Legume production paddocks to improve beef enterprise productivity and grassland management

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Abstract

Weaner or steer production of tropical cattle breeds for feeder or live export markets is the dominant primary industry in the seasonally-dry zone of northern Australia. Uncleared savannah woodlands and natural grasslands are key feed resources, with smaller cleared areas used for pasture development or cropping. Extended dry-seasons, soils of mostly low to moderate fertility and the maturation characteristics of native grasses limit animal growth and market options for producers. Land condition decline and the associated increase in early maturing introduced grasses (*Bothriochloa pertusa* and *Themeda quadrivalvis*) are emerging issues for beef producers. Recent research in north Queensland by the Queensland Government, with support from the Australian Government and Meat and Livestock Australia, has focussed on the development and promotion of 'production paddocks' using deep-rooted and productive legumes (*Clitoria, Desmanthus, Macroptilium, Stylosanthes*). These relatively intensively-managed paddocks target the nutrition of weaners and steers during the early to mid dry season to (1) enable earlier sale or higher sale weights of cattle, and (2) encourage sustainable grazing practices through spelling other areas on the property enabled by improved animal productivity. Small-plot studies of grass x legume combinations on commercial beef properties resulted in pasture yields 2-3 times those achieved on native pastures on fertile and infertile soils. Critically, the legume component contributed leaf with high feed value (15-20% crude protein and 8-10 MJ/kg metabolisable energy) when companion grasses had low feed value. The high quality of the dry season feed provided by legumes was confirmed using faecal sample testing.

Introduction

Beef cattle production is the principal land use in the monsoonal zone of northern Australia which includes the seasonally dry zone (600-900 mm AAR) in north Queensland north and west of Bowen. The area contains ~30% of the total Queensland herd which in turn approximates 45% of the 2024 national Australian herd of ~29.9 M head (Meat and Livestock Australia 2024). Weaners and steers of tropical cattle breeds for feeder (store) and live export markets are the key products in this zone. Key determinants of profit are breeder productivity (weaning and death rates) and sale weights (McLean et al., 2014). Native grass pastures in woodlands and natural treeless plains are the key feedbase for cattle in the seasonally dry zone, with the type of forage depending on geological soil development processes and rainfall (~600-900 mm average annual rainfall). Most (geologically older) soils are considered infertile, with low levels of plant available phosphorous and sulphur, but younger soils (basalt and alluvial) are considered more fertile and therefore productive overall.

The growth of native pastures is highly seasonal due to a brief (3-4 months) monsoonal summer growing period (December-March), followed by an extended dry season. For cattle producers, this results in deficits in feed volume and quality (digestible energy and protein) when they need to feed weaners and steers or maintain cow condition for reconception and during pregnancy. Management of the dry-season ‘feed gap’ in a variable climate and where pasture yields are inherently low is the greatest challenge to beef producers, requiring careful management to not damage native pastures (Rolfe et al 2016). Long-term declines in land condition, including declines in useful perennial grasses and increases in herbaceous and woody weeds presents an additional challenge and ultimately decreases the number of cattle which can be sustainably grazed on a property (Shaw et al. 2024).

A historical strategy to increase pasture productivity was to either sow introduced grasses considered to have desirable production characteristics (e.g. *Cenchrus ciliaris, Urochloa mosambicensis*) in small areas on better soils with or without legumes, or to integrate introduced hardy legumes (*Chamaecrista rotundifolia, Stylosanthes* spp.,) into native pastures by broadcasting during the wet season (Walker and Weston, 1990). In the 1990s, the potential to increase stocking rates and improve weaner and steer growth and potentially target new markets by incorporating *Stylosanthes* spp. and increasing legume growth by applying fertiliser phosphorous and sulphur was demonstrated on low fertility soils (Anon 1994a; 1994b). Development of this ‘production paddock’ concept stalled during the 1990s and 2000s due to disinvestment in sown pastures research and extension, but in 2014 the Queensland Government, collaborating with the Australian Beef Industry, began to assess new and historical grass and legume cultivars under management suitable for production paddocks. The results reported below relate to the second phase of the research, after which suitable grasses and legumes had been identified from single-taxa replicated plot experiments on a range of land-types (Cox et al. 2019). The specific objectives were to assess how combinations of promising grasses and legumes, exhibiting a range of growth habits, perform under grazing on soils of high or low fertility and gain insight into the potential for improving animal performance.

