DEPARTMENT OF
PRIMARY INDUSTRY AND RESOURCES

Primary Industries Annual Research Achievements Report 2017-18

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NORTHERN TERRITORY GOVERNMENT

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DEPARTMENT OF PRIMARY INDUSTRY AND RESOURCES

PRIMARY INDUSTRIES

ANNUAL RESEARCH ACHIEVEMENTS REPORT 2017-18

November 2018

Bibliography:

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Contents

About this report

This Report provides a summary of research and development activities conducted in 2017-18 in primary industries in the Northern Territory (NT) by the Department of Primary Industry and Resources (DPIR), excluding fisheries, for which there is a separate annual report series titled The Status of Key Northern Territory Fish Stocks Report, and Mines and Energy. The Report covers current and recently completed research in the pastoral and plant industries sectors. It highlights the effort of DPIR's primary industries researchers to provide essential services to NT primary producers to improve productivity and profitability.

The Department's Strategic Plan 2018-2022 aims to promote and facilitate the development of our primary industries and resources, collaborate and strengthen relationships with our stakeholders and the community, and use regulation of our industries and resources as a foundation for appropriate economic development. This includes undertaking research, development, extension and other services to improve the profitability and sustainability of our primary industries, engage with stakeholders, the community, other jurisdictions and the Australian Government to manage biosecurity risks and support Indigenous participation. Research project results in this Report address many of these challenges.

The Report contains contributions from Livestock Industries, Plant Industries and Market Enterprise Development.

Primary industries in the NT are involved in pastoral, crop and horticultural production. The main products, which include beef cattle raised mostly on native pastures, buffalo, crocodiles, field crops, improved pasture, hay, seeds, forestry products, mangoes, melons, vegetables and flowers, are marketed locally, interstate and overseas, particularly to our northern Asian neighbours. This trade contributes substantially to the economy of the NT.

The NT's primary industries also have significant links with other sectors of the local economy and contribute to manufacturing, transport, storage and retail, among others, thereby enhancing employment.

Comments and suggestions for improvements of future editions of this Report, including content, layout and structure, are most welcome. Please send your comments and suggestions to technical.publications@nt.gov.au.

Images/photos: Unless otherwise stated, all images and photos are sourced from the lead researcher.

Cover Images	Left: Cattle in one of the set stocked paddocks in January 2018 (Source: Tim Schatz) Centre: Learning about the remote calving monitoring system (Source: Tim Schatz) Right: Watermelon seedlings growing in contaminated soil (Source: David Lovelock)
Report compilation:	Hassan Bajhau, Max O'Brien, Tim Schatz and Cameron McConchie.

Glossary of abbreviations

AACo	Australian Agricultural Company
ACIAR	Australian Centre for International Agricultural Research
AGBU	Animal Genetics and Breeding Unit
AI	Artificial insemination
AMIA	Australian Mango Industry Association
APEN	Australian Pacific Extension Network
ASPIAC	Alice Springs Pastoral Industry Advisory Committee
AZRI	Arid Zone Research Institute
BF	Berrimah Farm
BHF	Beatrice Hill Farm
BRAC	Barkly Research Advisory Committee
CDU	Charles Darwin University
CPRF	Coastal Plains Research Farm
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific Industrial Research Organisation
DDRF	Douglas Daly Research Farm
DPIR	Department of Primary Industry and Resources (NT)
DSITI	Department of Science, Information Technology and Innovation
EBVs	Estimated breeding values
F1	First filial generation (the generation of hybrids arising from a first cross (animal genetics))
KPIAC	Katherine Pastoral Industry Advisory Committee
KRS	Katherine Research Station
MLA	Meat and Livestock Australia
MSA	Meat Standards Australia
NABRC	North Australia Beef Research Council
NAPCO	North Australian Pastoral Company
NAQS	North Australia Quarantine Service
NESP	National Environmental Science Program
NRM	Natural Resource Management
NT	Northern Territory
NTCA	NT Cattlemen's Association
OMPRS	Old Man Plains Research Station
PD	Pregnancy diagnosis
PDS	Producer demonstration site
QAAFI	Queensland Alliance for Agriculture and Food Innovation
QDAF	Queensland Department of Agriculture and Fisheries
QUT	Queensland University of Technology
RIRDC	Rural Industries Research and Development Corporation
SRM	Society for Rangeland Management
UNE	University of New England
USQ	University of Southern Queensland
VRD	Victoria River District
VRRS	Victoria River Research Station

1 Livestock Industries

1.1 The Effect of Wild Dog Control on the Prevalence of Mauled Young Cattle

Contact: Kieren McCosker

Collaborating staff: Jane Douglas, William Dobbie (DENR) and Glenn Edwards (DENR).

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

2.2 Strengthen collaborative partnering with Northern Territory Government Departments.

Project Status: Commenced.

Monitoring the effect of wild dogs on cattle is a matter of interest to beef cattle producers in the Northern Territory (NT). Producers believe that baiting to control wild dogs is beneficial. However, many studies have been inconclusive on this issue with similar calf losses being observed despite baiting (Eldridge et al. 2002) and an increase in non-fatal attacks in spite of baiting (Eldridge et al. 2002; Allen 2014). These findings highlight the need to better understand the factors associated with wild dog activity and its impact on beef production. The project intends to quantify the prevalence of non-fatal attacks by wild dogs on young cattle and analyse current management strategies.

Results

Two electronic surveys have obtained data from producers.

Paddock and wild dog attack data can be electronically entered at:
https://www.surveymonkey.com/r/dogbite

Data on a property's management strategy to manage wild dogs can be electronically entered at:
https://www.surveymonkey.com/r/dogmanagement

Caution should be exercised in interpreting these results as they are from a limited number of observations. However, a preliminary observation indicates that on average, 6.2% of unbranded cattle at first muster show signs of wild dog attack. Attack rates are highly variable between properties and between paddocks within properties, ranging between 0.2% and 18.2% across the NT.

1.2 Producer Fast-tracking: Increasing Reconception Rates using Liquid Supplements

Contact: Kieren McCosker

Collaborating staff: Tim Schatz.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Commenced.

The project is investigating the effect of a high energy liquid supplement (1 kg/day ULTRALIX) in cows during pregnancy and lactation on reproductive performance (proportion of cows lactating while pregnant and calf mortality). The ULTRALIX supplemented group consisted of 277 pregnant cows (3.9 body condition and average live-weight 449 kg) and the control group consisted of 255 pregnant cows (3.9 body condition and average live-weight 441 kg).

Results

Preliminary results indicate a supplement intake of about 1.28 kg/cow/day at a cost of $0.58/day.

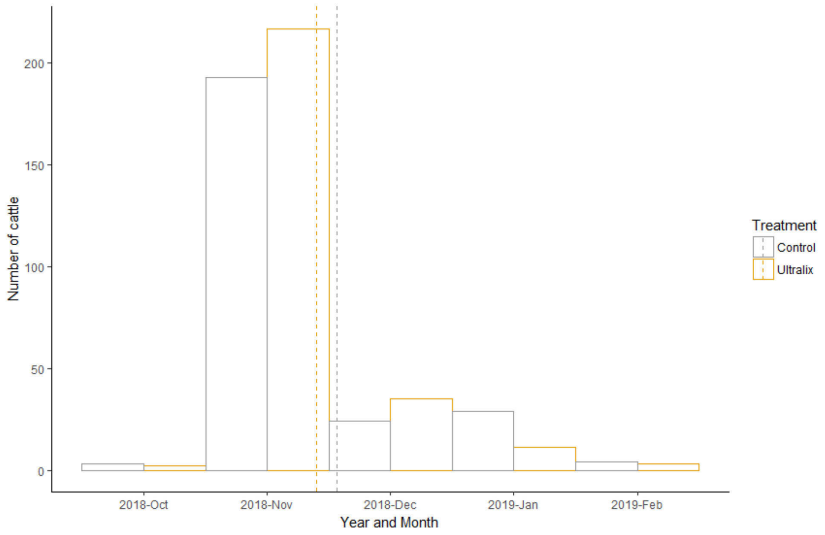


Figure 1. The estimated calving distribution in each group based on foetal age recorded at the initial inspection muster

The mean estimated calving date for each group is represented by a dashed vertical line (Control: 1 December 2018, ULTRALIX: 27 November 2018).

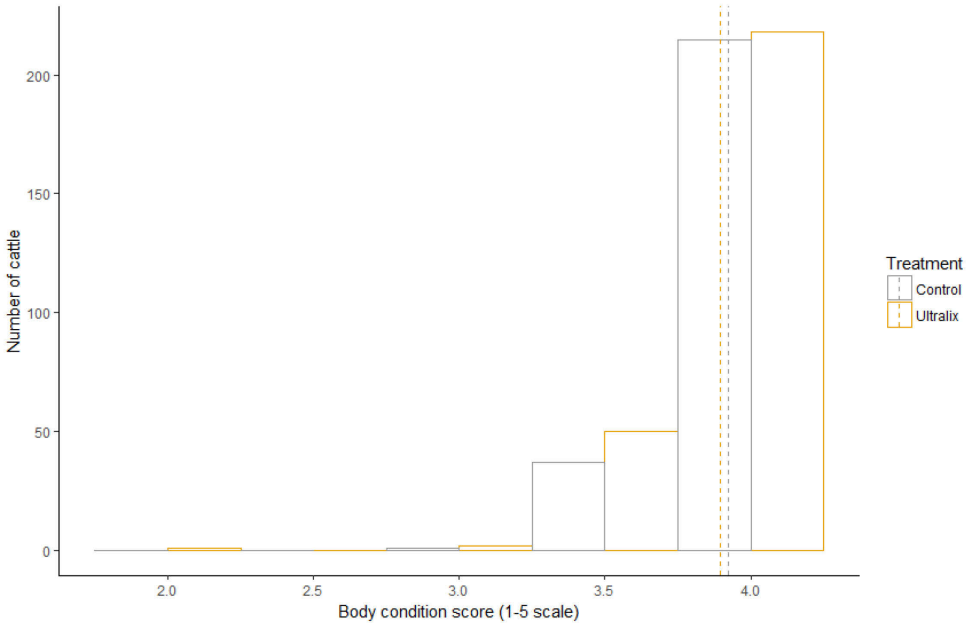


Figure 2. Body condition scores at the initial inspection muster

The group mean body condition score is represented by a dashed vertical line (control: 3.9, ULTRALIX: 3.9).

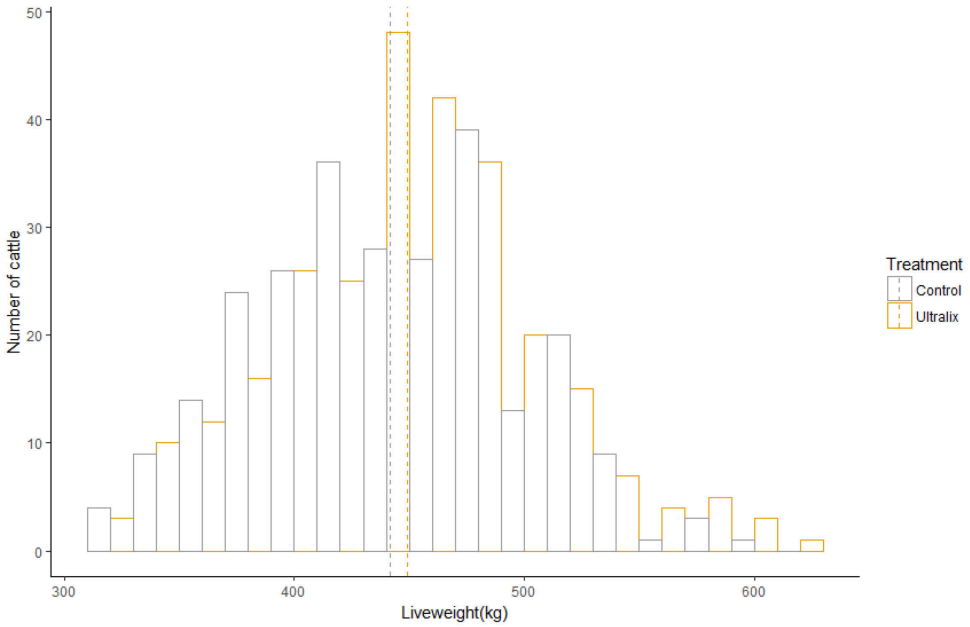


Figure 3. Live-weights at the initial inspection muster

The group mean live-weight is represented by a dashed vertical line (Control: 441 kg, ULTRALIX: 449 kg).

1.3 Reducing Calf Losses due to Exposure

Contact: Kieren McCosker

Collaborating staff: Dionne Walsh and Tim Schatz.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Commenced.

Calf losses constitute a major economic loss to beef cattle producers in northern Australia. On the Barkly Tableland and in similar country types where large numbers of breeding cows graze treeless rangelands, the provision of shade is likely to increase calf survival, particularly in calves born during the hot October-December period.

A trial is being conducted on two paddocks of similar size and productive capacity, each on a separate property on the Barkly Tableland. One paddock (Mary's) has a shade structure at each permanent watering point and the other does not. Each paddock had about 415 heifers (70% pregnant) and 20 steers. Calf losses between confirmed pregnancy and weaning on the two paddocks will be compared to test the effect of shade on reducing calf losses.

Results

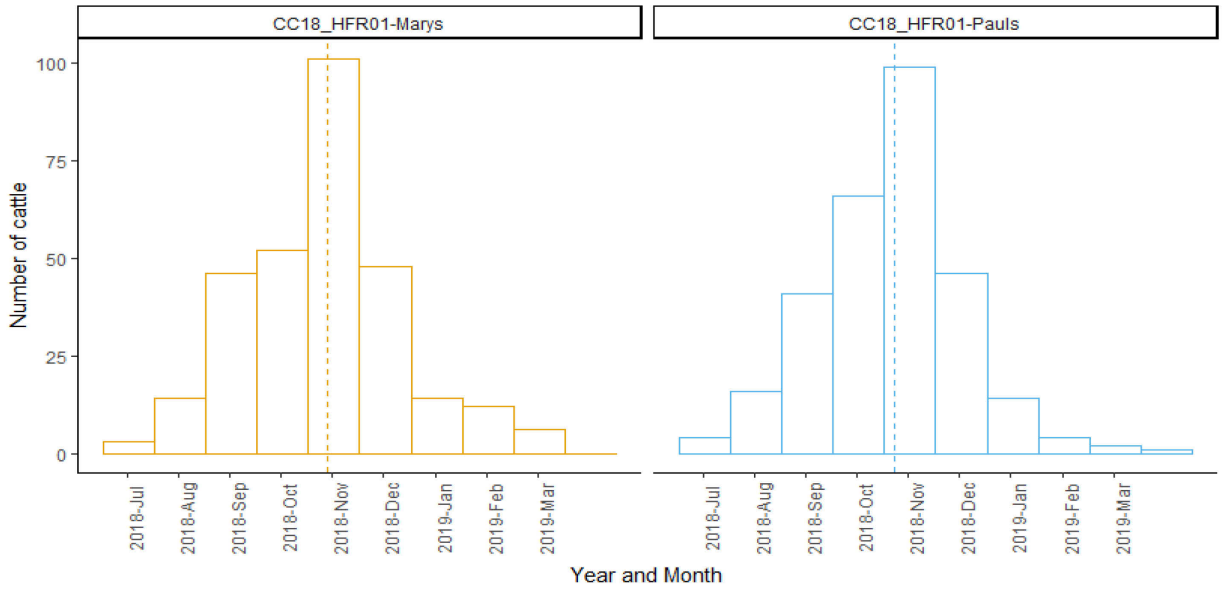


Figure 1. Estimated calving distribution in the two groups based on foetal age recorded at the initial inspection muster

The mean estimated calving date for each group is represented by a dashed vertical line (Mary's 10 November 2018, Paul's 5 November 2018).

The average weight in pregnant heifers was 377 kg and in empty heifers it was 322 kg. There was a slight insignificant difference in weight between paddocks. Mary's paddock animals averaged 379.3 kg and Paul's paddock animals averaged 375.2 kg (Figure 2). There was a strong association between live-weight and pregnancy rate (P<0.001), which is presented in Figure 3.

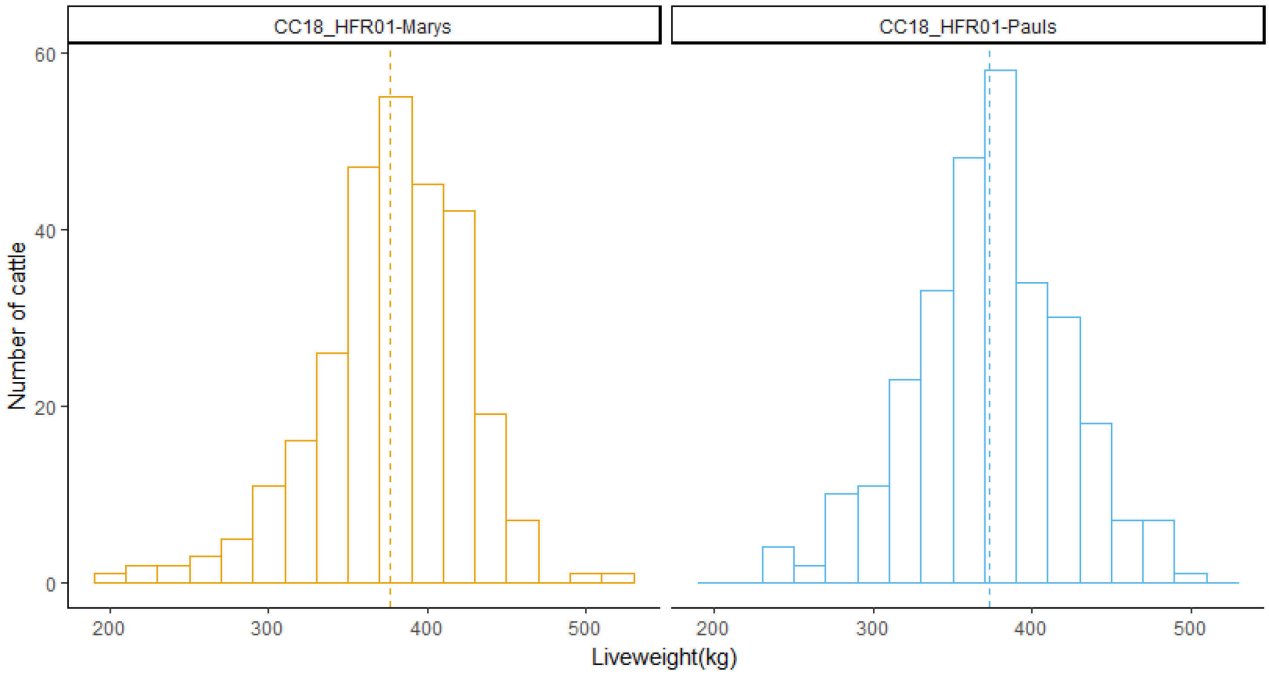


Figure 2. Live-weights at the initial inspection muster

The group mean live-weight is represented by a dashed vertical line (Mary's: 379 kg, Pauls: 375 kg).

