

ILC2018 Keynote paper*

Establishment of leucaena in Australia

Establecimiento de leucaena en Australia

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Abstract

Leucaena (*Leucaena leucocephala* ssp. *glabrata*) is a highly productive tropical perennial legume used primarily in extensive beef grazing systems across northern Australia. Its productivity provides substantial benefits to grazing businesses and economically significant areas of leucaena have been established in Queensland, with much smaller areas in both the Northern Territory and Western Australia. Specific environmental conditions (particularly soil type) and management practices are required to obtain reliable establishment and high productivity from leucaena-grass grazing systems. Significant research, development and extension have been undertaken in northern Australia, particularly in central Queensland, resulting in management packages which ensure establishment reliability and long-term productivity. However expansion into new areas can be constrained by regionally-specific establishment issues. Adaptation of known establishment and management practices together with research and development are required for leucaena-grass grazing systems in new regions.

Keywords: Planting, seed, tree legumes, tropical pastures.

Resumen

Leucaena (*Leucaena leucocephala* ssp. *glabrata*) es una leguminosa perenne tropical altamente productiva que se utiliza principalmente en sistemas extensivos de pastoreo de ganado de carne en todo el norte de Australia. Su productividad proporciona beneficios económicos sustanciales para los productores, y se han establecido significativas áreas de leucaena económicamente significantes en el estado de Queensland y en menor medida en los estados Northern Territory y Western Australia. Se requieren condiciones específicas tanto ambientales (particularmente respecto al tipo de suelo) como de prácticas de manejo para obtener un establecimiento confiable y una alta productividad de los sistemas de pastoreo con leucaena asociada con gramíneas. Se han llevado a cabo importantes actividades de investigación, desarrollo y extensión en el norte de Australia, particularmente en el centro del estado de Queensland, las cuales han resultado en paquetes tecnológicos que garantizan el establecimiento confiable y productividad a largo plazo. Sin embargo, la expansión a nuevas áreas puede verse limitada por problemas de establecimiento específicos de cada región. Se requiere que las prácticas de establecimiento y manejo conocidas sean adaptadas y acompañadas por actividades de investigación y desarrollo para los sistemas de pastoreo de leucaena-gramíneas en esas nuevas regiones.

Palabras clave: Árboles leguminosos, pastos tropicales, semilla, siembra.

Introduction

Leucaena is a highly productive tropical perennial legume which has been sown on many extensive beef grazing properties across northern Australia. When successfully established in ‘rundown’ (declining productivity due to the

reduction of plant-available nutrients) grass-only sown pastures in tropical and subtropical environments, well-managed leucaena can improve both stocking rate and animal liveweight gain by up to 100% (Dalzell et al. 2006), providing significantly higher animal production per hectare per year (Bowen et al. 2018).

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

Despite these advantages only around 130,000 ha, i.e. about 0.5% of the potential area ([Buck et al. 2019](#)), has been sown across northern Australia. Early attempts at establishing leucaena often failed, typically due to graziers not following recommended cultural practices for reliable establishment ([Lesleighter and Shelton 1986](#)). In Australia, most cultivated leucaena is sown where suitable soils occur ([Beutel et al. 2018](#)), primarily under suboptimal climatic conditions of low and variable rainfall and cool winter temperatures, i.e. the subtropics ([Middleton et al. 1995](#)), that exacerbate the difficulties of establishment and management over time.

Significant research, development and extension have been conducted to overcome the establishment and management issues hampering adoption. This paper outlines the critical aspects for reliable establishment of leucaena across northern Australia.

