Using the Australian tropical forages collection to develop new pasture legumes for Australian rangelands

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Key words: genetic resources, regeneration, Queensland

Abstract

Beef cattle production is the key agricultural industry in the seasonally-dry and moderate rainfall zones of northern Australia. Uncleared natural woodlands are the key feed resource in the northern monsoonal zone, whereas sown pastures dominate the moderate rainfall zone further south. In additional to seasonal feed gaps, beef producers face emerging challenges from declining land condition, a warming and more variable climate and pasture dieback associated with mealy bugs. Sown deep-rooted legumes (*Desmanthus, Leucaena, Macroptilium, Stylosanthes*) can improve productivity on these pastures by improving nitrogen cycling and improving diet quality. The development of tropical pasture cultivars in Australia is underpinned by the Australian Tropical Forages Collection (ATFC), now held in the Australian Pastures Genebank supported by state and federal governments and primary industry research and development corporations. The ATFC comprises ~10100 warm season grasses and 7300 legumes sourced from other tropical countries and within Australia over 40+ years, including over 4000 legumes from genera with potential in permanent or semi-permanent pastures in the dry zone. Comprehensive plant evaluation and release activities by federal and state governments saw the development of a network of on-property plant evaluation sites and the release of useful legume cultivars for key beef production land-types. However, some environments have no well-adapted pasture legumes. The evaluation site network has recently been exploited to develop legumes for frost-prone areas on light-textured soils and clay soils in the monsoonal zone. A Queensland government regeneration and characterisation program has also prioritised the development of legumes for the seasonally dry and moderate rainfall zones to enable access to seeds and plant traits to breeders both in Australia and overseas.

Challenges faced by north Australian beef producers to manage their feedbase

The production of beef cattle is the dominant primary industry and land use in northern Australia. The total Australian cattle herd was 29.9 M head in June 2023, with over half in the 'North' (44.5% in Queensland and 6.4% in the Northern Territory) (Meat and Livestock Australia 2024). Most of the lower rainfall sub-coastal and inland zones comprise native grasslands within extensive savannah woodlands (*Bothriochloa, Dichanthium, Heteropogon*) and naturally treeless (*Astrebla*) plains (Tothill and Gillies, 1992). The northern range of this zone is characterised by a 7-9 month dry-season, and businesses mostly target feeder steer and live export markets. Key profit drivers in the northern dry zone are breeder productivity (weaning and death rates) and heavier sale weights (McLean et al., 2014). Cattle production further south in central and southern Queensland and extending into northern New South Wales is supported by a greater proportion of sown tropical grass (*Cenchrus, Chloris*) pastures

on previously cleared woodland. This is the principal area of beef production in northern Australia, where a more even rainfall distribution combined with many relatively fertile soils enables additional marketing options including backgrounding cattle for slaughter.

Limitations to cattle production on native and grass pastures relate to the amount and quality of feed produced over the year. In the northern monsoonal zone, the short summer growing period results in a few months of high quality feed before native grasses seed, senesce and become dormant. This presents the greatest challenge to graziers seeking to raise young cattle over the dry season and maintain reproductive females (Rolfe et al 2016). Management of the dry-season 'feed gap' is exacerbated by a significant decline in land condition on many soils within the seasonally dry zone (Shaw et al. 2024). This includes declines in useful perennial grasses and increases in herbaceous and woody weeds, resulting in decreased sustainable carrying capacities. The productivity of sown grass pastures is compromised by a decline in nitrogen cycling which limits grass growth. This limits both the productivity of the grazing business and the capacity to sequester carbon within the pasture system, an emerging consideration for beef producers. Peck et al. (2011) tested a range of methods to overcome this problem in southern and central Queensland and concluded the adoption of legumes as the best long-term economic solution. A recent challenge to graziers using sown grasses has been damage or death of plants due to 'pasture dieback', a condition associated with mealy bugs and which can significantly affect profitability at a beef business level (Buck et al. 2022). Legumes seem unaffected, so can potentially act as a temporary source of feed and competition for weeds while grass pastures recover. Finally, the omnipresent trend in increasing temperatures and recently measured increases in rainfall and temperature anomalies (CSIRO, 2024), all which can influence pasture growth in extensive grazing systems, presents a new and perhaps greatest challenge to beef graziers managing their feed-base.