The likely association between live-weight and pregnancy is shown in Figure 3.

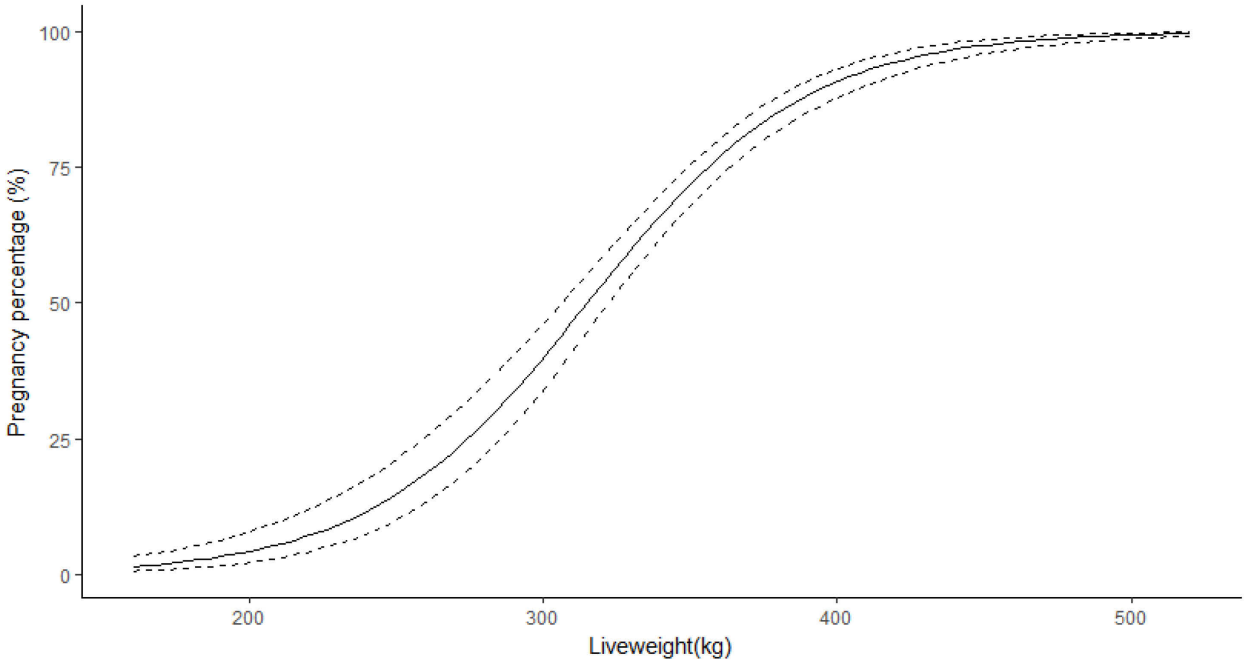


Figure 3. The association between the likelihood of pregnancy and live-weight of maiden heifers at pregnancy diagnosis as predicted by a logistic regression model

A treeless rangeland typical of large areas of the Barkly Tableland

Trial heifers at Ucharondige Station (shaded) after pregnancy testing

1.4 Cow Productivity at Victoria River Research Station

Contact: Kieren McCosker

Collaborating staff: Whitney Dollemore.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Commenced.

The last systematic analysis of breeder performance at Victoria River Research Station (VRRS) was completed in 1994. It led to the development of the best-bet management system, which resulted in a number of changes in management and significant improvements in herd productivity (O'Rourke et al. 1995a; O'Rourke et al. 1995b; Sullivan and O'Rourke 1997; Sullivan et al. 1997). Since 1994, there have been significant changes in breeding herd management: the *Bos indicus* content of the base herd has increased, progeny are routinely weaned twice a year, stocking rates are estimated on the predicted productive capacity of individual land systems and controlled mating has been introduced. The project will analyse the data collected since 1997 to determine the factors that influenced reproductive performance, including those caused during continuous mating and controlled mating. The database contains information from 27 999 inspections of 4896 females representing 18 000 annual production cycles. Lactation was summarised to an annual lactation status of either a heifer/cow being recorded as "WET" at some stage throughout the year or, was only recorded as "DRY". Pregnancy information was summarised using a two-step process which used "Empty" and "Pregnant" records separately.

Results

The overall pregnancy rate was 73.0% (95% CI 69.6-76.5) and the overall foetal calf loss was 8.4% (95% CI 6.4-10.3).

1.5 Profitable Feeding Strategies for Smallholder Cattle in Indonesia

Contact: Kieren McCosker

Collaborating staff: Ian Biggs, Jack Wheeler and Katherine Research Station staff.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Commenced.

A significant challenge in the Northern Territory (NT) is to cost-effectively raise the weight, or even maintain it, in growing cattle during the dry season. Energy is the major limiting nutritional factor.

Cassava, which has a high nutritional content, has emerged as a potential crop in the tropical regions of Australia. The project will investigate the effect of feeding cassava to cattle on live-weight gain in the NT and in Indonesia.

Results

The first cassava crop yield at Katherine Research Station in 2016 was 7.6 tonne (t)/hectare (ha) leaf dry matter (DM) and stem and tuber DM was 10 t/ha. Yield was expected to be up to 25 t DM/ha. It is hoped the second planting will have a much higher yield as there was a much better cutting strike and a higher plant density. With a yield of 25 t DM/ha, it is estimated that 80 ha will support 1000 steers for 200 days.

Tubers have high metabolisable energy (ME) but low crude protein (CP) (4%) (Table 1). The tops have low ME. We plan to trial a mix of tops and tubers in silage as a component of a mixed ration.

Table 1. Summary of the nutritional quality of cassava tops and tubers

Year	Tuber		Tops	
	CP%	ME (MJ ME/kg DM)	CP%	ME (MJ ME/kg DM)
2016	5.3	12.8	21.1	10.9
2017	1.5	13.5	9.0	7.1

A major issue is mechanising planting and harvesting. The 1.5 ha trial area was hand-planted using hand-cut stem billets. The next challenge will be to harvest the plant tops. It is intended to allow the tubers to reshoot so that a new crop of leaf, stem and tuber will be ready for harvest later in the year.

Planting cassava in 2017

The cassava crop before harvest (2017)

1.6 Can Prescribed Burning be used to Control Feathertop Wiregrass in Mitchell Grass Pastures in the Barkly Region?

Contact: Dionne Walsh

Collaborating staff: Jane Douglas, Gabrielle Penna, Ben Beumer, Arthur Cameron, Casey Collier, Caz Pettit, Mark Hearnden and Dale Jenner.

We also acknowledge the assistance of Jak Andrews and staff from Newcastle Waters Station, and Andy Bubb and Stephanie Grove from Barkly Landcare & Conservation Association.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Commenced

Feathertop wiregrass (*Aristida latifolia)* is a relatively unpalatable native perennial grass that builds up in Mitchell grass pastures. A burning trial of this grass in the middle of the dry season in western Queensland showed that it can be eradicated by up to 70%. However, most Northern Territory (NT) cattle producers are reluctant to burn valuable feed reserves during the dry season and the risk of wildfire is very high. The project, in association with the Barkly Landcare and Conservation Association, Territory NRM and the Consolidated Pastoral Company, is testing the viability of fire to reduce feathertop wiregrass in Mitchell grass pastures at Newcastle Waters Station in the Barkly region.

Results

Despite very low soil moisture at the time of burning and moderately hot clean burns, feathertop grass mortality rate was only 1%. There were no plant deaths in weeping Mitchell grass or curly bluegrass. Burning actually had a stimulatory effect on seed production in curly bluegrass. The fire was probably insufficient to kill the grass. The trial will be repeated.

Feathertop grass burning

1.7 Testing "Rangelands Self Herding" at Victoria River Research Station

Contact: Dionne Walsh

Collaborating staff: Spud Thomas, Luke Farr, Craig Maxwell, Caz Pettit, Dale Jenner, Kieren McCosker, Tim Schatz, Dean Revell (Revell Science), Bruce Maynard (Stress Free Stockmanship), Trudi Oxley (Oxley Grazing) and Mel McDonald (Territory NRM).

R*elevant Goal/S*trategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Commenced.

Self-herding is an internationally-recognised livestock management system that influences grazing behaviour. The project will examine if this system can be used to establish rotational grazing that does not rely on expensive and immovable fencing, yet is able to reduce over-grazing in heavily-grazed areas and increase grazing in under-grazed areas.

Results

Initial results indicate that the trial animals were influenced by the self-herding techniques as they gradually moved away from over-grazed areas. More results will be reported after the trial is completed in 2019.

Self-herding – cattle getting used to feed rewards and audio-visual cues

Self-herding – fitting a GPS collar to a trial cow

1.8 Calf Watch – Investigating the Causes of Calf Losses in Extensive Pastoral Systems

Contact: Tim Schatz

Collaborating staff: Kieren McCosker, Raoul Boughton (University of Florida), Jack Wheeler, Will Mathers and Dave Hancock.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Commenced.

Calf mortality is a major cause of loss of income for northern beef producers. It is not uncommon for calf losses to exceed 30% in first-calving heifers and 15% in cows. It has been estimated that neonatal calf losses cost the north Australian cattle industry over $53 million annually. While it is often difficult to improve pregnancy rates in harsh northern environments, reducing calf losses can improve weaning rates and profitability. This project intends to develop a system to monitor calving remotely to assist in discovering the causes of calf mortality and ways to reduce it. The project will collaborate with researchers from the University of Florida who are using birthing sensors to remotely monitor calving. To be effective in northern Australia, where mobile phone coverage is limited, the method needs to be adapted. The project will also test and adapt a VHF tracking system that will enable farmers to determine the time and location of calf losses.

Results

There are no results yet.

University of Florida researchers preparing birth sensors for insertion

Learning about the remote calving monitoring system

1.9 Profiling Cattle with Estimated Breeding Values in an Arid Region: Herd Bulls with Objective Measures for Improved Meat Quality; and Adapted, Productive Cows for High Herd Fertility.

Contact: Jocelyn Coventry

Collaborating staff: Coral Allan, Simon Carr, Bryan Gill, Roger Harvey, Chris Materne, Debbie Roberts, Sally Sims, Dillon Williams, Peter Saville and Greg Crawford.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.13 Align our research, development and extension with industry needs.

Project Status: Commenced.

The project follows a five-year performance benchmarking study of a Droughtmaster breeding herd at Old Man Plains Research Station (OMPRS). It targets performance measures for two breeding herd components: herd bulls with objective data on carcase traits; and breeder cows that are adapted and productive. The project involves recording and analysis of progeny cohorts in order to identify and predict optimal performance based on standard indicators of estimated breeding values (EBVs).

Selected interstate 'carcase quality' bulls and OMPRS bulls were mated to breeder cows to produce steers to measure carcase quality. It is hoped the results will encourage the use of EBVs, culling and selection to improve productivity in local cattle.

Results

Preliminary indicators of breeder cow productivity include observations of shared mothering of calves outside the water-yard. It is too early to report more comprehensive results.

Small calves supervised in a 'fortified kindergarten'

Medium-sized calves drinking at the trough

1.10 Live-weight Losses in Young Cattle during Transport

Contact: Kieren McCosker

Collaborating staff: Spud Thomas, Cameron Heeb, DDRF and VRRS staff.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

The project is determining live-weight losses in young cattle during commercial transport from Victoria River Research Station (VRS) to Douglas Daly Research Farm (DDRF), a distance of about 560 km and the effect of trailer position. Live-weight changes were recorded in three cohorts of weaners that were transported from VRRS to DDRF. In 2016 and 2018, post-transport live-weights (PTLW) were recorded within an hour of disembarkation. In 2017, however, live-weights were recorded following access to hay and water for about 12 hours. Live-weight losses in transported animals were calculated by comparing them with weights taken about 12 hours before transport (BTLW).

Results

The results are shown in Table 1. The changes in live-weight were similar in 2016 and 2018 when weights were taken soon after disembarkation (-8.9%, 95% CI 8.5-9.2%, and -9.2%, 95% CI 8.9-9.5%, respectively). However, when initial live-weights were compared with those taken after a 12-hour access to feed and water, the loss was only 5.6% (95% CI 5.3-6.0%). These results indicate that animals require more than 12 hours to fully regain the weight lost during transport. Regression analyses of each year's results showed a strong positive association between BTLW and live-weight losses in all years (P<0.001). However, a similar association did not exist between the percentage live-weight loss and BTLW, suggesting that live-weight loss as a percentage of the BTLW is similar within the range of weights observed in this study.

During both years, trailer number and deck level were independent of live-weight losses. However, in 2018, a significant association was found between live-weight losses and the top deck of the middle trailer, which cannot be easily explained.

Table 1. Changes in weaner live-weights due to trailer position during transport from VRRS to DDRF in 2016-18

Trailer	Level	Year	No	Average BTLW (kg)	Change in live-weight (kg)			
					Average	SD	Max	Min
Front	Bottom	2016	42	193.9	-16.5	5.1	-29	-7
		2017*	43	184.1	-9.9	6.1	-34	-0.5
		2018	43	186.0	-14.8	5.2	-34	-4
	Top	2016	42	196.9	-16.8	4.5	-26	-5
		2017*	48	179.1	-9.6	5.1	-21	1
		2018	45	187.8	-17.2	4.8	-34	-9

Table 1. Continued

Trailer	Level	Year	No	Average BTLW (kg)	Change in live-weight (kg)			
					Average	SD	Max	Min
Middle	Bottom	2016	21	194.7	-17.5	3.4	-23	-10
		2017*	45	188.6	-10.3	6.7	-26	4
		2018	45	184.0	-17.9	4.7	-27	-4
	Top	2016	39	201.1	-18.2	4.6	-28	-8
		2018	45	190.9	-21.1	5.5	-35	-7
Rear	Bottom	2016	21	192.5	-17.2	3.6	-23.5	-11
		2017*	45	187.0	-12.0	5.3	-26	-3
		2018	46	195.3	-16.4	5.9	-32	-2
	Top	2016	40	189.0	-16.3	5.1	-29	-7
		2018	46	179.7	-16.1	5.6	-29	-4

* Live-weight loss was calculated after animals had about 12 hours access to hay and water

1.11 Shruburn (Victoria River Research Station Long-term Fire Experiment)

Contact: Robyn Cowley

Collaborating staff: Caroline Pettit, Jodie Ward, Jane Douglas, Dionne Walsh, Dale Jenner and Gabrielle Penna.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

The long-term Kidman Springs Fire experiment (established in 1993), assesses the impact of fire management on woody vegetation cover and pasture condition. The experiment is replicated on red and black soil sites, with grazed experimental plots burnt early or later in the dry season, every two, four and six years and compared with unburnt control plots. This is the longest running fire experiment in northern Australia. In recent years, additional studies have been conducted by invited scientists. In 2017, Dr Wendy Williams and Professor Susanne Schmidt of The University of Queensland, collected soil biological crusts and soil samples to measure the effect of fire and grazing on biological crust species composition and nitrogen fixation potential and on all soil life through DNA sequencing. Dr Garry Cook and Associate Professor Sean Levick also measured vegetation structure across the fire plots using LIDAR.

Results

The 2016 full plant diversity (Lebbink et al. 2018) study found that the number of plant species increases after fire due to more annuals and forbs, but perennial grasses were not affected. Fire reduced the prevalence of feathertop wiregrass on the black soil and woody plant species on the red soil.

Palatable perennial grasses' yield doubled from 24% to 50% on average across the black soil following wet season spelling after fire between 2013 and 2017. This compares with an increase of 25% to 38% in the surrounding paddock that was not spelled (Figure 1). Palatable perennial grasses did not respond as well following wet season spelling on the red soil, but increased from 3 to 8% of total yield compared with only a 1% increase in the surrounding paddock. Early-burnt plots on the red soil had a lower perennial grass basal area than late-burnt plots. Woody cover is still increasing on the fire plots, but the rate of increase varies with the burning regime. Four yearly late fires halve the rate of increase on red soils and prevent it on black soils.

