NORTHERN TERRITORY DEPARTMENT OF REGIONAL DEVELOPMENT, PRIMARY INDUSTRY, FISHERIES AND RESOURCES

PRIMARY INDUSTRIES

TECHNICAL ANNUAL REPORT 2007-08

Please note:

Although the research and development work described in this Technical Annual Report was conducted under the previous Department of Primary Industry, Fisheries and Mines, it is being reported under the new Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR). This is being done to promote the new DRDPIFR among the Northern Territory primary industries and because the work is of an ongoing nature.

October 2008

Bibliography:

Northern Territory Government Department of Regional Development, Primary Industry, Fisheries and Resources (2008). Primary Industries Technical Annual Report 2007-08. *Technical Bulletin No. 329*.

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INTRODUCTION

The Primary Industries Group in the Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR) in the Northern Territory (NT) of Australia conducts research, development and extension (RD&E) projects in four major areas: Crops, Forestry and Horticulture; Pastoral Production; Diagnostic Services; and Biosecurity and Product Integrity. Much of this work is conducted at the Department's headquarters at Berrimah Farm, in Darwin and at its regional facilities in Alice Springs, Katherine and Tennant Creek. Much work is also conducted at the Department's RD&E Farms and on private properties in collaboration with owners. RD&E projects are conducted in response to the needs of industry. This Technical Annual Report (TAR) provides a summary of new and continuing R&D work conducted during the 2007-08 financial year, together with results, where possible, and general recommendations. A separate new annual report dealing specifically with extension activities will be published next year.

The estimated gross value of plant industries in 2007 was $111.1m. Compared with 2006, this reflects a 32% decline in production. However, it is likely that due to an incomplete transmission of farm records, actual production may have been higher than reported here.

Total fruit production was 40 065 tonnes, valued at $64.1m. In spite of a 29% decline in value compared with last year, mangoes continued to dominate plant industries and were valued at $37.9m. Yield declined from 18 115 tonnes in 2006 to 15 425 tonnes in 2007.

Melon production declined from 21 901 in 2006 to 21 101 in 2007. The value fell by 29% from $25m in 2006 to $17.8m in 2007.

Banana and table grape production declined by over 60% and was valued at only $3.4 m and $3.3m, respectively. Returns from bananas declined in 2007 compared with the previous year because cyclone damage to the banana crop in Queensland in 2006 had increased demand for NT bananas in that year. However, production also declined in 2007 by almost 300 tonnes, reaching only 1790 tonnes.

Based predominantly in the Katherine region, citrus production more than doubled in 2007 to reach 722 tonnes, doubling in value compared with the previous year to reach $1.4m.

Vegetable production declined in 2007 reaching only 5772 tonnes, valued at only $14.6m, which reflected a 46% decline compared with 2006. The largest amount was produced in the Darwin region, reaching 3252 tonnes, valued at $13.4m.

The largest increases in value in the vegetable industry were in gourds ($3.5m) and snake beans ($2.6m), which reflected a 192% and a 168% rise, respectively. The production of pumpkins, zucchini and squash doubled, contributing an extra $1m to the industry.

The value of pasture, field crops and fodder produced was $14.7m, reflecting a decline of 22% compared with the previous year. Douglas Daly and Katherine regions are the main producers, earning $4.7m and $6.9m, respectively. The Darwin and Alice Springs regions accounted for about $1.5m each in pasture, field crop and fodder production.

There was rapid expansion in hardwood plantation development in the NT. In 2007, trees were planted on 5410 ha on the Tiwi Islands and in the Douglas Daly region. This included 3000 ha of *Acacia mangium* for hardwood pulp production and 2410 ha of African mahogany for high value timber.

The ornamental industry was valued at $17.7m in 2007, of which $15m was the share of the nursery industry. This reflects a slight increase in value of 4% compared with 2006. In 2007, the value of cut-flowers

declined by 10% due to a lower bloom production. The industry began exporting cut-flowers to Dubai in the United Arab Emirates in 2007.

The Pastoral Division supports the sustainable development of animal industries. In 2007, the industry turned off more than 500 000 beef cattle of which over 247 000 went to the live export market. The rest were shipped interstate to feedlots or for slaughter. Market demand remained high, but drought in the Barkly and Central regions reduced stock numbers in those areas.

Animal industries are addressing issues of profitability, production cost reductions, increasing public accountability on the use of natural resources, animal welfare practices and the uncertainty surrounding climate change.

DRDPIFR is assisting producers to address these issues by conducting focused research, development and extension programs to improve the efficiency of sustainable production on pastoral properties. This includes improving breeding herd efficiency, grazing management, increasing carrying capacity through infrastructure development and assisting indigenous land owners to increase pastoral production on their land. It also provides clear and concise information on emerging issues such as climate change.

The Diagnostic Services Division is relatively new and includes the Berrimah Veterinary Laboratories, Water Microbiology in Darwin and Alice Springs, Water Chemistry, Agricultural Chemistry, Plant Pathology in Darwin and Katherine, and the Seeds Laboratory.

Apart from providing services to animal and plant health, and the export sector, the Division monitors water quality, conducts chemical and plant analyses and seed testing, including certification. It also conducts strategic and targeted research on arbo-viruses, termites, integrated pest management, Fusarium wilt in bananas and snake beans, and grapevine leaf rust.

The Biosecurity and Product Integrity Division aims to prevent the introduction of exotic pests and diseases into the NT, eradicate pests and diseases that are already present in the NT, and effectively manage risks posed by pests, diseases and chemical residues to the economy, the environment and to human health. It is responsible for ensuring continued access for NT primary industry products to domestic and international markets. It also provides a quality-assured laboratory service to support the horticulture, pastoral and aquaculture industries in the NT.

Projects related to plant industries are listed under the heading ‘Plant Industries’, irrespective of which departmental Division they come under. Similarly, projects related to animal industries are listed under the heading ‘Animal Industries’, irrespective of which departmental Division they come under. To assist readers to find projects of interest quickly in this TAR, two indexes are included at the end.

PLANT INDUSTRIES

Plant industries projects conduct applied research in controlled trials to discover solutions to problems that affect productivity and profitability of the industry and, where possible, to protect the environment and human health.

PROJECT: Bio-fuel Crops for the NT

Project Officers: M .Bennett, M. Kahl and D. Renfree

Division:	Plant Industries
Location:	Katherine
Keyword(s):	bio-fuel, Pongamia, ethanol, Katherine Research Station

Objective:

To investigate the establishment of Pongamia pinnata (Pongamia) in the NT with minimum inputs and no irrigation.

Background:

An Australian native tree, the Pongamia, is promising to be a bio-fuel plant for the NT. Although normally adapted to coastal regions, vigorous specimens of the tree are found in parks and school grounds as far south as Mataranka, 400 km south of Darwin. Pongamia is drought tolerant, fast growing and produces its first harvest in five to six years. Bio-diesel yields of 2.5 – 3.0 t/ha are expected. As Pongamia is a legume, it produces its own nitrogen, reducing fertiliser needs. If Pongamia plantations can be successfully established on less arable land, with minimum fertiliser use and variable summer rainfall, then there is a significant potential for a renewable fuels industry in the NT.

