed to the use of commercial inoculant strain CB3126 at the time of sowing. Later in 2017, CB3126 was found to have poor efficacy during quality assurance testing and it was temporarily removed from the market.

Notwithstanding the above, the growth of nitrogen fixing trees may be limited by phosphorus availability (Binkley et al. 2003). Despite generous applications of superphosphate in 2016 and 2017, soil phosphorus levels from soil tests conducted at Pinnarendi in 2017 were low.

6.1.2 Sooty mould

Sooty mould has been observed on Redlands at the site. In some areas, this was most noticeable between adjacent paddocks of Redlands and Wondergraze. Whereas Wondergraze was unaffected, the trunks and branches of Redlands in the neighbouring paddock were obviously blackened. If sooty mould also affects younger stems and leaf, this may reduce its acceptability to cattle. Sooty mould has also been observed on Redlands growing at nearby 'Whitewater' (with other varieties unaffected).

6.1.3 Inter-row pasture

The decision to leave the inter-row pasture uncultivated during the establishment phase was the appropriate strategy. The inter-row pasture did not compete appreciably with the young leucaena. The benefits of maintaining ground cover, minimising the cost of cultivation and avoiding the cost and risk in re-establishing pasture prior to grazing were greater than any set-back of leucaena from pasture competition.

The dry-matter yield of the inter-row pasture in Paddocks 1-4 in July 2018 was close to 6,000 kg/ha and was measured after the onset of the dry-season when the pasture was more than 80% cured. This is a high yield and reflective of the pasture being spelled since June 2016 (over two wet-seasons) and receiving fertiliser prior to the 2017-18 wet-season. The pasture is also of reasonable quality comprising grass and legumes in about equal proportions. Whilst the legume component comprises Stylosanthes spp., there is also a significant amount of Wynn cassia (*Chamaecrista rotundifolia*).

6.2 Psyllid activity

No attempt has been made to control psyllids at the site. Determining the difference in productivity between psyllid tolerant Redlands and psyllid susceptible Wondergraze (expressed as liveweight performance) under a commercial scale is the main objective of the trial.

From May to October 2017, psyllid presence and damage was significantly greater on Wondergraze compared with Redlands. Psyllid damage caused obvious widespread leaf loss across most Wondergraze paddocks at the site. If cattle had been grazing on the trial during this period, it is likely that Wondergraze yield would have been reduced and acceptability degraded (due to sap and mould on leaf). During the same period, there was also some psyllid activity on Redlands, but it remained below the threshold for damage.

Psyllid activity during 2018 was minimal and had peaked by late June. Whilst Wondergraze recorded higher psyllid activity and damage relative to Redlands, there was negligible effect on productivity, even in paddocks which were not being grazed at the time of peak psyllid activity.

6.3 Pilot grazing liveweight performance data

A pilot grazing trial at the site was initiated in 2018. Liveweight performance data collected to date has not been analysed.

Liveweight data has been considered in the broader context of cattle performance on leucaena in northern Australian environments. The overall ADG for cattle grazing Redlands and Wondergraze at Pinnarendi from late June to early November 2018 was 0.33 kg. The discrete ADG's for the period were:

- April-May-June = 0.67 kg (min. 0.37 kg, max. 0.89 kg) for Pinnarendi animals only
- June-July-August = 0.50 kg (min. 0.15 kg, max. 0.93 kg) for all animals
- August-September = 0.38 kg (min. -0.02 kg, max. 0.64 kg) for all animals
- September-November = 0.15 kg (min. -0.24 kg, max. 0.41 kg) for all animals

Declining ADG's from the peak levels in the second quarter of the year to lows near the end of the year, reflect a typical seasonal pattern of declining pasture quality. Likewise, leucaena yield and new leaf production also declined over this period. These figures are encouraging as they were achieved without dietary supplementation and are at least double what would be expected for animals grazing native pasture only in this environment. Notably, animals gained weight on average during the latter part of the year, whereas they would usually loose or only maintain weight at the same time of year in most northern environments.

Good overall weight gains were achieved despite relatively low productivity of leucaena during the period and what would have been a small amount of leucaena in the diet of grazing animals (not quantified). Most grazing occurred over the dry-season and conditions in 2018 were drier than usual. Whilst heavy rainfall was received in March 2018, only 36 mm was received at the site over six months from the start of April to the end of September compared to an average of about 110 mm (Meadowbank median = 58 mm). This points to potentially higher productivity (and weight gain) in more favourable years with near average or above average rainfall. The response of leucaena at the site to warmer weather in September, producing new shoots and modest quantities of green leaf despite dry conditions is notable. All other pasture species at the site and in the region more generally, were dead or hayed off.

Pasture quality attributes of leucaena samples taken at the site in August 2018 (Tables 12 and 13) were high – particularly for leaf samples, which had about twice the forage quality of stem samples. Phosphorous, sulphur and inferred nitrogen levels were all high. Sulphur levels were of the order of four times higher than measured in pasture nitrogen trials being conducted on the Atherton Tablelands with high sulphur soils. Non-Fibre Carbohydrate (NFC), a key measure of pasture quality, was almost 40% in samples of leucaena leaf at Pinnarendi, which is comparable with high quality dairy pastures grown on the Atherton Tablelands. Crude protein from leaf and stem (≤ 5 mm diameter) samples were 21% and 8%, respectively. These are high values considering crude protein in grass pastures at Pinnarendi would likely peak around 10% for a few weeks in the year during the wet season. Total digestible nutrients for leaf samples averaged 61%. This is also a high value considering samples were taken during the dry season. In comparison, improved pastures on the Atherton Tablelands record peak total digestible nutrients of about 80% in the wet-season or under irrigation. Leaf samples recorded an average Relative Feed Value (indexed to lucerne hay cut at early flowering = 100) of 202.

6.3.1 Refining grazing trial methodology

There have been some learnings from the first year of grazing which was run as a pilot exercise. The minimum group size of cattle in paddocks (replicates) is six to seven animals to allow low-stress handling of cattle. Also, rotation of animals out of paddocks for strategic spelling of leucaena and the inter-row pasture is desirable, as is monitoring liveweight performance over a full 12 month grazing period (rather than 10.5 months originally proposed). Obtaining liveweight data with replication of treatments and using the same cohort of animals in an individual year will be important for analysis.

A modified grazing regime is proposed for 2019, using a new cohort of replacement animals in the trial:

- Continue to use weaner steers with an average entry weight of about 200 kg.
- Adopt a 12 month grazing period to obtain annual liveweight gain data.
- Use Paddocks 1-6 for grazing six groups of animals (three replications).
- Periodically spell these paddocks by combing groups within treatments and moving them into Paddocks 7 and 8 whilst remaining within same treatment/variety.
- Stocking rate based on nominally grazing entire trial site over a 12-month period (likely to be a total of 54 ± 6 head).
- Liveweight data from Paddocks 7 and 8 will not form part or the trial analysis but will continue to inform animal performance on leucaena generally.

Under this regime, animals will remain on leucaena for a full 12 months of grazing and within the same treatments. A possible strategy will be to spell the main trial Paddocks 1-6 for two to three months over the wet season to maximise leucaena biomass and inter-row pasture leading into the dry season. One or two short rotations out of these paddocks during the balance of grazing can be done as required for leucaena or parasite management. Nominally higher stocking rates during actual grazing of individual paddocks may assist with controlling leucaena height as animals knock it down to access the canopy. Notwithstanding this proposal, an adjusted methodology for grazing may be adopted for future cohorts of animals.

6.3.2 Rumen fluid collection and rumen inoculation

The proposed program of rumen fluid collection was not completed during 2018. Only naïve rumen fluid samples were collected. The low levels of leucaena in the diet of cattle grazing in the trial could not support further sampling. In addition, the low and declining levels of leucaena in the diet did not justify administering rumen inoculant. Animals were monitored and did not exhibit any signs of leucaena toxicity and have continued to gain weight.

In future, it is intended to inoculate all cattle on the trial once higher levels of leucaena are being consumed.

6.4 Economics of leucaena in northern environments

Whilst data from the grazing trial will assess any productivity advantage from using Redlands, animal performance data from the site will more generally inform the economics of leucaena adoption in north Queensland. Experience and learnings from the site during the establishment phase and during grazing trials will improve industry understanding of leucaena establishment and management in northern environments. Estimated costs of leucaena establishment on red-brown earths in north Queensland have been calculated based on experience of leucaena establishment at Pinnarendi and assumptions about the likely activities in a commercial situation (Appendix 6).

Preliminary liveweight performance data from the trial is already of value considering it was achieved during a period when leucaena productivity and animal performance is typically constrained due to seasonally dry conditions. Full year liveweight gains from the trial should be higher, and may provide compelling evidence for leucaena adoption in northern environments. If the economics are sound, leucaena adoption has the potential to improve profitability and sustainability of northern beef businesses through increased feedbase productivity and enabling access to premium slaughter markets. The potentially higher productivity offered by a psyllid resistant variety such as Redlands, would further improve the business case.

6.5 Project extension activities

Several extension events were held at the Pinnarendi trial site (Table 19), including a dedicated Field Day in May 2017 (Fig. 28). There has been two articles on ‘Beef Central’ about the project and/or its linkages with the new Redlands variety: “New psyllid resistant leucaena to feature at field day” (11 May 2017) and “New Redlands leucaena showing promise in initial trials” (31 May 2018). There was coverage on ABC Radio ‘North Queensland Rural Report’ and ‘Queensland Country Hour’ in 2017 and an article in ‘The North Queensland Register’, 1 August 2018: “Psyllid resistant leucaena doubling liveweight cattle gains in far north” (Appendix 4).

A poster paper highlighting the project was prepared for the International Leucaena Conference, 2018 at the University of Queensland and will be published in “Tropical Grasslands” journal (Appendix 5).

