LEGUME MANAGEMENT IN TOP END FARMING AND GRAZING SYSTEMS

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INTRODUCTION

Legumes are an integral component of sustainable farming and grazing systems. In the Top End, mixed legume-grass pastures increase pasture quality, cattle productivity and enhance soil health and nutrition compared to grass-only pastures. However, establishment of legumes into existing grass pastures is not widely practiced or understood in the Top End of the Northern Territory (NT).

To address this issue, a National Landcare Program, Smart Farms Small Grants (SFSG) project was initiated by Territory Natural Resource Management (TNRM) and Northern Tropical Agriculture (NTAg) to evaluate the establishment of legumes into grass pastures using "no-till" technology. The project ran from the 2021 wet season to the end of 2022.

The stated objective was: "Evaluation of legumes sown no-till into standing pastures to improve pasture quality, soil health and cattle production for sustainable conservation practices in the Top End."

The wider objectives were to expose more farmers and cattle producers to the benefits of legumes and no-till pasture establishment, enable producers to do their own on-farm trials, and facilitate the wider adoption of this technology in the Top End.

This report covers key concepts of legumes in agriculture, their establishment, productive and environmental benefits, and challenges in managing legume-grass pastures in the Top End.

The report also summarises the findings from the SFSG project, past research and development (R&D), farmer experience, and novel concepts and recommendations related to legume management in sustainable farming and grazing systems in the Top End of the NT.

CHAPTER 1
THE NITROGEN CYCLE, LEGUMES AND AGRICULTURE

Introduction

The benefit of legumes is their unique relationship with soil microbiology and *Rhizobium* bacteria which enables nitrogen (N) to be taken directly from the atmosphere and "fixed" or taken by legumes.

Nitrogen is the most abundant gas in the atmosphere at 72% of the total air composition. However, it cannot be directly used by most plants without the N "fixation" process facilitated by *Rhizobium* species growing in the root nodules of legume plants. This atmospheric N is "fixed" and then converted into an organic form of N that can then be used by the legume in its growth and productivity.

Without this amazing "symbiotic" (mutually beneficial) relationship between bacteria and legumes, there would little nitrogen "fixed" or accumulated in farming and grazing systems.

This relationship underpins the importance of soil microbiology to the health, resilience and productivity of agricultural systems. The entire N cycle is driven by the interaction between **atmosphere** – **plant** – **soil** - **microbes** with each component critical to the process of N fixation, storage and supply.

Nitrogen is essential to all life forms and is the building block for amino acids, proteins, enzymes and chlorophyll, and is essential for healthy plant growth and production. Legumes contribute N by providing organic matter, which decomposes over time to release N for plant use (Figure 1).

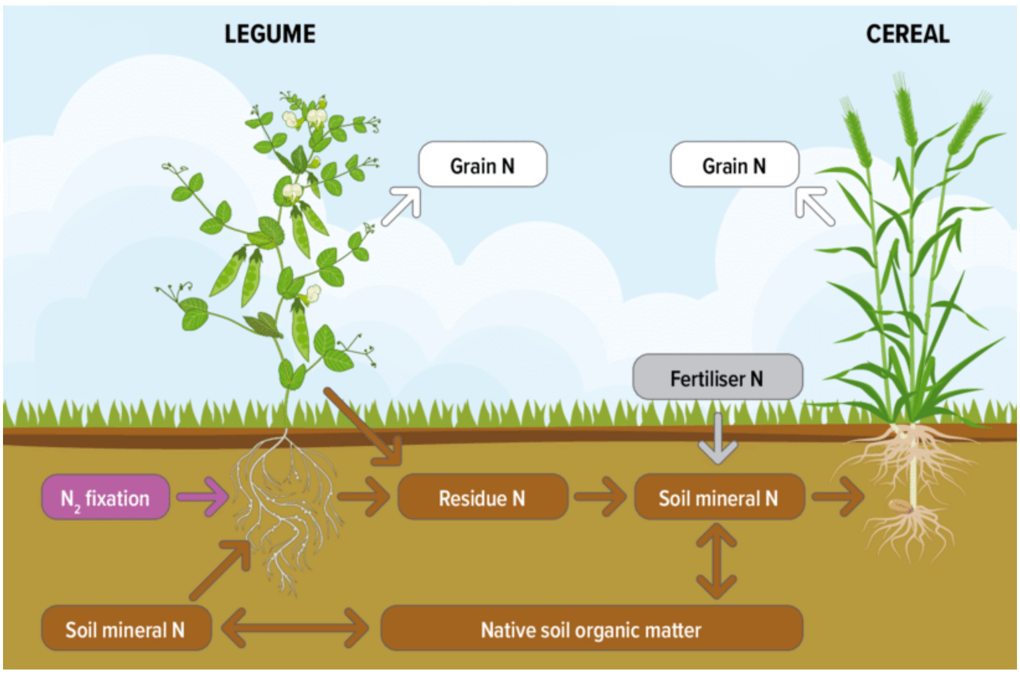

Figure 1. The cycling of nitrogen in a legume – cereal rotation (Source: Farquharson et al. 2020)

Pasture legumes improve soil fertility, increase livestock productivity, reduce feed and fertiliser costs and enhance pasture and soil biodiversity. They provide the N that companion grasses require to maintain quality and productivity. Legumes are rich in protein, minerals, and vitamins which improve animal health, weight gain and fertility. Legumes also reduce reliance on synthetic N fertiliser and help mitigate greenhouse gas emissions (GHG) caused by N fertiliser application.

It is estimated that legumes fix approximately 3.5 million tonnes of N annually, with a value of about $3.5 billion to Australian agriculture (Farquharson *et.al*., 2022). Globally the N contribution from legumes is estimated at $63 billion. Legumes can fix between 20 and 110 kilograms of N per hectare annually depending on legume species, plant density, health, growing conditions and many other factors.

Legumes and Organic Matter

This nitrogen-rich organic matter adds to the soil as the plant dies, which soil microorganisms then decompose through the process of mineralisation. This converts organic nitrogen into inorganic forms (ammonium (NH_4^+) and nitrate (NO_3^-)) which are then available for uptake by other plants, including grasses and other non- legume species. The microorganisms themselves also use the nitrogen to build their body tissues.

Soil Health

Legumes improve soil health, which in turn enhances soil carbon accumulation. They release root exudates, rich in sugars and amino acids, which bind soil particles into stable aggregates enhancing soil structure and reducing the potential for erosion and degradation. These energy rich exudates also stimulate beneficial bacteria and fungi, which in turn release nutrients that are utilised by other plants.

Additionally, legumes enhance above and below ground ecosystem diversity by attracting pollinators, providing habitat for beneficial insects, and enhancing soil microbial abundance and diversity. The extensive root systems of tropical legumes improve water infiltration, moisture retention and water use efficiency. This provides greater resilience to extremes of climate and greater drought tolerance of pastures.

This is especially important in the Top End where rainfall variability over the wet season and heavy tropical storms are a feature of the environment, and intermittent dry periods and erosion are constant threats.

Legumes and Emissions Reduction

Methane is a by-product of livestock digestion (enteric fermentation) and is a potent greenhouse gas with 28 times the global warming potential of carbon dioxide. In Australia, about 13% of all national emissions and two thirds of agricultural emissions come from methane produced by livestock. For the NT, agriculture accounted for 20% of emissions, of which 80% was attributed to livestock methane production (NT Government, 2020).

Meat and Livestock Australia (Meat & Livestock Australia, 2023) have embarked on an ambitious plan to have the red meat industry carbon neutral by 2030 (CN30).

Legumes contribute to this target by:

- Improving forage quality and feed efficiency
- Improving rumen health and function to reduce methane production
- Increasing productivity and more rapid turn-off of stock
- Improving the resilience and adaptation to severe weather, pests and disease
- Reducing reliance on synthetic nitrogenous fertilisers, reducing GHG emissions.

CHAPTER 2
LEGUME RESEARCH IN THE TOP END

Introduction

The Top End is characterised by intense and high rainfall variability (Figure 2) which is a key constraint in dryland agriculture (Mollah, 1986). Improving the efficiency and stability of farming and grazing systems has long been identified as a key priority for the northern agricultural industry. Incorporation of legumes is a potential strategy to reduce the constraints of climate, soil and fertiliser costs in the Top End (Dimes *et al*, 1996). A range of research trials have evaluated the importance of legumes as a component in crop and pasture rotations (Shotton, 2011).

Figure 2. Intense wet season rain and intermittent dry periods can be a challenge to crop and pasture establishment in the Top End.

Integrating Crops and Pastures

Agricultural research and development (R&D) in the 1980s specifically focused on grain crop production in the Katherine and the Douglas Daly regions, including the development of crop establishment practices adapted to northern conditions (e.g. Gould, *et.al*, 1996). Cattle production in northern Australia was traditionally based on extensive grazing on native pastures, and availability and adoption of improved legume species was generally limited to *Stylosanthes* species in native grassland (Miller and Stockwell, 1991). However, the development of the live export cattle trade in the late 1980s and 1990s changed the focus of R&D to a "farming systems" approach, and associated intensification of cattle production. This entailed looking at the interaction and components of a mixed farming system incorporating rotations of grain crops, legume and mixed legume-grass pastures, hay crops and cattle grazing practices.

Research Findings at Katherine and Douglas Daly

Research at Katherine Research Station (KRS) from 1982 to 1985 assessed performance of cattle grazing native pastures in the wet season, legume pastures and crop residues in the dry season. Results showed that incorporating Verano stylo (*Stylosanthes hamata)*, buffalo cover (*Alysicarpus vaginalis*) and Cavalcade (*Centrosema pascuorum)* increased cattle weight gains from 93 kg/head/yr on native grass to 123kg/head/yr with legume-based pastures (Winter *et al.*, 1996).