This project will investigate the establishment of Pongamia trees sown from seed at the start of the wet season with no fertiliser and no additional weed control after seedlings emerge.

Method:

Seed was sown in three experimental areas: at Katherine Research Station (KRS) on 20 December 2007 and 8 January 2008, and at Douglas Daly Research Farm (DDRF) on17 January 2008, in randomised complete blocks with two replications. The number of selections/entries in each trial was 8, 21 and 10, respectively. The number of positions sown depended on availability of seed and ranged from 11, between 14 to 50, and 50, respectively. Two seeds were sown in each position on 4-m centres. Rows were 8 m apart.

Emergence counts were taken weekly for five weeks. They will be taken again at 12, 18 and 24 months.

Results:

Establishment at five weeks after sowing was as follows:

Site	Range of establishment (%)
KRS, 20 December 2007	0 - 82
KRS, 8 January 2008	0 - 77
DDRF, 17 January 2008	0 - 44

The DDRF site was flooded in February.

Establishment of more than 85% was expected, as the same seed sown in pots in the KRS shade-house had an establishment of more than 92%.

General observations

All groups were very slow to emerge regardless of selection. Weeds will pose a significant challenge to emerging Pongamia seedlings if herbicides or zero tillage techniques are not employed to minimise competition. Pongamia seedlings are currently surviving the dry season but the two hottest months may influence their survival.

PROJECT: Biological Farming Systems for the Top End

Project Officers: M. Bennett, G. Ellis, M. Traynor and D. Renfree

Division:	Plant Industries
Location:	Katherine
Keyword(s):	biological farming

Objective:

To develop practical methods based on a sound scientific understanding of crop-biological interactions to significantly improve crop performance and profit margins.

Background:

Biological farming systems cover all aspects of investigating soft/biological options to enhance agricultural production. Good soil health is the foundation of all sustainable agricultural production. Healthy soils function optimally through balanced interactions between their biological, physio-chemical and mineral components. Farmers are well aware that many agricultural practices reduce the functional capacity of their soils. Local horticultural and agricultural industries are eager to learn how to reduce soil degradation and enhance soil health. Research in biological farming systems in the NT has been increased to include soft/biological solutions to problems of insects, weeds and diseases.

Method:

In the second year of this project, two action plans were proposed:

- Collect baseline soil health data from five wet season companion/cover crops, a mango orchard and a sabi grass pasture at Katherine Research Station (KRS). The crops will include sorghum, sunflower, millet, lablab and cowpeas. Test strips in each crop area will be tested for the effect of applied potassium chloride and potassium sulphate on soil biology.
- Collect soil health data from three farms in each of the three horticultural regions: Katherine, Darwin and Alice Springs. These farms represent the principal irrigated horticultural crops grown in the NT: mangoes, melons, grapes, rambutans and vegetables.

Results:

Experimental areas at KRS were not sown or sampled in January 2008 due to extensive damage to the research sites by fire.

Soil health data was collected from the nine commercial farms and will be compared with data to be collected in 2011 to measure the effect of current farm management practices on soil health (indicators).

Five biological indices will be used as key indicators of soil health:

1. Total carbon (C) is a measure of recent and historic organic additions to the soil. Measuring total soil organic C provides information on overall soil fertility. The expected range in local soils is 0 – 2.5%.

2. Liable C represents the recent additions of organic matter to the soil and is sensitive to changes in cropping practices. Liable C provides the food source for microbial activity. Microbial activity is essential for nutrient cycling. The expected range in local soils is 0 - 20% of total C.

3. Microbial biomass C is a measure of the mass of living micro-organisms. The greater the microbial biomass, the greater is the capacity for microbial activity and nutrient cycling. The expected range in local soils is 0 - 500 mg/kg soil.

4. Microbial activity is determined by carbon dioxide (CO_2) respiration and measures the amount of biological activity in the soil. Microbial activity depends on soil moisture, temperature and liable C. The expected range in local soils is 0 - 20 mg CO_2/kg soil/day.

5. Soil nitrogen (N) supply is an index of the potential for microbial activity to mineralise soil organic matter to plant-available N. The expected range in local soils is 0 - 50 mg N/kg soil.

PROJECT: Elite Rootstocks and Scion Cultivars for Improving Mango and Citrus Productivity in the NT

Project Officers: M. Hoult, C. Hennessy and M. Connelly

Division:	Plant Industries
Location:	Darwin
Keyword(s):	mango, citrus, rootstock, varieties

Objective:

To identify elite rootstocks and scion cultivars to improve mango and citrus productivity in the NT.

Background:

Improving productivity and efficiency are important issues for the NT horticulture industry which is striving to offset rising costs and declining returns. Rising “environmental pressures” on resource use have increased the urgency for achievable solutions. The simple selection of elite scion cultivars by rootstock combinations allows growers to improve productivity without increasing inputs, such as fertiliser and water, and leads to better resource management and higher returns. This project will identify elite rootstocks and scion cultivars which lead to improved productivity whilst maintaining quality and other critical market requirements.

The interest in citrus development is driven by two fundamental points. First, the domestic market opportunity is strong for very early mandarins and lemons - from January to March - before the Queensland season starts. Second, product diversity strengthens regional capacity and growth through better utilisation of capital, infrastructure, the supply chain and people. For example, mangoes, which are the NT’s major horticultural crop, have a short production period of only six to eight weeks, from October to November. Citrus could be a complementary crop, which would extend horticultural production from two to six months.

This was the final year for data collection for this project. In the 2008-09 TAR, yield data from the Fremont rootstock trial will be reported.

Method:

Mango rootstocks

Trials are conducted at two sites in the Katherine district on local Kandasol soil. However, soil depth and texture vary significantly between the two sites. The Zimmin Drive site is on a shallow (30-50 cm) “Tippera” clay loam overlaying fractured limestone. The site was planted in April 1996. The Fox Road Venn site is on a deep (> 200 cm) sandy “Blain” and was planted in December 1998. Under irrigation, all soil types in the district are characterized by high pH of up to 8 but low conductivity and organic carbon. The Zimmin trial has 64 stock treatments replicated with five single datum trees. The Venn trial has 100 stock treatments replicated in a similar way as the Zimmin site. Treatments 1 to 64 have the same stock in both sites and the same scion, which is Kensington Pride (KP) (Katherine Research Station (KRS) clone ex Ian Curtis). The data presented is only for the better performing stock treatments and for the poorest performing stock treatments. NT 16 KP is the standard.

For the 2007 assessment, the only data collected was for fruit number/datum tree (counts/tree) by two experienced mango workers and was then averaged. Also average data for fruit (weight/datum tree) was collected but is not presented.

Citrus rootstocks

Planting was done in May 2004 at Bees Creek, in the Darwin rural area. Fremont mandarin is the scion budded to 12 different rootstocks replicated four times with single datum trees. The data collected in 2008 included tree size (canopy area and trunk girths) - not presented - crop yield (fruit number by average fruit weight) and fruit quality. The trial site also serves as a "Best Practice/Training" block for citrus growers.