Table 19. Extension activities and events linked to the Pinnarendi leucaena trial site over 2017-18.

Date	*Event*	*No. producers present*	*No. properties represented* *Area (ha)* *Total no. cattle*	*Other attendees*
May 2017	Project Field Day, Pinnarendi and Whitewater, 24 May 2017 (**Fig.** 23)	27	14 properties 590,000 ha 56,000 head	5 agribusiness 5 DAF
August 2017	Site inspection to inform future leucaena development on Wrotham Park	1	3 properties 580,000 ha 31,000 head	2 DAF
September 2017	MLA and Beef & Feedbase site inspection	0	n/a	1 MLA 7 DAF
September 2017	Site inspection with Hayley Giles and Scott Dalzell	0	n/a	1 UQ 1 agribusiness 1 DAF
October 2017	NextGen and Grazing BMP Forum	10	7 properties 170,000 ha 16,500 head	4 DAF 2 NRM
November 2017	Redlands for Regions planning meeting	6	4 properties 120,000 ha 9,000 head	1 MLA 1 Leucaena Network 2 DAF
February 2018	Investigating leucaena options for the Atherton Tablelands	2	2 properties 200 ha 280 head	2 DAF
March 2018	Redlands for Regions meeting	6	4 properties 120,000 ha 9,000 head	2 DAF
March 2018	NGRMG Grazing Forum and Sown Pastures	7	5 properties 111,000 ha 10,000 head	4 NRM 4DAF
April 2018	Site inspection by Charters Towers DAF staff	0	n/a	3 DAF
April 2018	Site inspection to investigate plant nutrient deficiencies	0	n/a	1 agribusiness 1 DAF
June 2018	Redlands for Regions meeting and Goshen Field day; investigate plant nutrient deficiencies	7	5 properties 138,000 ha 14,000 head	3 DAF

Fig 28 Field Day Pinnarendi May 2017

6.5.1 Producer management group

The Producer Management Group (PMG) was proposed as a way for industry to be engaged with the project. The PMG was not formed during Phase 1 as the timeframe for site development, sowing and timely management decisions overtook the plan to engage and obtain input from the mooted PMG. With grazing underway and routine collection of ADG data, there is the prospect of formalising the PMG through regular updates of trial activities and cattle performance. This would also provide the opportunity for producer feedback and suggestions – particularly regarding future classes of cattle to be used in the trial and target markets/weights.

7 Conclusions and recommendations

The Pinnarendi trial site has been successfully set-up for progression to grazing. Leucaena and inter-row pasture is well established across the site with the exception of one Redlands treatment that has comparatively poor plant populations and vigour.

Sub-optimal leucaena growth at the end of the 2017-18 wet season across much of the site has been attributed to nitrogen deficiency caused by poor root colonization with rhizobium bacteria. Commercial inoculant used at sowing was likely to have not been viable. Anticipated growth improvement and productivity of leucaena over time is expected and will be monitored. This may take a few years assuming rhizobia bacteria progressively colonise roots. However, if leucaena at the site continues to exhibit sub-optimal growth then the cause of the issue needs to be confirmed and remediation actions considered. Re-inoculation by sub-soil injection during the wet-season could be tried, but the practicality and efficacy of this operation in established leucaena is not known.

Grazing at the site (2018) has demonstrated high liveweight gains relative to recognised performance on similar country without leucaena (native pasture). Performance of cattle grazing leucaena has been encouraging considering dry conditions and the relatively low yield of leucaena during this period. The preliminary grazing data from 2018 has not been analysed for differences in productivity between psyllid resistant Redlands and the conventional Wondergraze variety.

A more rigorous methodology for future grazing trials is proposed. This will be implemented with future cohorts of cattle. In conjunction, ongoing performance and management inputs at the site will further inform the economics of leucaena adoption in northern Australian environments where conventional grazing systems are characterised by highly seasonal productivity.

Psyllid activity at the site during 2017 resulted in significant damage to Wondergraze and there was an observable decline in yield. During the same period, Redlands recorded low levels of psyllid incidence but no appreciable damage. Psyllid activity during 2018 was minimal and insufficient to produce an appreciable difference between varieties at the site. The difference in psyllid activity at the site between 2017 and 2018 has shown the variability in annual psyllid infestations and corresponding severity of damage. This supports the need to conduct grazing trials over a few years, so that any productivity difference between Redlands and Wondergraze from psyllid damage can be expressed.

The incidence of sooty mould on Redlands leucaena at Pinnarendi is of some concern particularly since it has also been observed on other Redlands plantings in the region (Whitewater). Sooty mould has the potential to compromise grazing performance through reduced productivity and/or palatability. Its persistence or re-occurrence at Pinnarendi will be monitored.

Since the quality of the inter-row pasture will contribute significantly to the performance of cattle grazing in the trial, it would be useful to have comparable data for cattle grazing pasture only (no leucaena) in the same environment. It is proposed to obtain liveweight data from the landowner's cattle grazing in an adjoining paddock which has an established improved pasture of buffel grass (*Cenchrus ciliaris*) and *Stylosanthes spp*. Although not replicated, this data would provide a direct comparison between two alternative grazing systems at the site. To improve the comparison, this pasture would be fertilised in the same manner as the leucaena inter-row pasture.

Estimated costs for developing Redlands leucaena on near coastal red-earth sites in north Queensland are about $370/ha (Appendix 6). This is based on sowing leucaena into cultivated and fertilised strips at 10 m row spacing and retaining about 50% of the existing inter-row pasture in the uncultivated area between leucaena rows. The costings are based on experience from the Pinnarendi trial site and judgement of the likely management activities required for successful establishment of leucaena on these soils. This costing is higher than for 'frontage country' in north Queensland at $336/ha (Bowen et al. 2018), due to the higher fertiliser requirements of infertile red-earth soils and the $30/kg cost premium of Redlands seed. The economic payback period on this soil type will depend on the long-term productivity of leucaena (animal performance) and longer term fertiliser requirements.

Although the site at Pinnarendi was not deep ripped, the extra cost of this operation may be warranted on red-earth sites since there is evidence it improves leucaena establishment and early growth in non-cracking loam soils (Buck 2013). Trials on deep ripping of non-basalt soils in north Queensland environments need to be conducted to determine costs versus advantages.

8 Key messages

A large scale leucaena grazing trial has been successfully established on the red-earth soils at Pinnarendi and initial grazing performance (liveweight gain) is encouraging. Establishment and management has been conducted with the over-arching aim of setting up a replicated grazing trial. In commercial situations, the costs of site development to sow leucaena and management inputs to maintain productivity on similar soils (low fertility red-earths) may be prohibitive. Longer-term data collection on animal performance and management inputs at the site are required.

Experience and activities at the site have provided learnings to increase the knowledge and reduce the risks of leucaena adoption in northern environments:

Leucaena establishment on red earths
Relatively high rates of fertiliser have been applied at Pinnarendi to ensure successful establishment of the site for trial purposes. These rates may be unsustainable in commercial situations. Fertiliser applications may require considerable refinement to improve the economics. Costs of leucaena establishment on red-earth sites using Redlands are higher than for 'frontage sites' in north Queensland environments but long-term productivity differences are not known.

Seed quality
Lower viability and size variability of Redlands seed sourced from Walkamin and used at Pinnarendi was an issue and probably resulted in reduced germination rates and variable emergence. To avoid high sowing rates, commercially produced seed quality needs to be assured through optimised growing and harvesting techniques as well as seed testing and processing.

Seed inoculation and nitrogen deficiency
Inoculant used on leucaena seed for sowing at Pinnarendi had low efficacy which resulted in poor root colonisation by nitrogen fixing bacteria. Nitrogen deficiency was the probable cause of sub-optimal leucaena growth at the site over the 2017-18 wet-season.

Sowing depth
Light textured soils in north Queensland pose particular challenges for establishing leucaena. Sowing depth and moisture availability are critical. Better success was observed when seed is placed at depths no greater than 25 mm and there is ample soil moisture. Good seedbed preparation and well-designed planters are critical for maintaining accurate sowing depth. Sowing needs to occur when there is a reasonable outlook for additional rainfall (within 7 to 10 days after sowing).

Weed control
Pre-emergent weed control with the current suite of herbicides is limited by the prevalence of sown legumes such as *Stylosanthes spp.* and *Chamaecrista spp.* in the northern dry tropics. Whilst good weed control was achieved by cultivation either side of the plant row, this did deplete soil moisture and does nothing to control intra-row weeds. Mulching by slashing the adjacent inter-row pasture and/or intra-row cultivation may improve weed control and moisture retention.

Grasshopper control
Grasshoppers posed a threat to young leucaena at the site a few weeks after emergence. An aerial application of pesticide provided immediate and longer-term control of grasshoppers during the critical establishment phase. Such an option could be considered by producers establishing leucaena commercially. It was timely and relatively inexpensive considering the downside investment risk from widespread grasshopper damage at such a critical stage of leucaena development.

Vertebrate pest control
Erection of vermin-proof fencing at Pinnarendi protected young leucaena from rabbits and wallabies and helped ensure successful establishment. Such fencing would likely not be economic in commercial situations. Producers need to be mindful of the pest risk when planting leucaena. They should only develop areas for which they can provide the management and surveillance required during the critical establishment phase.

Inter-row pasture
Full paddock cultivation for leucaena establishment was avoided at Pinnarendi. This reduced costs and erosion risk and avoided the need to re-establish the inter-row pasture. Competition of the pasture with young leucaena was minimal. This system would be the preferred model in environments with no history of cultivation, high erosion risk and generous leucaena row spacing’s (around 10 m).