A long running *Pasture Species Evaluation* trial at Douglas Daly Research Farm (DDRF) showed that legume-grass pastures consistently provided the highest animal productivity on a per/head and per/hectare basis over the long term. Pangola, Jarra and buffel grass pastures with various combinations of Leucaena, butterfly pea, Oolloo Centro and Cavalcade, provided average weight gains of between 280 to 400 kg/ha/year depending on management, proportion of legume and stocking densities (Table 1).

Legume-grass combinations were better than grass-only pastures supplied N fertiliser, with lower annual costs of production. The highest productivity was achieved from Leucaena with various grass species. Butterfly pea/buffel grass and Arnhem finger grass/Oolloo Centro combinations were also highly productive achieving around 0.7 kg/head/day liveweight (LW) gain over a 182-day wet season period. Legume-grass pastures provided LW gains of around 0.4 kg/head/day up to about June and thereafter maintained LW condition.

Dixon *et.al*. (2000), compared the LW gain and diet of steers on a buffel/Oolloo Centro pasture at DDRF. Interestingly, legumes were not a major component of the cattle's diet over the wet season but contributed substantially to the diet in the transition period from the wet to the dry season and over the main dry season. Annual LW gain ranged from 159 to 209 kg/head/annum.

Table 1. Selected results from the long-term Pasture Species Evaluation Trial at DDRF (adapted from NTG, 1999).

Pasture	Grass (kg)	Legume (kg)	Weed (kg)	Liveweight gain (kg/head)#
Pangola / Leucaena	3902	115*	12	185
Sabi / Verano	2419	426	74	121
Jarra (N fertiliser applied)	3696	46	202	161
Buffel / Butterfly pea	4544	40	0	159
Arnhem / Oolloo	1624	2112	474	191

Plant biomass at May 1998 at time of introduction of weaners.
 # Stocked at 1 head/ha over 12 months.
** not including leucaena shrub biomass.*

The combination of which grass and which legume species to establish on-farm will depend on a range of factors including rainfall, soil type, seed availability, farmer preference and management considerations such as ability to rotate or rest paddocks, and commitment to weed control. Maintaining a long-term legume-grass balance is a challenge in a mixed pasture grazing system and is one of several management issues that has contributed to its minimal adoption across the northern agriculture industry.

While most pasture legumes are highly palatable and often preferentially selected by stock, there are exceptions. Wynn cassia (*Chamaecrista rotundifolia* cv. Wynn) for example, is arguably the least palatable of the sown legume species and can dominate a pasture completely, forming a dense monoculture. At higher stocking densities, cattle will preferentially graze the more palatable grasses and completely ignore the Wynn (O'Gara, 2005). Although Wynn cassia can make a valuable contribution to mixed pastures throughout the Top End, it's a case where **legumes are not all created equal** and knowledge and experience is essential in evaluating what should be sown and how should it be managed.

Another tangible but un-quantified benefit of legumes is a reduction in supplement (lick) consumption by cattle when grazing legume-grass pastures. Many producers report a noticeable drop in mineral lick consumption when stock have access to good quality legume-grass pasture and at times go completely off the supplement lick for a few weeks when introduced to a fresh, multi-species paddock.

Legumes also make a valuable contribution to the organic matter and carbon content of the soil through the deposition of leaf litter which ultimately decomposes to contribute to the nitrogen pool in the soil. The organic matter contributed to the soil can range from 1.6 to 3.0% N which represents 16 to 30 kg of organic N per tonne being added to the soil. Over a three-year pasture evaluation at Douglas Daly in the mid to late 1990s, butterfly pea consistently produced the highest protein and phosphorus levels with greater than 18% protein and 0.3 to 0.4 % phosphorus in the tissue (Bithell, et.al, 2013).

The research indicated that an appropriate grass-legume balance was necessary to sustain good LW gains from mixed pastures. Grazing pure or near-pure legume swards resulted in relatively low daily LW gain due to an imbalance in fibre, energy and protein levels, and low biomass persistence in transition periods between the dry season and the wet season. Pure legume swards of species such as Cavalcade, have found a more effective niche in farming systems as a high-quality hay, commonly used as a component in producing feed pellet or cubes destined for live export.

Grass-legume pasture generally provides higher levels of productivity and quality than straight grass pastures at significantly lower costs of production. Grass pastures require regular inputs of N fertiliser to produce a higher protein percentage to maintain viable levels of animal liveweight gain and fodder quality.

Observations from 20 Years of Pasture Species Evaluation Project at DDRF

Peter Shotton, Senior Professional Officer and leader of the Pasture Species Evaluation at DDRF, made the following comments after 20 years of data collection and observation:

Leucaena-grass is undoubtedly the most productive legume system but careful and intensive management is required from establishment to capitalise on its productive potential.

Leucaena does not provide N to companion grasses in the interrow space which needs to be considered in the overall management of the system.

Oolloo, butterfly pea and Cavalcade are all highly productive, highly palatable companion legumes but require careful management (strategic spelling etc.) for persistence and to ensure they realise their true potential.

There was an inverse relationship between legume palatability and persistence. The more palatable the quicker the exit from the system.

The project was designed around set-stocking, but significant production advantages were observed when spelling and rotational grazing was introduced.

The contribution of N could be seen for a few seasons after the legume disappeared from the system. This was evident in the Oolloo and butterfly pea pastures.

Broadleaf weed invasion was a constant management issue. Control is difficult due to a lack of selective herbicides, without collateral damage to the desirable legume component. Weeds like sicklepod, Sida and Hyptis continue to present real world challenges for farmers.

Leucaena – A Productive Browse Legume

Leucaena is a shrubby, browse legume with the highest nutritive value of all the tropical forages. It is commonly established in rows within grass pastures (Figure 3). At DDRF, Leucaena has been the most productive pasture combination with various grass species (pangola, buffel, sabi) consistently providing 0.7 kg/head/day over the wet season from November to April. Average yearly LW gains have been 0.5 to 0.6 kg/head/day or 190-240 kg/head/year (Lemcke and Shotton, 2018).

Figure 3. Leucaena in rows within a Jarra pasture (photo: Peter Shotton).

Maintaining livestock condition over the dry season is a key management objective for grazing systems in the NT. Cattle on native pasture or run-down improved pastures will lose substantial weight from about mid-dry season (i.e. July) to the onset of the wet season. Research showed the Leucaena-grass combinations again provided the best productivity gains of around 0.4 kg/head/day through the latter dry season period. This was due to the fresh, highly digestible protein leaf Leucaena provided throughout the dry season, which supplemented the grass pasture biomass in the interrow.

Although Leucaena-grass pasture is considerably more productive, it requires more intensive management from initial establishment through to weed and grazing management than most other grazing systems. There are also biodiversity issues associated with Leucaena due to its potential to spread into native habitats. It is a major weed around the Darwin foreshore where it is locally known as Coffee Bush. The Leucaena Network (https://www.leucaena.net/) provides comprehensive guidelines on growing and managing Leucaena.

Legume Contribution to Soil Nitrogen

The contribution of legumes to the soil nitrogen profile has been assessed in several trials in the Top End. Increase of soil nitrogen is influenced by the management system, and legume systems have been shown to substantially increase nitrogen levels in soil (Table 2).

Table 2. Differences in soil nitrogen with different pasture treatments.

Pasture	Soil nitrate content (kg nitrate/ha)
Virgin bush	0
Cavalcade / Sorghum (10 year rotation)	318
Cavalcade only (2 years old)	190
Sabi / Cavalcade (2 years old)	20
Sabi only (4 years old)	10

Source: NTG Technical Annual Report NT Primary Industries (1997)

Dimes *et al*. (1996) measured nitrate-N in the soil at the time of pasture kill in no-till farming systems at Katherine across clay and sandy soil types. For perennial grass treatments N-levels did not exceed 10kg N/ha, but for legume pastures, this was 42kg N/ha and 136kg N/ha for the sandy and clay soil respectively. This demonstrated the contribution that legumes can make to soil nitrogen in a pasture-cropping system.

Nitrogen contributions of between 25 to 75 kg of N/ha/year were measured from grazed Cavalcade and Stylo pastures depending on the density of the sward and length of growing period.

Figure 4. A high quality multi-species pasture of butterfly pea, cowpea, sabi and Jarra grass. This will enhance cattle liveweight gain and animal productivity but requires a high level of grazing management.

Improving the Feed Quality of Hay

Legumes improve the palatability, feed quality and intake of hay made from mixed pastures. The higher the percentage of legume in the hay, the greater the protein, energy and overall feed quality. When hay is normally harvested after the wet season i.e. late April, most tropical grasses are mature and passed optimum feed quality. They are high in indigestible fibre and have only about 3% to 5% crude protein, 40 to 50% digestibility and 6 to 7 megajoules/kg of energy (Mj/kg) at the time of harvest.

Incorporating legume into the hay will double the protein over straight grass hay as well as increasing its palatability and intake by stock.

Benefits from having legumes in hay include:

- Increased palatability and greater intake
- Higher feed efficiency and less wastage
- Less demand for lick/supplement
- Improved growth rates or better maintenance of body condition in tough times.

Figure 5. Good quality legume-grass hay can help maintain cattle liveweight condition at the end of the dry season when other quality feed sources are limiting.