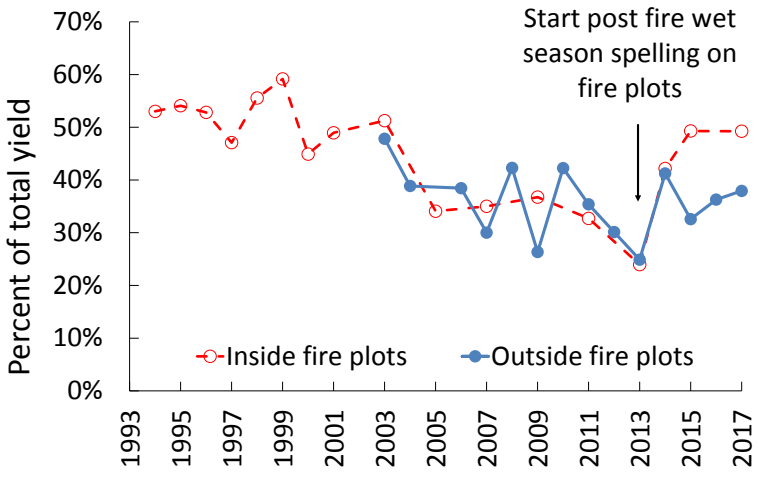


Figure 1. Palatable perennial grass yield on the black soil

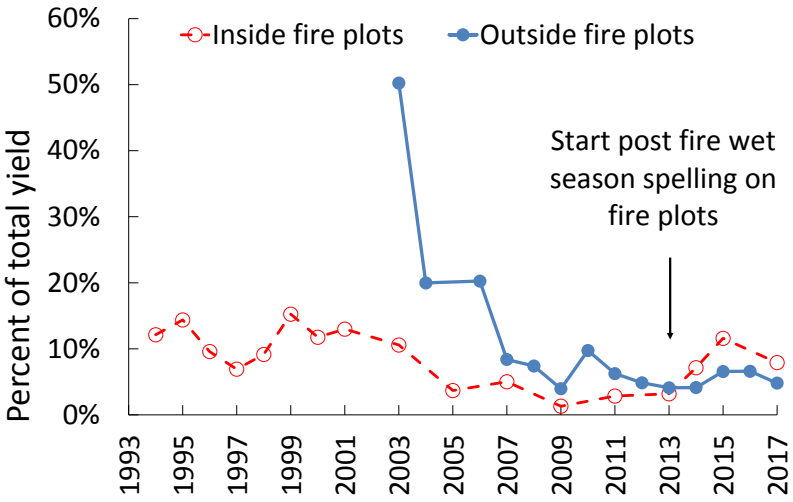
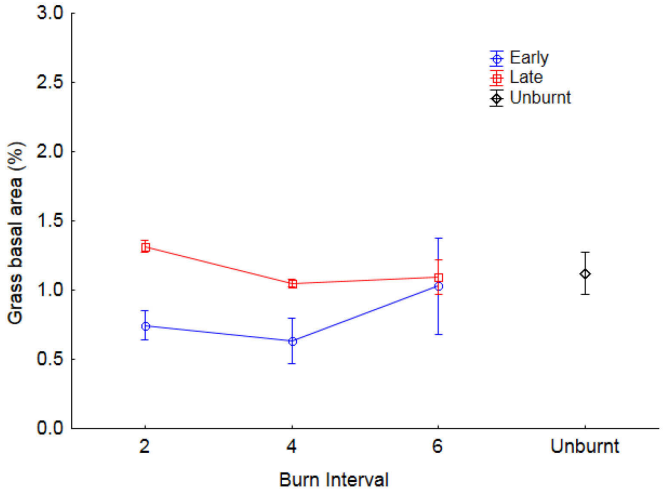


Figure 2. Palatable perennial grass yield on the red soil



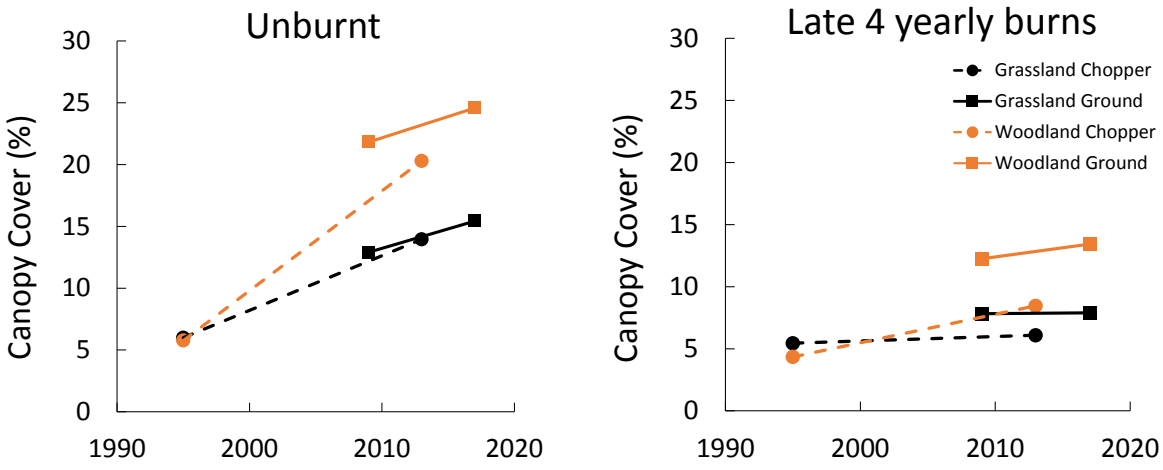


Figure 3. The effect of burning on canopy cover

Experimental fire, Rosewood West Paddock, Victoria River Research Station

1.12 Pasture Sustainability Kidman Springs: Land Condition Monitoring

Contact: Caroline Pettit

Collaborating staff: Dionne Walsh, Dale Jenner and Spud Thomas.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

The long-term carrying capacity at Kidman Springs has been calculated using pasture growth modelling and best practice guidelines. Between 2004 and 2017, data was collected annually during pasture monitoring to test the accuracy of the carrying capacity recommendations. In late 2017, Kidman Springs moved from set stocking to rotational grazing, incorporating wet season spelling and prescribed burning. A forage budgeting program was implemented and a series of permanent photo points were selected. The annual assessment was put on hold for 2018 and is likely to be conducted biennially in future to track long-term land condition trends.

Results

A forage budget assessment was conducted to provide current pasture availability data to the manager for planning stock movements for the year.

Estimating pasture yields at Kidman Springs

Burning Coolibah paddock to demonstrate property-scale fire management recommendations and improve land condition

1.13 Central Australia Quality Graze Trial

Contact: Chris Materne

Collaborating staff: Coral Allan, Dale Jenner, Pieter Conradie, Sally Sims, Jane Douglas, Casey Collier, Helen McMillan, Gabrielle Penna, Jodie Ward, Dionne Walsh, Ben Schumaher, Jillian Fisher, Steve Eldridge and Jocelyn Coventry.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

The project aims to demonstrate and test the impact of various grazing strategies on land condition and on consistent production of quality beef in Central Australia. Data on cattle performance was recorded in August 2017, December 2017, February/March 2018 and May 2018. In July 2017, 27 new 2017-branded steers from a local producer were added and in May 2018, 162 2018-branded steers from Old Man Plains Research Station were also added to the trial group.

Results

The 155 2016-branded steers were slaughtered in April 2018 and the meat was graded according to Meat Standards Australia specifications. Most of the 2016-branded steers (83%) reached target in terms of p8 fat depth of more than 5 mm (92%), rib fat (92%), fat colour of less than 4 (97%), meat pH of less than 5.7 (88%), meat colour of less than 4 (84%) and ossification hot score of less than 175 (86%). Only 57% of the steers reached their average targeted growth rate over the trial period (an average of more than 0.49 kg/day over the trial period).

The 2016-branded steers being yarded prior to loading to South Australia, April 2018

A supplementary feeding trial is investigating options to produce cattle for premium beef markets from Central Australia

1.14 Alexandria Spelling and Stocking Rate Trial

Contact: Casey-Anne Collier

Collaborating staff: Jane Douglas, Mark Hearnden and Dionne Walsh.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Continuing.

The project is investigating if wet season spelling and sustainable stocking rates can maintain good land condition at new bores and improve land condition at older bores. After very poor rainfall during the 2017-2018 wet season, the trial paddock has been de-stocked. All bores in the paddock will receive their first wet season spell since the trial started.

Results

The results show a decline in land condition across all three bores over the eight years of data collection.

Curious cows in the paddock

Cattle at a bore in the trial at Alexandria Station

1.15 Selected Brahmans - Improvement in the Fertility of the Brahman through the Use of BREEDPLAN EBVs and Selection

Contact: Whitney Dollemore

Collaborating staff: Tim Schatz, Christine Hazel and Kieren McCosker.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

Research to improve fertility in a Brahman herd started in 1986 using local cows and bulls. A high selection pressure involved the use of yearling heifer mating and culling of females over two years that failed to become pregnant and lactate, selecting bulls at 12 and 18 months of age on testicle size, growth and dam performance. Artificial insemination (AI) was also used to introduce new genes. AI sire selection was based on a selection index that places high importance on low days to calving and high scrotal circumference estimated breeding values (EBVs). The herd joined the Australian Brahman Breeders' Association and became a member of BREEDPLAN in 1994. In 2016-17, pressure on dam selection was increased. Breeders born since 2014 that missed a successful mating at yearling were removed from the herd to reduce the stocking rate. The herd now has 162 breeders at Victoria River Research Station (VRRS) and 282 first and second-calf heifers at Douglas Daly Research Farm (DDRF), and 165 bulls (of which 43 are used for mating at VRRS and Katherine Research Station and 122 are for sale) and 288 weaners are at DDRF.

Results

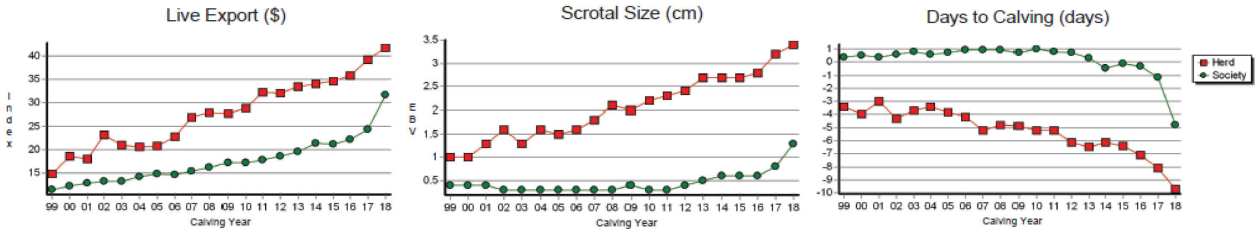
The success of this project is shown by the improvement in reproductive EBV traits, such as the average days to calving and scrotal circumference, which are better than the breed average for the Brahman Group BREEDPLAN, the Jap Ox Index and the Northern Live Export Index.

Emphasis will be on gaining linked sires with the Beef CRC herd for the collaborative project with AGBU: Intensive genotyping and phenotyping for accelerated genetic improvement of reproduction in northern Australia. Extension of this project has included presentations to students of the MLA Breeding EDGE course in WA and the NT. Inquiries were received from the Cattle Council of Australia and the joint Repronomics project (B.NBP.0759). This project has gained a lot of interest from external industry sources in the past year, particularly related to purchases of cows and bulls from this herd, which maintained average prices despite a general decline in market prices. Semen straws from two sires are currently available for sale (16450 and 16454).

The following notable results were observed at the first round muster (May 2018):

- 43% of yearling heifers (2017) were pregnant at DDRF.
- 44% (18/41) 2016 lactating first-calf heifers reconceived at DDRF.
- 73% (112/152) was the pregnancy rate in 2016 heifers at DDRF.
- 94% (62/66) was the reconception rate in wet 2015 heifers at DDRF.
- 81% (66/81) was the weaning rate in the 2015 heifers at DDRF.
- 75% (115/153) wet cows reconceived at VRRS.
- 6% (9/162) was the calf mortality at VRRS.

The wet cow pregnancy rate in the breeder herd at VRRS was below the long-term average (82%). It is assumed this is due to a greater loss of weight in the breeders over the wet season (26 kg) compared with the last two seasons. The pregnancy rate in yearling mated heifers at DDRF is at the long-term average of 41%. Calf loss was just below average.



Figures 1, 2 and 3. A comparison of estimated breeding values between our herd and the BREEEDPLAN herd

Top-priced bull at the sale in June 2017

Welcome to the world

1.16 The Multi-breed Composite Project

Contact: Whitney Dollemore

Collaborating staff: Barry Lemcke, Bob McDonald, Jared Palmer, Travis Messner and Christine Hazel.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

The Department of Primary Industry and Resources developed a multi-breed Composite in 2003 to improve market access of cattle adapted to Northern Territory conditions. The herd was established using females from the Selected Brahman program and bulls were sourced to give a composite comprising of 56% Brahman, 12.5% Tuli, 12.5% Afrikander, 6.3% Charolais, 6.3% Shorthorn and 6.3% Hereford. High selection pressure was adopted, which involved yearling mating of heifers and a strict culling policy on females more than two years old; bulls were selected at 12 months on testicle size, growth and dam performance. Artificial insemination (AI) was also used to introduce new genes. AI sires were selected using a selection index that placed a high importance on low days to calving and high scrotal circumference estimated breeding values (EBVs). The herd is registered with the Australian Brahman Breeders' Association and on BREEDPLAN. The project has compared the performance of the Composite herd with that of a Brahman herd. In 2017-18, management changed and the project will now be managed together with the Selected Brahman project and the collaborative Repronomics 2 project under the title "Enabling genetic improvement of reproduction in tropical beef cattle". The aim of this research being to improve the accuracy of fertility EBVs and across-breed EBVs for industry. The herd will make a significant contribution of phenotypic and genotypic information to the reference population.

Results

The herd has 185 breeders and 130 first and second-calf heifers at Beatrice Hill Farm (BHF), 137 bulls of which 35 are used for mating and 102 are for sale; there are also 235 weaners (a total of 687 animals).

The EBVs achieved in days to calving and scrotal circumference in this project are better than the breed average for the Brahman Group BREEDPLAN. The updated 2018 Group BREEDPLAN results show continued progress.

Extension has included two presentations at the MLA Breeding EDGE course in WA and the NT, the BHF field day and during the Department of Foreign Affairs officials visit to BHF in June 2018.

The following results were observed at the 2018 first round muster (May-June 2018):

- 58% of yearling heifers (2017) were pregnant at BHF.
- 83% (44/53) re-conception in 2016 lactating first-calf heifers at BHF.
- 87% (60/63) pregnancy rate in the 2016 heifers (regardless of lactation) at BHF.
- 94% (138/147) wet cow re-conception for breeders at BHF.
- 10% (17/164) calf loss at BHF.
- 76% (25/33) wet cow re-conception for breeders at DDRF.
- 6% (2/33) calf loss at DDRF.

Mums and bubs

Top priced bull

1.17 The Use of Alternative Tropical Breeds Part D: Senepol Crossbreeding Trial

Contact: Tim Schatz

Collaborating staff: Kieren McCosker, Whitney Dollemore, Jack Wheeler, Will Mathers and Dave Hancock.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Continuing.

Australian domestic markets consider Brahman cattle meat to have low tenderness. While this has not been a problem in live export markets, it has affected demand for high grade Brahman cattle in Australian domestic markets. The aim of this project is to investigate whether crossbreeding Senepol bulls with Brahman cows will produce offspring that will perform well under Northern Territory (NT) conditions and will also have better quality meat than Brahman cattle. If this happens to be the case, then this strategy would improve marketing options for NT Brahman cattle producers as they could then produce cattle that would be suitable for both the live export and the Australian domestic markets. The project evaluates a Senepol crossbreeding program in the northern NT and compares the performance of F1 Senepol x Brahman cattle with that of Brahman cattle.

Results

The steer performance phase of the project has been completed and has been reported in previous Annual Research Achievement Reports (ARARs) as well as in a number of publications. Although the results show that crossbreeding Brahman cattle with Senepols produces better performing steers that have better meat quality, it is also important to discover how the crossbred heifers perform under harsh northern Australian conditions since they are likely to be retained as breeders. To obtain this information, the performance of four year groups of F1 Senepol and Brahman heifers is being compared on native pasture in the Katherine area.

The performance of maiden and first lactation heifers was reported in the 2016-17 ARAR.

Mature (five to eight-years-old) F1 Senepol x Brahman cows appear to have a larger mature size/weight compared with Brahman cows by about 40 kg. The average weight of all wet and dry cows of both breeds at the first round muster in 2018 is shown in Table 1.

Table 1. The average weight of cows at the first weaning muster (WR1) in 2018.

Breed	Dry	Wet
Brahman	494 kg *(n=158)*	439 kg *(n=124)*
F1 Senepol	535 kg *(n=149)*	482 kg *(n=82)*
Diff (F1 Sen - Brah)	41 kg	43 kg

Figure 1 shows the proportion of cows that raised a calf to weaning each year in each year group for each breed. The results were similar in both breeds. Since only pregnant maiden heifers were retained, the proportion of cows that weaned a calf in year 3 was equal to total births minus the calf loss percentage. All groups weaned fewer calves in year 4 due to low re-conception rates the previous year as first lactation

heifers. This is typical for first lactation heifers in the NT. The proportion of cows that weaned a calf in year 4 was much higher in #13 cows of both breeds because bulls entered the paddock in the dry season after the first calves were weaned (a third weaning muster was needed in late October).

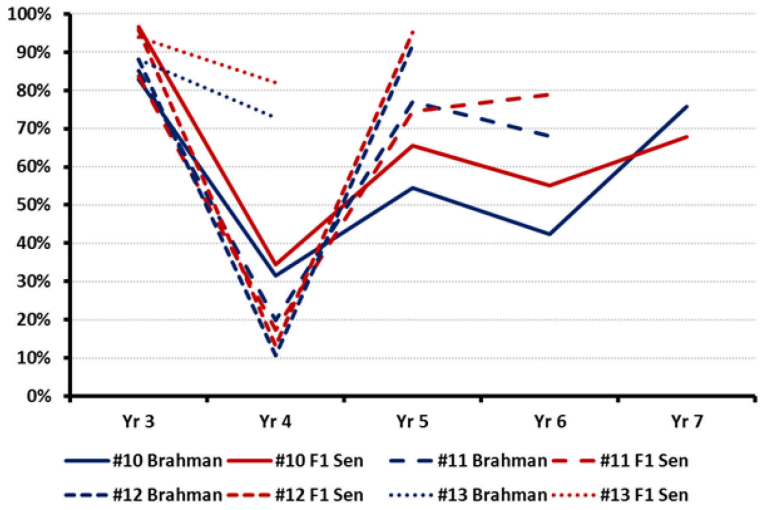


Figure 1. The proportion of Brahman and F1 Senepol cows that raised a calf to weaning each year in 4 year groups

Table 2 shows the weight of calves weaned in each breed in each year group in each year. These figures were calculated by multiplying the number of cows that weaned a calf at each muster in each age group of each breed by the average weight of calves weaned from that age group/breed of cows at each muster. Table 2 shows that in most years F1 Senepol cows weaned more calves per cow mated (except in #10 cows in year 7 and #11 cows in year 4) and on average over all years, in each year group the F1 Senepol cows weaned more weight of calves per cow mated than Brahman cows (as seen in the last column in Table 2). A statistical analysis is required to determine if the differences are significant, but overall the results appear to show that F1 Senepol cows are performing at least as well as Brahman cows.