Liveweight gain
Liveweight gain of cattle in the trial over 133 days during the dry-season averaged 0.33 ± 0.08 kg/day (mean ± standard deviation). This is notable relative to the lower performance expected from native pastures in the same environment at the same time of year. By the end of the dry season, overall ADG fell to 0.15 ± 0.19 kg/day meaning that liveweight losses were minimised when pasture quality was otherwise very low.

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The DAF northern beef research and extension team had a major input to the project, particularly during site development phase and set-up of infrastructure.

11 Precautionary note

Although highly palatable to cattle, leucaena can be potentially invasive in un-grazed areas if not managed correctly. The leucaena Code of Practice (http://www.leucaena.net/codeofconduct.pdf or admin@leucaena.net) describes the responsible management of leucaena. The Code of Practice is endorsed by DAF and the use of these protocols will assist landholders meet their obligations under the *Biosecurity Act 2014*, whereupon landholders are responsible to take practicable steps towards preventing the spread of potentially invasive plants.

Appendices

Appendix 1 Original trial site – concise report

A1.1 Introduction

A 62 ha site initially selected at St Ronans was prepared and planted over the 2015-16 northern wet season. Unfortunately, establishment was unsuccessful due to heavy rain after planting and poor soil drainage. Subsequently, a 61 ha site was selected at nearby Pinnarendi and developed for the trial during 2016.

A1.2 Methods

A1.2.1 Site selection and overview

The original site was selected for the trial in November 2015. St Ronans is located 60 km south-west of Mt Garnet in north Queensland and is approximately 250 km from the coast. The property lies within the 600-900 mm average annual rainfall band. Psyllids were known to occur at leucaena plantings within 30 km of the site at St Ronans.

About 70 ha of flat, previously cleared land was selected close to existing yard and station infrastructure. This area had basalt soils with good fertility and water holding capacity. The site is shown in Fig. A1.1 as at November 2015, before any preparation works had commenced. Although part of the site had been previously cropped, it was characteristically rocky, with patches of light regrowth. It was decided to plant leucaena at a 10 m row spacing and establish improved pasture between the leucaena rows. The rocky nature of the site did not allow sophisticated seedbed preparation or regular cultivation for weed control, leucaena was planted into deep-ripped rows.

Approximately 60% of the trial site had no history of cropping and had a light cover of native species including Kangaroo grass (*Themeda australis*), Black Spear grass (*Heteropogon contortus*) and Queensland Bluegrass (*Dicanthium sericeum*). These were mostly removed during site preparation and heavy weed growth occurred in the balance of the area previously farmed. The improved pasture was sown between the leucaena rows at about the same time as the leucaena sowing.

Fig. A1.1 Original leucaena trial site in November 2015 prior to any site development.

A1.2.2 Trial design and layout

The proposed grazing trial was based on two treatments – Wondergraze and Redlands, with each treatment being planted in separate paddocks (replicates). A trial design comprising four replicates per treatment was adopted; i.e. eight replicated paddocks with four paddocks planted to Wondergraze and four planted to Redlands.

After defining the extent of the block using a hand-held global positioning device (GPS), a trial layout was developed for the site as shown in Fig. A1.2. Due to the non-rectangular shape of the block, paddock widths were adjusted so that they all had the same enclosed area and total row-length of leucaena. Each paddock had an area of 7.8 ha which would allow stocking with 6-7 animals. Stocking calculations were based on the assumed productivity of the leucaena-grass pasture system, proposed duration of grazing and estimated average weight of animals during the grazing period.

Due to difference in the nature of soils across the site which became apparent after initial clean-up of the site, it was decided to adopt a randomised paired-block analysis rather than fully randomise the treatment allocation. As such, the randomly generated treatment allocation was:

- Wondergraze – Paddocks 1, 3, 6 and 7
- Redlands – Paddocks 2, 4, 5 and 8

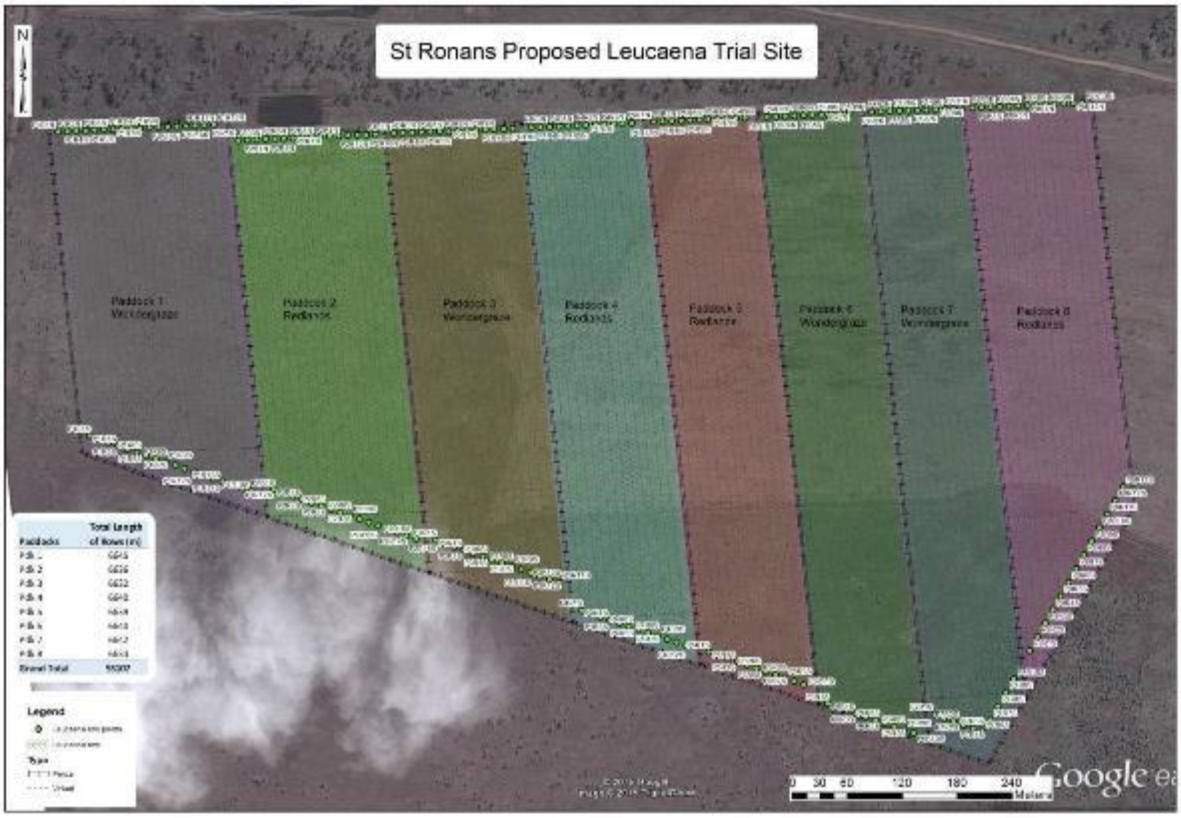


Fig. A1.2 Layout of proposed leucaena grazing trial at original site.

A1.2.3 Seed sourcing

A1.2.3.1 Leucaena seed

The Redlands seed for establishment of the grazing trial was sourced from a pilot block established in March 2014 at the DAF Walkamin Research Facility on the Atherton Tablelands. Redlands seed pods were hand-harvested from about August 2014 and throughout 2015. Pods were dried and hulled, with cleaned seed subsequently stored as separate batches in a cool store at about 18^{o}C

Prior to planting in February 2016, about 57 kg of Redlands seed had been collected. At a planting rate of 1-1.5 kg/ha, this more than sufficient the planting area of 31 ha. Wondergraze seed required for the trial was purchased commercially from Leucseeds Pty. Ltd.

A1.2.3.2 Inter-row pasture seed

The species composition for the inter-row pasture is shown in Table A1.1. Seed was sourced from Australian Premium Seeds at Walkamin. The mix was not tested. It was predominantly comprised of coated seed with some naked seed.

Table A1.1 Grass species sown at St Ronans.

Species	***Common name***	***Composition by weight** (%)*
Bothriochloa insculpta	Bisset	12
Bothriochloa pertusa	Keppel	7
Chloris gayana	Tolgar	15
Panicum maximum	Gatton	15
	G2	15
Urochloa mosambicensis	Sabi	36
Total		*100*

A1.2.4 Pre-planting site preparation

A1.2.4.1 Clean-up and ripping

In early December 2015, the standing grass cover was burned and small areas of re-growth were cleared. This revealed extensive rocky areas, mainly at the southern ends of Paddocks 4-8 which had not previously been farmed. Rougher areas of the block were stick-raked and levelled out. Finally, the entire block was cultivated in an east-west direction which was perpendicular to the planned direction of leucaena plant rows.

After clean-up of the site, the leucaena rows were deep ripped to a depth of 600-700 mm using a bulldozer with GPS guidance (Fig. A1.3). This was completed over a three day period, finishing 19 December.

Fig. A1.3 Ripping leucaena plant rows at St Ronans, December 2015.

A1.2.4.2 Fencing

Perimeter fencing was erected at the site in mid-January 2016 over two days. Since there was only a low risk of damage to young leucaena from rabbits and wallabies at the site in the post-emergent stage, a simple four-barb stock-proof fence was erected. No internal fencing was erected.

A1.2.4.3 Weed control

Conditions were seasonally dry prior to and after site preparations and the site was essentially weed-free prior to Christmas 2015. Between Christmas and New Year, 275 mm of steady rain was received at the site (Fig. A1.4) which resulted in significant weed germination and growth, particularly over the old cropping areas. Glyphosate was aerially applied across the entire site during the first week of January 2016. The application rate of 1,700 g/ha (active) was high and resulted in a thorough weed kill.

Fig. A1.4 St Ronans site after 275 mm of rain in late December 2015.