Table 3 summarises results from selected feed quality analysis, and Figures 6 and 7 provide examples of feed analysis comparison between Jarra only and a Jarra-cowpea pasture.

Table 3. Commercial Comparisons of Straight Grass Hay and Grass/Legume Hay.

Hay Types/ Comparisons	Location	Crude Protein (%)	Energy (MJ/kg)	Digestibility
Jarra only	Douglas Daly	4.2	5.7	42
Jarra / Verano	Douglas Daly	7.7	7.3	52
Jarra only	Sturt Plateau	2.7	6.5	47
Jarra / Butterfly Pea	Sturt Plateau	9.6	6.9	47

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23/03/2022

Lot #: 70756 Jarra Grass Fresh Sample

Grower Reference: Larazona Stn

SUMMARY

DOMINANT SPECIES	Jarra Grass	**COMMODITY**	Fresh Sample
ME (MJ/KG)	6.53		
% NDF	73.60		
PROTEIN (%)	2.70		

NIR - Feed Test

DETAILED FEED ANALYSIS (DRY MATTER BASIS)

LOT #: 70756 Jarra Grass Fresh Sa...

ENERGY & RELATED

ME 1X (MJ/kg)	6.53
Relative Feed Value	63.00
Relative Forage Quality	45.00
Horse DE (MJ/kg)	6.56
% Non Fibre Carbo. (NFC)	12.50
% ESC (Simple Sugars)	6.60
% Crude Fat	1.30
DE 1X (MJ/kg)	8.33
Net Energy Gain (MJ/kg)	0.81
Net Energy Lactation (MJ/kg)	2.98
Net Energy Maintenance (MJ/kg)	3.04

PROTEIN & RELATED

% Crude Protein	2.70
% Available Protein	1.90
% Soluble Protein	2.00
% Degradable Protein	2.00
% ADICP	0.80
% NDICP	1.80
Soluble Protein % of CP	58.00
Degradable Protein % of CP	68.00

FIBRE & RELATED

% Neutral Detergent Fibre	73.60
% Acid Detergent Fibre	49.90
% aNDFom	72.10
% WSC (Water Sol. Carbs.)	11.20
% TDN	47.00
% Starch	0.20
% Lignin	6.60
% Moisture	17.80
% Dry Matter	82.20
% Ash	11.60
% uNDFom 30hr	45.40
% uNDFom 120hr	31.30
% uNDFom 240hr	25.80
NDFD 24hr % of NDF	34.00

MINERALS & RELATED

% Potassium (K)	1.98
% Calcium (Ca)	0.28
% Magnesium (Mg)	0.16
% Phosphorus (P)	0.25
% Sulfur (S)	0.01
% Chloride (Cl)	0.85

FATTY ACIDS & RELATED

Total Fatty Acids	0.54
C18:1 Oleic	0.02
C18:2 Linoleic	0.01
C18:3 Linolenic	0.01

For information on interpreting feed test results visit https://www.feedcentral.com.au/feed-test-results-methods/. For information on the visual grading system and Feed Central's on farm inspection procedures please visit https://www.feedcentral.com.au/feed-testing/#why

Results are reported on an "as received" basis, unless otherwise indicated.

Any subsequent feed testing of product may experience variations of results. Feed Central can not be held responsible for any such variations.

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Figure 6. Example of feed analysis results from a grass only (Jarra) pasture.

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- ○ ON-FARM INSPECTION

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23/03/2022

Lot #: 68395 Jarra Grass Fresh Sample

Grower Reference: Cowpea/Jarra Mix, Larazona Stn

SUMMARY

DOMINANT SPECIES	Jarra Grass	**COMMODITY**	Fresh Sample
ME (MJ/KG)	6.97		
% NDF	62.10		
PROTEIN (%)	9.60		

NIR - Feed Test

DETAILED FEED ANALYSIS (DRY MATTER BASIS)

LOT #: 68395 Jarra Grass Fresh Sa...

ENERGY & RELATED	
ME 1X (MJ/kg)	6.97
Relative Feed Value	78.00
Relative Forage Quality	89.00
Horse DE (MJ/kg)	7.77
% Non Fibre Carbo. (NFC)	18.20
% ESC (Simple Sugars)	3.00
% Crude Fat	1.90
DE 1X (MJ/kg)	8.76
Net Energy Gain (MJ/kg)	1.00
Net Energy Lactation (MJ/kg)	3.84
Net Energy Maintenance (MJ/kg)	3.24

PROTEIN & RELATED	
% Crude Protein	9.60
% Available Protein	8.40
% Soluble Protein	4.00
% Degradable Protein	6.00
% ADICP	1.20
% NDICP	2.60
Soluble Protein % of CP	45.00
Degradable Protein % of CP	65.00

FIBRE & RELATED	
% Neutral Detergent Fibre	62.10
% Acid Detergent Fibre	47.50
% aNDFom	60.60
% WSC (Water Sol. Carbs.)	3.60
% TDN	47.00
% Starch	3.20
% Lignin	9.80
% Moisture	18.60
% Dry Matter	81.40
% Ash	10.80
% uNDFom 30hr	35.60
% uNDFom 120hr	27.10
% uNDFom 240hr	23.70
NDFD 24hr % of NDF	36.00

MINERALS & RELATED	
% Potassium (K)	2.98
% Calcium (Ca)	0.56
% Magnesium (Mg)	0.36
% Phosphorus (P)	0.27
% Sulfur (S)	0.20
% Chloride (Cl)	1.08

FATTY ACIDS & RELATED	
Total Fatty Acids	0.13
C18:1 Oleic	0.03
C18:2 Linoleic	0.01
C18:3 Linolenic	0.01

For information on interpreting feed test results visit https://www.feedcentral.com.au/feed-test-results-methods/. For information on the visual grading system and Feed Central's on farm inspection procedures please visit https://www.feedcentral.com.au/feed-testing/#why

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Figure 7. Example of feed analysis results from a grass – legume pasture (Jarra – Cowpea).

Conclusion

R &D (most of which is still unpublished) into pasture species evaluation has highlighted and quantified the most productive legumes and their role in tropical farming and grazing systems in the Top End. It has also identified the issues and limitations associated with incorporating legumes from a persistence and practical management perspective.

Legume persistence, weed incursion and weed control options are still the major management issues facing producers. Crop establishment and soil nutrition management have progressed over the decades with the development of highly efficient no-till machinery and the availability of a wide range of specialised nutritional products.

The role of innovative producers in developing management systems, and the availability of locally produced legume seed, have provided impetus to expanding the role of legumes in farming systems over the past 20 years. Although the adoption of improved pastures, including the incorporation of legumes, has come a long way since the 1980s, the adoption of no-till farming practices for mixed pastures remains relatively low.

CHAPTER 3
LESSONS LEARNED FROM FARMING EXPERIENCE IN THE TOP END

Inoculation

Legumes cannot fix nitrogen without the symbiotic association with *Rhizobium* bacteria growing within their roots, described earlier. As the *Rhizobium* grows, it enlarges the plant cells into nodules (Figure 8a) which are the site of nitrogen fixation. Nodules can be clearly seen on healthy legumes and, when inspected, should have a deep pink/red color, indicating healthy, nitrogen-fixing bacteria at work (Figure 8b).

Inoculation is the process of coating the seed with a commercial formulation of *Rhizobium* prior to planting, to ensure the right strain bacteria colonises the root system and effectively fixes N. Agricultural soils in the NT have a wide variety of naturally occurring *Rhizobium* that colonise tropical legumes and allow adequate N-fixation. However, when initially introducing a legume species into an area or paddock, it is advisable to “inoculate” the seed with the specific strain of *Rhizobium* compatible with that species. Inoculation is beneficial in cowpea, butterfly pea, Cavalcade and lablab if being introduced for the first time (Figures 9 and 10).

This is an insurance policy against poor nodulation and is relatively inexpensive, given the benefits of N-fixation. Failing to inoculate with the correct *Rhizobium* may result in unproductive legumes deficient in N. After the initial inoculation process, the *Rhizobium* can live and persist in the soil indefinitely.

Figure 8. a) Nodules on the roots of Centrosema spp. b) healthy nodules indicated by pink colour.

Figure 9. Inoculum is specific for legume species, as illustrated here for mungbean and Siratro. Inoculum can be in a range of forms including peat and freeze-dried.

Figure 10. Douglas Daly farmer Dan Thompson mixing inoculum with his legume seed.

Legume establishment and productivity is enhanced by phosphorus (P) and trace elements at planting. Most Top End soils are inherently low in P, and many other nutrients. Applying P and trace elements is recommended for legume crops and pastures to ensure rapid establishment and viable production levels. Rates and product type will depend on soil type, previous fertiliser and cropping history and ideally a recent soil test. Single superphosphate plus trace elements (copper (Cu), molybdenum (Mo) and zinc (Zn)) or pelletised guano at rates of 50 to 250 kg/ha are ballpark rates depending on the factors mentioned. Lower rates would be applied to grazing pastures with higher rates required for high yielding legume hay crops. Molybdenum is particularly beneficial for enhancing nodulation and nitrogen fixation.

Some soils in the Darwin, Batchelor and Adelaide River regions, are naturally acidic (pH range of 4.5 to 5.5 pH) and negatively affect the establishment and growth of sensitive legumes. Pelletised-micronised lime or dolomite broadcast or drilled into the seed zone have proven effective at rates of around 100 kg/ha (Figure 11). Many other products are available to enhance seed germination and stimulate soil biology including humic acid and many biostimulant products like seaweed/kelp extract and commercial beneficial microbe formulations, most have which need to be evaluated under NT conditions.