Methods

Two experiment sites were developed representing fertile (red basalt soil) and infertile (red earth soil) landtypes (Table 1). A complete factorial design of one grass and one legume in each plot was used: legumes were randomly allocated within grass strips laid out in a replicated (x3) complete block and seed sown into sites prepared by combinations of cultivation and herbicide to control previously established and emerging weeds. Fertiliser was applied prior to the final cultivation and sowing completed by broadcasting seeds onto a rolled seedbed and rolling again after broadcasting. Sowing rates were based on recommendations (www.tropicalforages.info) for each species and adjusted based on seed tests (top of paper, 35/20°C:16/8 hr).

The plots were not grazed in the first dry season (to allow complete establishment) and wet season spelled thereafter. Biomass accumulated over the growing season was measured before dry-season grazing (target residual of 1000 kg DM/ha). Herbage yield was estimated at the end of the growing period over 3 (red earth) or 4 (red basalt) years by cutting a minimum of two 0.5 m^2 quadrats per plot (360+/site), separating species while fresh, drying at 65°C until constant weight and separating legumes into leaf and stem components before weighing. Sub-samples were ground and submitted to an accredited laboratory (Dairy One™) for feed value analysis (presented) using wet chemistry. Once the legumes had spread from the plots into the surrounding native pastures, fresh faecal samples were collected from at least six grazing weaner heifers. The samples were submitted to an accredited laboratory to estimate feed value (eaten) using NIRS (Dixon and Coates 2010).

Table 1. Characteristics and management of sites used to test production paddocks in north Queensland.

Site feature/management	Fertile site	Infertile site
Location (°S/°E)	Mt Surprise (18.14/144.64)	Charters Towers (19.49/145.69)
Mean annual rainfall (median)[1]	791 (806)	556 (509)
Soil type	red basalt	red earth
pH_{water}; $P_{Colwell}$; PBI; S_{MCP}	6.6; 240; 220; 5	6.2; <5; 19; 7
Dominant vegetation (few)[2]	BP, HC (SH, SS) (uncleared)	BP, HC, SH, SS, UM (cleared)
Fenced site dimensions	6 ha	4 ha
Grass and legume treatments	7 grasses (1 failed) x 8 legumes	7 grasses x 9 legumes
Plot sizes; replicates (plots)	63 m^2; 3 reps (192 plots)	152 m^2; 3 reps (189 plots)
Site preparation methods	No fallow period; cultivation x 2; glyphosate x1; roll	One year fallow; cultivation x 2; glyphosate, roll
Pre-plant fertiliser (kg/ha)	120 ammonium sulphate	120 single superphosphate
Sowing date	27 Feb. 2019	5 Feb. 2020
Sowing methods	Broadcast and roll	Broadcast and roll
Sowing rates (kg/ha) and target viability	Grasses: (3): *Panicum/Urochloa* 80%, *Digitaria* 70%, *Bothriochloa* 50% Legumes: *Clitoria* (8, 80%), *Macroptilium (*6, 80%), *Desmanthus/Stylosanthes* (3, 60%)	
Rainfall after sowing (mm)	28 first 4 weeks + 20 (6 months)	201 first 4 weeks+173 (6 months)

1 Bureau of Meteorology (BoM) records: Mt Surprise (BoM station 30036) 1873-2022; Charters Towers (30137) 1993-2018

2 BP = Bothriochloa pertusa, CR = Chamaecrista rotundifolia, CC = Cenchrus ciliaris, HC = Heteropogon contortus, SH = Stylosanthes hamata, SS = Stylosanthes scabra, UM = Urochloa mosambicensis.