There was no useful rain during the first half of January and there was insufficient moisture for sowing. Regular rain was received from the third week in January until early February. During this period it was too wet for planting and weeds quickly re-established, mostly across the old cropping areas. By the time the site was just dry enough to allow machinery access for sowing, weed growth was heavy and needed to be controlled. Glyphosate was again applied across the entire site using a tractor mounted boom (Fig. A1.5) at a rate of 1,200 g/ha. This operation took a four days and a reasonably good kill was achieved (Fig. A1.5).

a.

b.

Fig. A1.5 Weed control with glyphosate at the original trial site (February 2016); a. tractor-based boom spraying; b. typical kill, five days after spraying.

A1.2.4.4 Soil testing and fertiliser application

A soil test conducted at the site confirmed high phosphorus levels (Colwell P = 150 mg/kg) but sulphur levels below 5 mg/kg. Summarised results from this test are given in Table A1.2.

Table A1.2 Soil test result from trial site at St Ronans in 2015.

Soil attribute	
pH (1.5 Water)	6.5
Phosphorus (mg/kg)	91
Sulphur (mg/kg)	5
Potassium (cmol(+)/kg)	1.6
Magnesium (cmol(+)/kg)	3.5
Zinc (mg/kg)	2.7
Copper (mg/kg)	1.7

Based on the test result, granulated sulphur (90% S) was applied along the leucaena plant rows over a 5 m swath at an average rate 56 kg/ha (i.e. 50 kg/ha S) two to three days prior to the leucaena planting. The application was made using a Vicon® 3-point linkage mounted pendulum spreader as shown in Fig. A1.8.

For the benefit of the grass pasture, GranAm® (20%N, 25%S) was applied over the entire site at a rate of 96 kg/ha. The application was made by driving parallel to and mid-way between the leucaena rows, spreading over a nominal 10 m swath (reaching the leucaena plant rows on each side). The application was made about one week prior to the grass seed planting.

Fig. A1.6 Sulphur application to leucaena plant rows at the original trial site (February 2016).

A1.2.5 Leucaena sowing

A1.2.5.1 Seed preparation and testing

Prior to sowing, batches of Redlands seed were removed from cool storage, combined and thoroughly mixed to ensure uniformity. The bulked seed was mechanically scarified and tested to determine its viability.

Germination tests were conducted in trays with moistened paper using two samples of 100 seeds taken from the scarified bulk batch. Tests were conducted for samples of Redlands and the commercially sourced Wondergraze seed.

As required on the day of sowing, batches of seed were inoculated by hand mixing seed with commercial inoculant strain CB3126 combined with water and household sugar. Inoculated seed was immediately air dried in the shade prior to being used in the planter.

A1.2.5.2 Equipment and method

Due to the rocky basalt occurring at the site, a heavy duty tined machine was used for sowing leucaena. The configuration of the planting set-up used is shown in Fig. A1.7 A toolbar was mounted between the tractor and the planter. It had three tines; one centrally mounted to cultivate the plant row and two either side to disintegrate clods which remained from deep ripping. A heavy steel beam was hung at an angle from the rear of the toolbar to help level the seed bed and clear the plant line of sticks and rocks.

The planter was trailed behind the toolbar and comprised a single planting tine with a press-wheel driven seed box. The seed tube was mounted immediately behind the planting tine. A depth gauge was added which allowed planting depth to be more accurately set and monitored from the tractor.

Fig. A1.7 Leucaena basalt planter used at the original trial site.

A1.2.5.3 Timing

Leucaena sowing began on 12 February starting in the western paddocks where the initial weed load had been lightest. Paddocks 1 and 3 were sown with Wondergraze whilst there was still sufficient soil moisture. The sowing rate was adjusted to just less than 1 kg/ha. The following day, Paddock 2 was sown with Redlands at rate of about 1.1 kg/ha. A slightly higher rate was adopted to account for the lower seed viability of Redlands.

Weather conditions during this time were hot and dry. Soil moisture in the upper 75 mm of the surface depleted rapidly on the lighter soils across the site. With no near-term rainfall forecast and considering the limited supply of Redlands seed, further sowing was deferred.

Good rainfall (40 mm) was received on the last day of February allowing resumption of sowing. Paddocks 4, 5 and 8 were sown with Redlands on 2 March and Paddocks 6 and 7 were sown with Wondergraze on 3 March. Whilst this completed sowing at the site, Paddocks 3 and 2 were then re-sown due to patchy germination from the initial sowing. This was started on 3 March and completed on the morning of 4 March.

A1.2.6 Inter-row pasture planting

Grass seed was sown around the same time as the leucaena in late February and early March. A seed bed was prepared by making a single pass with a 7 m wide set of weighted harrows between each of the leucaena plant rows. Grass seed was spread directly on the surface using the Vicon® fertiliser spreader. A follow-up pass with the harrows covered the seed and improved seed-soil contact (Fig. A1.8). The target sowing rate was 10 kg/ha of coated seed (approx. 6 kg/ha of naked seed). However a higher rate (15 kg/ha of coated seed) was required to reduce the occurrence of blockages in the spreader.

Fig. A1.8 Harrowing the inter-row area after sowing grass seed species mix.

A1.2.7 Post-planting management

A pre-emergent herbicide of Spinnaker® 700 (active constituent 700 g/kg imazethapyr) was applied at a nominal rate of 140 g/ha (active) over a 5 m swath along all plant rows within a few hours of leucaena being sown. The application was at the high end of recommended rates. The application was made using a tractor and boom.

A1.3 Results

A1.3.1 Pre-sowing germination tests

Test results from Redlands seed sourced from the Walkamin pilot block showed about 70% germination with about 14% hard seed (non-germinated). This was lower than results for commercially sourced Wondergraze seed which had germination of 90-95%. Although not quantified, the Redlands seed was more variable in size and smaller overall compared to the commercial Wondergraze seed.

A1.3.2 Leucaena germination and early development

During the two weeks after the initial sowing in mid-February, only light falls of rain were received and the weather was predominantly hot and dry. Leucaena emergence was patchy due to marginal soil moisture conditions. Following resumption and completion of sowing over 3-4 March (including re-sowing of Paddocks 2 and 3) intense rainfall occurred on each of the following two days – 40 mm on 5 March and 60 mm on 6 March.

A site inspection on 12 March confirmed that large areas of the site had surface wash of soil across plant furrows – effectively increasing the sowing depth. Emergence was poor and conditions were too wet for re-sowing. By 16 March there had been some continued emergence, particularly in the Redlands paddocks. It was judged that this might have been sufficient to achieve acceptable plant populations in some areas, although partial or full re-sowing would be required in most paddocks. However, inspections on 20 and 22 March revealed that there were almost no areas where plant populations were acceptable and areas with failed emergence or unthrifty/dying plants. By this time it was too late in the season for re-sowing. There was no return of the monsoon or any further useful rainfall. By mid-April there was no doubt that the establishment had failed.

Photos showing poor emergence and on-going development are shown in Fig. A1.9.


a.


b.


c.


d.

Fig. A1.9 Poor emergence and growth of leucaena at the original trial site in early 2016; a. patchy emergence (16 March); b. typical result in poorly drained soil type (22 March); c. unthrifty seedlings (22 March); d. poor ensuing growth (14 April).

A1.3.4 Inter-row pasture establishment

Improved pasture establishment across the site was generally a success (Fig. A1.10). There was good establishment and growth across most of the virgin and previously cropped sections of paddocks with poorer establishment in the rocky areas to the south of Paddocks 5-8.

a. b.

Fig. A1.10 Successful inter-row pasture establishment at the original trial site; a. 16 March (Paddock 2), b. 7 April (Paddock 3).

A1.4 Discussion

A1.4.1 Concerns about site suitability

Poor germination and growth of leucaena at the original trial site was initially attributed to the heavy rain received after sowing and possible herbicide damage. Concern also emerged about the long-term suitability of the site for the trial. Seedlings which had germinated and survived did not grow well and there was on-going seedling death. Other observations supported this concern:

- Yellow-coloured sub-soil being bought to the surface in during ripping of the plant rows (indicating clay at depth).
- Soils being more variable and predominantly heavier across the site than was originally assessed.
- Difficulty with using machinery on the site – red basalt soils can usually handle machinery within a few days of significant rain, whereas delays of up to a week were experienced at the site.
- About 40% of the site exhibited poor drainage after the rainfall received in late January and early February (water remaining on the surface).
- Areas of the site remained moist on the surface well after cessation of rainfall leading to growth of algae on the soil surface.
- Clods left over from deep ripping failing to disintegrate after rainfall and cultivation indicating higher clay content.

By late April 2016, it was decided that the site was not suited for establishment of the grazing trial. With perseverance, leucaena could possibly be established at the site, particularly with more favourable sowing conditions. However, it was felt that the variability of soils across the site, i.e. poorly drained and rocky areas, would compromise the integrity of the trial. Additionally, with near average rainfall received at the site over the 2015-16 wet-season, there was concern that the site would be even worse in wetter years – not just for plant establishment, but also for productivity of mature leucaena.

A1.4.2 Extension and media associated with St Ronans leucaena trial

Communications activities related to the project are summarised in Table A1.3.

Table A1.3 Project extension and media.

Forum	*Description*	*Date*
BeefCentral (WWW)	News article by James Nason "Grazing trial underway for new psyllid resistant leucaena variety".	17 March 2016
Leucaena Network Conference, Atherton	Presentation by Craig Lemin "Assessing productivity gains for cattle grazing 'Redlands' (R12) leucaena in northern Queensland".	11-12 May 2016
BeefUp Forum Mt Surprise	Poster presentation "Develop a large-scale research site to assess the new 'Redlands' leucaena hybrid". 105 participants (including 70 extensive beef producers) attended this two day forum.	1-2 June 2016

A1.5 Conclusions

Failure of leucaena establishment at the original trial site highlights the need for careful assessment of soil properties in selecting a site to develop for leucaena. Underlying problems at the original site were not apparent until heavy rainfall which revealed inhibited drainage and difficulty with machinery access. The main learnings from the failed establishment of leucaena at the original trial site were:

Soil type
The suitability of basalt soils for leucaena establishment in north Queensland should not be taken for granted. Yellow coloured sub-soil bought to the surface during ripping operations indicates clay at depth and associated poor drainage.