Mango scion cultivars

The mango cultivar planting at KRS consisted of two to four trees of 12 cultivars randomly distributed within the block. Trees were spaced at 8 m x 6.5 m. Cultivars Neldica, Heidi, Joa, Chene and E10-5/3 were planted in May 2001 (Table 1). Cultivars R2E2, Celebration and KP were planted in June 2001. Each of the cultivars R2E2, Celebration, N10E10, Neldica, E10-5/3, KP, Chene, Joa, Heidi, and N10E56 has four trees. Each of the cultivars N6E35 and N8E54 has only two trees. Fruit numbers, average fruit weight and estimated yield data was collected in November 2007.

Citrus scion cultivars

Data was collected only for the new lemon cultivars Eureka 'Allen', Eureka 'Yen Ben', and Lisbon 'Limoneira' for the 2008 season. The trees were established in May 2004 and the data presented is for their fourth year of growth. Data was collected from one or two trees for each scion/stock combination.

Results:

Mango rootstocks

Rootstock NT16 KP was grafted to KP seedlings and is a stock/scion combination that represents the bulk of existing commercial orchards in the Top End of the NT. As such, it serves as a useful standard to judge all other stock/scion combinations in these trials. As in previous years, a number of stocks have outperformed KP in fruit numbers per tree, depending on site. There is a clear trend that suggests a "rootstock by soil type" interaction where a number of stocks are showing low productivity on one site but a higher productivity on another. Other data which, is not presented, also shows that individual stock selections are influencing canopy size and there is a group of stocks which induce smaller canopies and yet maintain good production.

We are also observing trends in fruit quality and maturity time which are influenced by a given stock. Much of the current data supports earlier reports on the obvious effect of rootstock selection on scion performance in mangoes, which is also the case in other tree crops such as citrus and pome fruit.

We have identified a number of elite rootstocks that have influenced key commercial criteria for the main Australian commercial cultivar, KP. Soil type and site appear to influence different rootstocks and their performance. We have no information on the influence of rootstock on new cultivars such as Calypso and Honey Gold. Many of the cultivars/selections evaluated as potential rootstocks are held only as single trees in germ-plasm collections and as such the availability of seed in commercial quantities is very limited. Also a number of parent stock trees which were used as rootstocks have died.

Table 1. The effect of mango rootstocks on KP scions on fruit number per tree at Zimmin

Rootstock code	Average fruit number/tree (±s.d.)		
	2006	2007	Cumulative 2006-07
NT12	203 (19.1)	117 (31.1)	320
NT14	177 (19.9)	137 (19.2)	314
NT63	196 (31.4)	117 (37.1)	313
NT13	194 (40.9)	116 (28.6)	310
NT40	185 (5.3)	122 (28.3)	307
NT50	180 (23.7)	125 (23.1)	305
NT20	182 (16.9)	119 (15.7)	302
NT51	185 (31.0)	102 (38.2)	287
NT10	165 (30.8)	119 (34.6)	284
NT39	161 (25.6)	108 (24.1)	270
NT19	162 (27.4)	106 (19.1)	269
NT47	166 (18.8)	102 (55.5)	269
Kensington Pride (NT16)	157 (24.5)	100 (36.3)	258
NT52	179 (23.0)	78 (33.0)	257
NT9	156 (23.3)	84 (28.6)	240
NT46	161 (28.2)	70 (36.9)	231
NT55	129 (29.5)	93 (23.4)	223
NT45	109 (8.3)	94 (40.5)	203

Table 2. The effect of mango rootstock on KP scion on fruit number per tree at Venn

Rootstock code	Average fruit number/tree (±s.d.)		
	2006	2007	Cumulative 2006-07
NT33	168 (11.9)	167 (26.2)	335
NT50	160 (12.3)	174 (42.3)	334
NT10	176 (45.0)	147 (21.3)	323
NT52	192 (9.3)	127 (32.6)	319
NT12	163 (28.0)	155 (17.9)	318
NT1	177 (33.2)	141 (56.5)	318
NT94	163 (17.8)	152 (10.3)	315
NT41	171 (30.0)	144 (38.0)	315
NT14	170 (30.8)	138 (55.2)	308
NT40	167 (20.6)	133 (18.6)	300
NT63	148 (16.2)	150 (26.5)	298
NT46	164 (16.3)	132 (24.7)	296
NT39	154 (15.6)	142 (24.0)	296
KP (NT16)	145 (38.1)	145 (43.2)	290
NT3	159 (19.5)	129 (32.1)	288
NT45	158 (25.1)	116 (23.9)	274
NT13	154 (30.6)	116 (15.5)	270
NT47	145 (23.2)	120 (11.9)	265
NT18	138 (28.1)	125 (33.5)	263
NT19	125 (33.0)	127 (40.7)	252
NT20	146 (14.0)	100 (21.9)	246
NT51	105 (7.8)	112 (14.7)	217
NT55	118 (23.0)	95 (28.4)	213
NT68	91 (17.5)	98 (16.4)	189

Citrus rootstocks

Fruit yield data is for the first two significant fruiting years, which were the third and fourth years. A full fruit quality data set was collected. However, only average fruit weight and brix:acid ratio data is presented. Results from an observation of Daisy mandarin on four stocks, planted as guard trees for the stock trial, are also presented. This is the first evaluation of Daisy mandarin in the Darwin environment. One more season's yield data will be collected in this trial. Both Fremont and Daisy mandarins displayed good precocity in the hot monsoonal environment of Darwin, supporting previous observations on these cultivars in the Katherine district.

Table 3. The effect of rootstock on yield, fruit weight and brix:acid ratio (2008) of Fremont mandarin scion, at Bees Creek, Darwin

Rootstock	Fruit weight (g) (±s. d.)[1]	Brix:acid ratio (±s. d.) [1]	Average total yield (kg) (±s. d.)/tree		
			2007	2008	Cumulative 2007- 08
"Lockyer" rough lemon	122 (16)	12.8 (1.8)	11.8 (2.0)	36.6 (7.8)	48.4
US812 hybrid	112 (11)	15.2 (1.9)	6.5 (0.5)	35.3 (10.8)	41.8
Poncirus trifoliate	110 (14)	13.8 (2.0)	8.0 (2.2)	30.6 (10.9)	38.6
Cox mandarin hybrid	109 (2)	14.2 (1.4)	6.4 (1.5)	31.7 (9.3)	38.1
Fraser hybrid	109 (12)	13.3 (0.6)	5.3 (2.5)	32.5 (5.8)	37.8
Troyer citrange	109 (7)	13.9 (1.7)	5.2 (3.0)	29.8 (3.1)	35.0
Swingle citrumello	109 (5)	14.6 (0.7)	5.7 (3.6)	28.5 (11.6)	34.2
Volkermeriana	121 (10)	13.6 (1.3)	6.7 (2.6)	25.7 (17.3)	32.4
Rangpur lime	122 (16)	12.7 (2.2)	7.1 (1.7)	24.7 (7.1)	31.9
C35 citrange	116 (15)	13.8 (1.3)	5.8 (3.2)	21.1 (13.5)	26.9
Benton citrange	114 (6)	13.8 (1.6)	3.0 (1.7)	22.2 (11.1)	25.1
C32 citrange	106 (10)	14.1 (1.6)	3.2 (2.7)	21.0 (11.5)	24.2
Cleopatra mandarin	94 (2)	13.2 (0.9)	2.3 (0.7)	16.3 (3.4)	18.6
Tetraploid Benton citrange	99 (6)	12.0 (0.9)	3.2 (3.1)	11.4 (4.8)	14.6

[1]Note: Fruit weight and brix:acid measurements were derived from the 27/1/2008 harvest of a 15-fruit sub-sample per datum tree.