Historical development of pasture legumes using the Australian Tropical Forages Collection (pre-2000s)

The use of legumes to lift the productivity of grass pastures through nitrogen fixation and improving the quality of the ruminant diet is well understood and has been applied for over 150 years throughout the world. The development of sown grass pastures in northern Australia was initiated by acclimatisation societies and individuals, including a small number of legumes (Clements and Henzell, 2010). However, it was not until federal and state programs from the 1960s, championed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), that development began *en masse*. Targeted plant collecting trips were conducted for promising taxa, with most legumes originating from south and central America. Seeds of up to 29,000 accessions were held by CSIRO in the Australian Tropical Forages Collection (ATFC) by the 1990s (Hacker et al, 1997). Refer to Smith *et al*. (2021) for a detailed description of the development of the ATFC.

Seed increase and plant evaluation programs were conducted by federal and state government agencies from the 1960s to the mid-1990s. Co-funded by the Beef Industry, the well-resourced and world-leading evaluation programs targeted a wide range of land-types with a particular focus on Queensland and the Northern Territory. Some involved assessment of a wide range of grasses and legumes across land types (Pengelley and Staples 1996), while others targeted legume development (Bishop and Hilder 2005; Clem and Jones 1996). Tropical pasture plant development was highly successful and supported by an effective pasture seed industry. By 1997 72 tropical grass and 65 tropical legume cultivars had been released in Australia, mostly in Queensland (Hacker et al., 1997), with approximately 220 t of legume seed (half stylos for light textured soils) being produced in Queensland (Walker and Weston 1990). There were still major gaps, however, particularly on clay soils where *Desmanthus* spp. and *Stylosanthes seabrana* cultivars had recently been developed (Walker et al. 1997).

Disinvestment in tropical sown pastures research from the 2000s saw the dismantling of research teams and reduction of the ATFC to priority taxa for development in Australia before transfer to the Queensland Government. The tropical forages database (www.tropicalforages.info) was developed to preserve 50 years of data and experience from international teams (Cook et al. 2020). A range of methods were used to progress promising

international legume cultivars, but only one species (S. guianensis) has some application to the seasonally dry tropics (Cox 2014). A review of seed viability and stocks found approximately 25% of the collection required regeneration (Lawrence 2002). A Queensland Government regeneration program in north Queensland regenerated 380 grass and 609 legume accessions over 3.5 years from 2005 (Cox et al 2009).

New legume development using the Australian Pastures Genebank

Uncertainty over the funding of genetic resources to support forage and pasture development resulted in the formation of the Australian Pastures Genebank (APG) in 2014, an amalgamation of 11 genebanks from across the country (Hughes et al 2017). The APG includes ~10100 warm season grasses and ~7350 legumes selected by an expert panel as having potential for development in Australia. The regeneration program resumed in 2014. Priority was placed on legumes for seasonally dry areas, multi-purpose legumes and high-quality grasses (Cox and Dayes 2019). The new program better accounted for genetic diversity within accessions and 170 grasses and 318 legumes were regenerated over 4 years. Traits useful for plant breeders were measured and the data transferred to a public access website for breeders to assess and request seeds for evaluation (https://pir.sa.gov.au/research/services/australian_pastures_genebank).

A specialist panel review and meta-analysis of 40 years of plant evaluation data (persistence and herbage yield) covering 950 species across 567 sites collected was used to identify priorities for future sown pastures development in northern Australia (Bell et al. 2015). The analyses identified large potential for legume adoption broadly to improve beef productivity and profitability across northern Australia. Priority areas for investment in new legumes for the dry zone included legumes for sandy soils in cooler (frost prone) areas of the subtropics and legumes for clay (grey and black) soils in northern areas. The ATFC contains a wide range of legume taxa with application to the dry zones of the tropics and sub-tropics (Table 1). The accessions represent a wide range of growing environments so have the potential to address current and emerging needs.

The operation of the APG continued in 2023 under a new funding arrangement facilitated by Meat and Livestock Australia. The regeneration and characterisation program resumed, with a focus on legume taxa for the dry zones of northern Australia (Table 1). The 2024 regeneration included 40 *Desmanthus* accessions identified (APG website) by James Cook University (JCU) researchers. Expanded plots were grown to supply seed for evaluation over the next few years (in addition to the 5000 seeds for the APG), principally on heavy clay soils in the seasonally dry zone. This complements recent activities (Queensland Government/Tropical Dairy) in north Queensland to assess 17 *Vigna parkeri* APG accessions (entire collection) for herbage and seed production performance to improve supply to beef and dairy farmers (Gorman 2021), plus progressing the development of *Macroptilium atropurpureum, M. gracile* and *Centrosema brasilianum* accessions (one of each) considered by researchers to have application for the seasonally dry tropics (Cox *pers. comm.* 2024).

Table 1. Number of APG accessions of key taxa with potential in the dry zones of the tropics and subtropics. Genera marked with * included in the 2024 Queensland Government regeneration program.