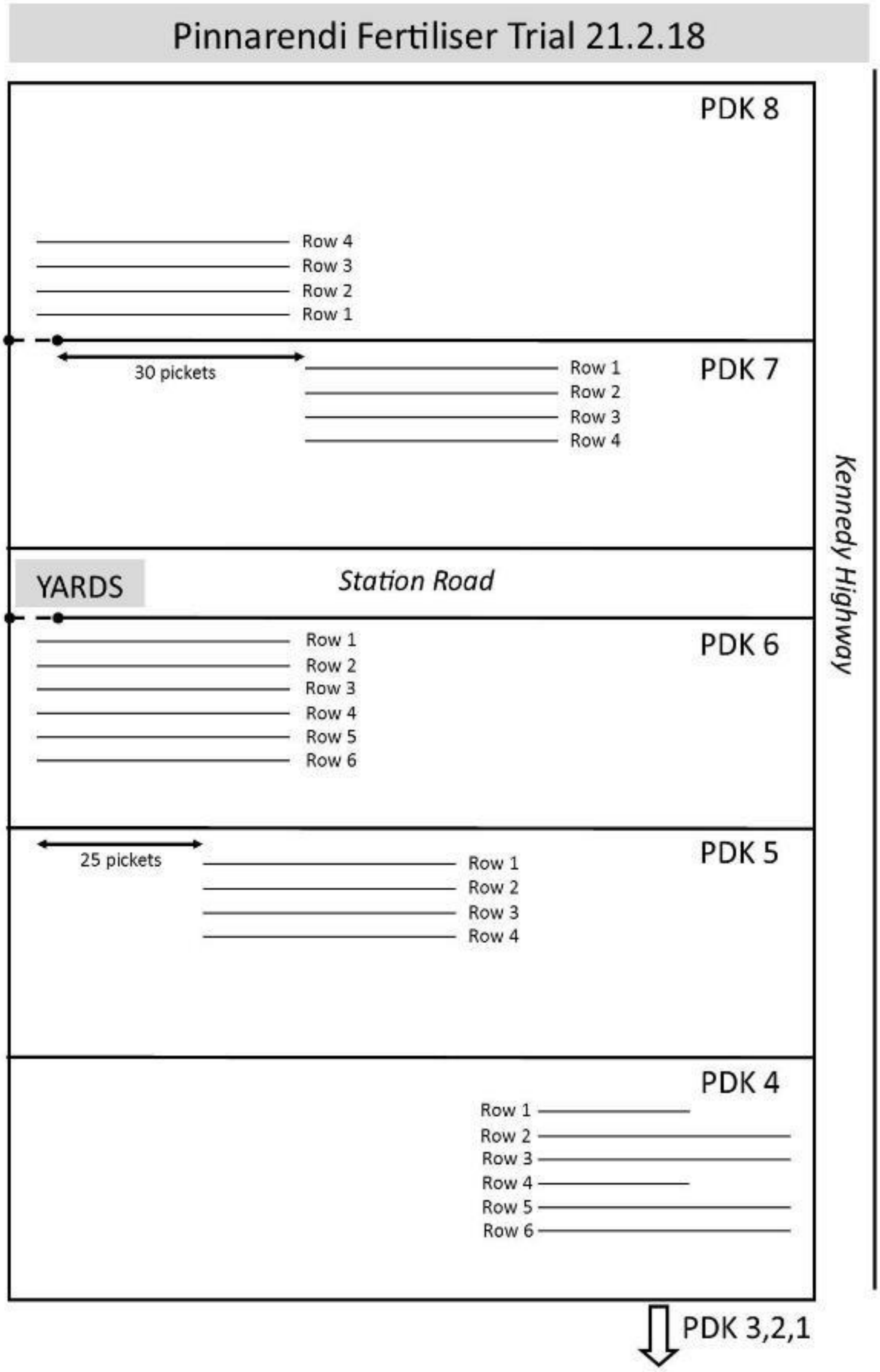
Pre-emergent herbicide
Heavy rainfall received immediately after sowing may have resulted in pre-emergent herbicide damage. Pre-emergent herbicide does carry the risk of crop damage if herbicide is translocated due to heavy rainfall soon after application particularly if there are surface furrows from sowing. Application rates may need to be reduced if significant rainfall is likely after application or on more risky soil types which include soils with low organic matter content (especially lighter and sandy soils).

Time constraints
Notwithstanding failed establishment of leucaena at the original trial site due to soil limitations, the time frame for development of the site in readiness for sowing was too short. Weather conditions and the seasonal outlook during the preparation and sowing phase were unfavourable and the history of cropping over some areas of the site led to heavy weed growth. Under less pressing

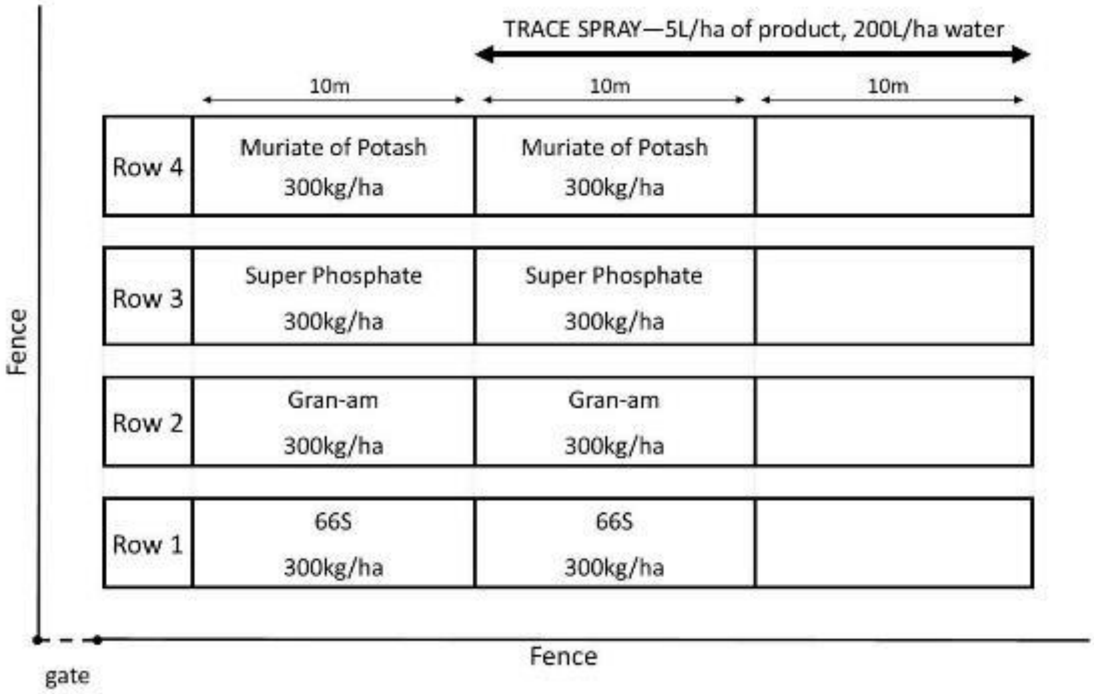
circumstances, these factors may have led to a decision to defer sowing until the following season in anticipation of better conditions. This would have allowed better site preparation and potentially more than one opportunity for sowing. In north Queensland environments without irrigation, there is usually only one or two opportunities for sowing leucaena during the wet-season. Sowing prior to about mid-February is preferable due to greater likelihood of follow-up rainfall.

Appendix 2 Pinnarendi fertiliser trial, February-March 2018

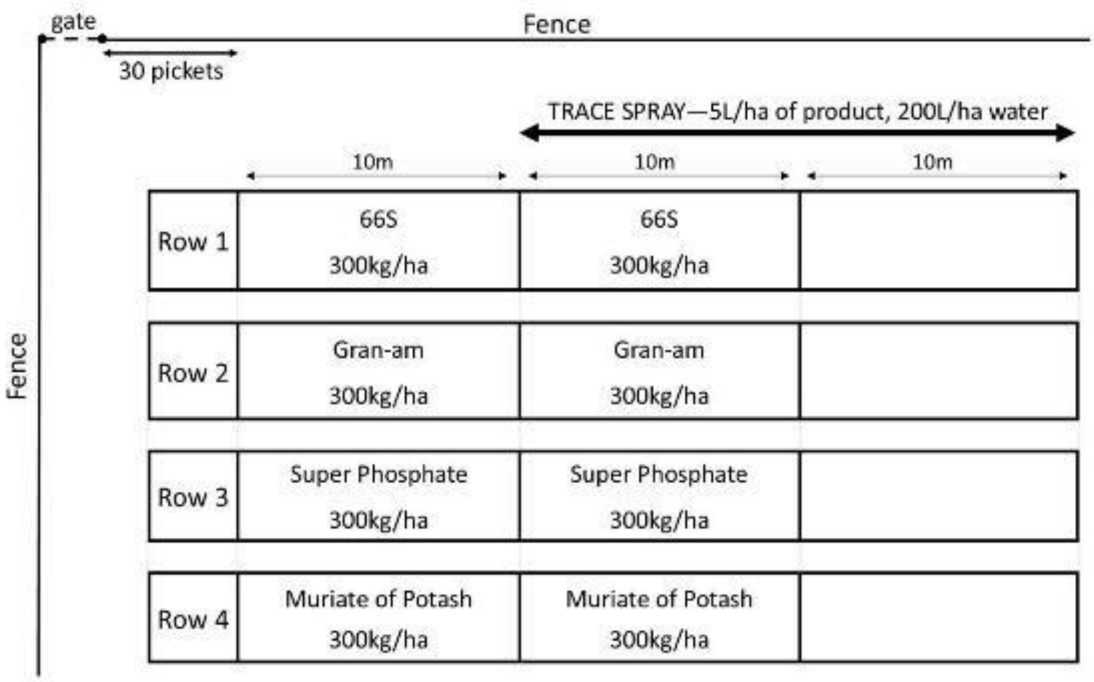
The following schematics show the layout and treatments for the applications of fertiliser in late February 2017 in response to perceived poor growth of leucaena during the 2018 wet-season.