Background of leucaena adoption and establishment in Australia

While a number of factors impeded the initial adoption of leucaena ([Buck et al. 2019](#)), unreliable establishment was a key reason ([Lesleighter and Shelton 1986](#); [Pratchett and Triglone 1989](#); [Middleton et al. 1995](#)). Slow early growth of seedlings is a biological characteristic of the leucaena plant ([Piggin et al. 1995](#)), which increases vulnerability to environmental setbacks ([Shelton and Jones 1995](#)). However, establishment failures are often due to: a poor understanding of climatic and soil requirements and agronomic traits; the use of inappropriate cultural practices; and limited supply of high-quality seed ([Lesleighter and Shelton 1986](#); [Piggin et al. 1995](#); [Shelton and Jones 1995](#); [Middleton et al. 1995](#); [Larsen et al. 1998](#)). While knowledge of suitable climate and soil characteristics for leucaena were quickly determined ([Gray 1968](#); [Cooksley et al. 1988](#)), the understanding of agronomic traits and implementation of best management practices took longer and was achieved only through the combined efforts of research workers, extension practitioners and graziers. Training courses were delivered in the early 2000s and a practical manual outlining effective establishment and management practices ([Dalzell et al. 2006](#)) was published in 2006 ([Shelton and Dalzell 2007](#)).

Site selection and layout for successful leucaena establishment in Australia

Climatic requirements

Leucaena is a tropical plant that grows best in warm-hot climates with mild winters and annual rainfall >600 mm. Temperature determines where leucaena should be

established and how it is managed over the grazing year. Seed germination is highly influenced by temperature and soil temperature at planting should be at least 18 °C ([Dalzell et al. 2006](#)). Leucaena growth also depends on temperature and typically slows or stops during the winter months, when annual average daily ambient temperatures fall below about 15 °C ([Cooksley 1986](#)). Under irrigation in Western Australia, leucaena growth was depressed during June and July (winter) with average minimum temperatures of 14 °C ([Middleton et al. 1995](#)). Frost can significantly limit growth with light frosts causing leaf drop, while stems usually survive. Heavy frosts can kill stems with subsequent regrowth occurring from the crown or larger surviving branches.

Leucaena is most productive in higher rainfall environments in the warmer subtropics and tropics, but psyllid infestations (*Heteropsylla cubana*) frequently, and sometimes severely, limit growth of susceptible cultivars (cvv. Peru, Cunningham, Tarramba and Wondergraze). The release of the highly psyllid-tolerant cultivar Redlands in 2017 should provide the opportunity for a further 1.2 million ha of previously unsuited coastal and northern Australian landscapes to be established to leucaena ([Shelton and Dalzell 2007](#)).

Soil requirements

Leucaena grows poorly in shallow and infertile soils, particularly those with chemical imbalances and soil structural issues ([Cooksley et al. 1988](#)) and should be sown into well-drained soils with high water holding capacity and fertility, i.e. arable soils. It has a high capacity to access soil water and nutrients from depth and can maintain growth during dry conditions when established in deep (>1 m) soils with high water holding capacity (loams - clays).

Leucaena does not grow well in acid soils and soil pH_{1.5} below 5.5 restricts performance. While acidity in the top soil can be addressed economically with lime application(s), subsoil acidity is common in northern Australia and is difficult and costly to correct. Adequate on-going supplies of phosphorus, sulphur, potassium, calcium and zinc are critical for leucaena growth. While all can be supplied from fertilizer if the soil is deficient, correcting major deficiencies will significantly increase production costs and may reduce profitability.

Soils should be free-draining. Soils prone to prolonged waterlogging are unsuitable for leucaena, although mature plants are more tolerant than seedlings. Clay soils with high magnesium and/or sodium concentrations have poor soil structure and cause production limitations, so should be avoided. High levels in the topsoil reduce

seedling establishment, while high levels in the subsoil impede drainage and root penetration. In addition, on clay soils with high salt (chloride) levels in the subsoil, growth is limited through a direct toxic impact and/or restricting root penetration plus water and nutrient uptake. The key is to undertake a comprehensive soil test of both topsoil and subsoil prior to sowing new stands as an aide to decision making on paddock suitability and fertilizer requirements.