Table 4. Observations on yield and fruit quality from single trees of Daisy mandarin scion harvested on 28/1/08 at Bees Creek Darwin

Rootstock	Fruit weight (g)[1]	Brix:acid ratio[1]	Juice (%)	Average seed no./fruit	Total yield (kg/tree)
Troyer citrange	201	12.6	48	30	19.2
Fraser hybrid	197	12.3	49	-	24.3
Benton citrange	235	13.1	45	26	16.4
Cox mandarin hybrid	226	10.8	50	24	20.2

[1]Note: Fruit quality data was derived from the 27/1/2008 harvest for a six-fruit sub-sample per datum tree

Mango scion cultivars

Table 5. New mango cultivar yield and average fruit weight at KRS, November 2007

Cultivar	2007		Cumulative yield kg/tree 2004-07 (four years)
	Average yield[1] (kg/tree) (±s. d.)	Average fruit weight (g)	
N6E35	46 (9)	296	149
Celebration	52 (10)	644	142
Joa	49 (14)	364	142
KP	33 (7)	460	131
Heidi	45 (27)	512	127
N10E10	25 (10)	612	99
Neldica	38 (14)	452	95
R2E2	26 (15)	736	83
N10E56	26 (17)	472	73
N8E54	7 (4)	428	66
Chene	18 (13)	470	63

[1]Estimated from fruit numbers per tree and average fruit weight of a five-fruit sub-sample/tree

The 2007 season was the fourth and final harvest year for this screening trial. A number of local growers have observed these new cultivars. The general view is that there is little to warrant commercial planting. Most of the South African patented cultivars have unsuitable flavours for the Australian market and mature later than KP.

Citrus scion cultivars

Table 6. Yield and fruit quality for three new lemon cultivars at KRS, January 2008

Scion cultivar (n = tree numbers)	Stock	Average fruit weight (g) (±s. d.)	Juice (%) (±s. d.)	Brix:acid ratio (±s. d.)	Average yield1 (kg/tree) (±s. d.)	Average seed numbers /fruit (±s. d.)
Limoneira (n=1)	Benton	138	41	6	87	10
Limoneira (n=2)	Cox	170(38)	38(1)	5.9(0)	60(9)	13(1)
Limoneira (n=2)	Fraser	145(10)	42(6)	5.7(0.4)	71(1)	12(1)
Yen Ben Eureka (n=2)	Fraser	101(5)	40(1)	6(0.9)	38(9)	3(2)
Yen Ben Eureka (n=1)	Benton	95	46	5.8	59	3
Yen Ben Eureka (n=2)	Cox	100(5)	47(2)	5.6(0.2)	38(5)	3(1)
Allan Eureka (n=1)	Cox	132	38	7	29	12
Allan Eureka (n=1)	Fraser	147	41	5	35	10

[1]Estimated from fruit numbers per tree and average fruit weight of a ten-fruit sub-sample/tree

The high productivity of the Lisbon clone ‘Limoneira’ reflects the earlier screening of other Lisbon clones in the Katherine region. Lisbon clones have been the most productive of the available lemon cultivars in Australia. Yen Ben Eureka is a low-seeded clone. It is a small cultivar with very smooth rind and low seed numbers. Fruit size is variable and there appears to be a large proportion of very small, un-marketable fruit, which was selectively excluded from fruit quality assessments in the 2008 season. It also exhibited stylar end breakdown of up to 10-15% of the crop, irrespective of rootstock.

As observed in past trials, production of quality lemons in January through to March is possible in the Katherine region with appropriate cultivar and stock selection coupled with modified tree phenology, which is achieved through strategic nutrient inputs and moisture stress to concentrate flowering.

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PROJECT: Delivering Mango Technology

Project Officers: H. Foster, D. Hamilton and T. Williams

Division: Plant Industries

Location: Darwin

Keyword(s): mango

Objective:

To improve the profitability of mangoes through the adoption of improved production systems.

Background:

To increase the adoption of existing and new technology, research trials are conducted, strategic monitoring tools are developed, communication strategies are put in place, and new information products and delivery systems and training packages are delivered to growers and consultants.

The three main service providers on mangoes in Queensland, the NT and Western Australia are collaborating to deliver a participatory research approach to solve key constraints to profitability. The program targets two regions in the NT (Darwin and Katherine), Kununurra in WA and Mareeba, Burdekin and Southern Queensland. Regionally-based grower steering groups were established to identify and prioritise the regional constraints to profitability.

Having ensured local relevance, each region is independently developing a program of regionally-based participatory research trials specifically adapted to each area focussing on the demonstration of the benefits of improved production practices. Two training workshops are developed per year and are delivered in 12 locations during each year of the three-year project. This serves to communicate the results of research between areas maximising communication between regions and challenging each region to deliver practice change. To enhance adoption by industry, the workshops will also be delivered to consultants and field representatives of resellers and service providers.

Method:

The target audiences for this extension project are:

- Mango growers across all mango producing regions of Australia
- Agribusiness
- Horticulture Australia/Australian Mango Industry Association (AMIA)/RD&E providers.

The strategies of the project for extension and adoption of existing research include:

- Regionally-based participatory research approaches. In the Darwin and Katherine regions the participatory research trials focus on mango nutrition, post-harvest disease control and irrigation strategies.
- Conducting research on-farm so that industry members can directly see the benefits of new management practices. The best extension support comes from growers who recommend changes in management to their fellow growers.
- Regular use of newsletters and R&D supplements to report project findings and yearly workshops/field days to discuss with growers how the project findings are relevant to their situation

Results:

The outputs for the proposed work include:

- Monitoring tools to monitor improvements due to practice change to improve productivity and profitability.
- Identification and project activities in the six regions to overcome key constraints to profitability in those regions across Australia.
- Regionally-delivered and focused training workshops: two workshops per area per year, delivered in six regions with possible delivery in other mango growing regions.
- Participatory research trials sites in six major regions to demonstrate the advantages of improved practice.
- Information systems targeted at the grower sector to deliver current and new information and technology on a broad range of mango production issues.
- Presentations of project progress and outcomes at AMIA national conferences and other organised events.
- Continued liaison with industry through the project steering committees and a communication strategy.

The expected benefits of the work will include the potential to increase tree yields. Since the costs of production are similar for low and high yielding trees, an increase in production through improved management practices will improve efficiency and profitability. Examples of improved outcomes are practice change amongst industry in key areas that the industry and regional steering groups identify and evidence that this leads to greater productivity and profitability. Other expected benefits include dissemination of past and current research findings to growers, researchers, agribusiness personnel and consultants, a greater return on AMIA investment in RD&E through increased adoption of research findings, and better communication between and within industry and research providers about priority issues.

PROJECT: Developing a Crop Forecasting System for the Australian Mango Industry

Project Officers: C. Hennessy and G. Owens

Division:	Plant Industries
Location:	NT
Keyword(s):	mango, crop timing, forecasting

Objective:

To develop a crop forecasting system for the Australian mango industry.