Table 2. The performance of older females - weight of calf weaned per cow mated in each year

Year group	Breed	Year 1st calf weaned	Year 3	Year 4	Year 5	Year 6	Year 7	Average all years
#10	Brah	2013	139.1	49.7	103.4	73.4	118.5	
#10	F1 Sen	2013	151.9	51.8	132.0	93.5	108.0	
	Diff (F1 Sen - Brah)		*12.8*	*2.1*	*28.6*	*20.2*	*-10.5*	*10.6*
#11	Brah	2014	128.4	33.4	122.3	100.0		
#11	F1 Sen	2014	134.3	32.8	132.8	118.7		
	Diff (F1 Sen - Brah)		*5.9*	*-0.6*	*10.5*	*18.6*		*8.6*
#12	Brah	2015	119.5	15.6	131.1			
#12	F1 Sen	2015	124.0	23.1	144.0			
	Diff (F1 Sen - Brah)		*4.5*	*7.5*	*12.8*			*8.3*
#13	Brah	2016	121.7	105.9				

Year group	Breed	Year 1st calf weaned	Year 3	Year 4	Year 5	Year 6	Year 7	Average all years
#13	F1 Sen	2016	143.4	122.6				
	Diff (F1 Sen - Brah)		*21.7*	*13.5*				*17.6*

Brahman and F1 Senepol cows at Manbulloo

Brahman and F1 Senepol cows at Manbulloo

1.18 The Effect of Phosphorus Supplementation on Female Cattle Growth and Fertility

Contact: Tim Schatz

Collaborating staff: Kieren McCosker, Spud Thomas, Luke Farr, Becky Klingenberg and Craig Maxwell.

The supplement was supplied by Ridley Corporation.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Continuing.

This project is determining the effect of phosphorus (P) supplementation on growth and reproductive performance in female cattle grazing native pasture on P-deficient soils at Victoria River Research Station. The +P group receive a P supplement throughout their life while the –P group do not. Both groups graze in adjacent paddocks that soil testing has found to be P-deficient and the groups alternate paddocks each year. Despite common acceptance among scientists that P supplementation in P-deficient country is beneficial to cows, the benefits in cattle reproduction in northern Australia remain largely unproven and records show that P supplementation is much lower than expected. It is hypothesised that P supplementation may be increased if studies clearly show real benefits.

Results

P-supplemented animals gained an average of 33 kg more in each of the two wet seasons after weaning. On average P-supplemented animals were 65 kg heavier than unsupplemented animals after maiden mating. The pregnancy rate was 10% higher in supplemented maiden heifers. However, for an unknown reason, the pregnancy rate was lower than expected. Ultrasound ovary scanning found more cycling heifers in the supplemented group and if all cycling heifers in each group had become pregnant, the difference would have been 23% (+P = 87%, -P = 64%). Calf losses were similar in the two groups. The re-conception rate was 25% higher in supplemented first-lactation heifers. The average weight of supplemented first-lactation heifers was 120 kg higher when their calves were weaned at the first weaning round (WR1) in 2017. The cumulative mortality rate over the three years from weaning to 3.5 years old was 7% lower in the supplemented group. At WR1 in 2017, 18 unsupplemented heifers were removed for crisis feeding as they were at risk reflected by a low body condition score. The mortality/morbidity rate in unsupplemented heifers was 28%. The average calf weaning weight at WR1 2017 was 34 kg heavier in the supplemented group. Fifty calves were weaned in the supplemented group compared with 40 in the unsupplemented group. The total weight of calves weaned at WR1 in 2017 was 3072 kg higher in the supplemented group, which at the current price of $3.50/kg, was worth $10 751. The cost of the supplement was $1744.05. Comparing the extra cost of the supplement in the +P group with the extra value of calves weaned from first-lactation heifers gave a return on investment of 268%. At WR1 in 2018 (when heifers had the opportunity to wean a second calf) the pregnancy rate was 37% higher in wet supplemented cows. The average weaner weight was 13 kg higher and the total weight of weaners was 2806 kg more in the supplemented group. Pregnancy rates in dry cows were similar in both groups (+P=96%, -P=92%).

While this trial is showing large benefits from P supplementation, the response on other properties will vary depending on the level of P deficiency in the soils on which cattle graze. Benefits of this scale may not be seen where P deficiency is not as severe.

-P cows and calves in March 2018

+P cows and calves in March 2018

1.19 The Repronomics Project – An AGBU Collaborative Genetics Project

Contact: Tim Schatz

Collaborating staff: Whitney Dollemore, Chris Hazel, Cameron Heeb and Damian Bethel.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Continuing.

This is a collaborative project with the Animal Genetics and Breeding Unit (AGBU) and QDAFF/QAFFI, which uses heifers from the Department of Primary Industry and Resources selected Brahman herd to determine genetic effects on age at puberty and postpartum anoestrus interval after first calving. It is hoped the project results will increase the accuracy of fertility estimated breeding values (EBVs), which will improve the rate of progress through selection. It may also develop new fertility EBVs and find genomic markers for fertility traits. Ovaries of four year groups of heifers were scanned at regular intervals to determine age at puberty (age at which a *corpus luteum* is present on an ovary). Ovary scanning commences in the December following weaning just prior to the heifers being mated for the first time as yearlings and continues until all have reached puberty after mating at two years of age. Age at puberty of heifers was determined by ultrasound scanning their ovaries at regular intervals to determine when a corpus luteum was first present on an ovary. Five year groups of heifers have been studied in this way.

Results

The cumulative percentage of heifers that reached puberty in each month is shown in Figure 1 for the five year drops (2013 – 2017). All heifers reached puberty by the end of the two-year old mating. The 2013 year heifers were slower to reach puberty than the other year groups as they were lighter (Table 1).

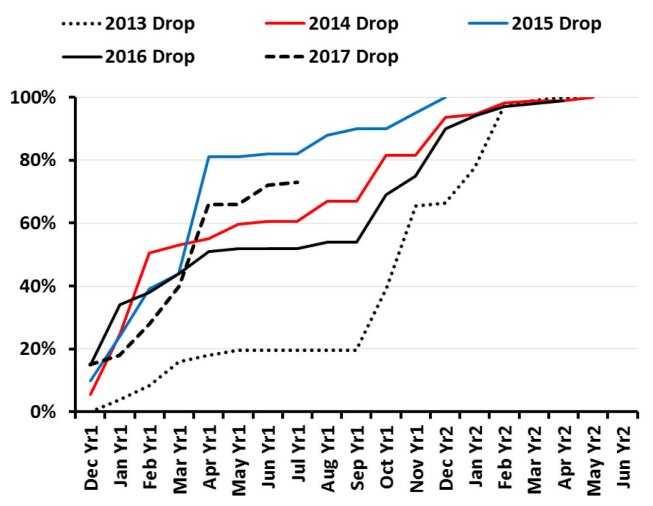


Figure 1. The time at which heifers reached puberty (weaned in April of year 1)

Heifers were mated for the first time as yearlings and then those that do not conceive during yearling mating are mated again the following year. The average weight at the start of mating (SOM), end of mating (EOM) and the pregnancy rate from that mating is shown in Table 1 for the five year groups of heifers. The pregnancy rate from yearling mating was lower in the 2013 heifers than in the other year groups as they were lighter (Table 1).

Table 1. Yearling mating data for five year groups of selected Brahman heifers in the Repronomics project

Year group	Avg wt SOM (kg)	Avg wt EOM (kg)	Pregnant (%) (yearling mating)
2013 drop	188	259	15
2014 Drop	227	293	50
2015 Drop	245	306	57
2016 Drop	221	269	43
2017 Drop	227	292	43

The pregnancy rates from yearling mating for the five year groups of selected Brahman heifers were well above the pregnancy rates predicted for yearling mated commercial Brahman heifers of the same weight (Figure 2).

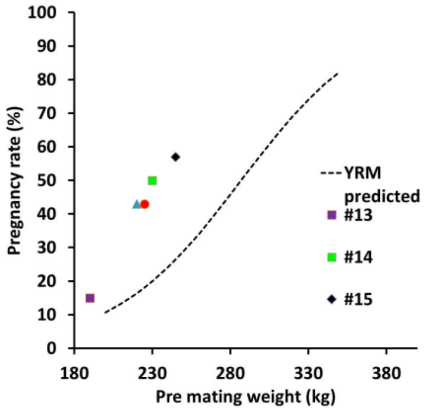


Figure 2. The pregnancy rates from yearling mating of five year groups of selected Brahman heifers relative to the predicted pregnancy rates in commercial Brahman heifers mated as yearlings

The post-partum anoestrus interval (PPAI), or time taken to resume cycling after calving, was determined for the five year groups of first lactation heifers using pregnancy testing and ovary scanning data. PPAI length in heifers in this project is much shorter than is common for most commercial Brahman heifers in the NT as they are from the selected Brahman herd and nutrition at DDRF during calving and lactation is good. As a result, most heifers reconceive before their calves are weaned. For example, the re-conception rate was 68% in the 2015 drop lactating first-calf heifers that had conceived as yearlings.

Table 2. Average post-partum anoestrus interval in first lactation heifers in the Repronomics project

Year group	Avg. PPAI length (days)
2011 drop	114
2012 drop	118
2013 drop	108
2014 drop	109
2015 drop	109

DNA samples (tail hairs) are collected to genotype all the females in the study. The information from genotyping and ovarian scanning is used to search for gene markers for high fertility and to develop new indicators for fertility EBVs that have improved accuracy. The genomic studies are conducted by AGBU; the findings are not available yet.

Ultrasound ovary scanning heifers at DDRF

1.20 'Meating' the Grid with Culled Cows in the Northern Territory

Contact: Kieren McCosker

Collaborating staff: Tim Schatz, Grant Hamilton, Jack Wheeler, Matt Stanley, Dave Hancock, Will Mathers, Bob MacDonald and Jared Palmer.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Completed.

The objective of this study was to generate biological and economic data to estimate potential economic benefits of feeding three groups of cull cows with three different rations. Two of the groups were fed in feedlots each on a different diet (the first group was fed a high grain ration (HGR) for 82 days at a cost of $729/tonne (t) (11% protein and 11.5 MJ ME)); the second group was fed a locally sourced pellet (PEL) for 82 days at a cost of $430/t (14% protein and 10 MJ ME). The third group grazed on floodplains (FP) at Beatrice Hill Farm for 102 days. The aim was to determine which group increased in market value the most based on a grid system to supply a northern abattoir. The cost of live-weight gain was estimated by calculating the average dietary intake of individual pens over the entire trial period and multiplied by the cost of the diet and then divided by the average live-weight of the pen. Average carcase weight was recorded at the start and the end of the period and carcase saleability was assessed based on the slaughter grid. A graduated price structure was used by the abattoir while a flat price across all live-weights was used by the domestic market. The initial value of cows and the subsequent increased value at slaughter were calculated using the actual purchase price and the estimated carcase weight and slaughter grid price, respectively. Rumen fluid samples were collected at key times to determine the effect of rumen microbes on growth rate in animals on floodplain pasture.

Cull cows in pens at Katherine Research Station

Results

The results are shown in Table 1. Lighter cows generally had the largest increase in value; floodplain pastures cost the least and provided the best returns.

Table 1. A summary of performance

Weight category	Diet	Obs	Average growth (kg)		Average daily gain (g/d)		Average live-weight at slaughter (kg)	
			Mean	SD	Mean	SD	Mean	SD
Lightest ⅓ (261-327 kg)	FP	17	55.5	29.0	544	284	361	33
	HGR	11	51.2	20.0	624	243	354	24
	PEL	12	57.8	28.2	704	344	358	33
Middle ⅓ (329-361 kg)	FP	12	50.0	21.7	490	212	393	25
	HGR	12	55.9	37.3	682	455	402	39
	PEL	11	67.1	38.2	818	466	411	38
Heaviest ⅓ (362-461 kg)	FP	13	41.8	17.2	410	168	440	41
	HGR	10	52.0	19.6	634	239	438	23
	PEL	13	63.0	33.2	768	405	458	30

Table 2. Average feed cost and estimated returns by diet and weight category

Weight category	Diet	Obs	Average cost of gain ($/kg)	Average value at slaughter ($)		Estimated value of gain ($/kg)	
				Mean	SD	Mean	SD
Lightest ⅓ (261-327 kg)	FP	17	1.05	494	176	5.35	2.80
	HGR	11	11.68	353	136	5.73	1.90
	PEL	12	7.34	408	83	5.90	1.62
Middle ⅓ (329-361 kg)	FP	12	1.17	645	140	5.14	3.21
	HGR	12	9.62	516	126	3.05	10.22
	PEL	11	6.32	528	163	0.47	14.76
Heaviest ⅓ (362-461 kg)	FP	13	1.39	728	124	2.10	2.33
	HGR	10	11.50	716	97	3.91	2.42
	PEL	13	6.73	743	107	3.38	2.30

Conclusions

These results show that high inputs in cattle feeding are often not profitable and benefits will depend on the market value of the meat.

Recommendations

If pen feeding is used, it should be for short periods and should result in high live-weight gains to remain profitable.

Cull cows in pens at Katherine Research Station

1.21 Cell Grazing of Improved Pastures for Increased Beef Production and Soil Carbon Sequestration

Contact: Tim Schatz

Collaborating staff: Cameron Heeb, Chris Hazel, Damien Bethel, Peter Shotton, David Ffoulkes and Spud Thomas.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Completed.

This project compared the effects of set stocking and cell grazing regimes on animal and pasture production, pasture composition and sequestration of soil organic carbon. The trial started in mid-2009. Over the first six years (2009-15) animal performance (live-weight gain) was higher both per head and per hectare (ha) under set stocking than under cell grazing (see Figures 1 and 2). In mid-2015, some changes were made to increase the number of paddocks in the rotation and increase the rest period for paddocks between grazes so as to improve weight gain in the cell group. During the first six years, there were three treatment groups: cell grazing in a 26-paddock rotation (cell), three replicate paddocks set stocked at a constant stocking rate of 1.5 animals per ha or 1.2 animal equivalent (AE) per ha (each animal is about 0.8 AE) (SSC) and three replicate paddocks set at a variable stocking rate that is the same as the effective stocking rate as the cell group (SSV). From mid-2015 the SSC group was discontinued and its three paddocks were added to the cell group, which increased the number of paddocks in the cell rotation to 29 and added three extra days rest for paddocks between grazes in the wet season and nine extra days in the dry season. In 2016-17 and 2017-18 another large paddock (33 ha) was added to the cell rotation so that the minimum time between grazes was 34 days in the wet season and 102 days in the dry season. Producer feedback in 2016 suggested that it would be a good idea to run the cell group at a lower stocking rate during the dry season and increase it during the wet season. This was done and as a result, in 2016-17 the overall stocking rate throughout the year was lower in the cell group than in the SS paddocks. Despite this, in 2016-17 animal growth was still higher both per head and per ha in the set stocking (SSV) group and so the stocking rate in the cell group was further reduced during 2017-18 while the stocking rate in the SSV group remained the same. Table 1 shows the start and finish dates and the stocking rate of each group in each year.

Results

Table 1. The periods of grazing, average initial weight of cattle and stocking rates in each year

Year	Start date	End date	No. of days	Avg. initial weight (kg)	SS^C Stocking rate (head/ha)	SS^V stocking rate (head/ha)	Cell stocking rate (head/ha)
2009-10	1/09/2009	9/6/2010	281	188	1.5	1.33	1.33
2010-11	9/6/2010	21/6/2011	377	155	1.5	1.67	1.67
2011-12	19/7/2011	4/7/2012	351	179	1.5	1.83	1.83
2012-13	18/7/2012	13/5/2013	299	180	1.5	1.83	1.83
2013-14	31/7/2013	12/6/2014	316	183	1.5	1.5	1.5

Year	Start date	End date	No. of days	Avg. initial weight (kg)	SS^C Stocking rate (head/ha)	SS^V stocking rate (head/ha)	Cell stocking rate (head/ha)
2014-15	3/7/2014	19/6/2015	351	167	1.5	1.33	1.33
2015-16	7/7/2015	3/6/2016	332	173		1.33	1.33
2016-17	19/7/2016	7/6/2017	323	179		1.33	1.27
2017-18	8/8/2017	29/5/2018	294	162		1.33	1.16

During every year of the trial, animal performance (live-weight gain) was higher, both per head and per ha in the SS group than in the cell group. In the first six years, when there were two SS groups, live-weight gain per head was highest in the SS treatment with the lowest stocking rate, and live-weight gain per ha was highest in the SS treatment with the highest stocking rate (Table 2 [stocking rates can be referenced from Table 1]). In the last three years of the study, there was only one SS group (SSV) and annual live-weight gain was higher both per head and per ha in this group. During all years, live-weight gain was 18.5 kg higher per head and 42.1 kg higher per ha in the SSV group than in the cell group (Table 2). Figures 1 and 2 conclusively show live-weight gain per animal and per ha was higher in the SSV group in each year of the trial.