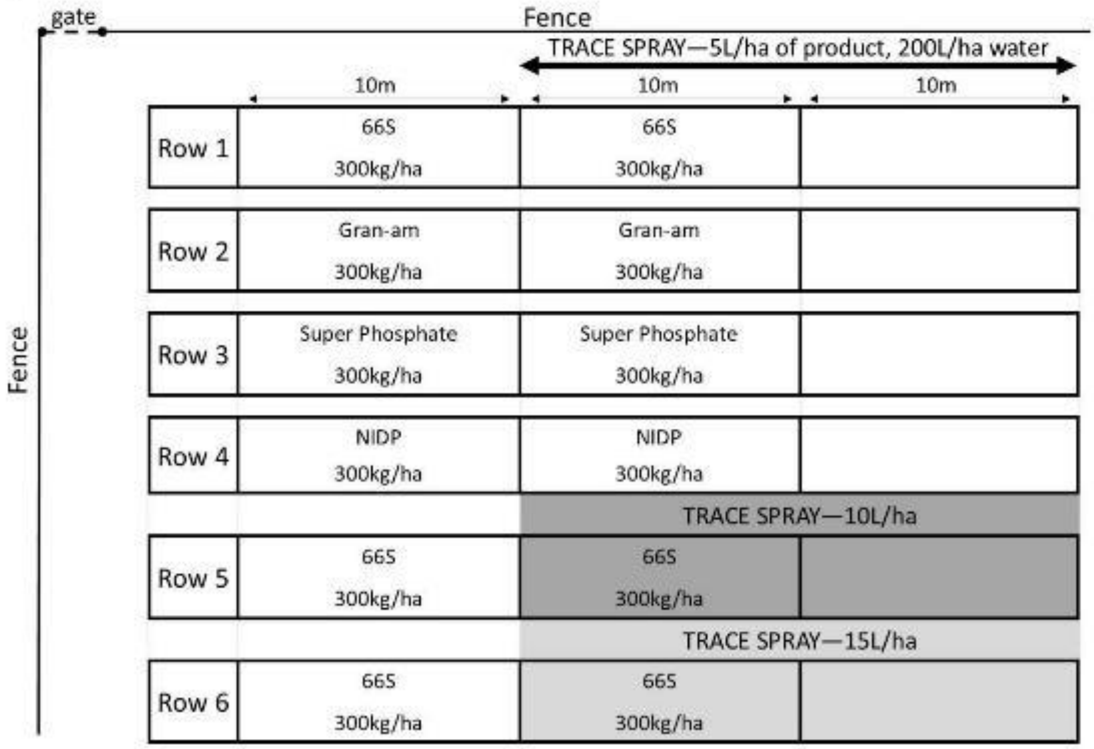
Paddock 8—Redlands Fertiliser application 21.2.18



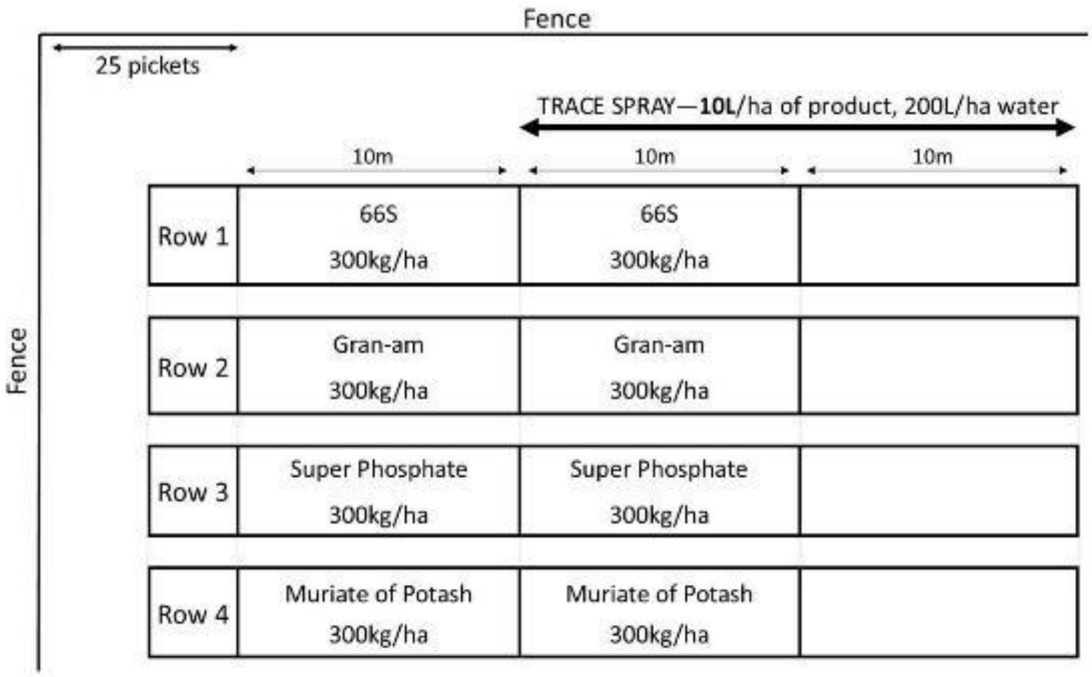
Paddock 7—Wondergraze Fertiliser application 21.2.18

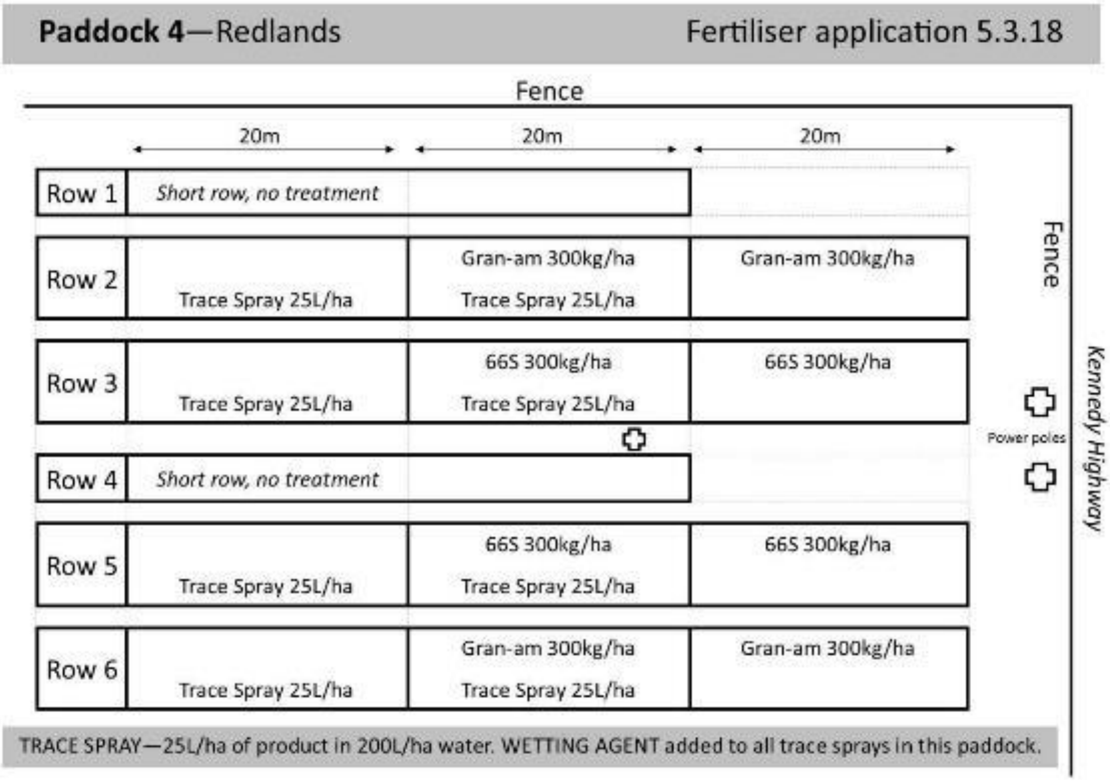


Paddock 6—Wondergraze   Fertiliser application 21.2.18



Paddock 5—Redlands   Fertiliser application 21.2.18




Paddock 4—Redlands
Fertiliser application 5.3.18
Fence
20m
20m
20m
Row 1
Short row, no treatment
Row 2
Trace Spray 25L/ha
Gran-am 300kg/ha
Trace Spray 25L/ha
Gran-am 300kg/ha
Row 3
Trace Spray 25L/ha
66S 300kg/ha
Trace Spray 25L/ha
66S 300kg/ha
Row 4
Short row, no treatment
Row 5
Trace Spray 25L/ha
66S 300kg/ha
Trace Spray 25L/ha
66S 300kg/ha
Row 6
Trace Spray 25L/ha
Gran-am 300kg/ha
Trace Spray 25L/ha
Gran-am 300kg/ha
Fence
Power poles
Kennedy Highway
TRACE SPRAY—25L/ha of product in 200L/ha water. WETTING AGENT added to all trace sprays in this paddock.