Taxon	Habit	Number	Key genera (in decreasing order of accessions in APG)
Alysicarpus	Herbaceous	311	*vaginalis*, rugossus*, monilifer*
Centrosema	Herbaceous	928	*molle*, pascuorum*, brasilianum*, schottii, pubescens**
Chamaecrista	Herbaceous	155	*rotundifolia*
Clitoria	Herbaceous	157	*ternatea**
Desmanthus	Shrub	490	*virgatus*, leptophyllus+, bicornutus*, pernambucanus*, pubescens**
Leucaena	Small tree	627	*leucocephala,* hybrid
Macroptilium	Herbaceous	691	*atropurpureum*, lathyroides*, bracteatum*, gracile**
Stylosanthes	Shrub	2050	*scabra*, hamata*, guianensis*, viscosa*, seabrana*

Developing new cultivars using old plant evaluation sites

The historical plant evaluation activities saw the establishment of a large network of sites over some 40+ years, particularly in Queensland. Records of many of these sites, the plants sown and plant performance data are held in the Queensland Government QPastures database. Although active work at these sites has been long completed and fences removed, the sites provide an opportunity to identify material originally sourced from the ATFC which has persisted under grazing over decades. Used in combination with data from the various final reports and scientific papers and senior researcher experience, this can be used to identify new legumes where there are perceived shortages. Critically, this addresses the need for long term assessment of pasture plants to identify those persistent under long-term climate cycles (droughts), changes in soil fertility and the capacity to coexist with pasture grasses. Two recent examples include:

Desmanthus* spp. *for heavy clay soils in the tropics

Desmanthus is a diverse genus of sub-shrubs and shrubs, many originating from dry areas on clay soils in central and southern America, and a large collection was introduced from the 1950s (Smith et al, 2021). Plant evaluation included six sites established in the 1980s across the semi-arid, cracking clay region of north and western Queensland. JCU researchers revisited the sites and collected seeds of the best survivors at sites in the Mitchell Grass Downs Bioregion (Gardiner et al 2016). Queensland Government seed increase and further plant evaluation was conducted on these, and other, accessions from other abandoned sites (Gardiner et al. 2017). Further development and selection resulted in the release of 'Progardes', a blend of *D. bicornutus, D. leptophyllus* and *D. virgatus* accessions with a range of growth habits and flowering times. Another five lines were selected and similarly commercialised, including high-biomass types better suited to higher rainfall areas. There are currently reliable supplies of commercial seed and adoption has steadily increased since release.

Stylosanthes for cold (frost-prone) areas within the sub-tropics and tropics

Pasture legumes are sought to address pasture productivity decline associated with nitrogen rundown but there are no reliable options for light-textured soils in the frost-prone sub-tropics (Peck et al. 2011). Observations by pasture researchers that legumes, mostly stylos, were persisting in old evaluation sites in frost-prone areas of southern Queensland resulted in a Queensland Government-Beef Industry program to collect, test and release new stylo varieties (Peck et al. 2022). Forty lines, mostly *Stylosanthes scabra* and *S. seabrana*, were collected and seed increase conducted in north Queensland before field testing over 3 years against current cultivars on two soil types in three frost-prone districts. The capacity to produce commercially viable amounts of seeds and susceptibility to diseases of historical significance (*Colletotrichum* spp.) was assessed at this time. Three *S. seabrana* and two *S. scabra* lines which out-yielded commercial legume varieties were identified for release and seed increase

undertaken to progress commercialisation. Although the stylo lines have immediate application to frost prone areas in the dry sub-tropics, stylo persistence is also poor on productive alluvial soils in the tropics where cold air is concentrated along waterways (Cox pers. comm. 2024), and the new stylos might therefore have broader application.

Conclusions

The legacy of fifty years of (mostly) government investment in sown pastures in northern Australia presents on-going opportunities to develop new pasture plants for the dryer zone of northern Australia. Decades-old plantings of thousands of accessions of pasture legumes across land types can yield useful cultivars but only while records are maintained and there are pasture researchers to exploit them. Similarly, the APG contains a wealth of useful germplasm collected from a wide range of environments for developing new pasture legumes to address current productivity gaps and respond to emerging needs such as climate adaptation. Current funding and regeneration and characterisation programs are focussed on ensuring these resources are accessible for plant breeding programs.

Acknowledgements

The authors wish to recognise the broader APG team of genetic resource specialists and the funding provided by the Australian and State Governments, Meat and Livestock Australia and other primary industries agencies.

References

Bishop HG, Hilder T (2005) Backup legumes for stylos. Final Report DAQ.083. Meat and Livestock Australia, Sydney

Buck S, Brazier N, Reid D (2022) Management solutions for pasture dieback: Outcomes of field research. Proceedings 20th Agronomy Australia Conference (Toowoomba, Aust.) www.agronomyaustraliaproceedings.org.