Figure 11. Effects of soil acidity on the establishment and growth of legumes; roots stunted and distorted and seedlings necrotic. Note healthy plant on extreme left.

Novel Establishment Techniques

Faecal Seeding

Faecal seeding is a method of establishing legumes where hard legume seed is fed directly to livestock and the seeds are eventually excreted throughout their grazing range. The hard seed can pass through the digestive system without damage, and ends up in the dung, where it germinates when conditions are favourable (Figure 12). The seed can be mixed with molasses or dry-lick supplements strategically spaced to achieve maximum dispersal of seed.

The concept has been the subject of research in the early 1990s with several producers trialing it in the past. It is described by Agrimix (2022) and is gradually gaining more recognition in the NT.

Research and experience have found there is considerable variability in the time that seed remains in the gut, the level of breakdown it is exposed to, the percentage of viable seed excreted, and the germination and survival of seedlings. Larger-seeded legumes such as cowpea, lablab and butterfly pea are excreted faster than small-seeded legumes like Desmanthus, Stylo and Wynn Cassia but are more prone to damage and breakdown during digestion.

Figure 12. Feeding cattle legume seed and resulting seedlings emerging from cowpats illustrate the potential to distribute seed across a large area.

Seeding-Out

Seeding-out is a term and concept given to the process of feeding out of bales of legume hay that contain a high content of viable seed. Just as weeds can be spread by contaminated hay, desirable legume seeds can be spread by hay containing preferred species (Figure 13). The distribution of seed will occur in two main pathways.

1. Seed is distributed at strategic locations on the property as the legume hay is fed out. The positioning of the bales is determined by where the producer/manager wants to establish legumes. As stock feed on the hay, seeds will naturally fall on the ground and work into the soil by trampling. The waste hay is the portion the stock leave due to spoilage and forms a protective mulch that creates an ideal environment for germination and establishment once rain arrives.
2. Seed ingested by stock will be deposited in dung at points in between feeding sites and through the grazing range.

Strategic positioning of bales is critical to achieve maximum distribution of legume seed and to minimise grazing pressure on legumes that do germinate and survive. Placement of bales well away from high stocking areas such as water and supplement points will help ensure that there is maximum distribution and chance of seedling survival.

The hay ideally should be fed out in the latter part of the dry season and preferably closer to the build-up when good rainfall is imminent. Monitoring the establishment and distribution of emerging legume seedlings will help determine if changes in stocking density is required.

It is recommended that the seeding-out technique is trialed on smaller paddocks where access is good and stock numbers can easily be manipulated. Producers can buy good quality legume hay from reputable hay producers and trial the seeding-out concept without having to commit to growing and harvesting their own hay.

The potential advantages of growing hay and seeding-out include:

- Eliminates the risks of buying in contaminated, weedy hay
- The legume hay crop can be harvested over multiple seasons
- Reduces the cost of buying in legume seed on a seasonal basis
- Legume hay is a more efficient supplement for stock and the seed is a bonus
- Seed can be spread without the need for additional farm machinery
- Any bale type can be used if it contains legume seed
- Distribution of hay is flexible in timing and can fit in with other farm/station operations
- A low cost, low risk option initiating a legume establishment program in extensive areas

Figure 13. A bale of high-quality legume hay can potentially be a bale of high-quality seed for seeding-out.

Managing Legume-Grass Pastures

Introduction

Challenges of managing legume-grass pastures include optimising grazing and seasonal production to maintain the legume versus grass proportion, controlling weeds and managing for longevity and persistence.

The driver of pasture and crop production is soil chemical, physical and biological health. Soil with good physical structure, protected by mulch and growing a diverse range of plants with a balanced nutritional status and pH of 6 to 7, will support an active population of beneficial microbes and promote healthy, vibrant pastures. Good grazing and stock management is then required to maintain and enhance the system.

Grazing Management

The key to grazing management is timing, grazing duration, and intensity or stocking rate. Managing these well will lead to good pasture condition and legume persistence and determine a pasture's short and long-term production. Legumes are susceptible to heavy and even moderate continuous grazing, as stock constantly seek out legumes as the most palatable species (Figure 14 a, b).

Figure 14. a) Butterfly pea seedling in a grass sward where grazing pressure is reduced to allow establishment. b) Butterfly pea is heavily grazed and will disappear unless rested and allowed to recover.

Strategic, rotational grazing is required to enable plants to regenerate, rebuild energy and biomass to ensure the persistence of legumes in a sward. Spelling at seeding time allows the production of seed and the re-establishment of legumes. Most tropical legumes produce significant amounts of 'hard seed' which can continually add to the seedbank if grazing is effectively managed.

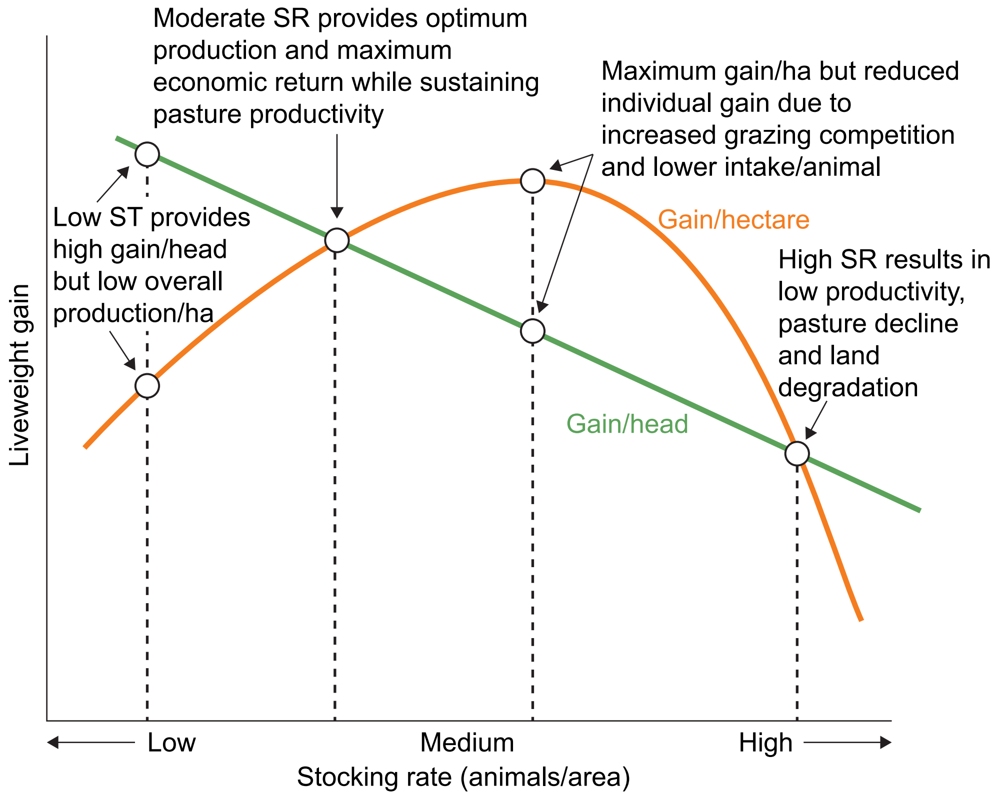

Figure 15. The balance between stocking rate and liveweight gain per head and per hectare. (O'Gara, 2012).

Grass pastures, whether native or improved, cannot meet the nutritional demands (protein and energy) of stock over the dry season, especially the late dry, hence the need for mineral supplementation. This is when perennial legumes can contribute to the diet and provide valuable high protein pick. However, over-utilisation at this time will threaten the persistence of the legume component and needs to be managed by reducing grazing pressure.

Manipulating stock numbers at both the start of wet season to enable legume regeneration and in the late dry to protect the persistence of legumes is the key to a sustainable and resilient legume-grass pasture system. This is a constant challenge and can vary seasonally. Understanding the carrying capacity of the land and the pasture system is key to making the right decisions at the right time.

Weed management

Weed management is the most challenging aspect of legume and legume-grass pasture production in the Top End. Weed incursion, spread and growth is prolific in tropical environments and causes significant competition and economic loss in Top End farming systems. Weed seeds may persist in the soil for over a decade, depending on species.

Hay producers are particularly concerned about weed contamination as it downgrades hay quality, reduces potential sales and increases costs of production. Buyers want to source clean hay to reduce the potential for weed infestation on their own properties. There are legal obligations under the *NT Weed Management Act* to prevent the spread of weeds and significant penalties for spreading declared weeds.

In most farming systems there will be an acceptable level of weed tolerance or weed “threshold” before an economic loss is incurred or they become an aesthetic, animal health or environmental issue. However, the threshold will vary between farms and vary according to weed species and its impact on productivity. Reputable hay producers have a low to nil tolerance of most weeds because of the difficulty in containing many species once introduced on-farm.

An Integrated Pest Management (IPM) approach is the most practical and viable approach to weed management. This involves a multi-faceted approach of quarantine or exclusion, chemical, physical and cultural methods. Chemical control through the strategic use of selective and non-selective herbicides is a highly efficient means for weed control and commonly used in hay production systems.

Mulch management, utilising no-till farming in conjunction with herbicides, is considered a cultural system of both crop establishment and weed management. The system has been proven in both R&D and commercial systems to be a highly effective weed management strategy.

Eastick (2004) evaluated the interaction between herbicide, mulch level and rotation (Figure 16), to minimise the germination, establishment and impact from weeds in Cavalcade to ensure a high-quality product was produced. The system was particularly effective in suppressing the germination and establishment of sicklepod (*Senna obtusifolia*) considered to be the most economically damaging weed in legume hay production.