Table 2. Total live-weight gain (fasted animal weights) during the post-weaning year in each group in each year

Year	Avg growth/head (kg)			Avg growth/ha (kg)		
	SS^C	SS^V	Cell	SS^C	SS^V	Cell
2009-10	132.7	137.3	114.6	199.0	183.0	152.9
2010-11	186.0	174.0	161.2	279.0	289.9	268.6
2011-12	167.7	151.9	119.9	251.6	278.5	219.9
2012-13	135.6	138.0	122.1	203.4	253.0	223.8
2013-14	141.2	139.4	127.3	211.8	209.0	191.0
2014-15	148.8	150.6	134.6	223.2	200.7	179.4
2015-16		157.7	125.2		209.7	166.6
2016-17		165.8	100.5		221.0	127.9
2017-8		150.8	118.0		200.5	136.9
Avg. all years	152.0	148.5	130.0	228.0	227.3	185.2

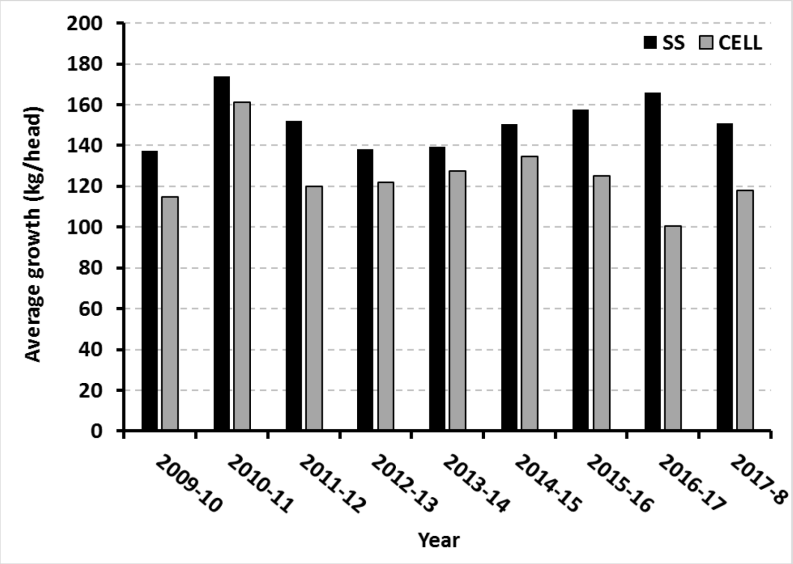


Figure 1. The average live-weight gain per head in the SS^V and cell groups

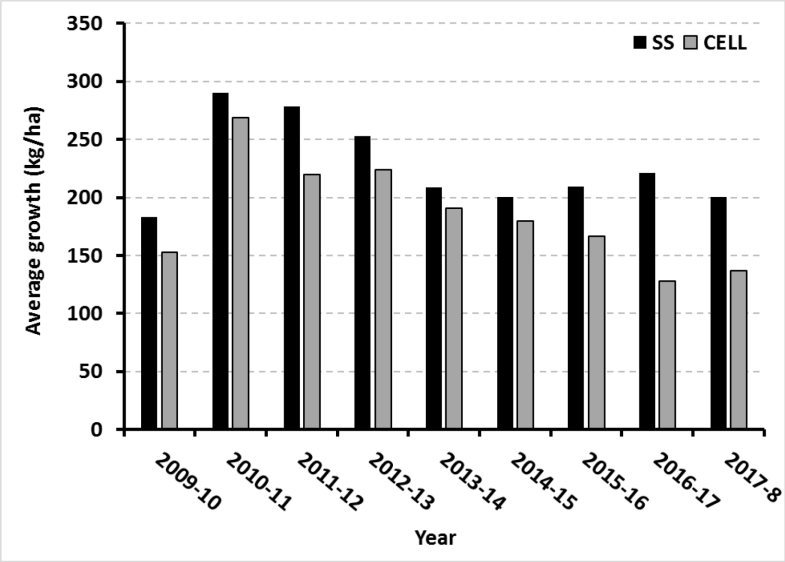


Figure 2. The average live-weight gain per hectare in the SSV and cell groups

Conclusions

Conclusions will be reported next year when statistical analysis is completed.

Cattle in one of the set stocked paddocks in January 2018

Cattle in the cell group in January 2018

2 Plant Industries

2.1 An Assessment of the National Mango Breeding Cultivars

Contact: Cameron McConchie

Collaborating staff: Tony Asis, Ali Sarkosh, Maddison Clonan, Mark Hoult, Nickolas Anderson, Alan Niscioli and Heather Wallace.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Commenced.

The national mango breeding program (NMBP) selected three elite mango cultivars to produce 20 000 plants by 2018. As cultivar Kensington Pride (KP) productivity declined and other cultivar productivity increased in the Northern Territory, local growers have shown considerable interest in the new cultivars. To support commercialisation of the NMBP cultivars, this project is investigating their nutritional and production needs and responses to phytosanitary treatment. Harvest maturity, fruit texture and colour, and gamma irradiation trials to meet export requirements will be conducted in due course. The effect of rootstock/scion growth on leaf nutritional content of NMBP cultivars 1243, 1201 and 4069, KP and B74 was examined.

Results

Growth in mango plants varied with rootstock/scion combinations. NT 117 can be used as a rootstock to obtain low-vigour trees for high density planting as they had the smallest canopy size, were short and had small trunk diameter. High-vigour trees resulted from scion cultivars grafted onto rootstocks NT 16, NT 63 and NT 50 as the trees were taller, had larger canopy size and wider trunk diameter. Among scions, NMBP 1243 and B74 can produce low-vigour trees across all rootstocks. Grafting NMBP 4069, NMBP 1201, or KP onto any rootstock produced trees with larger canopy size and wider trunk diameter.

Mango rootstock trial trees soon after planting at Katherine Research Station

Measuring mango flesh colour using a Minolta chromameter

2.2 An Outbreak of Citrus Canker

Contact: Lucy Tran-Nguyen

Collaborating staff: Jose Liberato, Lorenzo Meschiari, Sharl Mintoff, David Lovelock, Merran Neilsen, Nadine Kurz and Shreya Patel.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

3.6 Deliver strong surveillance and monitoring programs to ensure protection against threats and incidents.

Project Status: Commenced.

Citrus canker, which is an exotic plant pathogen caused by *Xanthomonas citri* subsp *citri,* was detected in the Darwin area in April, 2018. Plant samples were examined using microscopic and molecular techniques based on the National Diagnostic Protocol to achieve high levels of containment (Quarantine Level 3 and Physical Containment Level 2). There has been a continued effort since the outbreak was reported to identify infected plants in order to eradicate the disease.

Results

Citrus canker was identified on 11 premises and control measures were initiated.

Citrus canker on young citrus seedlings

2.3 Optimising Foliar Nitrogen Uptake in Mango Trees: The Effect of Adjuvant, Leaf Position and Time of Potassium Nitrate Spray

Contact: Constancio (Tony) Asis

Collaborating staff: Cameron McConchie, Teagan Alexander, Marije ten Napel and Ali Sarkhosh.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

Mango growers regularly apply foliar potassium nitrate (KNO_3) to promote flowering, especially during the off season (Barba, 1974; Bondad and Lisangan, 1979; Yeshitela et al., 2005). Flowering is the first of several events that set the stage for mango production. The timing and intensity of flowering determine when and how much fruit is produced. By controlling flowering time and intensity of flowering, growers are able to harvest their crops at the most profitable time. Reliable flowering is necessary for consistent mango production (Davenport, 2009). The role of KNO_3 in flowering is not fully understood. Growers apply varying spray concentrations of KNO_3, which may contribute to inconsistencies in the response of trees to it. Therefore, it is necessary to explain the factors that optimise the uptake of KNO_3 by mango trees. The project attempts to determine the effect of an adjuvant, leaf position and time of application on the leaf nitrogen (N) content in Kensington Pride mango trees.

The soil type at Katherine Research Station is haplic mesotrophic red Kandosol (Isbell, 2018) with 6% clay, 19% silt, 75% sand and sandy loam soil texture. The soil had 1.35% C, 0.08% total N, pH 6.0, electrical conductivity 78.2 µS/cm and cation exchange capacity of 12.0 cmol+/kg of soil. The study was a 2 x 2 x 4 factorial experiment arranged in randomised complete block design with five replications. The treatments included spraying to run-off 3% KNO3 with 0, 100, 250 and 500 mL adjuvant Li-700/100 L solution on tagged mango terminals from the east (sunny side) and west (shaded side) of trees in the morning (8 am) or night (8 pm) in the east-west orientated rows of trees (Figure 1). Ten trees were used, five for morning spraying and five for night spraying. In each side of the tree, 20 leaf terminals with growth stages of BCCH scale 319 (Rajan et al., 2011) were tagged and labelled according to the treatment. Spraying was done on both sides of the leaves and leaf terminals were covered with a bag to avoid contamination from spray drift. Leaf samples were collected at 4, 12, 24, and 48 hours after spraying (HAS), rinsed thoroughly with running water and washed with distilled water. Samples were oven-dried at 60° C until constant weight, ground and analysed for total N using the Kjeldahl method (Bremner and Mulvaney, 1982). The N content of the leaf samples was statistically tested using analysis of variance (ANOVA) with means separation at 5% LSD (Statistical Tools for Agricultural Research version 2.0.1 software (http://bbi.irri.org)).

Results

Total N contents were comparable in the mango leaves across rates, time of application and location of the leaves at 4 and 12 HAS but varied significantly at 24 and 48 HAS. The total N content of leaves varied significantly with time of application, which was observed 24 HAS KNO_3. The total N in the leaves differed with the time of KNO_3 spraying (Figure 1). N content was higher in the leaves sprayed in the evening, than in those sprayed in the morning. This difference could be attributed partly to the higher ion penetration during the night due to cooler temperatures and higher relative humidity. According to Schönherr et al. (2005), foliar penetration of salts requires very high humidity, which is expected to be highest when dew occurs at night. Stagnant air layers over stomatous leaf surfaces at low wind velocities will favour penetration when the humidity in bulk air is 100% or lower. Moreover, at high relative humidity, drying of the salt deposit is delayed and cuticle permeability may increase through hydration (Schönherr and Luber, 2001).

Total N content was higher in mango leaves in the western side than in the eastern side of the tree at 24 and 48 HAS (Figure 2), indicating a higher N use efficiency in the leaves in the western than in the eastern part of the tree. N use efficiency diminishes at higher irradiance and may be enhanced at low irradiance (Evans, 1989a; Rosati et al., 1999). Seemann et al. (1987) also reported greater N partitioning to RuBP carboxylase at low irradiances in *Phaseolus* and *Alocasia* plants. Leaf N content is closely correlated with leaf photosynthetic capacity and N use efficiency in several species (Field and Mooney, 1986; Hirose and Werger, 1987). Moreover, when light is the cause of variation in leaf N content, the photosynthesis to N relationship shows great scatter because of partitioning of N among the different N fractions (Evans, 1989b; Rosati et al., 1999). Acclimation to low light was reported in many species in combination with a decline in the rate of N transferred in electron transport and carboxylation proteins (Terashima and Evans, 1988; Evans, 1989b). Field (1983) also indicated that N could be allocated in a plant canopy once the marginal increase in assimilation with a rise in N was continuous in the canopy. This theory is supported by various studies on N allocation in diverse tree and crop species suggesting that more N is allocated to the higher irradiance on the top of the canopy (Ellsworth and Reich, 1993; Hollinger, 1996). The result also indicates that leaf position is a significant factor during leaf sampling to evaluate the nutrient status after foliar application.

The addition of adjuvant LI-700® also increased the total N content at 48 HAS. However, total N content did not vary significantly with different levels of adjuvant, such that total N content in leaves applied with 1 mL LI-700®/L of KNO_3 spray solution was similar to those applied with 2.5 mL, and 5 mL/L of KNO_3 spray solution, respectively (Figure 3). This result indicates that for foliar application of 3% KNO_3 the small amount of at least 1 mL/L spray solution is enough to provide an adjuvant effect on N uptake from KNO_3. This amount is substantially lower than the recommended rate of 3 mL/L by the manufacturer (https://www.garrards.com.au/images/stories/zone_files/labels/spraymate_li_700_24107840.pdf).
Adjuvants improve the physicochemical characteristics of the spray solution and consequently increase the effectiveness of foliar sprays (Stagnari, 2007). Adjuvants also reduce the surface tension between the liquid and leaf, which leads to an increase in leaf wetting (Somerville et al., 2014). The surfactant group of adjuvants reduces the air layer between the liquid and leaf surfaces, increases penetration of solutes through the stomata, cuticle membranes and the cell walls and limits the drying of droplets (Wojcik, 2004).

The study has shown that leaf N content was higher in leaves that were sprayed with an adjuvant than in those sprayed without an adjuvant; also N content was higher when the spray was applied in the evening. Total N content was higher in the leaves in the shaded part of the tree than in that exposed to sunlight. To conclude, the results indicate that the addition of an adjuvant and spraying in the evening assist N uptake in mango leaves.

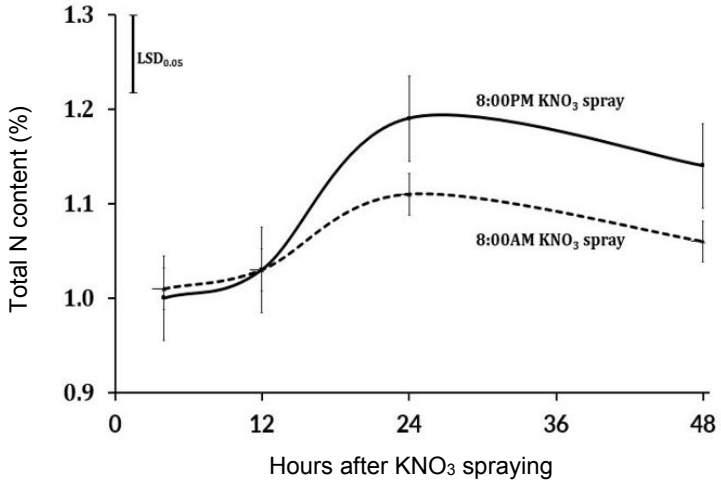


Figure 1. Changes in the total N content of mango leaves as influenced by KNO_3 spray

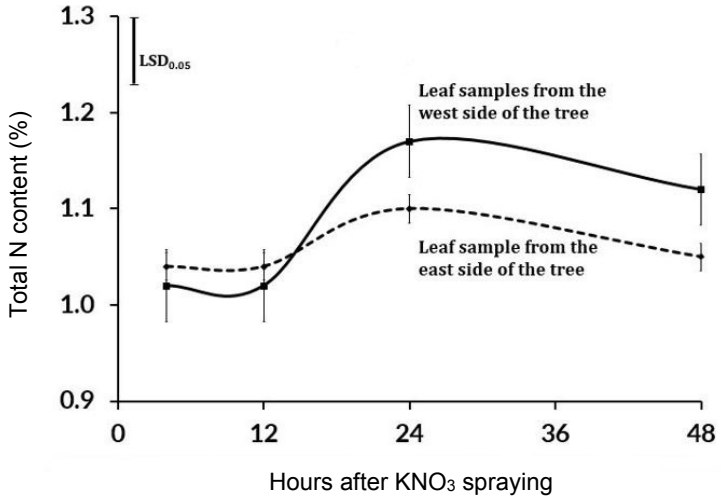


Figure 2. Changes in the total N content of mango leaves from the west and east part of the tree as influenced by KNO_3 **spray**

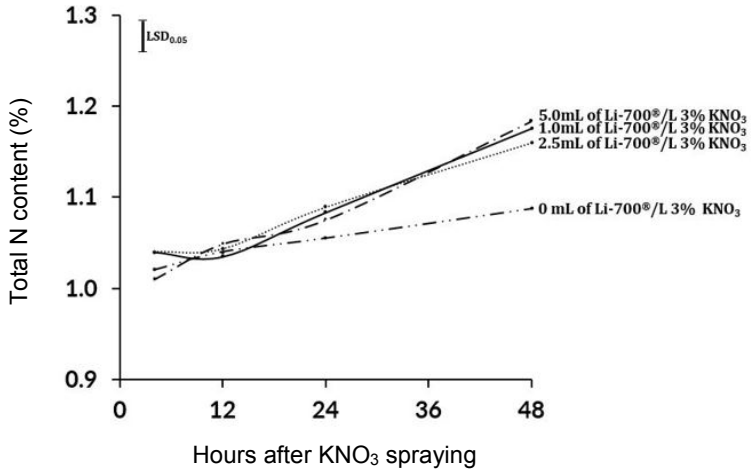


Figure 3. Changes in the total N content of mango leaves as influenced by KNO_3 spray with varying level of adjuvant Li-700®

2.4 Investigating the Spread of CGMMV in Infected Soil and its Transmission through Weeds

Contact: David Lovelock

Collaborating staff: Nadine Kurz, Merran Neilsen, Shreya Patel and Lucy Tran-Nguyen.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

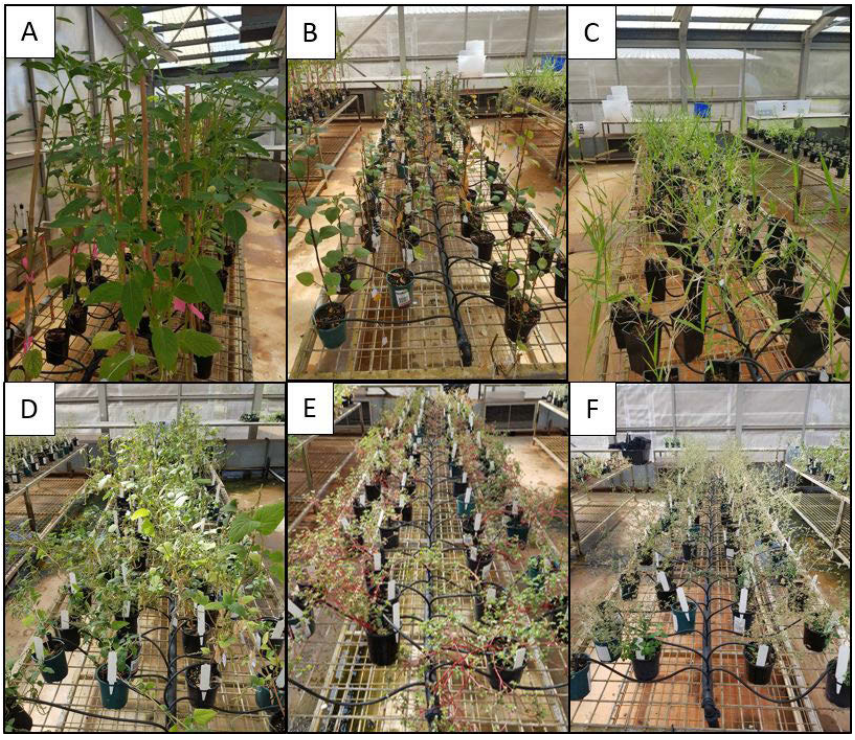
1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

This project is examining the transmission of the cucumber green mottle mosaic virus (CGMMV) through infected soil and potential weed hosts to crops. This is to highlight the need to keep host plants and weeds away from contaminated soils. Contaminated soil limits the ability to produce disease-free crops. Sowing cucurbit seeds and seedlings in infected soil can indicate the effect of CGMMV by determining the number of infected plants. Since the spread of the virus is through mechanical means, determining the likely transmitter is critical to control the virus. Studies indicated a larger weed host range than first reported. In 2017-18 the presence of the virus was examined in several weeds and grasses, such as *Physalis minima* (wild gooseberry), *Solanum nigrum* (black nightshade), *Urochloa mosambicensis* (sabi grass), *Amaranthus viridis* (amaranth), *Portulaca oleracea* (pigweed) and *Chenopodium album* (fat hen).