Mangoes are a highly seasonal fruit with a fluctuating supply from one year to the next. This forecasting system will identify peaks in supply to assist the mango industry to better plan its harvesting and marketing programs. This would prevent flooding the market with immature fruit, which could affect the returns of those in the supply chain.

The crop forecasting system was designed by DRDPIFR in conjunction with the local NT Mango Industry Association. The system uses predictions based on information obtained from growers through flowering surveys and the application of heat sum calculations to convert the flowering data into a harvesting pattern.

Now in its fourth year and supported by Horticulture Australia, the system provides an accurate prediction of harvest timing and yield of mangoes in Darwin, Katherine and Kununurra. In 2007 the system was extended to predict the Burdekin and Mareeba mango harvest timing and yield. The system is an effective tool for organizing resources and avoiding bottlenecks.

The forecast has been refined over the years to provide more accurate predictions with the use of such items as fruit dry matter content predictions. The forecast is now available on-line, by mail, fax and email.

Each year the forecast is compared with actual production patterns for the season.

PROJECT: Implementing a Top End Better Mangoes Project

Project Officers: C. Hennessy and G. Owens

Division: Plant Industries

Location: NT

Keyword(s): mango

Objective:

To implement a Top End better mangoes project.

Mango-producing areas such as the Top End, Katherine and Kununurra in WA are thousands of kilometres from major markets. It takes fruit about six to ten days – and sometimes even two weeks - to get to market. Top End supply chains mostly send mature unripe fruit to market. It is then ripened naturally or with gas.

This project is in its third year, having collected data for two seasons from growers, packers and others from Darwin, Katherine and Kununurra. The final season was expected to start in the middle to late September.

Each season up to four consignments were logged for temperature and were independently assessed by Rudge Produce Systems at destination and were subjected to static control. Each consignment and static control was assessed for shelf life index (SLI). The benchmark for SLI is set at seven days. That means the fruit should be at least 60% ripe for seven days before rots in it are visible. Less than seven days is poor performance. Twenty days is the ultimate goal.

As shown in Table 1 SLI has varied between regions and years. As there is only one grower from Kununurra, his SLI has been grouped with Katherine to protect confidentiality.

Table 1. Average SLIs for the Darwin, Katherine and Kununurra regions

	2006	**2007**
Darwin (days)	11	5
Katherine & Kununurra (days)	7	10

PROJECT: Mango Flower Insects and Their Effect on Fruit Quality in the Northern Territory

Project Officers: D. Chin, H. Brown, M. Neal and B. M. Thistleton

Division: Plant Industries

Location: Darwin

Keyword(s): mango, flower panicle, fruit, insect, thrips, dimpling bug

Objective:

To develop a species list of invertebrates found in mango flower panicles and on developing fruit, and to determine their effect on fruit quality.

Background:

Mangoes are the most important horticultural crop in the Northern Territory in terms of value and production. The main production areas are in the Darwin region and in the Katherine region, 300 km south of Darwin. Mangoes are a dry season crop. Flowering occurs from May onwards and fruit is harvested between October and December. DRDPIFR provides a support service to primary producers, including the promotion and implementation of integrated pest management (IPM) strategies. This report outlines one of the IPM projects in mangoes.

In the last few years there has been growing concern about the effect of thrips and dimpling bugs in mango flower panicles. As growers were concerned that flowers contained a vast number of thrips and/or dimpling bugs, the DRDPIFR conducted trials on flower panicles, following through any damage to the skin of the fruit, from the fruit-let stage to post harvest. Orchard trials were previously conducted during the flowering and fruit development period from July to September in 2004 and 2005, and also during post harvest in October 2005. The trials conducted during the dry season in 2004 concentrated on monitoring mango flower panicles in Katherine for thrips and dimpling bugs and on assessing the level of damage to young developing fruit. The trials conducted in 2005 were based in Darwin and included sampling for thrips and dimpling bugs and collecting data on the distribution of other insect orders found in flower panicles.

When conducting the trials, staff also provided growers with advice on insect identification and pest management. Demonstrations were also provided on monitoring techniques, keeping field records of pest monitoring in orchards and the implementation of IPM strategies.

Trials were continued during the 2007 season in Katherine to examine the diversity of invertebrates in flower panicles and to assess the species range of thrips on small developing fruit-lets. The study attempted to determine and understand the effect flower pests have on fruit quality and to observe the diversity of pollinators and natural enemies of the pests that visit or occupy the flower panicles.

Method:

Study sites 2007

Mangoes are grown in a wide range of soils from sandy loams through to shallow gravel soils in the Darwin and Katherine regions (pers. comm. J. Bird, 2007). The production period from flowering to harvest occurs during the dry season and requires irrigation from flowering through to the completion of fruit development (Owens, 2003). The main pests of mango flowers which require monitoring at the end of the wet season (April-May) leading up to flowering are mango leafhoppers, flatids and caterpillars (Chin et al. 2002).

Four commercial mango orchards were monitored in 2007: Eumarella, Greenvale, Manbulloo and Tukanap. All are within 30 km of Katherine and all studied trees were Kensington Pride.

Field sampling

Flower panicles and fruit set panicles

Sampling of mango flower panicles and fruit-lets was carried out on 27 and 28 August. The samples taken from each orchard were 25 flower panicles, 25 fruit-let panicles and 25 larger fruit-lets (10-15 mm diameter). All trees were selected randomly and flower and fruit set panicles were taken by 'tapping' flower panicles into plastic bags and collecting all species that were on the flower panicle. The fruit-lets were harvested in ethanol vials.

Specimen identifications

Identifications were conducted by Entomology staff ands interstate specialists.

Mature fruit – pre and post harvest

Mature fruit were sampled on 20-21 November from each of the orchards. In each orchard 52 mature fruit were randomly selected and assessed for thrips or dimpling bug damage (damage to the skin of the fruit). A sample of randomly-selected fruit (16-30 depending on availability per property) was harvested or collected (after harvesting by farm staff) and taken to the laboratory in Darwin for further observations as the fruit ripened.

Results:

The specimens from the flower panicles and fruit set panicles were sorted. The main categories are shown in Table 1 and Figure 1. The largest group of insects were thrips (96%), followed by wasps (2%), dimpling bugs (1%) and others, which included spiders, beetles, ants, flies, bees, plant hoppers, caterpillars and pirate bugs (*Orius* sp), predatory bugs of thrips and mites (1%). A similar composition of species was found in Darwin mango properties (Chin et al. 2007) where flower thrips constituted 93%, ants 2%, spiders 2%, beetles 1%, dimpling bugs 1% and others 1%.

The most common thrips were *Thrips imaginis* Bagnall, *Frankliniella schultzei* (Trybom), *Haplothrips* spp. and *Thrips hawaiiensis* Morgan. *Scirtothrips dorsalis* Hood were found in very low numbers and there were also various other species in low numbers (Tables 2 and 3). *Campylomma* sp was the only species of dimpling bug in the panicles. The thrips identification process is continuing.