Clem RL, Jones RM (1996) Legumes for clay soils. Final Report DAQ.086. Meat and Livestock Australia, Sydney, Aust.

Cook BG, Pengelly BC, Schultze-Kraft R, Taylor M, Burkart S, Arango JAC, Guzman JJG, Cox K, Jones C, Peters M, (2020). Tropical Forages: an interactive selection tool www.tropicalforages.info (accessed 21/11/24).

Cox K (2014) Recent development of pasture plants in Queensland. Tropical Grasslands – Forrajes tropicales 2, 33-35.

Cox K, Dayes S, Bambling (2019) Rejuvenating the tropical forages genebank to develop new pasture cultivars. Proceedings North Australian Beef Research Update Conference (Brisbane, Aust.).

Cox K, Scrivener N, Kilpatrick F (2009) Reversing the declining quality of tropical forages collection. Tropical Grasslands 43, 259-262.

CSIRO (2024) State of the climate. www.csiro.au/en/research/envoronmental-impacts/climate-change/State-of-the-climate (accessed 21/11/24).

Gardiner CP (2016) Developing and commercializing new pasture legumes for clay soils in the semiarid rangelands of northern Australia In (Lazier JR and Ahmad N eds) Tropical Forage Legumes. CABI 2016.

Gardiner C, Ossiya, de Alburquerque RJ (2017) Discontinued legume trials yield potentially valuable genotypes. Proceedings 18th Australian Agronomy Conference (Ballarat, Aust). ASA2017 (agronomyaustraliaproceedings.org).

Gorman J (2021) AS11726 Appraisal of Vigna parkeri germplasm for seed production. Internal Report Department of Primary Industries and Fisheries, Brisbane, Aust.

Hacker JB, Date RB, Pengelley BC (1997) Conclusions from the workshop: Forage Genetic Resources: Meeting the requirements of industry. Tropical Grasslands 31: 370-375.

Hughes S, Smith R, Cox K, Humphries A, McClements D, Harris C, Rogers M (2017) 'The Australian Pastures Genebank: short history and update of progress, Proceedings 18th Australian Society of Agronomy Conference. (Ballarat, Aust.).

Lawrence PL (2002) Status of tropical forage germplasm collection. Internal Report Department of Primary Industries and Fisheries, Brisbane, Aust.

Meat and Livestock Australia (2024) Beef Industry Report https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/soti-report/mla-state-of-the-industry-report-2324-web.pdf (accessed 27/11/24).

Peck G, Buck S, Hofmann A, Holloway C, Johnson B, Lawrence D, Paton C (2011) Review of productivity decline in sown pastures. Final Report project B.NBP.0624. Meat and Livestock Australia, Sydney, Aust.

Peck G, Johnson B, Newman L, Cox K, Sila T, O'Reagain J, Kedzlie G, Taylor B, McLean A (2022) Experimental stylo accessions produce higher yields than commercial pasture legume varieties on light textured soils in southern Queensland. Proceedings 20th Agronomy Australia Conference (Toowoomba, Aust.)

Pengelley BC, Staples IB (1996) Development of new legumes and grasses for the cattle industry of northern Australia. Final Reports CS.054/185 and DAQ.053/081, Meat and Livestock Australia, Sydney, Aust.

Rolfe JW, Larard AE, English BH, Hegarty ES, McGrath TB, Gobius NR, De Faveri J, Shroj JR, Digby MJ, Musgrove RJ (2016) Rangeland profitability in the northern Gulf region of Queensland: understanding beef business complexity and the subsequent impact on land resource management and environmental outcomes. The Rangeland Journal 38, 261-272.

Shaw KA, Rolfe JW, Beutel TS, English BH, Gobius NR, Jones D (2024, in press). Decline in grazing land condition and productivity in the northern Gulf region of Queensland 1990 - 2016. The Rangeland Journal.

Smith RW, Harris CA, Cox K, McClements CD, Clark DSG, Hossain Z, Humphries AW (2021) A history of Australian pasture genetic resource collections. Crop and Pasture Science 72, 591-612.

Tothill JC, Gillies C (1992) The pasture lands of northern Australia. Occasional publication number 5 of the Tropical Grassland Society of Australia. Cranbrook Press, Toowoomba, Aust.

Walker B, Weston EJ (1990) Pasture development in Queensland – a success story. Tropical Grasslands 24, 257-268.

Walker B, Baker J, Becker M, Brunkhorst R, Heatley D, Simms J, Skerman DS, Walsh S (1997) Sown pasture priorities for the subtropical and tropical beef industry. Tropical Grasslands 31, 266-272.