While leucaena performs best on deep, well-drained fertile soils, these soils are often located on low-lying parts of the landscape close to water courses. Establishing leucaena in these situations can pose a high risk in the form of unwanted leucaena (weed) spread if not managed appropriately. The Leucaena Network, a not-for-profit organization promoting the sustainable adoption of leucaena, has developed a Code of Practice that outlines where leucaena should be established and managed to maximize production while minimizing the environmental risks (Christensen 2019). Amongst other things, the Code of Practice states that leucaena should not be sown in areas close to where rivers, creeks and flood channels can disperse seed pods and seed.

Layout of leucaena plantations (row systems) in Australia

Conventionally, leucaena is sown in rows with native or sown grass pastures in the inter-row spaces. Initially, single rows were sown but to minimize gaps from failed establishment, twin rows ~1m apart are now commonly used in central and southern Queensland, while single rows are typical in north Queensland. It has also been suggested that double-row plantings restrict leucaena height due to competition between the rows, which increases accessibility to forage by stock (Dalzell et al. 2006). Double-row sowing may improve establishment uniformity in northern environments where adequate seedbed preparation, lighter soils and access to modern planters can be significant issues.

One of the most hotly debated topics at the International Leucaena Conference 2018, Brisbane, was the optimal inter-row width, i.e. between pairs of twin rows. Early plantings were based on narrow inter-row width of 1.5–5 m (Jones et al. 1982) but later plantings are more commonly at wider spacing of 6–10 m (Dalzell et al. 2006). This trend reflects the desire of some producers to maintain an adequate grass component in the diet of grazing animals relative to available leucaena biomass. Grass is a critical component of the leucaena-grass grazing system and can provide around 50% of the diet over the grazing year (Bowen et al. 2018). Grass also gives other benefits including: a feed supply during the drier and colder winter period when leucaena is less

productive in tropical and subtropical regions; improved ground cover to increase water infiltration; reduced opportunities for weed colonization; an outlet for nitrogen fixed by leucaena to lift overall pasture productivity and encourage on-going fixation; and improved soil organic matter levels and carbon storage. Other reasons for widening inter-rows include lowering the seed cost per hectare, ease of mustering livestock and lower cultivation costs when sowing leucaena in fallowed strips. Some producers prefer wider inter-row spacing as it allows the operation of machinery between the rows to permit flexibility in terms of spraying inter-row weeds or trimming out-of-reach branches to improve forage utilization. Other producers require enough space for machinery to sow annual forage crops between the rows to improve overall forage production. On the other hand, since 100% leucaena is successfully fed to cattle in Southeast Asia (Dahlanuddin et al. 2014; 2019), some research workers and graziers argue that narrow inter-row spacing can be more productive. This topic warrants investigation.

The alignment of leucaena rows requires careful consideration. In general, rows should align with the direction of cattle movement for ease of mustering and, where possible, run across the slope to minimize erosion on sloping land. Aligning rows east-west to minimize shading of the inter-row grass pasture is being considered by graziers to maximize overall pasture production, although no research has been conducted into this aspect. The shading effect when rows are aligned north-south is less significant when wider inter-row spacings (>10 m) are used on soils of lower productivity. However when grown on productive soils at closer inter-row spacings (<8 m), the leucaena canopy can converge and substantially reduce grass growth, particularly when companion species are not shade-tolerant (Lemcke and Shotton 2018).

Best practice considerations for successful establishment in Australia

High rates of establishment failure have been linked to poor adherence to recommended seed preparation practices (Lesleighter and Shelton 1986) and poor weed control (Larsen et al. 1998). Graziers who do not follow recommended agronomic practices face significantly higher risks of establishment failure (Dalzell et al. 2006; Buck et al. 2012). A friable seedbed, high amount of stored soil moisture, effective pre- and post-sowing weed control, good quality seed, adequate planting rates, correct planting depth and good seed-soil contact are all critical for consistent leucaena germination and vigorous seedling growth. Seed should also be mechanically scarified and inoculated with the correct rhizobium.