Figure 16. Silk sorghum and cavalcade make excellent hay or standing dry season pasture and assists in weed suppression.

There are few chemical options for use in legume-grass pastures, so other management practices are required. Herbicide rollers have been trialled (Figure 17) but have met with limited success. Rotational grazing, cover-cropping, planting several competitive species and slashing are practices used to minimise the impact of weeds in non-chemical or regenerative farming systems.

Figure 17. Herbicide rollers have been trialled but had variable results.

Experience has shown that slashing height may be a critical determinant of weed management in some instances. Slashing followed by grazing may result in a higher weed burden due to stock preferentially grazing the short sweet grass and allowing weeds to proliferate.

Conclusions

Key considerations when establishing legumes:

- Select adapted and proven legumes for the specific location, rainfall and soil type
- Buy clean (weed free), viable seed from a reputable retailer/grower based on a seed analysis
- Choose the best soil type and area with the least potential weed
- Control weeds prior to sowing to minimise their spread and competition
- Do not skimp on seeding rate. Sow at or above the recommended rate
- Ensure legumes have adequate nutrition, soil pH and inoculate if required
- Give legumes adequate time to establish before grazing
- Rotationally graze and allow legumes to seed at the end of the season
- Strategically slash or spray areas to reduce weed density and seed set to encourage legumes to grow over them
- Allow legumes to re-establish the following season and monitor regularly

CHAPTER 4
DISCUSSION AND LEARNING FROM THE LEGUME PROJECT

Introduction

The project focused on establishing legumes into existing pastures using no-tillage ('no-till') sowing methods across a range of sites in the Top End.

There were two key goals for this project:

1. **Facilitating a learning experience for producers around no-till legume establishment**
2. **Promoting the role and benefits of legumes in a farming system**.

No-till Plant Establishment

No-till is a system of sowing crops and pastures directly into soil without cultivation, using specifically designed planting machinery. It is also referred to as zero-till, direct-drill, conservation tillage and sod-seeding, depending on where you come from.

The concept of no-till technology was progressively developed in the 1940s and 50s in the United States as a result of the "dust-bowl" and excessive erosion caused by continuous cultivation. With the release of the herbicides 2,4-D in the 1940s and glyphosate (original trade name Roundup®) in the 1970s, no-till technology advanced rapidly all over the world. The system became synonymous with the application of Roundup®, where weeds are sprayed and killed prior to planting ('blown-out'), avoiding the need for cultivation for weed control.

No-till is acknowledged as one of the most significant advances in agriculture with many direct and in-direct benefits.

- Reduced soil erosion
- Increased water infiltration and moisture retention
- Insulation of soil against extremes in temperature
- Enhanced environment for seed germination
- Better plant establishment and survival
- Reduced soil compaction
- Enhanced soil organic matter, soil protection and biological health
- Reduced time, labour, machinery hours and fuel consumption
- Improved timing of sowing and increase crop and pasture yields

These advantages are no more evident than they are in the NT, where no-till farming systems have been shown to improve crop establishment and growth through the amelioration of the adverse effects of high soil temperature, high rainfall intensity and water deficits (Thiagalingam, 1996).

Several cooperating producers had no prior experience with no-till seeding. This project gave them direct access to a planter to allow them to gain firsthand experience with the system on their own properties. The common response after trialling the system was genuine amazement at “how easy and simple the system was compared to ploughing paddocks”.

Machinery

Advances in the design and efficiency of no-till machinery have been made over the past 40 years and there are hundreds of different brands on the market. However, the basic principles of a good no-till machine remain the same regardless of brand.

No-till planters must:

- Drill seeds into the soil through a heavy trash or mulch layer
- Create minimal disturbance or blockages
- Achieve good seed to soil contact to promote rapid germination
- Place seed at optimum depth and rate to ensure maximum germination and emergence
- Cover or close the seed furrow to protect seed and conserve moisture using press wheels

The planter used in this project was sponsored by **Direct Seeding and Harvesting Equipment (directseeding.com.au).** The planter was equipped with the next generation K-Hart Gent® double disk openers and press-wheels which close the slot once the seed is deposited in the soil. The angle of the disks is a unique feature which allows the planter to get through thick mulch with practically no soil disturbance or blockages.

DIRECT SEEDING

WE SPECIALIZE IN ZERO-TILLAGE, PRECISION AND CONTROLLED TRAFFIC SEEDING SYSTEMS

Introducing
The NT 'TOMMY' DRILL

With insights from research, field work and expert consultants, this specialized no-till drill is designed to specifically meet the unique challenges of seeding in the semi-arid tropics of the Northern Territory.

Featuring the **K-Hart Gent Openers,** strategically spaced for wider row gaps, the NT 'Tommy' Drill is customized to align with conservation farming systems in the Northern Territory landscape.
The Gent Angled Double Disc Openers provide minimal soil disturbance, effective penetration in tough terrain, reduced hair-pinning and blockages, as well as, excellent residue cutting capability, for all-round efficient planting experience.

The **NT 'TOMMY' DRILL** strategically strikes the balance between value, durability and efficiency, making it your powerful precision planting solution!

Improve Soil Health | **Time Savings** | **Conserve Moisture** | **Reduce Erosion** | **Build Carbon**

Luke 8:15

LIVING SEEDS

The Good Seed Company.

Suppliers of high-quality seed

Locally sourced and grown

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Legumes

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Cow Pea

Butterfly pea

Verano

Serving the Northern Territory for over 10 years with Integrity, Honesty and Value. Dedicated to ensuring progression and development through quality seed and services.

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Figure 18. Close-up of Gent® double disk opener and press-wheel giving zero soil disturbance and maximum soil protection. This planting machinery was evaluated on-farm across a range of sites as part of the 'Legume Project'. Planter sponsored by Direct Seeding. https://directseeding.com.au/

Cooperating producers had direct access to the planter to undertake their own trial area which provided a unique learning opportunity. After an induction in how the planter works, how to set it up and calibrate, the producers were given several days with the planter to establish their own trials.

Management of Existing Vegetation before Sowing

Introduction

Most producers chose to plant directly into existing grass pastures without using herbicide to kill the existing vegetation or weeds. This not only protected the existing pasture but ensured there was no loss in pasture growth or productivity during the season.

One of the terms which came from the Project was **"No-kill, No-till"** referring to the system of keeping the existing pasture intact and drilling the legumes amongst living plants. One of the drawbacks of this system is the potential for existing pastures or weeds to compete with establishing legumes.

Management techniques employed to reduce competition, included:

- A short period of heavy grazing prior to seeding
- A moderate level of grazing with and without slashing
- Slashing only
- Selective herbicide to reduce weed competition
- No management, planting into whatever was there

Some consideration and planning is required before investing in seed and planting into a dense grass sward:

- How dense is the pasture?
- Is there too much competition?
- What is the weed spectrum and do I need to control them?
- What are the chances of legume survival if I do nothing?
- What can I do to increase legume establishment, i.e. graze, slash, spray?

Planting into a full grass sward can create too much competition for the emerging legume seedlings. It is recommended some action is undertaken to reduce potential competition and create a better environment for successful establishment of the new legumes.

Grazing

Strategic grazing i.e. heavy stocking for short time, offers the most cost-effective form of biomass reduction. Stock should be removed before any damage is done to the pasture or the soil (Figure 19). Heavy grazing in wet periods will cause compaction, pugging and excessive damage to the soil surface. This can be more pronounced on heavier clay soils early in the wet season. Timing of the grazing period and duration is critical for protecting both the pasture resource and the soil.

The grazing period may be as short as a few days or up to a few weeks depending on the initial condition of the pasture, the number and weight of stock and the soil moisture status at the time.

If broadleaf weeds (*Sida* spp, sicklepod, Hyptis) are an issue, grazing will open the canopy exposing the weeds, which can then be sprayed with a **short-term or non-residual**, selective herbicide. This will reduce the competition at sowing and improve the conditions for legume establishment.

Once legumes are established, there are very few options for chemical weed control in legume-grass pastures. Most selective broadleaf herbicides will damage or kill legumes.

In situations where herbicides are not an option, heavy grazing followed by slashing the weeds is the best option for broadleaf weed control. Other options are available but have largely been un-tried or un-tested in the NT for example organic herbicides, flame weed controllers or roller-crimpers.

Figure 19. Jeremy Trembath, Katherine, seeding legumes directly into a well grazed pasture, where mulch level and initial competition to legume seedlings has been minimised. Pastures which have only been lightly grazed have the advantage of maintaining more soil cover and competition against broadleaf weeds, but may provide competition to the emerging legumes.

Slashing

Slashing was discussed earlier as a tool used in combination with grazing. Slashing is both time and energy intensive but can be strategically used to manage dense patches of weeds. Over large areas the economics of slashing may be questionable.

Another concern with slashing is that weeds can be transferred from dirty paddocks to clean paddocks, due to the accumulation of debris and weed seeds on the slasher. Having a paddock slashing sequence from clean to dirty and cleaning the slasher in between transporting from one paddock to the next will help reduce weed spread on farm.

Herbicide, Weed Management and Pasture Rejuvenation

In situations where the existing pasture is run-down, excessively weedy and unproductive, a complete pasture rejuvenation may be warranted. This may require one or two knockdown applications of glyphosate, with or without other herbicide options. This would be followed up with a complete resowing using no-till practices and fertilising with the desired pasture species at recommended seed and fertiliser rates. (Figures 20, 21.a, b).