Results

Plant establishment was successful for all grasses and legumes except for one grass (*Urochloa* hybrid) at the red basalt site (poor quality of available seed). Grasses dominated at the red earth site under higher than usual rainfall, whereas exceptionally dry conditions in first dry season suppressed grasses at the red basalt site (data not presented). Plant growth was rapid at both sites thereafter and the sites were considered to be suitable for full grazing by April in the year after sowing. Once established, rainfall was at, or above, long-term means.

Herbage yields averaged across the grass treatments and for a well-adapted competitive grass (*Bothriochloa insculpta*) are presented for 2021 and 2023 growing seasons along with legume percentage leaf and key feed value indices for samples collected in 2021 (Table 2). Yields increased from 2021 to 2023 at both sites and were higher overall on the red basalt site. The highest yields on both land-types were achieved in the plots containing *Stylosanthes seabrana*, with *Clitoria ternatea, Macroptilium atropurpureum* and *Stylosanthes scabra* also performing well on the red basalt site, and *S. scabra* on the red earth. In general, plots with higher legume yields tended to have higher overall pasture yield.

Table 2. Total pasture and legume herbage yields, legume leaf content and feed quality from small-plot testing of grass x legume combinations. Means with different letters were considered different (95% level).

Year	Measure	Grass / Season	Part	*Clitoria ternatea* Milgarra	*Desmanthus spp.* Progardes	*Macroptilium atropurpureum* TGS84989	*Macroptilium gracile* TGS849	*Stylosanthes hamata* Amiga	*Stylosanthes guianensis* ATF3308	*Stylosanthes scabra* Seca	*Stylosanthes seabrana* Unica
Fertile soil (red basalt)											
2021	Total pasture yield (t DM/ha)	Across all grasses[1]		6.89 de	4.47 abc	5.75 cd	5.94 d	4.03 a	4.17 ab	5.56 bcd	7.94 e
		B. insculpta		5.40 a	4.53 a	5.55 a	4.76 a	6.07 ab	5.11 a	6.46 ab	9.79 b
	Legume yield (t DM/ha)	Across all grasses[1]		2.28 b	0.75 a	0.65 a	0.01 a	0.23 a	0.01 a	2.66 b	5.76 c
		B. insculpta		0.96 a	0.00 a	0.41 a	0.41 a	0.23 a	0.15 a	0.94 a	5.33 b
	Percentage legume leaf (%)			43.5 a	36.7 ab	61.1 c	37.6 ab	66.2 c	33.6 a	44.6 b	31.3 a
2023	Total pasture yield (t DM/ha)	Across all grasses[1]		9.91 b	4.92 d	8.46 bc	4.83 d	5.29 d	5.38 d	7.48 c	14.07 a
		B. insculpta		12.75	4.61	7.67	4.96	7.45	6.37	9.38	14.58
	Legume yield (t DM/ha)	Across all grasses[1]		3.01 b	0.19 e	1.21 c	0.06 f	0.39 d	0.04 f	2.13 b	7.79 a
		B. insculpta		2.78	0.21	1.25	0.02	0.41	0.15	2.66	5.38
Infertile soil (red earth)											
2021	Total pasture yield (t DM/ha)	Across all grasses[1]		3.18	3.21	3.40	3.34	3.17		3.43	3.98
		B. insculpta		2.17	2.14	3.00	2.85	2.17		3.02	3.87
	Legume yield (t DM/ha)	Across all grasses[1]		0.02 ab	0.01 a	0.08 b	0.01 a	0.18 c		0.35 d	0.63 e
		B. insculpta		0.03	0	0.01	0.04	0.17		1.01	1.28
	Percentage legume leaf (%)			42.6 b	38 b	60.4 c	54.3 c	40.7 b		39.9 b	26.1 a
2023	Total pasture yield (t DM/ha)	Across all grasses[1]		4.62 bcd	4.48 cd	5.16 bc	4.45 cd	5.08 bcd		5.20 ab	5.89 a
		B. insculpta		4.82	3.81	3.14	3.97	3.16		4.53	7.14
	Legume yield (t DM/ha)	Across all grasses[1]		0.43 d	0.04 e	0.91 c	0.10 e	1.31 b		2.32 a	2.60 a
		B. insculpta		0.7	0.19	0.47	0.05	0.62		1.93	3.47
Feed quality indices (pooled across sites)[2]											
2021	Crude protein (%)	wet season	Leaf	18.6	14.1	17.3	19.71*	16.9	10.2*	16.0	16.5
			Stem	12.4	7.10	12.6		11.8		8.00	7.80
		dry season	Leaf	20.3	16.5	15.7	14.7	17.4	6.49*	13.9	15.7
			Stem	10.1	6.00	9.30	8.00	9.70		6.50	6.20
	Metabolisable energy (MJ/kg DM)	wet season	Leaf	8.92	10.4	8.15	9.37*	8.83	13.8	9.20	8.68
			Stem	5.38	5.87	5.34		6.81	6.80	4.99	4.87
		dry season	Leaf	9.04	9.76	8.51	8.94	9.30	8.00	8.53	8.51
			Stem	5.67	5.57	6.59	7.93	7.07	5.23	5.21	5.10