Planting depth

Although *leucaena* has a relatively large seed (~22,000 seeds/kg), precision planting at depths ranging from 20 to 40 mm, depending on soil characteristics, is essential. Planting depths can be up to 40 mm in heavier, friable soils with good soil moisture but should be shallower in lighter soils. In more northern environments the risks associated with sowing into lighter soils include: greater evaporative potential leading to more rapid depletion of soil moisture; a propensity for soil surface sealing; and high probability of heavy rainfall after sowing washing soil onto the plant row (burying seedlings) and translocation of surface-applied pre-emergent herbicide, either reducing its effectiveness or making it toxic to the crop. Sowing at depths >25 mm in these soils, to access soil moisture at depth, generally leads to slow and poor emergence. The key to establishment success in these situations is timely and precise sowing (at depths of 20–25 mm) into good soil moisture with the reasonable assurance of imminent rainfall (within 5–7 days). In heavier soils, moist conditions for up to 7 days after sowing should ensure good germination and reliable emergence ([Dalzell et al. 2006](#)).

Ripping the plant row

Deep-ripping the soil where *leucaena* will be planted prior to sowing may improve water penetration and moisture storage during the fallow period, and promote a more vigorous root system after planting. One study recommends that decisions on ripping be based on the soil type to avoid unnecessary costs in undertaking this operation ([Buck 2013](#)). Ripping the soil along the plant row before sowing improved establishment (plant population) and growth (edible biomass) at 4 months after sowing on a non-cracking loam soil, whereas no benefits were measured on a cracking clay soil. Even though the benefits are short-lived on a responsive soil, techniques that improve the reliability of *leucaena* establishment are worth considering owing to the high cost of replanting. In north Queensland, basalt soils are suited to *leucaena* but typically contain many rocks. Deep ripping of these soils is required to develop a seedbed and allow the passage of heavy-duty planting machinery.

Planter technology

Leucaena is normally sown at 1–2 kg seed/ha depending on inter-row spacing (wider rows decrease seeding rate/ha), seed size (larger seed increases the seeding rate/ha) and seed viability (aim for >85% germination). Planters must

have press-wheels behind the soil-opener (tyne or disc), ideally configured as a pair pressing from both sides of the plant line (not over the top) to carefully pack moist soil around the seed to maximize seed-soil contact. Planters fitted with water injection equipment are considered to significantly improve the reliability of nodulation by directly placing rhizobium into the seed furrow. This technique is now commonly used by contractors and experienced *leucaena* growers and is particularly beneficial when planting during hot conditions.

Weed control

As *leucaena* seedlings are slow to develop, weed control during establishment is critical. Water extraction by weeds and grasses in close proximity (<2 m) to the planted row can significantly inhibit growth of establishing *leucaena* seedlings. It is necessary to control weeds in this zone for up to 6 months post sowing ([Dalzell et al. 2006](#); [Peck et al. 2017](#)). Traditionally weeds emerging after sowing have been controlled in part by inter-row (with tyned cultivators) and in-row (with Yetter™ wheels) cultivation. However, in recent years the availability of a residual herbicide, 700 g/kg Imazethapyr (trade names include Spinnaker, Impale, Amaze and Vezir), used under Australian Pesticides and Veterinary Medicines Authority (APVMA) permit no. PER82166, has revolutionized establishment success of *leucaena* through pre-emergent control of many broadleaf and grass species for up to 6 months. Larsen et al. ([1998](#)) suggested that consistently high establishment success rate (>90%) across the *leucaena* industry would be achievable only when effective and selective chemical weed control methods were available, and that time has now arrived.

Leucaena establishment in different regions of Australia

Central Queensland

The major region for *leucaena* production in Australia is the inland areas of central Queensland owing to the favorable climate, low psyllid incidence and availability of productive soils across large areas of cleared and readily-cultivated landscapes ([Buck et al. 2019](#)). One landholder in this area has 6,000 ha established to *leucaena* and sown grass pastures ([Harris and Harris 2019](#)). A history of cropping in the region has provided the combination of infrastructure, equipment and knowledge, which has enabled consistent and reliable establishment.