Results

Watermelon plants grown in infected soil had an infection rate of 5% after 12 weeks from germination. Weed species that were inoculated with CGMMV had low infection levels across all species. The results indicate that weeds probably do not suffer systemically from CGMMV and may only show localised infection.



Weed and grass pot trials for *Physalis minima* (native gooseberry) (A), *Solanum nigrum* (black nightshade) (B), *Urochloa mosambicensis* (sabi grass) (C), *Amaranthus viridis* (amaranth) (D), *Portulaca oleracea* (pigweed) (E) and *Chenopodium album* (fat hen) (F)

Watermelon seedlings growing in contaminated soil

2.5 Rice and Soybean Small Plot Trials

Contact: Ian Biggs

Collaborating staff: Nick Hartley, Peter Shotton, Arthur Cameron and Callen Thompson.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.13 Align our research, development and extension with industry needs.

Project Status: Continuing.

Ten cultivars of rice were planted at Tortilla Flats in the 2017 dry season. Due to varietal selection, most cultivars had different maturity/harvest dates. The harvest period commenced in September and finished in October. Three sub plots were hand-harvested and the crop was weighed. The samples were threshed and slowly dried to maintain grain quality. The remaining areas were then machine-harvested. Grain sub samples from each variety were cleaned and sent for quality assessment. Soybeans were also planted in a small plot in the caged area at Tortilla Flats in June and harvested in October, 120 days after sowing. A number of plots were randomly hand-harvested. The samples of plant material and grain were dried, processed and weighed.

Results

Early field observations at rice harvest indicate that there will be large variability in yields, which is expected when conducting varietal screening for suitable lines.

The results from the soybean trial will be evaluated.

Soybean plants

2.6 Developing New Varieties of Ornamental Curcuma through Mutagenesis

Contact: Doris Marcsik

Collaborating staff: Heather Wallace, Peter Bergin and Mark Hoult.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Continuing.

This project follows the RIRDC project titled "Investigating Closed Production Systems for Ornamental Ginger Production". The nursey industry identified a number of hybrids from DPIR's *Curcuma* germplasm, which had desirable attributes for production as potted plants. The industry is interested in the commercialisation of some of these hybrids and also the development of new varieties. However, this is difficult at the moment as most of the hybrids are sterile. To overcome the problem, a preliminary trial was conducted using the mutation technique of gamma irradiation to determine the optimal lethal dose (LD_{50}) for radio-sensitivity of the plant and the effect of induced mutation on three *Curcuma* hybrids. The sensitivity of the three *Curcuma* hybrids to radiation was evaluated by comparing the mortality rate of irradiated plants at about 40 days after irradiation.

Results

Plant mortality rate increased with increasing irradiation. No plants survived at the highest dose of 75 Gy. The survival rate in the three hybrids ranged between 60% and 90% at 30 Gy. Leaf aberrations, such as shape and chlorophyll mutations, were the main changes in plant morphology. Flower shape and colour changed in plants that survived higher doses of irradiation. A trial will now look at *in-vitro* mutagenesis using gamma irradiation, for which *Cucurma* hybrids are being multiplied in tissue culture.

Curcuma plant displaying split leaves and strong variation in green colour intensity from effects of gamma irradiation

Non-treated Curcuma inflorescence (A) and a mutant inflorescence (B)

2.7 Intensive Cropping Systems in the Douglas Daly District

Contact: Peter Shotton

Collaborating staff: Robert Parker, Chris Hazel and Cameron Heeb.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

The project is using irrigation during the dry season to rotationally grow grain and fodder crops year round in the Katherine-Daly region. The project will assess suitable crop agronomy, phenology and yield to prepare guidelines for economic industry best practice. Earlier attempts to grow forage sorghum, lablab and guar failed due to nematode infestation, bird damage and wild fire.

Results

The 2017 irrigated sorghum grain yield was 2.4 tonnes (t)/hectare (ha) and the 2017-18 wet season mung yield was 1.7 t/ha. The forage sorghum will be harvested later.

Uneven growth in a sorghum crop at the Douglas Daly Research Farm

Maize harvesting at Douglas Daly Research Farm

2.8 The Banana Plant Protection Program (BA10020)

Contact: Sharl Mintoff

Collaborating staff: Vu Tuan-Nguyen, Lucy Tran-Nguyen, Samantha Cullen, Chris Kelly, Kenny Haycock and Doris Marcsik.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

3.6 Deliver strong surveillance and monitoring programs to ensure protection against threats and incidents.

Project Status: Continuing.

Panama disease, which is caused by *Fusarium oxysporum* f.sp. *cubense* (Foc) Tropical race 4 (TR4), is a major threat to the Australian and global banana industries, as its hosts include most of the commercially important banana varies. Foc TR4 is endemic in the Northern Territory and is a major threat to the local banana industry and of extreme concern to the interstate banana industries. The project is screening a banana variety at Coastal Plains Research Farm to identify resistant or tolerant cultivars to Foc TR4, which could be used to improve resistance in particular varieties. The project is also investigating if Foc TR4 moves undetected through tissue culture from material collected from an infested field.

Results

Several banana varieties have been identified as resistant to Foc TR4, including Cavendish varieties CJ19, GCTCV 215 and 217. Variety FHIA 02 is also resistant. No Foc TR4 tissue culture was detected in subsequent potted plants.

Susceptible Cavendish varieties

Highly tolerant Cavendish varieties

Susceptible and tolerant/resistant varieties exposed to Foc TR4

The above pictures show susceptible varieties with classic signs of panama disease (leaf yellowing and wilting followed by death) and tolerant/resistant varieties appearing healthy.

Potted tissue culture banana plants which originally had been collected from contaminated land and put through tissue culture and screened for Foc TR4

2.9 Facing Fusarium: Better Banana Biosecurity (BA14013)

Contact: Sharl Mintoff

Collaborating staff: Vu Tuan Nguyen and Lucy Tran-Nguyen.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

3.6 Deliver strong surveillance and monitoring programs to ensure protection against threats and incidents.

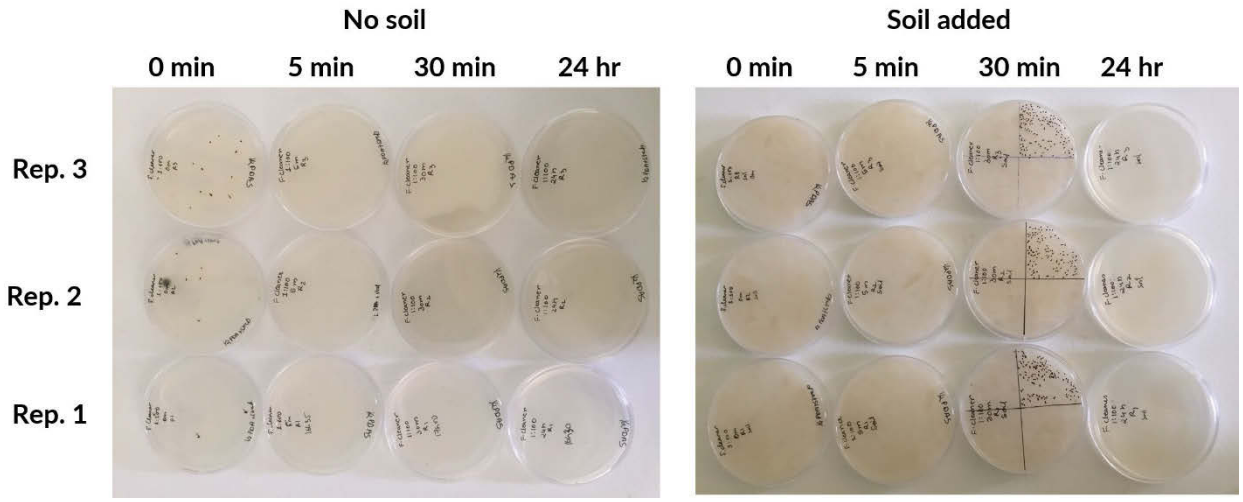
Project Status: Continuing.

The project is attempting to find the most effective disinfectants for decontaminating tools, machinery and footwear, as well as develop a PCR assay to detect and monitor levels of Foc TR4 in the soil. A number of disinfectants were tested for their ability to inhibit Foc spore germination in the presence or absence of soil and were tested against spores of Race 1 and TR4. We are only testing the TR4 component of this trial. The project is also helping to create and validate a PCR assay that can determine the presence and quantity of Foc TR4 in soil samples.

Results

A TR4 soil PCR assay has been developed and is currently being tested for its sensitivity and specificity. Disinfectants containing quaternary ammonium compounds provided the best inhibition of *F. oxysporum* spore germination, both in the presence and absence of soil.

Initial tests clearly show differences in Foc TR4 levels between susceptible and resistant varieties. The results are being used to measure pathogen levels in the soil.



A representative photo of colony development on ½ PDAS following treatment of *Foc* TR4 with a disinfectant for 0, 5, 30 minutes and 24 hours in the absence and presence of soil

2.10 Fusarium wilt Tropical Race 4: Beyond the First Response (BA14014)

Contact: Sharl Mintoff

Collaborating staff: Vu Tuan Nguyen, Lucy Tran-Nguyen, Samantha Cullen, Chris Kelly, Kenny Haycock and Doris Marcsik.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

3.6 Deliver strong surveillance and monitoring programs to ensure protection against threats and incidents.

Project Status: Commenced.

The project focuses on the management of TR4-infested sites. Weed species were identified and collected from different properties that were known to be infested with Foc TR4. It will be attempted to reduce the amount of inoculum in the soil through a crop rotation field experiment using various crops and will be compared with bare or fallow sites. The first variety (GCTCV 119) and the second variety (Dwarf Nathan) of mutagenesis trial plants were planted and the third (CJ19) variety is expected to be planted later in the year.

Results

There are no results yet.

First variety of the mutagenesis trial, GCTCV119 planted at CPRF in June 2017

Alternative host pot trial at Coastal Plains Research Farm

2.11 Evaluation of Quinoa Varieties in Central Australia

Contact: Sarah Tsai

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Completed.

This project was part of a national quinoa production program. Two quinoa varieties were grown in Alice Springs in 2017 and 2018. The first trial was planted as an autumn crop and the second as a spring crop. Yield and seed quality were analysed in conjunction with the Department of Food and Agriculture, Western Australia.

Results

The best quinoa seed was from Alice Springs, based on kernel quality and amino acid content. However, yield in Alice Springs was poor as the autumn-sown crop was affected by frost and the spring-sown crop was affected by high temperatures at flowering.

Conclusion

Quinoa was a risky crop to grow in Central Australia due to heat and frost. However, the good quality seed produced means Central Australia is a potential quinoa seed-producing area.

Heat damage on quinoa (December 2017)

2.12 The Effect of Recycled Water Irrigation on the Soil at the Arid Zone Research Institute

Contact: Sarah Tsai

Collaborating staff: Roojan Bista, Callen Thompson, Dylan Williams and Simon Carr.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

Recycled water was used for irrigation to determine its effect on the soil. Initially, the recycled water quality was Class B, but following wastewater treatment, it has become Class A. Lucerne was grown at the time as it can be used in livestock projects. The water has significant levels of nitrogen, potassium, magnesium, calcium, bicarbonate, copper, zinc and iron, and is reasonably saline and alkaline. The effect of these elements on the soil on which lucerne is grown will be evaluated. The results will provide the producers of the water with marketing information for selling the water. The fodder industry in Central Australia is small but has the potential to expand. Shortage of irrigation water is one of the biggest constraints to the development of the industry. There is some hesitation to use recycled water, especially on plants for human consumption. This project will help gather information to reliably inform the community of the effects of using recycled water on the soil and generally on agriculture.

Results

Salt has accumulated in the soil over time, but there was no obvious effect on the lucerne crop, which is being used to feed livestock in other projects.

2.13 Rural Research and Development for Profit: Optimising Nutrient Management for improved Productivity and Fruit Quality in Mangoes

Contact: Mila Bristow

Collaborating staff: Tony Asis, Joanne Tilbrook, Alan Niscioli, Dallas Anson, Maddison Clonan and Matt Hall.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

Nitrogen (N) is an essential nutrient for mango production and quality. The cost of N fertiliser constitutes a major part of farming costs. Mangoes are a significant tree crop in tropical Australia, annually valued at $140 million (http://www.industry.mangoes.net.au/mango-production/). There is little information on mango plant requirements for N and N losses due to current management. The ability to mitigate N losses is limited by a poor understanding of mango plant N requirements and effective management options. This project is attempting to quantify N needs of mango plants and reduce N losses through the soil-plant-atmosphere to improve mango productivity. Stable isotopes are used to quantify plant N needs, soil N availability and the effect of current practice on N utilisation and losses. The results should help to develop better management practices to optimise N fertiliser use, improve productivity and reduce negative environmental effects. Leaf N content is commonly measured in commercial orchards to indicate N requirement. However, leaf N content changes throughout the year. Over the last six months, we conducted a range of trials to understand N storage and movement linked to the phenology of mango trees. A rapid labelling method was developed to obtain direct quantitative information on leaf uptake of N from fertiliser. The xylem infusion method was able to rapidly create ^{15}N labelled mango litter. To achieve the target enrichment level, we tested several infusions using a lower-enriched fertiliser (10 atom%). At 10 days after infusion of 40 g N, some leaves fell off. Further infusions successfully labelled the mature leaves to 3 atom% ^{15}N and the new leaves to 5 atom% ^{15}N. With the method now established, we are using the technique to quantify the effect of N levels on fruit quality on a commercial orchard. Using mature Kensington Pride (KP) mangoes, we started a trial to measure the effect of the rate of N applied on fruit quality. To ensure we get rapid results in the timeframe of the project, we are using N xylem infusion. The trial is investigating replicated trees with variable rates of N (0, 50, 100, 200 g N/tree), applied post-harvest and following regular seasonal pruning in January-February. Observations include monthly sampling of new leaves produced on labelled branches and monitoring terminal bud and floral development (May – August), with planned replicate fruit to be sampled and assessed for quality during the 2018 harvest (November-December). An accurate determination of mango yield parameters, such as fruit weight (kg/tree) and fruit number prior to harvest, can greatly assist growers to determine harvest logistics, such as labour, equipment, packing, storage, transport and forward selling. Tree crown areas (TACs) were measured from 30 cm-resolution WorldView 3 satellite imagery. Eighteen trees per orchard were selected for ground-truthing the imagery and to establish an 'orchard specific algorithm' between the yield parameters to TCA and a number of vegetation indices were derived from the canopy reflectance values. Using this algorithm, a yield prediction for the rest of the trees in the orchard was made. This process was applied to a number of mango orchards in the Northern Territory (NT) and Bundaberg (Queensland) growing regions during the 2016 and 2017 harvest seasons. Mango leaf litter is also believed to be a major N contributor in mango growing soils and its combined application with urea can significantly contribute to soil N_2O and CO_2 production under high rainfall and temperature conditions of the tropics. This is being examined in a trial at Coastal Plains Research Station and the Katherine Research Station in KP mango trees. Soil characteristics for the two areas are shown in Table 1.

Results

We can now use the xylem infusion technique to measure timing of movement of N through short-term sampling over hours and days; quantify cycling/recycling of N through longer-term sampling over weeks, seasons and years; develop a collection method for xylem sap; quantify N content in xylem sap and analyse it for N and ^{15}N.

These trials characterised N content and movement within mango trees at critical developmental time points. They provided baseline data relative to current grower fertilisation practices. They rapidly develop labelled leaves for decomposition studies. The commercial orchard trials will allow fruit quality to be assessed on mature productive trees, providing direct information to growers on the effect of N application rates on mango production.

In summary, the project is striving to deliver three major outcomes:

- Greater knowledge and understanding of the interplay of soil, weather, climatic and farm management factors to optimise N formulation, rate and timing across industries and farming regions in mango.
- Greater knowledge and understanding of the contribution (quantifying rate and timing) of mineralisation to a mango's nitrogen budget.
- Greater knowledge and understanding of the role of N in mango fruit quality.

This research is a part of the "More Profit from Nitrogen: enhancing the nutrient use efficiency of intensive cropping and pasture systems" program and is supported by funding from the Australian Department of Agriculture and Water Resources as part of its Rural R&D for Profit program, Cotton Research and Development Corporation, Dairy Australia, Sugar Research Australia, and Horticulture Innovation – https://www.crdc.com.au/more-profit-nitrogen.

A mango tree with highly ^{15}N enriched litter from leaves caught in a net, Katherine Research Station

Preparing the labelled N solutions (left) and using the xylem infusion method to directly infuse labelled N into the mango xylem for transmission around the plant (right)

2.14 Optimise Silviculture in High Value Mahogany Plantations

Contact: Mila Bristow

Collaborating staff: Dallas Anson.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Project Status: Continuing.