Table 1. The number of thrips, dimpling bugs, other insects and spiders in mango flower panicles (25 flower panicles sampled from each of four orchards)

Species	Eumarella	Greenvale	Manbulloo	Tukanap	Total
Thrips	448	4802	4738	3518	13 506
Dimpling bugs	21	48	111	18	198
Beetles	4	25	25	10	64
Wasps	33	107	50	92	282
Ants	0	2	1	6	9
Spiders	5	12	14	9	40
Flies	1	0	1	1	3
Bees	0	1	0	1	2
Plant hoppers	6	1	0	1	8
Caterpillars	2	1	1	3	7
Pirate bug (*Orius* sp.- thrips and mite predator)	0	13	0	0	13
Total	520	5012	4941	3659	14 132

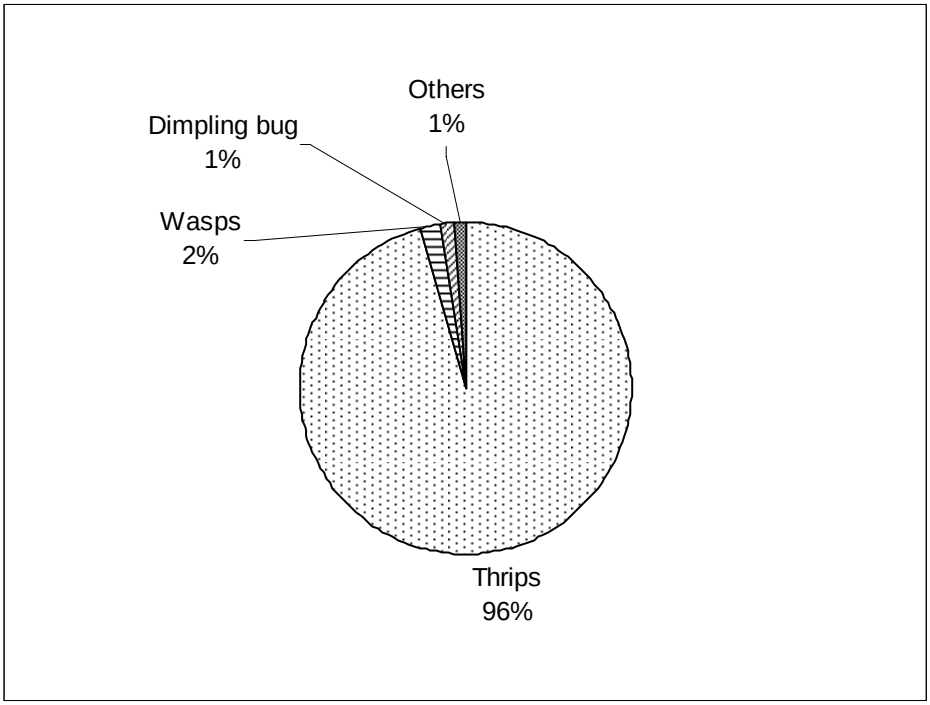

Figure 1. The distribution of invertebrates in mango flower panicles from four orchards in Katherine

Table 2. Thrips and dimpling bug species list

Thrips
Thripidae:
Thrips imaginis Bagnall
Frankliniella schultzei Trybom
Thrips hawaiiensis Morgan
Scirtothrips dorsalis Hood
Megalurothrips spp.
Phlaeothripidae:
Haplothrips spp.
Dimpling bugs
Miridae:
Campylomma austrina Malipatil

Table 3. Distribution of thrips and dimpling bug in flower and fruit set panicles

Property	**Flower thrips**			**Scirtothrips**		**Dimpling bug**		**Fruit-let (10 mm) n = 25**	
	Flower panicle	Fruit set panicle	Mean/ flower panicle	Flower panicle	Fruit set panicle	Flower panicle	Fruit set panicle	Thrips	Scirtothrips
Eumarella	447	599	17.88	1	2	21	38	1	0
Greenvale	4802	3531	192	0	0	48	43	2	0
Manbulloo	4732	4411	188.84	6	7	111	100	14	1
Tukanup	3517	3310	140.68	1	1	18	32	7	0

The main pests that contribute to damage in flower panicles are mango leafhoppers and caterpillars. However, orchards that were selected for monitoring either did not have high numbers of these pests or they had adequate pest management practices in place to keep these pests at low levels. Flower thrips are suspected of causing blemishes to the skin of small developing fruit and dimpling bugs (*Campylomma* sp.) may cause pits or dimples. Both types of damage are more obvious on fruit during early development when it is between 5-65 mm in length as this is when the fruit is most likely attacked. As the fruit increases in size, the dimpling bug damage generally expands, fades and becomes less obvious (Chin et al. 2007).

Only a small number of thrips (*Thrips* spp. and *Scirtothrips dorsalis)* were collected from fruit-lets (around 10 mm in size) (see Table 3) which ranged from 1-14 per 25 fruit-lets. Thrip damage to young developing fruit (up to 30 mm) has been observed in previous trials (Chin et al. 2004).

When mature fruit was assessed (see Table 4), the damage was grouped as “mean % damage per fruit”. By the time the fruit is mature very little evidence of thrips or dimpling bug damage is obvious. Most of the damage recorded as insect blemishes which is seen as white streaks or marks, was attributed to plant hoppers. This damage can sometimes be mistaken for thrip damage, physical damage caused by the swarming bug (*Graptostethus* spp.) or wind abrasion.

Table 4. Assessment of insect related damage on mature and ripe mangoes

Date sampled	Property	Fruit stage	No. of fruit	Mean % damage per fruit (insect related blemishes on skin)	Mean % damage per fruit (insect related blemishes on skin)
21/11/2007	Eumarella	Pre-harvest: mature	52	0.98	
26/11/2007		Post-harvest: mature	30		13.05
4/12/2007		Post-harvest: ripe	30		2.67
21/11/2007	Greenvale	Pre-harvest: mature	52	2.72	
22/11/2007	Manbulloo	Post-harvest: mature	28		0.125
28/11/2007		Post-harvest: ripe	28		0.031
20/11/2007	Tukanap	Pre-harvest: mature	52	2.96	
26/11/2007		Post-harvest: mature	16		3.19
6/12/2007		Post-harvest: ripe	16		0.78

Acknowledgements:

We are grateful to Katherine growers David Higgins, Peter Sinnott, Bill Davey and Ken Rayner for allowing the use of their orchards for this work.

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PROJECT: New and Improved Ornamental Crops

Project Officers: D. Marcsik, M. MacRae and J. Bonson

Division: Plant Industries

Location: Darwin

Keyword(s): cut-flower, Curcuma

Objectives:

To provide the local ornamental industry with new and improved Curcuma cut-flower and potted flower varieties.

To enhance the market opportunities of Curcumas in Australia as cut-flowers and potted plants.

Background:

Curcumas are a member of the ginger family Zingiberaceae and are highly valued for their medicinal properties and as ornamentals. Over the last 10 years, *Curcumas* have become very popular ornamentals with many new cut-flower and potted-flower varieties being developed. Many of these new varieties have come from intensive breeding work in Thailand, primarily on the native species *C. alismatifollia,* commonly known as 'Siam tulip' or 'Thailand tulip'. *Curcumas* have become an important commercial flower bulb crop in Thailand with about a million rhizomes a year exported to Japan, the Netherlands and the USA.