This will achieve several objectives:

- Create conditions for successful no-till seeding
- Maintain optimum mulch cover to protect soil and reduce weed germination
- Clean up paddock and control existing weeds
- Ensure timely planting and establishment of new pasture
- Create optimum conditions for a highly productive pasture with desirable legume:grass ratio

Disclaimer on Herbicide Recommendations and Usage: The use of glyphosate and other herbicides suggested in this document is entirely at the discretion of the of the reader. Chemicals mentioned herein are registered products and legally permitted under the Australian Pesticides and Veterinary and Medicines Authority (APVMA). All agricultural chemicals registered in Australia and available for sale must be used in accordance with the label recommendations (a legal requirement), using all precautions and safety procedures listed on the label. Readers are directed to the APVMA site for information on glyphosate and other agricultural chemicals. (https://www.apvma.gov.au/).

Figure 20. Sowing into a chemically killed pasture sprayed with glyphosate two weeks prior to sowing.

Figure 21. a) Cowpea emerging through mulch, which had been ‘blown-out’ with glyphosate prior to sowing no-till. b) Well established butterfly pea in Jarra grass pasture.

Optimum Timing for Pasture Establishment

The time of sowing of any crop or pasture is the key to successful establishment. There is no precise time to start or finish sowing, but there is a specific window in most seasons where sowing should be carried out to maximise the probability of successful establishment and persistence. For most regions in the Top End, the optimum window for sowing is from **mid-December to mid-January**. In most years if a crop or pasture is planted within this time frame it has a high probability of establishing and finishing off well. This period coincides with a more consistent pattern of rainfall and a good probability of follow-up rain from monsoonal weather patterns, rather than the convection storms more typical of the early wet season.

However, it is important that good rainfall has already been received and that the soil has already built a good reserve of moisture. Planting on a dry or drying soil is risky, especially if it turns dry for a period after planting. Planting too early in November or early December can result in a false start where early rain stimulates germination but there is no follow-up rain. Under these conditions germinated seeds and small seedlings will perish giving a very patchy stand. Planting too late in the season in late January to February may result in the crop or pasture running out of moisture if the wet season ends early.

Fortunately, there are several resources available on weather predictions, forecasting and rainfall probabilities that can assist in making timely decisions on planting and other agricultural operations. These include the **Bureau of Meteorology** (BOM) (http://www.bom.gov.au/), **CliMate App**, **MetEye** and **Windy.com**.

Suitable Legumes for Top End Pastures

Numerous pasture legume species have been assessed in the Top End over decades of R&D (Cameron *et.al*, 1984). Some of these species are no longer commercially grown due to undesirable traits, or the difficulty in producing seed. Not all legumes are created equal. Choosing the right legume or combination of legumes for a specific purpose, geographical area, soil type and environment requires knowledge of its growth habit and adaptation to specific conditions.

The most popular legumes in the Top End are Cavalcade, Bundy, various Stylo species, butterfly pea, cowpea, lablab and to a lesser degree burgundy bean, Wynn cassia and Desmanthus (Figure 22).

Table 4 lists a range of legumes and their characteristics which are or could be used in the NT.

Figure 22. Butterfly pea (purple flower), a deep-rooted perennial legume, successfully established in Jarra grass on the Sturt Plateau. This has significantly improved the pasture quality.

Table 4. Legumes for No-till Seeding into Pastures (cv = cultivar)

Legume		Comment
Cowpea *Vigna unguiculata*		Large-seeded annual, establishes readily and provides vigorous growth. Highly palatable, improves bulk and quality of grass pastures and ideal for wet-season grazing or hay production. Seeds @15,000/kg. See Figure 21.
Butterfly Pea *Clitoria ternatea*		Mid-sized seed, highly productive, perennial legume. Also called 'blue pea'. Will persist for many years if well managed. Improves protein content of pasture forage and provides substantial nitrogen inputs to companion grasses. Most common cultivar is Milgarra. Seeds @23,000/kg. See Figure 22 a,b.
Lablab *Lablab purpureus*		Large-seeded annual climbing legume. Ideal for companion with forage sorghum. Rapid establishment and early growth. Seeds @4000/kg
cv. Cavalcade and Bundey *Centrosema pascuorum*		Predominantly grown as a monoculture for hay production but can be added to a legume mix to enhance pasture diversity and quality of forage. Free seeding annual and can come back each season from seed if well managed. Seeds Cavalcade @48,000/kg, Bundey @58,000/kg
cv. Oolloo *Centrosema brasilianum*		Short-lived perennial twining legume similar to *C.pascuorum*. A useful addition to mixed pastures due to its low growth habit and quality, high protein fodder. Unfortunately, its use is limited by the availability of seed. Seeds @39,000/kg.
Stylos (Caribbean) *Stylosanthes hamata*		Small seeded, drought hardy legume, adapted and grows in most regions of the Top End and inland areas. Offers a late season protein source when most species have hayed off. Will increase resilience of improved and native pastures. Most common cultivars are Verano and Amiga. Seeds @450,000/kg.

Legume		Comment
Stylos (Shrubby) *Stylosanthes scabra*		Similar to *S.hamata*. Most common cultivar is Seca. Seeds @800,000/kg. **Shrubby stylo and other cultivars have become an environmental weed in some parts of Queensland, NT and WA**
Other Stylos *S. guianensis* *S. viscosa* S. *humilis* *S. seabrana*		Common stylo *(S.guianensis),* sticky stylo *(S. viscosa),* Townsville stylo *(*S. *humilis)* and Caatinga stylo *(S.seabrana)* are other cultivars which have been either trialled or grown at some point. Townsville stylo revolutionised pasture development in northern Australia in the 1960s and 70s. It was the original species sown in the early days of pasture introduction. It has largely been replaced by Caribbean and shrubby stylos. Common stylo is still occasionally grown as a hay crop or mixed pasture and is marketed as "V8 Stylo" by a commercial seed company.
Desmanthus spp e.g. cv Progardes®		Very small seeded deep-rooted perennial legume, adapted to alkaline clay soils. More suited to grazing than hay production due to its woody stems. When sowing no-till, care needs to be taken to prevent the seed being sown too deep. Alternative planting methods may need to be used. Seeds @350,000/kg. See Figure 23.
Burgundy Bean *Macroptilium bracteatum*		Annual twining and deep-rooted legume. Not used in the Top End as frequently as other legumes but can be added to increase diversity and enhance forage quality. Seeds @160,000/kg
Wynn Cassia *Chamaecrista rotundifolia*		Small-seeded annual legume naturalised throughout the Top End. It is a prolific seeder and has relatively low palatability. It can become dominant in pastures that are continually and heavily grazed. Seeds @250,000/kg

Legume		Comment
Leucaena (Coffee bush) *Leucaena leucocephala*		A perennial browse shrub/tree that is sown in rows 5 to 10 metres apart. The rows form a continuous hedge once fully established and it requires specific management to keep the vegetation in reach of stock. Leucaena is a long-term investment and provides some of the highest productivity of tropical pastures. Seeds @24,000/kg
Sunn hemp *Crotalaria juncea*		A fast-growing legume being trialled by some producers in the NT. Used as a cover crop or as pasture mix to add plant diversity, build carbon and contribute N (Dillard, 2018). The seeds may contain alkaloids and be toxic if eaten in sufficient quantities.
Lucerne *Medicago sativa*		Lucerne is known in Australia as the “king of fodders” due to its quality and productivity as a pasture and fodder crop. There have been many attempts to grow it commercially in the NT with limited success. Experience and research to date suggests lucerne may persist under irrigation 2 to 3 years in the Top End (O’Gara, pers. comm.) after which it dies out due to insects and disease.
Pigeon Pea *Cajanus cajan*		A perennial legume shrub/tree that produces edible peas and is used as a source of food and livestock fodder. In the NT it has been used as trap crop for integrated pest management in cotton systems. It is gaining prominence in other parts of the world as a multi-functional species for cover-cropping, grazing, carbon sequestration and as a soil conditioner.
Perennial Peanut *Arachis glabrata*		A relatively little-known perennial and vegetative (non-seeding) legume. It was introduced to the NT by the Department of Primary Industry in the 1980s. The need to plant rhizomes (underground stems) limits its application for large scale production. Given sufficient planting material, perennial peanut offers considerable scope for small scale sustainable mixed pastures and hay crops. Similar to *A.pintoi*

Figure 23. a) Desmanthus establishment on Larrizona station. b) Well established butterfly pea in a jarra grass pasture

Figure 24. a) Mixed sward of butterfly pea and Jarra grass in Douglas Daly, and b) cowpea and butterfly pea, providing highly productive grazing or high-quality legume-grass hay.

Practicalities of Legume Establishment and Management after Sowing

There are many practical and agronomic points that will enhance the establishment when no-tilling legumes into existing pastures. The obvious ones are choosing the right paddock and soil type, choosing the best species and rate of seed for the intended purpose, preparing the paddock as required, sowing at the appropriate time and when conditions are right and having the appropriate machinery to do the job. Without satisfying these basic requirements the chances of success are low.

Less obvious issues are associated with seed size and sowing depth, specific nutritional requirements, pH of the soil and amendments, growth habit and palatability, perennial species versus annual species, companion species, and weed potential. Post sowing management is also vital to the success of the final establishment and longer-term productivity of the pastures. The following is a list of critical factors that will enhance establishment and long-term productivity.