African mahogany (*Khaya senegalensis*) is an internationally important high-value forest tree species. Trials in northern Australia have demonstrated significant potential for plantation expansion. Commercial plantation establishment commenced in 2006 in the Northern Territory and covers about 14 000 hectares. The project's objective is to promote commercial and environmental outcomes for the industry by providing optimum production information.

Results

The main constraint to productivity in the dry tropics is shortage of water. The strong understory and weeds are significant competitors to trees for water and nutrients during the wet season. Productivity varies depending on topography, soil water-holding capacity and fertility.

Integrating cattle grazing with low-density plantations reduces weed and understory competition, fuel load, wild fire risks and provides an extra source of income to the enterprise.

2.15 Evaluation of Garlic Production in Central Australia

Contact: Sarah Tsai

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Project Status: Completed.

Garlic production has potential in Alice Springs because of its relatively low latitude (23° South), particularly when Australian-grown garlic is in short supply in domestic markets. Onions have been successfully grown in commercial trials in recent years in Alice Springs and Ali Curung. Nine garlic varieties were grown in autumn in 2016 in association with Australian garlic producers and the Queensland Department of Agriculture, Forestry and Fisheries.

Results

Garlic will grow in Alice Springs, but the correct varieties need to be selected to exploit markets. Glen Large had the lowest yield. This variety did not recover after herbicide spray with ioxynil and methabenzthiazuron. All other varieties did not have appreciable symptoms of herbicide toxicity. Of the other varieties, only AF showed promise as an early variety that could fill a niche in the Australian market in October. Yields were not large, but bulb size was reasonable. One reason for low yields may have been the use of saline water (3460 uS/cm), which showed symptoms of leaf end necrosis. Domfield had large bulbs and the highest yield, but quality was poor. In storage, the bulbs developed penicillium mould. Domfield did not produce bulbs until around two months after AF, at a time of the year when the weather was quite hot. The other minor varieties, such as Ger, Mof, Cas, WHT and AUP, did not bulb well, but yield was high; however, bulb quality was poor.

Conclusion

There were some encouraging results, but it may be years of trials before garlic production is established in Central Australia.

Recommendation

It is recommended that variety AF be further improved for small scale production.

Greenhouse drying of garlic variety AF on racks

Garlic variety maturity (October 2016)

2.16 Building a Resilient Mango Industry in Cambodia and Australia through improved Production and Supply Chain Practices

Contact: Cameron McConchie

Collaborating staff: Brian Thistleton, Lucy Tran-Nguyen and Maddison Clonan.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.12 Co-innovate with stakeholders to leverage our research and development capability.

Project Status: Completed.

This ACIAR-funded project focused on mango production, phytosanitary requirements for export and pest and disease management. This assists Australia against potential disease incursions. The effect of ethephon, potassium nitrate and thiourea on leaf flushing and flowering in Kensington Pride (KP) mangoes was studied.

Results

Thiourea effectively increased flowering in seasons with high temperatures, which usually reduce normal flowering. Ethephon removed unwanted flush growth and maximised synchronised bud growth. The project also identified a number of genes that regulated flowering in mango trees, such as *Arabidopsis thaliana*-specific flowering genes. A range of chemical treatments capable of manipulating mango flushing to improve mango flowering in the Northern Territory (NT) have been identified. Precise descriptions of the temperatures that initiate flowering in major commercial cultivars have enabled growers to target maximum mango flowering. The results have demonstrated that flowering in KP can be increased by using thiourea in the absence of cold conditions. The project has also shown that potassium nitrate increases flowering in KP trees when used during cool conditions and also demonstrated that ethephon can be used to reset flushing patterns in KP mango trees and can also be used to delay vegetative flushing. Scholar® used at 52 ^{0}C to control stem end rot caused scalds and slightly reduced infection. In contrast to published data, vapour heat treatment was effective in reducing these forms of rots in Cambodia.

Conclusions

Chemical treatment can manipulate flushing to improve flowering in mango trees.

Recommendations

Further research is needed to quantify the level of cool conditions needed to initiate flowering in Cambodian mango cultivars. More environmentally acceptable and safe chemicals are needed to initiate flowering in mango trees to maintain production in tropical regions to sustain production. The identified chemical treatments should be used in mango farms in the NT.

2.17 Commencing Projects

Evaluating Ginger Production in the Northern Territory

Contact: Cameron McConchie

Collaborating staff: Nick Hartley, Mark Traynor, Mark Hoult, Doris Mausik and Chris Kuo.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Ginger is currently grown by 45 farmers on about 8000 hectares in coastal south-east and northern Queensland, valued at $20 million. About 60% of the product is consumed fresh locally and the rest is exported in confectionery and as spice. Ginger is susceptible to pathogens associated with water-logging, including *Pythium* and *Fusarium*. The project will examine the possibility of growing disease-free ginger in the Northern Territory during the dry season to supply the local fresh market and planting material for the Queensland industry. Gold and Canton varieties from Queensland were grown in a decontaminated sterile tissue culture in a nursery for multiplication. An area has been prepared for growing the crop.

Management of Vegetable Diseases: Viruses and Bacteria (VG16086)

Contact: Lucy Tran-Nguyen

Collaborating staff: Brian Thistleton and Haidee Brown.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018 2022:

3.6 Deliver strong surveillance and monitoring programs to ensure protection against threats and incidents.

The project will investigate the effect of viruses, bacteria and phytoplasmas on vegetable production in the Northern Territory and develop on-farm rapid diagnosis and treatment. It will also monitor the effect of insect populations and the weather on the prevalence of diseases.

Evaluation of Self-pollinating Almond Varieties in Central Australia

Contact: Sarah Tsai

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

1.13 Align our research, development and extension with industry needs.

Self-pollinating almond varieties are a recent event in Australia. The self-fertile, high-yielding and disease-resistant varieties resulted from the efforts of the Australian Almond Breeding Program. Traditionally, almond trees rely heavily on bees for pollination. The USA produces 78.9% of the world's almond crop, mostly from California, which now has areas classified as suffering from severe drought. Australia is the second biggest almond producer in the world with one of the highest per capita consumption rates (1 kg/person/year). Consumption is increasing. Almonds were used in 297 new products in Australia in 2015. Alice Springs and the surrounding area have the chill factors required by almond trees. Although currently there is no commercial production of almonds in Alice Springs, there is potential for future production. We have selected five locations to plant three varieties of almonds to assess their performance in Central Australia. We are still distributing the small trees, which will take five to seven years to reach maturity.

Evaluation of Chinese Dates (Jujubes) in Central Australia

Contact: Sarah Tsai

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.11 Undertake research, development, extension and services to improve the profitability and sustainability of our industries.

Chinese date *Ziziphus jujuba* Mill. (commonly known as Chinese date, red date, or Hong-Zao) is different from *Ziziphus mauritiana* Lamk. (commonly known as India Jujube, ber, desert apple, Chinese apple, or Indian plum), which is a declared weed in the Northern Territory (NT). Chinese jujube is a hardy plant, which can withstand the harsh environment (extreme heat and cold) of Central Australia. Currently, Western Australia leads in establishing an Australian jujube industry. Studies were conducted in Central Australia on the Indian jujube varieties before they were declared a weed in the NT. Chinese jujubes have a high economic value both internationally and domestically. Four popular varieties are currently grown at the Arid Zone Research Institute. They have high health benefits (higher vitamin C than oranges, for example) and are well-known in the Asian community. With our proximity to South-East Asia and our different seasonal production time to the northern hemisphere, we have a potential to export to Asian countries. Fresh jujube is becoming more popular in the domestic markets too.

3 Market Enterprise Development

3.1 Monitoring Mangoes through the Supply Chain to the United States (2017-18)

Contact: Michael Daysh

Collaborating staff: Generous support from colleagues across several disciplines over the life of this project is acknowledged.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.2 Maintain market access and expand market options for Territory products.

Project Status: Completed.

The project supported the development of a US market for Australian mangoes by monitoring the quality of the fruit through the supply chain to the US consumer. For more details, see the 2015-16 Annual Research Achievements Report.

Results

While there were some quality issues with overheated, overripe, old, out of grade and lenticel- discoloured fruit, most of the Australian mangoes at retail had a very attractive appearance and good flavour, and were very popular with US retailers and consumers. Near real-time feedback of fruit quality in the supply chain was provided to growers and exporters. A post-season debrief was provided to growers, exporters and stakeholders, including a final report.

Conclusions

There are attractive market opportunities for well-flavoured and well-coloured Australian mangoes in the US market. Although high quality Australian mangoes can be delivered to US consumers, there is a need for improved consistency, which requires continued attention to cool chain performance, stage of ripeness at treatment, matching supply to actual demand and compliance requirements.

Recommendations

More work is needed to improve the consistency of the fruit and its condition at arrival in the US. It is recommended that the performance of Australian mangoes be monitored during the cool chain process from the farm to the consumer to identify problems and suggest solutions. Continued attention should be paid to the actual level of retail demand and match supply to demand to minimise the volume of old fruit on display. Continue to monitor compliance requirements.

Darwin grown mangoes on sale in Dallas, Texas

Darwin grown mangoes awaiting irradiation treatment prior to export to the US

3.2 The Feasibility of Commercially Harvesting Agile Wallabies in the Northern Territory

Contact: Warren Hunt

Collaborating staff: Cameron Heeb, Ben Beumer and David Frost.

External collaborators: Agrifutures Australia, Dr Geert Geesink and Mr Aaron Van Den Heuvel (University of New England), Ms Julie Bird (RIRDC) and Mr Duncan Farquhar, Mr Keith Saalfeld (Department of the Environment and Natural Resources), Dan and Sarah Thompson (Ceres Downs), Joe and Catherine Scottney (Garibaldi), Rohan and Sally Sullivan (Cave Creek Station), Chris and Amanda Howie (Bundaroo Station), Phillip and Annette Howie (Maneroo Station) and many others.

Relevant Goal/Strategic Action from the NT DPIR Strategic Plan 2018-2022:

1.1 Promote the potential of our resources and help industry to attract investment.

1.2 Maintain market access and expand market options for Territory products.

Project Status: Completed.

This project investigated the feasibility of commercially harvesting agile wallabies, which are found in large numbers in the Northern Territory (NT). The study, which was supported by Agrifutures Australia, was carried out on developed agricultural land in the Douglas Daly region of the Top End of the NT. It investigated the possibility of a game meat business based on wallabies to provide economic development as well as to mitigate their impact as pests on agricultural production in the Top End of the NT. Agrifutures also asked the project to explore other wildlife species for meat production, such as feral pigs (*Sus scrofa*) and magpie geese (*Anseranas semipalmata*), to enhance regional economic development opportunities in northern Australia.

Results

Mean weights of male and female harvested wallabies were 16.2 and 10.4 kg, respectively. Dressing percentage was not affected by either sex or harvesting period; it ranged between 69.5% and 71.5% across three harvesting periods. The meat has a higher pH and darker colour than beef or lamb. Wallaby muscle displayed a relatively higher proteolysis and tenderisation, with a relatively modest aging response during longer storage. Meat tenderness in the loins and topside was comparable with that of high value cuts of lamb and beef but was superior to kangaroo meat. Sensory analysis indicated that the quality of wallaby muscles was comparable with the same muscles in lambs. Results showed that harvesting season and carcase suspension affect wallaby meat quality. An initial desktop analysis indicated that profitable harvesting of feral pigs and magpie geese may be possible. There is a need for market access, resource access (i.e. particular sites where animals can be harvested), supply chain integrity and engagement of established and credible game harvesters with suitable equipment.

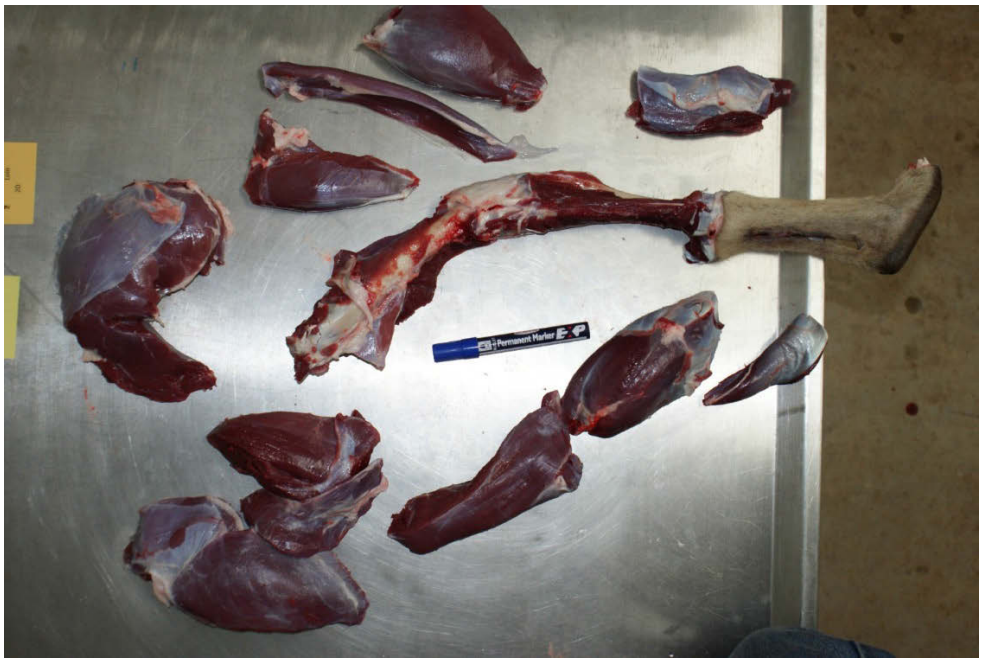
Conclusions

Harvesting agile wallabies is at present a marginal economic proposition for the shooter/game harvester. Estimates indicate that a high extraction rate of 50 wallabies per night using a field harvester would yield a gross margin of around $182 per night. This harvest rate is highly conjectural and the return may be very optimistic. Low live average weights (13.3 kg between sexes), and a market parity price of only $0.85/kg do not provide a strong incentive to potential harvesters to make a living. Although the current economic modelling does not support business development, the study has established the meat quality attributes of agile wallabies and has provided a set of useful parameters that could be used by regulators should an industry develop on harvesting agile wallabies in the future.

Recommendations

Should a wallaby harvesting industry emerge in the future, the NT Government should balance both the industry's economic development priorities and wildlife conservation responsibilities by setting up a number of regional monitoring sites across developed and native landscapes. These could be used to monitor relative fluctuations or change in populations over time and provide useful intelligence for commercial and conservation purposes, such as when to commence, forestall, or pull back from proposed harvesting activities. There is a need to investigate the viability of foreign markets, such as Vietnam, for wild pork and high-end Australian markets for wild magpie geese. Assurance of disease freedom in harvested wild pigs would be essential for export markets.

A typical loin cut from an agile wallaby



Boning out an agile wallaby leg

External Recognition

The following is a summary of the 2017-18 internal and external awards and invitations to significant meetings and conferences.

Constancio (Tony) Asis	Certificate of Appreciation from the Philippine Society of Soil Science and Technology (PSSST) for a Plenary Lecture during its 21st Annual Meeting, Apo View Hotel, Davao City, the Philippines, 2-5 May 2018.
	Achievement Award from PSSST for the outstanding research in soil science for more than three decades on integrated nutrient management, biological nitrogen fixation and the use of beneficial microorganisms in agronomic and horticultural crops.
	Third Best Poster on the effect of a plant growth regulator on growth and yield of aromatic rice. PSSST Annual Meeting, Apo View Hotel, Davao City, the Philippines, 2- 5 May 2018.
Arthur Cameron	Presented at the Beatrice Hill Farm field day.
	Presented at the Coastal Plains Research Station field day.
	Presented at the NRMB Mimosa field day at Twin Hills Station.
	Presented at the first Indonesian cattle breeding course.
	Presented at the Grazing Land Management course in Katherine.
	Led a grass identification tour for the Darwin Grazing Land Management course.
Jocelyn Coventry	Invited to speak at the Alice Springs LANDMARK Animal Health Day in August 2017 on cattle gut parasites.
	Interviewed on the NT Country Hour radio program on “Outback research cattle station works to stem calf mortality, increases breeding productivity”. (http://www.abc.net.au/news/rural/2017-10-20/central-australian-research-station-combats-calf-mortality/9061784)
	A comment on research by the Department in Alice Springs: A. Jackson 2018, ‘Old Man Plains Research Station’, *Australian Veterinary Journal,* **96**:4, pp. 10-11. (http://www.ava.com.au/17216).
	Invited to the Zoetis/ DPIR Northern Australia Cattle Veterinarians’ Workshop in March 2018.
Robyn Cowley	Invited speaker at the Northern Australian Development Session of the 19th Biennial Australian Rangeland Society Conference, Port Augusta, September 2017. Invited to present a seminar on fire and grazing to third year science students at The School of Agriculture and Food Sciences, The University of Queensland, August 2017.

External Recognition

The following is a summary of the 2017-18 internal and external awards and invitations to significant meetings and conferences.

David Lovelock	Oral presentation: "Longevity of CGMMV in the Northern Territory, Australia." *In:* the American Phytopathological Society Conference in Texas, USA, 2017.
	Oral presentation: "Investigating the longevity and host range of CGMMV in Northern Territory soils." *In:* the Australian Plant Pathology Society Conference, Brisbane, 2017.
Sharl Mintoff	Attended the "Powdery Mildew Taxonomic and Diagnostic Workshop" hosted by the University of Southern Queensland, June 11-15 2018.
	Attended and presented at the SciPlant Conference - Brisbane 26- 28 September 2017.
	Invited to present a talk about the Panama TR4 research work being conducted in the NT. Banana Industry Roadshow in Tully, Innisfail and Mareeba, Queensland, August 2018.
Tim Schatz	Presented a talk at 'Beef 2018' (Rockhampton) on the phosphorus supplementation project.
Lucy Tran-Nguyen	Attended Panama Wilt TR4 workshops.
	Attended the vegetable CGMMV growers meetings (Katherine and Darwin).
	Attended the CGMMV mid project review meeting.
	Attended the Fusarium wilt mid project review meeting.
	Attended the Seed Symposium, September 2017.
	Attended the Australasian Plant Pathology Conference.
	Attended the Horticulture Innovation (VG16086) project inception meeting.
	Attended the Annual Diagnostician workshop.
	Attended the Australasian Plant Virus Working group meeting.
Sarah Tsai	Chaired a concurrent session at 'Developing Northern Australia' (June 2018).
	Was nominated for the Star Award (September 2017).