Appendix 3 Animal ethics approval

The animal ethics approval for the project (AEC Application Reference SA 2017/12/628) is attached. It provides for use of up to 172 head of cattle in the trial and is valid from 1 February 2018 to 31 January 2021.

1. Applicant (or Applicant contact person) details

Name: Craig Lemin		
Organisation: DAF		Centre:
Postal Address: 28 Peters Street Mareeba Qld 4880		
Phone:	Mobile: 0467 804 870	E-Mail: craig.lemin@daf.qld.gov.au

2. Project Details

Title of the Project	AEC Application Reference Number
Assessing productivity of cattle grazing “Redlands” (R12) leucaena in northern Queensland.	**SA 2017/12/628**

3. AEC Decision

The project application has been considered by the AEC and is: **Approved** *Any inquiry regarding this response should be directed to the AEC Coordinator or Chair in the first instance. The Coordinator or Chair may be contacted via the DAF Call Centre on 13 25 23.*
Purpose: The improvement of animal management or production Category: Minor conscious intervention without anaesthesia
Comments: We believe that the experiment as described will allow you to achieve your two stated objectives (in 2.2.1) but that your results will be exactly applicable only to the conditions applying in your experiment (eg composition of the inter-row grasses. The secondary measurements (eg grass from grass diet composition, feed intake, etc as noted in “big picture’ and in 2.2.1) maybe of less reliability because of the potential difficulties in applying NIRS prediction equations developed under specific conditions to a leucaena/grass diet, and that while faecal

content gives a reasonable indication of feed P content it is not a particularly good indicator of the animal's P status.

Animal growth responds to total feed intake as well as feed composition. Please consider using exclosures to allow estimation of grass intake and an external indicator such as Cr_2O_3 to estimate faecal DM excretion and thus give an estimate of DM intake. Please note that you would have to get ethics approval for this technique.

Period of approval inclusive of the following start and end dates: Approved Start Date: 1 February 2018 Approved End Date: 31 January 2021	Animal type and number approved: Cattle - 172

Important information

1. This approval is for that work as approved in this decision and only within the start and end dates unless amended by a subsequent AEC decision made in accordance with the requirements of the *Animal Care and Protection Act 2001*, the *Australian code for the care and use of animals for scientific purposes* (refer to 2 b) below).

Any animal use outside this approval will constitute a breach of Section 91 of the *Animal Care and Protection Act 2001* and is subject to a maximum penalty of 300 penalty units or one year's imprisonment.

As well as obtaining an AEC approval, a person must not use an animal for a scientific purpose unless the person is registered.

Unless otherwise stated, this approval applies only to work conducted within Queensland.

2. The AEC requires the Applicant to:

a) ensure compliance by all investigators with all conditions set out in this decision in addition to the general requirements of the *Animal Care and Protection Act 2001*, the *Australian code for the care and use of animals for scientific purposes* and all other relevant Commonwealth and State legislation.

b) submit an Amendment Request (Form AE 08) for any proposed change to a project approval prior to that change being implemented (refer to Procedural Guideline 04);

c) report any unexpected or adverse event that impacts on the welfare of any animal used in this project (refer to Procedural Guideline 03);

d) submit Annual Progress Reports (Form AE 10) early each year; and

e) submit a Project Completion Advice (Form AE 09) upon completion of this project.

3. Endorsement: Approval of your project application/amendment request by the AEC is not an endorsement of the project by either the Department of Agriculture and Fisheries or the Queensland Government and is not an endorsement of the Applicant, its products or its processes generally by the AEC, Department of Agriculture and Fisheries or the Queensland Government and no one should assert any such endorsement.

4. Correspondence: All correspondence with the AEC in relation to this project should be via email to your AEC contact and cite the name of the Applicant, title of the project and the AEC Application Reference Number.

5. Grievance: If the Applicant feels that the AEC has erred in its decision regarding any aspect of the project, the Applicant can submit a complaint (refer to Procedural Guideline 05).

Name of AEC	Staff Access AEC
AEC Address	Ecosciences Precinct 41 Boggo Road Dutton Park Qld 4102
Name of AEC Chair	Lex Turner
Chair contact details	T: 07 3708 8507 M: 0427 001 427 email: lex.turner@daf.qld.gov.au
Signature	
Date of Decision	11 December 2017

Appendix 4. Article in 'The North Queensland Register', 1 August 2018

Psyllid resistant leucaena doubling liveweight cattle gains in far north

1 Aug 2018, 1:30 pm

Although highly palatable to cattle, leucaena can be potentially invasive in ungrazed areas if not managed correctly. The Leucaena Code of Practice describes practices for the productive and responsible management of leucaena.

We asked Department of Agriculture and Fisheries research officer, Craig Lemin, about the Redlands leucaena trials in the far north. This is what he had to say:

"Redlands is a psyllid-resistant leucaena arising from a breeding program undertaken by the University of Queensland and supported by Meat and Livestock Australia.

"It has potential to open up large areas for leucaena-based beef grazing systems in northern Australia with a number of different trials completed or underway.

"The first of the trials was a producer demonstration site established at Whitewater Station, near Mount Surprise in 2014. The Whitewater site included a 1 hectare replicated experiment to assess the palatability of new leucaena lines bred specifically for psyllid resistance, relative to traditional varieties Cunningham and Wondergraze.

"The site also includes a 33ha planting of Wondergraze aimed at improving industry understanding of the establishment costs and options of growing leucaena in an open woodland (uncleared) situation.

“The Department of Agriculture and Fisheries has recently established a large-scale grazing trial in north Queensland to evaluate the liveweight gain performance of Redlands relative to the existing commercial Wondergraze variety.

“The Redlands leucaena pasture trial was established with support from MLA in 2017 on a 61 hectare site at Pinnarendi near Mt Garnet.

“Planting at the site occurred during January and February 2017 and was completed using old inoculant which has likely affected the ongoing performance of the plants.

“The first cattle were introduced to the trial in April 2018 at a low and cautionary stocking rate.

“The trials so far have been positive and confirm that Redlands is psyllid resistant. Although psyllids can be found in smalls populations of Redlands, they have not significantly affected productivity.

“Redlands’ liveweight gain performance data is expected to be available in 2019.

“Six producers have been recruited to establish Redlands, including at Quincan Springs and Goshen, with ongoing efforts to establish two additional sites each around Townsville and Mackay.

“DAF is also investigating establishment of leucaena on its Spyglass beef research facility near Charters Towers.

“Commercial interest in leucaena in north Queensland is very strong with an additional 15 beef businesses also looking at leucaena systems.

“In the Mount Garnet and Mount Surprise areas, leucaena can double annual liveweight gains of cattle and increase the carrying capacity of beef enterprises.”

Appendix 5 Poster paper - 2018 International Leucaena Conference, Brisbane

Tropical Grasslands-Forrajes Tropicales (2019) Vol. 7(2):96–99 96
DOI: 10.17138/TGFT(7)96-99

*ILC2018 Poster and Producer paper**

Comparing the grazing productivity of 'Redlands' and 'Wondergraze' leucaena varieties

Comparando la productividad de las variedades de leucaena 'Redlands' y 'Wondergraze' bajo pastoreo

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Keywords: Cattle, liveweight gains, psyllids, Queensland Gulf Country, tree legumes.

Introduction

Leucaena is a rapid-growing, perennial, leguminous tree with the potential to sustainably intensify beef production in the northern rangelands of Australia (Harrison et al. 2015). Adoption of leucaena in the northern Australian beef industry has been slow, partly due to the prevalence of the sap-sucking leucaena psyllid (*Heteropsylla cubana*). Recent efforts to develop new psyllid-resistant varieties have resulted in the release of cultivar Redlands, which has the potential to improve beef production in northern environments. A large-scale trial has been established to compare liveweight gains of cattle grazing Redlands, with that of the established cultivar Wondergraze in a psyllid-prone environment of north Queensland. This paper presents some preliminary results from the trial as the grazing phase commenced only in June 2018. Weight changes of successive groups of weaner steers (*Bos indicus* type) will be monitored over at least three 12 month grazing periods. Stocking rates in the first year are light to protect young leucaena plants, but will be increased in subsequent years when the leucaena is fully grown.

Materials and Methods

Preparation of trial site and psyllid monitoring

A 61 ha cleared trial site was selected at Pinnarendi Station (18.03849° S, 144.872453° E; 759 masl) on yellow to red-brown granite-derived soil with an average pH of 6.4 ± 0.07. Average annual rainfall is approx. 690 mm with the majority falling between November and April. Soil phosphorus and sulphur concentrations were low (5.1 ± 0.06 and 2.6 ± 0.15 mg/kg, respectively).

Prior to the 2016/2017 wet season, plant rows were set-out and prepared by strip cultivation. Superphosphate (9% P, 11% S) was applied at 300 kg/ha (27 kg P/ha; 33 kg S/ha) to a 1 m strip along plant rows before planting. Two leucaena treatments, cvv. Redlands and Wondergraze, were sown in an 8-paddock paired block design (Figure 1) in early 2017 during the wet season. After initial establishment, superphosphate was again applied at 280 kg/ha (25 kg P/ha; 31 kg S/ha) to a strip over the plant rows. Six months after planting, granulated sulphur (90% S) was applied over the leucaena rows at 160 kg/ha (144 kg S/ha) to provide sulphur for leucaena over the longer

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*Poster presented at the International Leucaena Conference, 1–3 November 2018, Brisbane, Queensland, Australia.

Figure 1. Trial layout with 4 replicates of Redlands (R'lnds) and Wondergraze (W'grz) in 8 paddocks.