- Large-seeded legumes are the easiest to plant no-till, and have a wide tolerance of sowing depth i.e. from 5 to 25 mm. They are also more vigorous and competitive as seedlings and establish rapidly.
- Small-seeded legumes, like stylos, Desmanthus, Wynn Cassia ideally need to be sown just below the soil surface so require more precision. They have small fragile seedlings and are prone to competition from established plants.
- Although inoculating seed is unnecessary for many legumes, it is beneficial for legumes such as Cavalcade, cowpea, butterfly pea and lablab that are being introduced into a paddock for the first time and when growing for hay production.
- Legumes have a high requirement for phosphorus, sulphur and trace elements. Top End soils are inherently low in these nutrients. Recommended rates of P, S and trace elements will promote rapid establishment and productive growth. Molybdenum will enhance nodulation and N fixation.
- Soil pH is a critical factor in legume establishment and productivity. Some soils in the Darwin-Litchfield and Adelaide River area are acidic with pH values of pH 5.0 and below. Lime or dolomite is recommended in such instances and can be applied as a powdered bulk or pelletised product.
- Some legumes are potential environmental weeds. Carefully consider which species to sow and where. Legume species should be monitored around natural habitats and destroyed if showing signs of invasiveness.

Once sown, paddocks should be de-stocked for a period of 6 to 12 weeks depending on seasonal conditions to allow legumes to fully establish. The larger-seeded legumes (lablab, cowpea and butterfly pea) are more vigorous and establish readily compared to small seeded legumes like Desmanthus and stylo, which require a longer period to establish before grazing.

Depending on seasonal conditions, rate of establishment and growth, it may be possible to lightly graze the pasture mid-season (i.e. late January) to open the canopy and get the benefit of the highly nutritious pasture on offer. This could ideally be done with small weaners for over a short period, giving the pasture ample time to recover before the end of the wet season.

In some cases, it may take two seasons for perennial legumes like butterfly pea, stylos and Desmanthus to fully establish. Annual legumes like cowpea and lablab will dominate in the first season and may smother the smaller species, but in many cases these are still alive and establishing beneath the canopy.

Monitor the pasture carefully and use caution and conservative grazing in the first season to prevent small seedlings from being preferentially grazed out.

Project Impact

The Project demonstrated that legumes could be successfully established into existing pastures with a range of pre-seeding mulch management practices using appropriate and well-designed no-till planting equipment. The term "no-kill, no till" was coined to describe the process of drilling straight into existing pasture without the use of herbicide, a system which most producers in the project favoured.

Producers saw the benefit of some form of pre-plant paddock preparation (slashing, grazing, herbicide etc) to give the legumes the best chance of establishing with minimal competition.

Large-seeded legumes such as cowpea and butterfly pea proved to be an ideal combination of annual and perennial legumes, which were predominantly used in this project. Smaller-seeded legumes were more difficult to establish in a competitive situation with mulch and pre-existing living pasture plants.

From an extension, promotion and technology transfer perspective it was a highly successful project, given the limited scope and time frame. There were five cooperators in strategic locations from the Darwin, Litchfield, Douglas Daly, Katherine and Sturt Plateau involved, with different levels of knowledge and experience.

The extension days promoted through Territory NRM highlighted the benefit and outcome of establishing legumes using no-till to a wide audience, including producers, researchers and Departmental and NRM staff and influential agri-businesses.

The project was instrumental in providing:

- A greater understanding of legumes, the range of species and their role and attributes in pasture improvement
- Information on the benefits of no-till seeding, equipment required and the simplicity of the system
- The catchy term "no-kill, no-till" which encapsulates the philosophy and methodology many producers want to adopt
- The impetus for a much wider conversation on soil health, sustainability and multi-species pastures
- A spotlight on the pros and cons of managing legumes in mixed pastures with a particular focus on weed management and persistence. Hopefully this can be used to lever R & D funding to address these critical management issues
- The stimulus for one of the largest pastoral companies in Australia to purchase their own no-till machine and embark on a program of pasture improvement and legume hay production
- The resources to publish this technical document which continue the conversation and have a lasting impact years after the conclusion of the project

Figure 25. a) Direct drilling legumes into a grass pasture 'coming away' at the start of the wet season; and b) the resultant cowpea and butterfly pea establishment.

CASE STUDIES

Case Study 1: Jeremy and Amy Trembath, Katherine

Jeremy and Amy Trembath are keen proponents of sustainable and regenerative agriculture and have been growing legume-grass pastures on their property 'Lonesome Duck' for several years.

Jeremy is one of the most vocal proponents of sustainable and regenerative agriculture in the NT. He has been incorporating butterfly pea, cowpea, Cavalcade and sunn hemp in their pastures for some years and was instrumental demonstrating no-till and providing information at field days. He is quick to point out that time and patience is required and not every planting will be successful.

Figure 26. Jeremy Trembath with happy cows, good pastures. (Photo, TNRM).

As part of the legume project, butterfly pea and cowpea were sown no-till into well-grazed sabi grass pasture in the 2020/21 wet season. The rains cut out in mid-February and the planting was deemed a complete failure. In the following season, some of the butterfly pea which had germinated the previous year and appeared to be completely dead, sprung to life with good rains, demonstrating the resilience of this species.

Jeremy sees legumes as the ideal plants to fill any bare patches in a paddock that would otherwise be occupied by weeds. Butterfly pea is a key species due to its persistence and ability to smother weeds and woody re-growth, which he believes assists in weed control in conjunction with slashing. His philosophy on legumes, weeds and ground cover is encapsulated in the statements "Legumes are recommended for humans, so why not provide them to livestock too" and "you shouldn't be more afraid of a weed than of bare ground".

Jeremy has achieved good results with "faecal seeding", the method of feeding legume seed to cattle in mineral supplement, to spread the seed in their dung as they wander around native pastures. He believes it is cost-effective and an efficient way of dispersing seed on country that will never be cultivated. The cow manure provides a good micro-environment with nutrients for the seed to germinate.

The methodology is described "Faecal Seeding with Progardes Desmanthus" (Agrimix 2022).

Case Study 2: Peter Cogill and Fiona McBean, Batchelor

Peter Cogill and Fiona McBean operate Eva Valley Meats on Old Cameron Downs near Batchelor, 100 kms south of Darwin. Their farm and grazing system is based on a regenerative model of native and improved pastures. Artificial fertilizer and herbicides are avoided as much as possible.

Peter didn't have much experience with legume introduction or no-till seeding so was given access to the demonstration planter for a few weeks to plant his trials. Peter commented on how easy the system was compared with ploughing and sowing paddocks. He is considering buying or making a small machine to continue no-tilling legumes.

Peter and Fiona got reasonably good results from the trials. They gained a lot of experience in operating the planter, inoculating seed, comparing results from different paddocks and monitoring the establishment and growth rates.

They have observed an increase in butterfly pea in areas they didn't think it would grow and a response in legume growth to higher phosphorus levels around lick and supplement areas. Cattle provided with P supplement over the wet season concentrate P and other nutrients around the lick, and this has resulted in a significant increase in legume productivity in a radius around the feeding area. This highlighted the natural P deficiency in soils in the Top End, and how it limits the potential of legumes, and the association with *Rhizobium* – bacteria need P too. As a result, they applied guano, a natural source of P, Ca and S, to boost nutrient levels and promote legume productivity.

Fiona is keen to trial organic liquid fertilisers and biostimulants with the seed at sowing to stimulate germination and growth and reduce the need for fertiliser.

The stated benefits from the trial include:

- more diverse pastures providing better feed quality over a wider seasonal window
- contribution to pasture quality, palatability and improved cattle nutrition
- ability to fill the bare ground between the grass tussocks
- improved water infiltration by intercepting rain and slowing down the flow of water

Figure 27. Inspecting legumes sown directly into Gamba pasture .

Comments from Other Cooperators and Experienced Legume Growers

Other cooperators including Dan Thompson (Douglas Daly), Jed Fawcett (Adelaide River), and Dan Chapman (AACo) were all enthusiastic cooperators and gave their time freely to participate in the project, learn as much as they could, and share it with their peers and wider agricultural community.

Chris Howie and Marcus Trevenen, both long term legume producers, were willing to share their thoughts and experience on practical aspects of legume production and management in the Top End. It would be remiss not to include their wisdom in a publication like this.

Chris and Amanda Howie run a highly successful mixed farming enterprise in the Douglas Daly region. They produce high-quality legume and grass hay, pasture seed and high grade brahman cattle. Chris is a long-term proponent of no-tillage. He understands the complexity of managing pasture and hay production systems in a tropical environment. He is adamant on the need for no-till, legumes and maximum mulch cover in building a sustainable and healthy farming system.

Figure 28. Chris Howie has many years of experience fine-tuning no-till farming practices and incorporating legumes into his farming systems.

Chris says legumes are vital for crop productivity, economic viability, soil fertility, weed management and cattle nutrition on their operation. Cavalcade, cowpea and other legumes are used in a rotation with Jarra hay and seed crops over a two-to-three-year phase. Legumes are also critical for animal health, nutrition and productivity. Cattle on legume pastures and stubbles consume far less supplement, which again is a major financial, labour and logistical saving for their operation.

Mulch and no-till is strategically used to manage weeds. After a two-to-three-year grass phase, Cavalcade is no-tilled into sprayed out Jarra grass. Chris states weed management would be very difficult and cost prohibitive without mulch.

At the end of the legume phase, Jarra is sown no-till back into Cavalcade mulch. Glyphosate and selective herbicides are necessary tools in the no-till system and to keep seed and hay crops clean. Two years of legume provides a substantial N boost for the following grass crop and reduces fertiliser inputs.

Chris has successfully grown mixed butterfly pea and Jarra grass hay which had significantly higher protein than straight grass hay and was well accepted by the market. However, the incursion of broad leaf weeds became too difficult to manage and were sprayed out, with the butterfly pea being collateral damage.