Based on advice to plant leucaena on high-quality soils, typically paddocks used for dryland crops or forages were initially sown. Following success in these situations, paddocks with a legacy of cultivation but having reverted to perennial grass-only pastures were also sown. In this situation leucaena provides significant production and economic benefits by increasing protein supply to grazing stock and adding soil nutrients to boost nitrogen-deficient grasses. Without legume inclusion, production from these grass-only pastures progressively declines over time as the supply of plant-available nitrogen also declines, commonly called pasture rundown (Peck et al. 2011). In these (existing) pasture situations, the following methods have been used successfully to establish leucaena: (i) Fully remove the existing pasture and fallow the whole paddock. This is the most appropriate method for pastures with severe rundown and/or pastures containing undesirable grass species, and provides the best opportunity for reliable and quick establishment. However fallow costs are significant, re-seeding of grasses is generally required and grazing must be withheld for a longer period of time. (ii) Prepare strips for sowing leucaena and retain the existing pasture in the inter-row spaces. This method is better suited to pastures that are still productive (i.e. low-moderate rundown) and contain desirable grass species. The strips need to be wide (~5 m) and either cultivated or sprayed to minimize competition for soil moisture between leucaena and inter-row grass pasture. With this technique, fallow costs are lower (around 50%), re-sowing of the grass is (generally) not required, and non-grazing periods are significantly reduced. Regardless of the method adopted, establishment success depends on: a fallow period of up to 12 months prior to sowing to store sufficient soil moisture to sustain the young plant (soil moisture profiles under pastures are typically very dry); a friable seedbed free of weeds; and the use of fertilizer to correct initial soil nutrient deficiencies and promote rapid establishment and initial growth.

Commonly, little or no fertilizer is applied to new or existing leucaena pastures (Radrizzani et al. 2010) and poor productivity from older leucaena-grass systems in paddocks previously used for grain or forage cropping is an emerging issue in central Queensland (Buck et al. 2019). It is likely that soil nutrient deficiency is a key cause of low biomass production and animal performance in many existing stands. This issue warrants investigation to identify and promote cost-effective fertilizer solutions.

Southern inland Queensland and New South Wales

Historically, inland southern Queensland from Wandoan to the New South Wales border was deemed too cold for acceptable leucaena growth (Lambert 2009). However

over the last 10–15 years increasing areas are being sown to leucaena due to declining production from grass-only pastures, and issues associated with annual cropping systems including soil fertility decline and unreliable rainfall conditions (Lambert 2009; Emery and Sneath 2015). Establishment techniques used in southern Queensland generally mirror those used in central Queensland. Leucaena is commonly sown into a fully-prepared paddock rather than prepared strips owing to the abundance of cultivated paddocks used for growing annual crops or forages and the lower costs compared with establishing into an existing grass paddock. Planting times are generally earlier (spring to early summer) than in central Queensland (mid-summer to early autumn) to maximize the size, therefore the robustness, of the plant before the onset of winter. Many paddocks sown to leucaena in southern Queensland are deficient in critical soil nutrients owing to the long history of cropping and so have a high fertilizer requirement.

Leucaena has not been adopted in northern New South Wales and is currently not recommended owing to its weed potential (Boschma et al. 2018). Given the large areas of cropping land and the presence of a farming culture, many approaches used to establish leucaena in central and southern Queensland should be applicable for New South Wales if/when leucaena is seen as a viable forage option in that State.

North Queensland

Of the estimated 1,500 ha of leucaena recently (since 2015) planted, only about 900 ha has established successfully, emphasizing some region-specific risks associated with sowing leucaena in more northern environments and the continued need to improve producer skills and refine establishment practices. The adoption of the new cultivar Redlands is being treated with caution until its commercial productivity in northern environments is confirmed in current grazing experiments. This follows previous research in north Queensland where Redlands was found to be less palatable to cattle than other commercial but psyllid-susceptible varieties (Mark Keating pers. com. 2018).