External Recognition

The following is a summary of the 2017-18 internal and external awards and invitations to significant meetings and conferences.

Dionne Walsh	Best spoken short paper – The 19th Biennial Australian Rangeland Society Conference, Port Augusta, September, 2017.
	Lead presenter – Grazing Land Management Workshop for the Indigenous Land Corporation, Darwin. 4-5 April, 2018.
	Lead presenter – Grazing Land Management Workshop, Katherine. 11-12 April, 2018.
	Lead presenter – Grazing Fundamentals Workshop, Katherine. 15 February, 2018.
	Lead presenter – Grazing Fundamentals Workshop, Delamere Station. 3 October, 2017.
	Invited speaker - 2017 Barkly Landcare and Conservation Association field day, Brunette Downs Station.
	Invited speaker - 2018 Barkly Landcare and Conservation Association field day, Alexandria Station.
	Invited briefing - NT Pastoral Land Board – Land management considerations for a donkey industry in the NT. 15 September, 2017.
	Invited Speaker - Katherine NRM Forum – Territory NRM. 13 June, 2018.
	Invited speaker - 2018 NT Ecosystem Services Workshop – Territory NRM. March 2018. https://www.territorynrm.org.au/ntecosystemservices

Staff and Students

Science Staff	Graduate Students
Livestock Industries	
Kieren McCosker	Windu Negara: PhD in rumen microbial population changes - the University of Queensland (Animal Studies).
Plant Industries	
Constancio (Tony) Asis	Hemant Raj Pandeya: Sources and sinks of nitrogen during mango farming in northern Australian soils - the Queensland University of Technology (Earth, Environmental and Biological Sciences).
Mila Bristow	Ms Kamy Melvani: Valuing forest gardens in Sri Lanka - Charles Darwin University (RIEL).
Cameron McConchie	Julian Gorman: Indigenous enterprise development, population ecology and phenotype variation of the tropical tree (Terminalia ferdinandiana) in the Thamarrurr region of the Northern Territory - Charles Darwin University (Research Institute for the Environment and Livelihoods).
Lucy Tran-Nguyen	Victor Puno: PhD in Fusarium wilt of watermelon – the University of Sydney. Stacey Cook: PhD in mango flowering – targeting flower molecular markers – the University of Queensland. Muhammed Umar: Mango resin canal disorder – the University of Tasmania.

Research Visitors

Visitor	Affiliation	DPIR Contact
Aaron Aeberli	UNE	Sharl Mintoff
Nickolas Anderson	PhD student, the Central Queensland University.	Cameron McConchie
Ms. K. Beavan	ABC Rural Radio	Jocelyn Coventry
Hamish Campbell	CDU	Mila Bristow
Ms. S. Carson	UK Department of Defence	Jocelyn Coventry
Andy Chen	UQ	Sharl Mintoff
Dr Neil Cliffe	QDAF	Dionne Walsh
Dr David Cobon	USQ	Dionne Walsh
Jeff Daniels	Queensland DAF	Sharl Mintoff
Dr Geoff Dickinson	QDAF	Mila Bristow
Rosie Godwin	ABGC	Sharl Mintoff
Sharon Hamill	Queensland DAF	Sharl Mintoff
Dr A. Jackson	Australian Veterinary Journal	Jocelyn Coventry
Stewart Lindsay	Queensland DAF	Sharl Mintoff
Grey Mackay	Rangelands NRM WA	Dionne Walsh
Freddy Magdama	Centre for Biotechnological Research, Ecuador	Sharl Mintoff
Bruce Maynard	Stress Free Stockmanship, NSW	Dionne Walsh
Dr John Mullen	John Mullen Consulting, Orange NSW	Warren Hunt
Damien O'Sullivan	QDAF	Dionne Walsh
Tony Pattison	Queensland DAF	Sharl Mintoff
Dr David Phelps	QDAF	Dionne Walsh
Dr Dean Revell	Revell Science, WA	Dionne Walsh
A/Prof Andrew Robson	UNE	Mila Bristow
Dr Dave Rowlings	QUT	Mila Bristow
Kath Ryan	WA DPIRD	Dionne Walsh
Michelle Sargent	AES committee student representative	Sarah Tsai
Muhammad Umar	PhD student, the University of Tasmania	Cameron McConchie
Prof Kerry Walsh	CQU	Mila Bristow
Philip Weinstein	The University of Adelaide	Sarah Tsai

Research Service

The following is a summary of science staff participation on significant scientific, industry or policy development committees and editorial boards.

Constancio (Tony) Asis	Editorial Board member and reviewer, the *Philippine e-Journal of Applied Research and Development,* Saint Louis University, Baguio City, the Philippines.
	Reviewer, *CMU Journal of Science*, Central Mindanao University, Maramag, Bukidnon, the Philippines.
	Member, the International Society of Horticultural Science.
	Member, the Australian Society of Horticultural Science.
	Member, the Philippine Society of Soil Science and Technology.
Mila Bristow	NT representative on AgSOC Climate Change (2018-19).
	NT representative on the national Climate Strategy for Primary Industries Committee.
	Member of the National CRSPI Strategy Development 2017-2022 Working Group.
	DPIR representative on the NTG Climate Change Policy Working Group.
	NT Representative on the Montreal Process Implementation Group for Australia (Forestry).
	Adjunct Research Fellow, CDU School of the Environment.
	Member of Australian Forest Growers (AFG) and member of the editorial committee of the AFG Magazine.
	Member of the Institute of Foresters Australia.
	Member of the International Society of Horticultural Scientists.
	Member the Australian Society of Horticultural Scientists.
Arthur Cameron	Member of the NT Native Vegetation Assessment Panel.
	Member of the Weed Risk Technical Committee.
Casey-Anne Collier	Secretary of the Barkly Research Advisory Committee.
Jocelyn Coventry	Cooperated with Murdoch University to promote post-graduate ruminant research opportunities and sharing of research knowledge.
Robyn Cowley	Regional partner for the North Australia Climate Program, the University of Southern Queensland.
	Reviewed two draft papers for *The Rangeland Journal.*
Michael Daysh	Participated in *Horticulture Innovation's* Trade Assessment Panel.
David Lovelock	Regional Councillor for the NT, for the Australasian Plant Pathology Society.

Research Service

The following is a summary of science staff participation on significant scientific, industry or policy development committees and editorial boards.

Cameron McConchie	Invited reviewer for *Acta Horticulturae.*
	Invited reviewer for *Postharvest Biology and Technology.*
	MSc assessor for the University of Central Queensland.
Tim Schatz	Attended the Katherine Pastoral Industry Advisory Committee meetings.
	NT representative on the North Australian Beef Research Council (NABRC).
	Member of the NABRC management committee.
Kieren McCosker	Reviewer for the *Journal of Animal Production Science*.
Lucy Tran-Nguyen	Senior Editor for *Australasian Plant Disease Notes.*
	Reviewer for *Australasian Plant Pathology, Federation of European Microbiological Societies, Plant Pathology, Plasmid, Plant Disease, Journal of Phytopathology, Annals of Applied Biology, Australasian Plant Disease Notes* and *Public Library of Sciences*.
	Member of the Scientific Advisory Panel for the Department of Water Resources.
	Member of the cucumber green mottle mosaic virus working group.
	Member of the mango malformation disease working group.
	Member of the national banana plant protection working group.
	Member of the melon necrotic spot virus scientific advisory group.
	Member of the national plant biosecurity diagnostic network.
	Member of the citrus canker working group.
Sarah Tsai	Participated in the Citrus Canker Response Group in Darwin (May 2018).
Dionne Walsh	Member of the NT Weeds Advisory Committee.
	Council member of the Australian Rangeland Society.
	Invited convener for the “Northern Australian Development” session – The 19th Biennial Australian Rangeland Society Conference Program Subcommittee.

External Linkages

Industry Collaboration – details of specific collaborative industry-focused projects.
Research Collaboration - details of specific collaborative research projects or consortia.

Name	(I) Industry Collaboration / (R) Research Collaboration
Constancio (Tony) Asis	(I) Collaborating with Horticulture Innovation, Cotton RDC, Sugar RDC and Dairy Australia on the development and implementation of the Rural Research and Development for Profit "More Profit from Nitrogen" project. Strengthened collaboration with the Australian Mango Industry Association through this project. Conducted an ionomic analysis of historical data from Nutrano (formerly Sevenfields) orchard in Katherine and presented the results to the management staff. (R) Continued collaborating with QUT and the University of Tasmania on the RD4P project "Optimising Nutrient Management for Improved Productivity and Fruit Quality in Mangoes". (R) Assisted a year 12 student from the Good Shepherd Lutheran High School with her science investigatory project on the role of plant hormone gibberellic acid on germination of rice. (R) Initiated collaboration with Dr Serge-Etiene Parent, Department of Soils and Agri-Engineering, Laval University using the ionome balance approach in diagnosing nutrient status in mango.
Mila Bristow	(I) Collaborating with Horticulture Innovation, the Cotton RDC, the Sugar RDC and Dairy Australia on the development and implementation of the Rural Research and Development for Profit "More Profit from Nitrogen" project. (I) Collaborated with Territory NRM and the NT Farmers Association through various projects. (I) Contributed data and information to the State of the Forests report 2018. (R) Collaborated with the Queensland University of Technology and the University of Tasmania.
Arthur Cameron	Provided a pasture/hay/seed extension service in the NT. Member of the DPIR carrying capacity assessment team.
Casey-Anne Collier	(I) Collaborated in the Alexandria Station spelling and stocking rate trial. (I) Member of the Barkly Research Advisory Committee.

External Linkages

Industry Collaboration – details of specific collaborative industry-focused projects.
Research Collaboration - details of specific collaborative research projects or consortia.

Name	(I) Industry Collaboration / (R) Research Collaboration
Jocelyn Coventry	(I) Provided support to Animal Health Australia for emergency animal disease exclusion cases. (I) Provided support to CT Ag Consulting (South Australia) for tutoring a remote agricultural student. (I) Provided support to Research Farms (AZRI and OMPRS) for industry-based Johne's disease beef assurance (scoring) program sampling. (R) Supported the University of Sydney (School of Veterinary Science) and NSW Department of Primary Industries, Elizabeth Macarthur Agricultural Institute in postgraduate research of inherited diseases in sheep and cattle. (R) Collaborated with Neogen Australasia for DNA testing and recording of cattle genetic markers for scurs.
Robyn Cowley	(R) Collaborating on the Sweet Spot project - an interagency, cross-border collaborative modelling project with DSITI, QDAF and economic modellers to investigate the impact of utilisation on reproduction in northern Australian beef herds using existing datasets. (R) Collaborating with the University of Queensland to understand the implications of fire and grazing on soil biological crusts and soil life. (R) Collaborating with Gabrielle Lebbink and Professor Rod Fensham of the University of Queensland on fire impacts on plant diversity. (R) Collaborating with Queensland DES and DAF on the Inside Edge project to deliver better climate management tools to the pastoral industry.
Michael Daysh	(I) The project 'Monitoring Mangoes through the Supply Chain to the United States 2017/-8 (MG16003)' was industry focused and depended on collaboration with growers, exporters and importers.
Whitney Dollemore	(R) AGBU: Intensive genotyping and phenotyping for accelerated genetic improvement of reproduction in northern Australia.
Warren Hunt	(I) The wallaby project was supported by the Douglas-Daly Region Producer Group. (R) The wallaby project was supported by Agrifutures Australia, Charles Darwin University and Meat and Livestock Australia.

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Name	(I) Industry Collaboration / (R) Research Collaboration
David Lovelock	(I) Collaborated with Horticulture Australia on the project (VG15013) "Improved management options for CGMMV".
	(I) Collaborated with AusVeg.
	(I) Collaborated with the Australian Melon Association.
	(I) Collaborated with HM Clause, USA - CGMMV symptomology photos in the field and in the glasshouse.
	(R) Department of Economic Development, Jobs, Transport and Resources, Victoria - Fiona Constable.
	(R) Department of Agriculture and Food, Western Australia - Brenda Coutts.
	(R) Queensland Department of Agriculture & Fisheries - Denis Persley.
	(R) NSW Department of Industry, Skills and Regional Development - Len Tesoriero.
	(R) NT Farmers - Greg Owens.
Cameron McConchie	(I) Australian Mango Industry Association.
	(R) NSW DPI, DAF, WADPI&RD, the University of Tasmania and Central Queensland University.
Kieren McCosker	(I) Secretary of the Katherine Pastoral Industry Advisory Committee.
	(R) Chief investigator in the 'Reducing Calf Loss from Exposure' project, in collaboration with the University of Queensland, the University of Southern Queensland and Queensland Department of Agriculture and Fisheries.
	(R) Collaborating scientist in the ACIAR-funded 'Improving Smallholder Beef Supply and Livelihoods through Palm-Cattle Integration in Indonesia' project.
	(R) Collaborating scientist on the ACIAR-funded 'Profitable Feeding Strategies for Smallholder Cattle in Indonesia' project, with the University of Queensland.

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Name	(I) Industry Collaboration / (R) Research Collaboration
Sharl Mintoff	(I) Australian Banana Growers Council.
	(I) Horticulture Innovation Australia.
	(I) Hosted the "Next Gen" banana growers at CPRF in September 2017, where the TR4 research program in the NT was showcased to the national banana industry, which included growers and representatives and Chair of the Australian Banana Growers Council.
	(I) Hosted two local banana growers: Matt Pheeney and Mark Smith, November 2017.
	(I) Attended the "Identifying *Fusarium* Species" workshop at North Stradbroke Island, Queensland, September 2017.
	(R) The Queensland Department of Agriculture and Fisheries.
	(R) The University of Queensland.
Caroline Pettit	(R) Collaborating with the Sweet Spot project - an interagency, cross-border collaborative modelling project with DSITI, QDAF and economic modellers to investigate the impact of utilisation on reproduction in northern Australian beef herds using existing datasets.
Tim Schatz	(I) Katherine Pastoral Industry Advisory Committee meetings.
	(R) Collaborated in the Repronomics project with AGBU and QDAFF/QAFFI.
	(R) Collaborated with the University of Queensland researchers on the Cull Cow Value Adding project.
	(R) Collaborating with the University of Florida researcher on the Calf Watch project.
Peter Shotton	(R) Collaborating in the Queensland Alliance for Agriculture and Food Innovation project "Diet selected and growth of steers grazing *Leucaena leucocephala*-grass pastures in a seasonally dry tropical environment".
	(R) Collaborating in the Queensland Alliance for Agriculture and Food Innovation project "Diets selected and growth of steers grazing buffel grass *(Cenchus ciliaru s* cv Gayndah*)*-Centro *(Centrosema brasilianum* cv Ooloo*)* pastures in a seasonally dry tropical environment".

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Name	(I) Industry Collaboration / (R) Research Collaboration
Lucy Tran-Nguyen	(I) Collaborated on the Horticulture Innovation (VG15013) "Improved Management Options for CGMMV".
	(I) Collaborated on the Horticulture Innovation (VG16086) "Area-wide Management of Vegetable Diseases: viruses and bacteria".
	(I) Collaborated on the ACIAR – Cambodia project "Building a Resilient Mango Industry in Cambodia and Australia through Improved Production and Post-harvest Practices".
	(I) Collaborated on the Horticulture Innovation Australia (BA14014) "Fusarium wilt Tropical Race 4 Research Program".
	(I) Collaborated with the Australian Melon Association.
	(I) Collaborated with the Australian Mango Industry Association.
	(I) Collaborated with the Australian Banana Growers Council.
	(I) Collaborated with the Plant Biosecurity CRC.
Sarah Tsai	(I) Collaborated with Australian garlic producers.
	(I) Collaborated with the National Mango Breeding Program.
	(I) Conducted trials on producer properties at Rocky Hill, Ti Tree, Mt Zeil and Ali Curung.
	(R) Collaborated with the CSIRO on table grape production.
	(R) Collaborated with Western Australia's Department of Primary Industries and Regional Development on quinoa production.
	(R) Collaborated with the Queensland Department of Agriculture, Forestry and Fisheries on garlic production.
	(R) Collaborated with the Plant Research Centre, the University of Adelaide on self-pollinating almond plants.
Dionne Walsh	(I) Feathertop burning experiment at Newcastle Waters Station in collaboration with Barkly Landcare, Territory NRM and the Consolidated Pastoral Company.
	(R) NT project leader – "Rangelands Self-herding" trial at Kidman Springs in collaboration with Revell Science, Bruce Maynard - Stress Free Stock-handling, Territory NRM, Rangelands NRM, Oxley Grazing and Meat & Livestock Australia.
	(R) Member - Project Leadership Group - Northern Australian Climate Program – Extension Project In collaboration with the University of Southern Queensland, the Queensland Government, WA DPIRD and Rangelands NRM WA.

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Name	(I) Industry Collaboration / (R) Research Collaboration
	(R) NT representative on the FutureBeef Project Advisory Committee which includes WA DPIRD, Qld DAF and MLA.
	(R) Provided technical grazing land management and carrying capacity advice to the “Northern Savannas Ecosystem Services Case Study” (Dr Kamaljit Sangha, Charles Darwin University).
	(R) Provided technical grazing land management and carrying capacity advice to the “Natural Capital Accounting Project” (Sue Ogilvy and the Indigenous Land Corporation).

Publications

Scientific papers, peer reviews and other publications

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