In Australia, the range of *Curcuma* cultivars sold as a cut-flower and potted colour has mostly consisted of selections from overseas. A number of these cultivars have been used both as a cut-flower and potted colour. However, only a select few have been good cut-flower types, predominantly *C. alismatifolia* cultivars.

In 2002, a *Curcuma* breeding project was initiated in the 'New and Improved Ornamental Crops' program as a continuation of the ginger breeding work that was already in progress to successfully generate a range of new and improved cut-flower ginger varieties. At the beginning, the focus of the *Curcuma* breeding work was on cut-flower varieties; however, as the breeding work progressed, the focus widened towards identifying promising potted colour types.

In early 2008, 16 promising new cut-flower varieties were selected from the hybrid field trial after evaluating them for a number of flowering characteristics. The outcomes of the flowering evaluation for these 16 varieties are discussed.

Method:

The hybrids in the field trial were assessed over two flowering seasons 2005-06 and 2006-07 for several flowering characteristics (see Table 1). For the post-harvest studies, flower stems were cut just above the soil level and when up to 50% of the day flowers in the inflorescences were open. For each of the flower stems, data was recorded on vase-life, stem length and inflorescence head length.

In the field, hybrid vigour and performance were observed and recorded in relation to flowering period, productivity, adaptability to the full sun and the incidence of spotting on the inflorescence. The incidence of spotting was only assessed on those hybrids crossed with the species *C. alismatifolia* and *C. thorelli* which are prone to this disorder. This spotting disorder is caused by a fungus that leads to the appearance of small dark pin-hole spots on the inflorescence bracts, stems and sometime on leaves (sees Figure 2). In rainy and high humidity conditions the severity of spotting increases.

In addition, the inflorescence colour and form of the hybrids was also observed during the field assessment.

Table 1. Evaluation of flower characteristics for cut -lowers

Characteristics	**Minimum standard**	**Priority**
Vase-life	10 days from pick to first sign of ageing	Essential
Yield	>10 stems/plant	Essential
Stem length	30cm	Important
No. of colourful floral bracts per spike	Numerous	Important
Spotting - response or tolerance to Phomas fungus	Good	Important

Results:

From the field and post-harvest assessments, 62 hybrids were selected and dug-up from the field trial and potted. Six of the hybrids were found dead when dug-up. The remaining hybrids were evaluated and ranked for flowering characteristics of cut-flowers. The result was a selection of 16 ‘best-bet’ cut-flower types based on improved commercial traits, yield, vase-life, stem length, hybrid vigour, colour and form.

A successful “*Curcuma* naming competition” was held through the Department’s intranet site that resulted in the 16 hybrids being named.

Evaluation of flowering characteristics

In general, in most of the 16 varieties, stem length ranged from 20 cm to 30 cm. ‘Waterlily’ had the shortest stem length of less than 20 cm and ‘Pink Ruffle’ had the longest stem length of 50 cm. From Table 1 the flowering characteristic for stem length was rated as important with the minimum standard for cut-flowers being 30 cm. However, stem length less than 30 cm was still considered acceptable for some of the smaller head inflorescences such as ‘Waterlily’, ‘Sophia’ and ‘Tip Top’ that could be used in small flower table arrangements.

All 16 varieties exhibited good hybrid vigour with regards to their performance in the full sun. As for productivity, the most productive varieties were ‘Pink Ruffle’, ‘Triumph’, ‘Bella Vista’ and ‘Vabesi’, producing 10 to 20 flowers per plant. Five varieties produced fewer than 10 flowers per plant and were ‘Desire’, ‘Valentine’s Blush’, ‘Whitecap’, ‘Fairy Wings’ and ‘Venita’. The remaining cut-flower varieties had moderate yields of up to 10 flowers per plant. It is expected that as the plants mature, their productivity will increase, as rhizomes grow and increase in size.

All of the 16 varieties met the minimum vase-life cut-flower standard of 10 days from pick to first sign of ageing. In the post-harvest studies, inflorescences were rendered undesirable when up to 30% of the coloured bracts showed visible signs of drying and discolouration on the tips and margins (see Figure 2). The vase-life for the 16 cut-flower varieties ranged from reasonable (7 to 10 days) to excellent (10 to 14 days). Varieties such as 'Territory Splendour', 'Top End Peak' and 'Fairy Wings' had reasonable vase-life; varieties 'Pink Ruffle', 'Valentine's Blush', 'Festive' and 'Vabesi' had excellent vase-life.

The degree of spotting was found to be generally low for those varieties derived from crosses between *C. alismatifolia* x *C. alismatifolia* and *C. alismatifolia* x *C. thorelli* parents. At the start of the flowering season in October there was none to very little spotting observed on the inflorescences, primarily due to the infrequent rainy days at this time of the year. However, the incidence of spotting became more prevalent later on in the flowering season as the frequency of rainy days increased as did high humidity. Varieties that experienced moderate spotting under these conditions were 'Whitecap', 'Festive' and 'Fairy Wings'. Only two varieties, 'Vabesi' and 'Venita' had no symptoms of spotting on the inflorescence throughout the flowering season. This was due to both of 'Vabesi' parents being non-susceptible to the spotting disorder. However, the variety 'Venita' is a resistant hybrid that has resulted from a cross between *C. alismatifolia* and a non-susceptible *Curcuma* species.

Figure 1. Incidence of spotting on *Curcuma* inflorescence

Figure 2. Visible signs of ageing with drying and discolouration of inflorescence bracts.

The inflorescence form of most of the 16 varieties was either like *C. alismatifolia* variety 'Pink Ruffle' or *C. thorelli* variety 'Whitecap'. Within the group of *C. alismatifolia* hybrid varieties, there were closed-bract inflorescence types such as 'Desire' and 'Triumph', and more open-bract types such as 'Territory Cerise' and 'Fairy Wings' varieties (see Figure 1). Also, the colour of the inflorescence bracts ranged from light pink in 'Fairy Wings' to dark pink/purple in 'Desire', and white with tinges of pink and green on the tips in the variety 'Top End Peak'. In the group of *C. thorelli* hybrid varieties, some had a strong pink tinge colour present on the tips and margins of the white coloured bracts, such as varieties 'Valentine's Blush' and 'Territory Splendour'. In addition, the foliage of some of the *C. thorelli* hybrid varieties like 'Bella Vista' and 'Territory Splendour' had an attractive dark purple colour stripe midrib on the leaves (see Figure 1). Only two varieties had very different inflorescence forms. They were 'Vabesi' and 'Venita'. Both were larger and had many colourful bracts.

Conclusion:

The 16 promising 'best-bet' *Curcuma* cut-flower varieties were evaluated and selected based on improved commercial traits: yield, vase-life, stem length, hybrid vigour, colour and form. A number of varieties such as 'Pink Ruffle', 'Bella Vista' and 'Desire' had highly desirable characteristics such as long stem of mote than 30 cm, excellent vase-life of more than10 days and a low incidence of spotting on the inflorescence. Tolerance to the spotting disease that significantly reduces the quality of the cut-flower was an important criterion in the flowering evaluation. The breeding work demonstrates that through rigorous crossing and selection with cultivars that had some tolerance to spotting, hybrids could be produced with a greater degree of tolerance. Furthermore, when susceptible species were crossed with non-susceptible species, resistant hybrids were produced such as the variety 'Venita'. In addition to the yield and marketable flowering characteristics, the 16 varieties also provided a wider range of colour and forms of *Curcuma* cut-flowers for the market.