Chris says the concept of grass-legume pastures is good but the realities of broadleaf weed management, a very low tolerance for weeds and the lack of selective herbicide options is a major limitation. This is an area that requires more R&D.

Chris is trialing pure swards of legume on one half of a pivot and pure sward of grass on the other half and rotationally grazing each half. He manages the weeds in either half with selective herbicides when required.

Cavalcade is the major legume produced both as a hay and seed crop, but Chris says butterfly pea is one of the most underrated legumes, due to perennial and productive capacity, and palatability under good management.

Marcus and Jenna Trevenen manage Larrizona Station on the Sturt Plateau. Marcus has been establishing legumes into grass and forage sorghum crops over the past three to four years. These are used for both grazing and hay production. Some of the mixes have occurred by default with residual Cavalcade seed growing through silk sorghum crops, while cowpea and butterfly pea have been sown directly into Jarra grass pastures.

Marcus has commented on the dominance of cowpea is in the first year of sowing with little evidence of butterfly pea. Experience has shown butterfly pea is better in the 2nd year and tends to get stronger year by year if well managed.

One of the challenges is the differential in drying time between legumes and grass when making hay. Legumes are slower than grasses to dry down and the more legume the longer the drying time. This has logistical and quality consequences as well as fire risks if hay is made too early. Another challenge is weed management given the low threshold for weeds in his farming system.

Marcus has found establishing legumes in Rhodes grass (*Chloris gayana)* relatively easy using his existing machinery and sees the system having a permanent place in the farm rotation. He also sees it as a low input way to improve the feed quality of pastures while improving animal productivity and reducing fertilizer inputs.

The importance of farmer cooperation, knowledge and experience in developing sustainable farming systems for the northern agricultural industry cannot be overstated. Given the reduced resources and involvement of Government agencies in R&D and extension, projects like this are essential in fostering the expansion of knowledge around sustainable agricultural development and resilient farming systems.

CONCLUSION

Incorporation of legumes is recognised as a means of improving the sustainability and viability of farming and grazing systems in northern Australia. The unique ability of legumes to fix nitrogen through their *Rhizobium* association enhances soil health, fertility, protein and fodder quality compared to grass only crops and pastures.

No-till practices and mulch management are also recognised as essential in protecting Top End soils from torrential tropical rainfall, reducing excessive soil temperatures, and retaining soil moisture during extended dry spells over the wet season.

Research and development over the past 50 years along with industry innovation has led to significant advances in the understanding and management of crops and pastures in the Top End. However, challenges and knowledge gaps remain for farmer adoption of legume-grass pastures, including establishment using no-till practices, maintenance of the legume-grass balance and difficulties with weed management.

This provided the impetus for a project to 'Evaluate Legumes Sown No-till into Standing Grass Pastures' in the Top End. This 'Legume Project' was a collaboration between Territory Natural Resource Management (TNRM) and Northern Tropical Agriculture, funded under the National Landcare Program.

The project's objective was to provide farmers with first-hand experience to sow different legume species using novel no-till planting machinery, into existing grass pastures on their own properties. This enabled farmers to trial a range of different mulch/pasture management practices to incorporate legumes into their farming systems with no loss of pasture, and minimal soil disturbance.

On-farm results showed that the large-seeded legumes such as cowpea and butterfly pea had the best establishment, and the perennial butterfly pea persisted into the second season. The project also gave rise to the term "no-kill, no-till", which describes the process of no-tilling legume seed directly into existing grass pastures in one pass without chemicals. This is a relatively simple process and an attractive concept to many producers.

The project also highlighted challenges and the practicalities of managing legume-grass pastures. Weed management remains a constant threat to the productivity and quality of mixed pastures, especially in hay production. This is not unique to the NT but a challenge in all farming systems that require on going R&D. Strategic grazing management was required to maintain the legume-grass balance, including spelling after sowing and at critical seed production times.

Farmers involved in the Project significantly improved their knowledge and understanding of the role of legumes and no-till practices in Top End farming and grazing systems and were able to extend these learnings to other farmers.

Knowledge gaps in northern agricultural systems still remain, and industry faces new challenges. These include climate change, extremes in temperature and weather events, a requirement to reduce carbon footprints, changing consumer demand and competition from non-meat substitutes. These issues and how they are addressed will be instrumental in the success of the meat industry locally, nationally and globally. The role of cattle and grazing systems in mitigating climate change, is one of the most emotive and divisive arguments in agriculture today, even amongst the scientific community (Garnett, et.al, 2017).

However, there is no question about the benefits of productive pasture legumes and no-till farming in improving soil health and fertility, reducing erosion and carbon release, and helping sequester additional carbon, which are definitive and positive climate-friendly practices. The increased productivity from legume-grass pastures is a significant component in reducing methane emissions from livestock, aligned with Climate Smart Agriculture (CSA). This is part of the Australian Government's net zero emissions 2050 target, and aims to reduce emissions, enhance climate change resilience, increase carbon capture, improve soil health and productivity and conserve natural capital (Department of Agriculture, Fisheries and Forestry, 2023).

It is predicted that climate change and land degradation will decrease global crop yields by 10%, the world will have 10 billion people, and 70% more food will be needed to feed this this population by 2050. https://www.theworldcounts.com/challenges/planet-earth/forests-and-deserts/global-land-degradation

The information, experience and learnings from the Legume project has added to the previous work in this area, stimulated new concepts and revitalised the conversation on legumes and no-tillage. The agricultural industry, and especially the new generation of farmers and pastoralists, are increasingly interested in sustainability issues, learning more and being involved in projects like these. It's essential this type of work and collaboration continues, and information and systems evolve and adapt to the challenges outlined.

It is hoped this document will keep the conversation going and stimulate more questions, ideas and actions that will help create a better future and environment for all.

Figure 29. Fiona, Peter and family assess their established mixed pasture. Legumes are one part of Climate Smart Agriculture to improve the productivity and resilience of Australia's farming and grazing industries for the benefit of future generations.

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APPENDIX 1

Flyer created for Delamere Victoria River Downs Conservation Association Field Day

SOWING LEGUMES INTO GRASS PASTURES USING NO-TILL PRACTICES

Crop and pasture establishment can be difficult in the Top End with high soil temperatures, hard setting soils, and intense rainfall events.

Conservation farming practices such as no-till sowing into mulch can improve plant establishment.

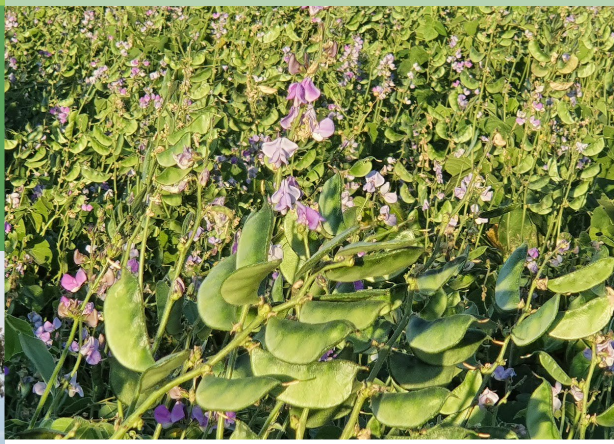
Legumes can be sown 'no-kill, no-till' into existing grass pastures.

I didn't know my N was broken

Legumes can 'fix' nitrogen

Healthy legumes form a bond with bacteria on their roots which 'fix' nitrogen from the atmosphere to the soil, making it available for plant uptake (e.g. grasses).

80% of air is nitrogen which is free. Legumes are the best way of getting your share.



Nitrogen from legumes is estimated to be worth about $3 million annually to Australian agriculture.

(Australian Journal of Experimental Agriculture Vol 45)

Legumes in association with Rhizobia bacteria produce about 80% of the nitrogen in Australian grains and underpins the productivity of pasture based livestock production.

Legumes boost pasture and animal productivity:

- A protein-rich feed source; grazed or hay production
- Provides soil-nitrogen for improved grass production
- Higher quality pasture (protein and digestibility)
- Improved weight gains and quicker turn off
- Less nitrogen fertilizer or lick required
- Improved soil health
- Extended growing period
- Reduced C footprint and methane emissions

Territory Natural Resource Management

Australian Government | National Landcare Program

Northern Tropical Agriculture

A Smart Farms Small Grants Project.
This project is supported by TNRM through funding from the Australian Government's National Landcare Program.

SOWING LEGUMES INTO GRASS PASTURES USING NO-TILL PRACTICES

A 2-year project to demonstrate legumes sown into grass pastures using no-till.

This included Butterfly pea, Cowpea and Desmanthes into Jarra, Sabi and Rhodes grass pastures.

Legumes are part of Climate Smart Agriculture:

- Reduced methane emissions from cattle grazing
- Decreased synthetic fertilizer use (production, transport and application costs)
- Deep-rooted perennial legumes will increase resilience to seasonal variability
- Improved soil health and soil carbon

Farmers collaborated in the project from Batchelor and Douglas Daly to Katherine and the Sturt Plateau

Supplementing with legume hay can mean stock can be sold months earlier

Develop a legume establishment plan

- Paddock, soil type and area
- Species and variety
- Seeding rate and quality
- Timing
- Application/ seeding method
- Monitor and manage

Territory Natural Resource Management

Australian Government

National Landcare Program

Northern Tropical Agriculture

A Smart Farms Small Grants Project.
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Territory Natural Resource Management

Australian Government

National Landcare Program

Northern Tropical Agriculture