In north Queensland the larger areas of cleared soils for conventional leucaena establishment are confined to deep soils of the Atherton Tablelands and alluvial soils along the wet coast (coastal soils with >900 mm mean annual rainfall). Smaller areas of cleared basalt and alluvial soils in the seasonally dry tropics are also well suited to leucaena. The challenges associated with establishment of leucaena in the seasonally dry tropics of north Queensland include the difficulties associated with rocky basalt soils and generally more extreme conditions

for sowing and establishment than in southern areas. These include high evaporation rates, lighter soils with lower moisture holding capacity, higher temperatures and the greater intensity of rainfall during the wet season.

Recommended practices for planting and establishing leucaena in central Queensland are generally transferable to north Queensland situations for conventional leucaena establishment into cleared paddocks, but this is not the case for large areas of timbered country, which are otherwise suited to leucaena. Leucaena establishment in the northern rocky basalt province was pioneered during the 1990s by Greg Brown, a beef producer on Meadowbank Station, on timbered country that was cleared by stem-injection. Planting leucaena into this situation doubled beef productivity compared with that obtained from native grass-only pastures (Buck et al. 2019). There are 2.3 million hectares of such high-phosphorus basaltic woodlands in north Queensland (Isbell et al. 1976), representing a significant opportunity for leucaena development. However, while current vegetation management legislation now prevents the removal of trees from this landscape, leucaena can be successfully established in these woodland environments with appropriate cultural practices (Mark Keating pers. comm. 2018). Following deep ripping of strips between the existing trees during the dry season, leucaena has been sown successfully using a custom-built, heavy-duty planter (single row). Other problems associated with these rocky basalt soils are: cultivation for weed control is impractical except at planting time; weed control is virtually totally dependent on the availability and effectiveness of pre- and post-emergent herbicides; and ongoing fertilizer applications appear essential to overcome inherent sulphur deficiencies in these soils. Once leucaena is established on these timbered and rocky landscapes, ground-based applications of sulphur are impractical (except immediately after heavy pruning) so aerial application is the only practical method. While leucaena can be successfully established, the long-term productivity (and profitability) of leucaena in these lightly-timbered environments, where trees compete for nutrients, moisture and light, is unknown.

Light-textured soils in north Queensland also pose particular challenges for establishing leucaena. Sowing depth and moisture availability are critical with greater success observed when seed is placed at depths no greater than 25 mm with ample soil moisture. 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 seasonally dry tropics. Finally, full-paddock cultivation for leucaena establishment is generally avoided owing to the difficulty

of cultivation in rocky soils (where cleared), erosion risk on lighter soils and cost and difficulty in re-establishing inter-row pastures in northern environments.

Northern Territory and Western Australia

Very small areas of leucaena have been established in other areas of northern Australia and only the Northern Territory currently contains any area of significance (Buck et al. 2019). The Katherine and Douglas Daly regions in the Northern Territory, and the Ord irrigation area in the Kimberly region of Western Australia are reported to contain suitable soils for leucaena (Peter Shotton and Clinton Revell pers. comm. 2018). Establishment methods are similar to those used in Queensland and include: removal of the existing pasture/crop and fallowing during the wet season to conserve soil moisture; seedbed preparation and weed control by cultivation; post-planting weed control with residual herbicide; accurate seed placement with suitable planter; and withholding of grazing for up to 12 months until fully established.

Conclusions

Leucaena is a highly productive perennial tree legume but the area currently established in northern Australia is very small compared with the potential. Suitable methods for establishing this valuable browse species in fertile cleared areas have been developed. Key practices include a friable seedbed, stored soil moisture prior to sowing, effective weed control, soil fertility management, timely sowing with high-quality seed and withholding grazing until fully established. Ongoing studies will develop suitable techniques for expansion into timbered situations and less-fertile soils in northern Australia with greater confidence. However there are still significant aspects which require elucidation to take full advantage of what leucaena has to offer, e.g. optimal fertilizer requirements, long-term productivity in competition with trees, production of sterile varieties to combat weediness risks and optimal inter-row spacing for differing situations.

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(Note of the editors: All hyperlinks were verified 6 May 2019.)

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(Accepted 2 May 2019 by the ILC2018 Editorial Panel and the Journal editors; published 31 May 2019)

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