[1] grasses tested at both sites: *Bothriochloa insculpta* 'CPI125652B, *Digitaria milanjiana* 'Jarra', *Panicum* hybrid 'Massai', *P. coloratum* 'ATF714', *P. maximum* 'Gatton', *Urochloa brizantha* 'Mekong' *U. mosambicensis* 'Manzini'.

[2] feed quality indices marked with a '*' represent a whole plant sample.

The legumes varied considerably in the proportion of leaf and stem and key feed value indices. The shrub legumes (*Desmanthus, Stylosanthes*) tended to have lower (~30-40%) leaf content than the twining legumes (*Clitoria, Macroptilium*) (50-60%) when sampled at the end of the growing season (at both sites). Crude protein (15-20%) and metabolisable energy (8-10 MJ/kg) contents were substantially higher in leaf than stem in the wet and dry seasons with values of both tending to decline over the growing season. Dry season values for legume stem were similar to the higher values of companion grasses (3-6% crude protein and 5-7% MJ/kg)(data not presented). Faecal NIRS testing of fresh dung from animals introduced into the red basalt site in September 2024 had higher crude protein (7.3%) and metabolisable energy (7.7 MJ/kg) than for cattle grazing in a similarly spelled adjacent native grass paddock (4.3% and 7.1 MJ/kg), presumably due to grazing *S. seabrana* and *C. ternatea* which have spread from plots.

Discussion

The small plot experiments indicate good potential for grass-legume 'production paddocks' to increase cattle productivity (stocking rate and growth rates) through improving the diet particularly in the dry season on fertile and infertile land types. The herbage yields achieved were in the order of 2-3 X those of undeveloped native pastures in good land condition (Queensland Government, 2024a; 2024b) and were sustained 3-4 years after sowing without the application of additional fertiliser (although additional application of S or S and P fertiliser is expected to maintain productivity in the longer term). Nitrogen fixation by the legumes would also likely contribute to improved forage yields through increased nitrogen cycling but this was not measured directly. Queensland Government analyses based on the findings of the experiments found gross margins per hectare after interest were 4-7 times those on native pastures when cattle prices and costs were averaged over 5 years, being higher on the fertile red basalt site due to higher herbage production and less fertiliser costs (Finlay and Cox 2022). These support the findings of Bowen et al (2019) whereupon the introduction and fertilising of stylos were found to be the most profitable interventions for beef producers in the northern Gulf region. An additional benefit of the competitive grass/legume systems was the suppression of *Bothriochloa pertusa* and *Chamaecrista rotundifolia* at the fertile and unfertile sites, respectively, providing a means to lift or restore productivity where these relatively unproductive species have become dominant (Cox et al., 2023a; 2023b). The adoption of production paddocks should enable cattle producers to spell pastures elsewhere on the property enabling grass recovery and more sustainable long-term management of native grasslands. It is recommended studies and demonstrations be completed at paddock-scale to refine methods for the establishment and management of production paddocks and confirm the economic benefits to assist decision making by graziers.

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