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

Table 1. Pinnarendi actual rainfall for 2017 and 2018 and the long-term median from the closest weather station.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pinnarendi 2017	235	131	126	15	16	5	2	8.5	0	80	5	40	663
Pinnarendi 2018	175	122	298	12	4	12	8	1	1	37	19	262	952
Long-term median[1]	152	191	98	25	16	11	6	0	0	12	50	118	679

[1]Long-term median from Meadowbank weather station (1956–2017; Bureau of Meteorology) located in the district.

term; superphosphate was broadcast across the whole site at 240 kg/ha (22 kg P/ha; 26 kg S/ha) to promote growth of the inter-row pasture. In February 2018, a contingency application of custom-blend fertilizer (12% N, 11% P, 10.5% S) was applied at 250 kg/ha (30 kg N/ha, 27.5 kg P/ha; 26 kg S/ha) over a 3 m strip along plant rows to address apparent suboptimal growth of leucaena during the 2017-2018 wet season.

Existing inter-row pasture species were retained and included Indian couch (*Bothriochloa pertusa*), Wynn cassia (*Chamaecrista rotundifolia*), Sabi grass (*Urochloa mosambicensis*) and *Stylosanthes* spp. The leucaena and pasture grew well, helped by useful late rainfall in May 2017 and unseasonal rainfall in October of the same year (Table 1, Figure 2).

Figure 2. Redlands leucaena in Sabi grass pasture at Pinnarendi after 2017 wet season.

The Pinnarendi site was deliberately selected in an environment where psyllids were known to be prevalent so that any productivity difference between Redlands and Wondergraze caused by psyllid damage could be expressed. No attempt is being made to control psyllids. A monitoring program using 9 sentinel plants per paddock (9 × 8 = 72 plants total) was set-up to record the degree of leaf damage caused by psyllid infestations. A modified rating scale (Wheeler 1988) was used, where 0 is no psyllids present and 9 is blackened stems with total leaf loss. Assessments were made on 9 occasions in 2017 and 4 in 2018.

Grazing Trial

The Queensland Department of Agriculture and Fisheries (DAF) Animal Ethics Committee approved animal handling and experimental procedures (SA 2017/12/628). Consistent groups of cattle have been grazing on the trial site since late June 2018 comprising 16 Droughtmaster (stabilized *Bos indicus* × *Bos taurus*) steers and 12 Brahman cross (*Bos indicus* × *Bos taurus*) steers. There are 4 treatment groups with 7 animals/group blocked according to breed (4 × Droughtmaster and 3 × Brahman cross per group) and weight (to achieve relatively similar initial total group weights). The groups were assigned at random to either Redlands or Wondergraze treatments. Sampling of biomass to estimate dry matter yields was done in the inter-row pasture in late July 2018. Leucaena biomass was sampled in paddocks 1–4 on 16 August prior to cattle entry and again after cattle were removed on 28 September. Paddocks 5 and 6 were also sampled in mid-September before cattle entry. A weather station was installed to monitor rainfall, temperature, wind speed and solar radiation. Electronic monitoring systems track tank water levels, while cameras remotely monitor watering points and cattle, while they are in proximity of the watering points.

Results

Establishment and psyllid observations

Growth of leucaena during the 2017-2018 wet season was suboptimal, despite earlier fertilizer applications. Potentially, this was attributable to nitrogen deficiency, caused by poor root colonization with non-viable rhizobium inoculum (CB 3126) applied to seed before sowing. Overall, establishment of Redlands was worse than that of Wondergraze owing to differences in germination rates (30–45 vs. 80–90%, respectively). However, Redlands mostly compensated with increased growth so that final biomass was relatively uniform across all paddocks with the exception of Paddock 8, which has produced poorly.

Psyllids were active across the trial site from May to September 2017. Monitoring of incidence and damage showed that Wondergraze suffered significantly more damage than Redlands (Figure 3), but Wondergraze recovered quickly once psyllid pressure declined after September. Psyllid populations and damage were comparatively low during 2018 and are not reported. Inter-row pasture biomass (dry matter basis, DM; ± s.e.) was 6,020 ± 1,527 kg/ha across replicate paddocks at the site early in the dry season (late July 2018), comprising about 45% legume and 55% grass. Edible biomass (leaf and stem <5 mm diameter) of leucaena was only 65 ± 33 kg DM/ha in early July 2018 but had increased to 158 ± 51 kg DM/ha by late September in paddocks which had been spelled since late June. This was due to warming weather as there was no significant rain at the site since March 2018. Average daily liveweight gains (ADGs) have been determined for Redlands and Wondergraze treatments for the period of grazing from weighing events conducted in August and September 2018 (Table 2). These data are preliminary only and have not been analyzed for statistical significance. During this period, trial animals were also sporadically fed molasses (equating to about 2.5 MJ ME/hd/d) to accustom them to routine handling.

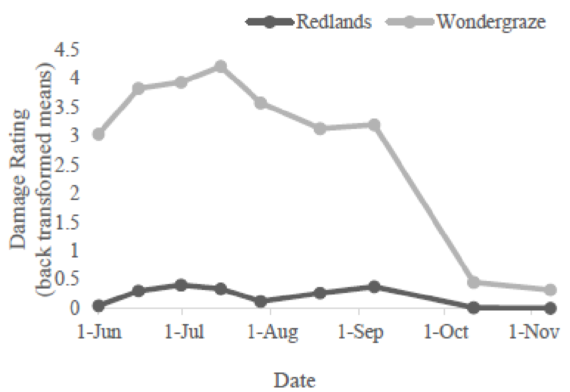

Figure 3. Psyllid incidence/damage in leucaena at Pinnarendi during 2017.

Table 2. Preliminary ADG data (± s.e.) for 28 steers grazing leucaena cvv. Redlands and Wondergraze at Pinnarendi Station, Mt Garnet district (28 June–20 September 2018).

	Average start weight (kg)	ADG (kg/hd/d)
28 Jun–7 Aug (40 days)		
Overall	231 ± 31	0.50 ± 0.21
Redlands	237 ± 35	0.47 ± 0.21
Wondergraze	225 ± 24	0.53 ± 0.20
7 Aug–20 Sep (44 days)		
Overall	248 ± 38	0.38 ± 0.18
Redlands	253 ± 43	0.32 ± 0.19
Wondergraze	244 ± 34	0.43 ± 0.15

Discussion and Conclusions

Preliminary results from the initial 3 months of grazing in the trial show cattle are gaining weight during the dry season with ADGs of about 0.4 kg. This is considerably higher than would be expected from native pastures at the same time of the year. While leucaena yield was low during the period and the grass-legume inter-row pasture will have contributed to this figure, leucaena was the only green feed available in the paddock and was high quality. Redlands was consumed readily by trial animals. To date, Wondergraze paddocks have produced slightly higher ADGs than those containing Redlands leucaena. However, the difference is not yet considered to be significant and the contribution of the inter-row pasture needs to be clarified. While psyllid resistance of Redlands was demonstrated during 2017, psyllid infestation during grazing in 2018 has been light and has not reduced growth of Wondergraze relative to Redlands. Performance of animals over the next 2–3 years is required to fully test the productivity of Redlands relative to Wondergraze grown within legume-grass pastures over a range of seasonal conditions.

Acknowledgments

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References

(Note of the editors: All hyperlinks were verified 2 May 2019.)

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Appendix 6. Leucaena establishment costs on red-brown earths in north Queensland

A6.1 Assumptions

- Redlands variety used due to psyllid risk on near coastal red-earth sites ($30/kg premium over Wondergraze variety)
- Sowing into cultivated strip approx. 5 m wide on 10 m centres (leucaena row spacing) with existing inter-row pasture retained
- Contract rates used for machinery (including labour) i.e. cultivating, spraying, fertiliser application, and sowing
- Three pre-sowing cultivations for seed-bed preparation and weed control
- Sowing rate of 2 kg/ha (1.5 kg/ha nominal plus contingency for partial re-sowing)
- Pre-sowing application of custom P-S fertiliser at 225 kg/ha over 3-4 m width centred along the leucaena plant row
- Pre-sowing application of glyphosate (Roundup CT®) to cultivated strip
- Application of pre-emergent herbicide (Spinnaker® 700) at sowing to cultivated strip
- Post-sowing application of selective herbicide (Verdict® 520) for grass control
- Two post-sowing cultivations for weed control
- No allowance for fencing or pest control

Table A6.1 Leucaena development costs on red-earth sites in northern Queensland – based on using Redlands variety at 10 m row spacing and retaining the inter-row pasture.

Item or treatment	*Rate of application*	*Cost / unit*	*Number of applications*	*Area treated (%)*	*Cost – across whole paddock (per/ha)*
Pre planting costs					
Cultivation	-	$45.00/ha	3	40	*$54.00*
Linkage spray rig	-	$8.35	1	50	*$4.18*
Roundup CT®	1.5 L/ha	$8.50/L	1	50	*$6.38*
Fertiliser blend (16.3% P, 20.2% S)	225 kg/ha	$0.91/kg	1	35	*$71.66*
Fertiliser spreader	-	$6.19/ha	1	35	*$2.17*
Planting costs					
Leucaena planter	-	$21.23	1	100	*$21.23*
Leucaena seed	2 kg/ha	$80.00/kg	1	100	*$160.00*
Leucaena inoculant	-	$0.24/ha	1	100	*$0.24*
Linkage spray rig	-	$8.35	2	50	*$8.35*
Spinnaker® 700	0.14 kg/ha	$107.50/kg	1	50	*$7.53*
Roundup CT®	1.5 L/ha	$8.50/L	1	50	*$6.38*
Linkage spray rig	-	$8.35	1	50	*$4.18*
Wetter	0.10 L/ha	$6.32/L	1	50	*$0.32*
Post Planting Costs					
Verdict® 520	0.30 kg/ha	$48.00	1	50	*$7.20*
Linkage spray rig	-	$8.35	1	50	*$4.18*
Cultivation	-	$20.00/ha	2	30	*$12.00*
Total					***$370***