PROJECT: Commercial Scale Production of *Solanum Centrale* - Inputs and Methods

Project Officer: G. Hargreaves

Division:	Plant Industries
Location:	Alice Springs
Keyword(s):	DKCRC, bush food, bush tomato, *Solanum centrale*, indigenous horticulture

Objectives:

To assess inputs, outputs and methods of producing Solanum centrale (bush tomatoes).

To transmit the technology to indigenous groups to facilitate commercial production of Solanum centrale.

Background:

Interest in cultivating and harvesting wild Australian native foods has increased significantly in recent years as more local and overseas people become aware of them. The potential development of such a traditional horticultural industry is still largely unexplored. The opportunities for commercial horticultural production of such foods as well as for harvesting them from the wild are considerable.

Currently, most of the supply is sourced from wild harvesting. Commercial production will supplement and encourage sustainable wild harvesting to meet increasing demand.

The Desert Knowledge CRC is receiving an increasing number of enquiries from Aboriginal people seeking information and advice about growing bush tomatoes commercially. This project will seek to provide answers to such enquiries and demonstrate alternative ways for Aboriginal people to benefit from participating in the bush foods industry through enterprise development and employment.

Method:

The horticulture block at AZRI has been used for research for many years. It was assumed that its soil was of questionable quality and most likely had fertiliser residue and/or poor fertility. Soil samples from the site were tested for total exchange capacity, organic matter, anions, cations and base elements. The site was

found to have extremely high or excessive levels of potassium (K) and phosphorous (P), but very low levels of nitrogen and organic matter. For this reason it was decided not to examine fertiliser regimes in this trial as the residual K and P could confound the results.

Stage 1 of the trial involved planting bush tomatoes in areas A1 and A2 in March 2007 at a spacing of 0.3 m in rows 1.5 m apart. The initial planting was to examine the effect of different geographical plant sources and of three irrigation regimes. The three identified sources were:

- Napperby
- Ambalindum
- Utopia

The effect of irrigation was examined by using three different types of drip lines with different rates of flow. The three types of drip line were:

- Typhoon Super 80, drip spacing 30 cm, delivering 1 L/hour 17 mm
- Netafim Dripline 2000, drip spacing 30 cm, delivering 2 L/hour 17mm
- Netafim Dripline 2000, drip spacing 30 cm, delivering 3 L/hour 17mm (Dripnet)

Block A1 was planted entirely with *Solanum centrale* sourced from Napperby. Block A2 had plants from all the three geographical sources randomly assigned to rows. The three different drip lines were randomly assigned to rows within both blocks.

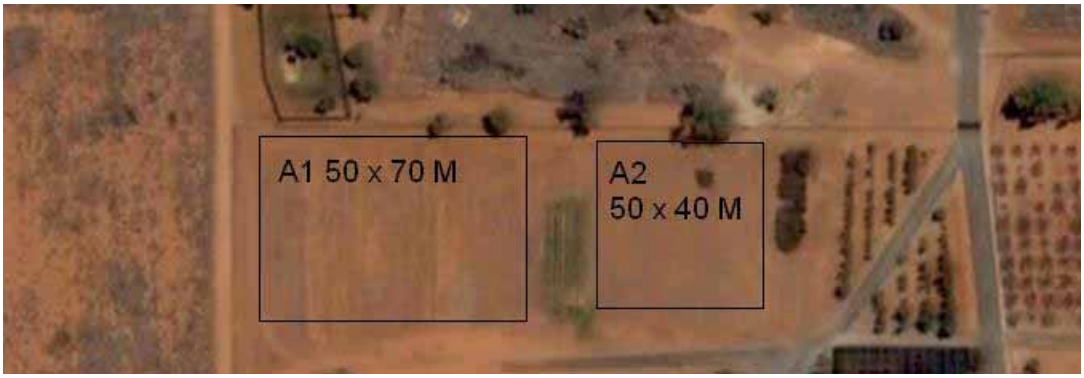

Figure 1. Satellite photo of the horticultural area at AZRI with trial areas marked

The irrigation water is from a bore located at the AZRI site RN16958. A chemical analysis conducted on the water on 18/08/2004 revealed it had electrical conductivity (EC) of 2390µS cm^{-1} indicating a high salt content. While this could have an effect on the growth of the bush tomato plants, it was considered to be a realistic scenario as many indigenous communities had bore water with high salt content and a high EC. Should the bore fail, there was a second on site that can be used as a back-up.

Monitoring

The plants were monitored throughout the growing season for insect damage and grazing by animals such as rabbits and kangaroos. The effect of the weather on flowering and fruit-set were noted. Plants with high yield and an upright habit were marked. The upright habit was preferred for mechanical harvesting. The plants were hand-picked and the fruit was weighed. To determine if a certain provenance was higher yielding, the fruit of each was hand-picked and weighed. The effect of different watering regimes was checked through the weight of fruit.

In April 2008 a mechanical harvesting was started.

Results:

Contact the author at AZRI for information available up to now.

PROJECT: Genetic Improvement of Hardwood

Project Officer: D. Reilly

Division:	Plant Industries
Location:	Darwin
Keyword(s)	forestry, provenance, hardwood

Objectives:

To rapidly improve stem straightness and to produce diverse, second-generation progeny.

To phenotypically select at least a few superior trees from each of the 24 provenances (from 11 countries of origin and one secondary) represented in the former CSIRO trials at Gunn Point and Melville Island.

To establish a series of clone tests for identification of superior genetic lines for further deployment and commercial adoption.

To match Khaya senegalensis to sites and determine optimal silviculture, nutrition, management regimes and wood improvement needs.

To collect seed from the clonal seed orchards established at Howard Springs and Berrimah Farm eight years ago from the provenances deployed and the best 20 selected trees available to enable a seedling deployment option (family selection) and planting a second generation seed orchard.

To plant a second cycle base population as an open-pollinated 'gene re-combination orchard' with selected families and infusions to enable further future selection of superior, second-generation trees for on-going deployment.

To improve the expertise of DRDPIFR staff in genetics and tree breeding.

Background:

Natural provenance trials of African mahogany (*Khaya senegalensis)* planted at Gunn Point and Melville Island in the early 1970s showed good growth. The stands contain trees from 12 African countries in which the species occur naturally - from Senegal in West Africa to Sudan and Uganda in the east of the continent - and from derived stands in New Caledonia.

Method:

Superior trees were selected in 2000; they were grafted and then planted in December 2001 in a clonal seed orchard and a gene re-combination orchard at Howard Springs and Berrimah Farm, respectively.

In October 2003, 38 mature age trees were selected and harvested for a timber evaluation study of the species. Most of the trees were from Gunn Point and were among the original 96 that were grafted and planted in the seed orchards. The remaining trees were selected from known provenances of the same age at Howard Springs.

Of the harvested trees at Gunn Point, 11 had mature seed pods which were collected, grown on and planted at Berrimah Farm in family rows. With the addition of seedling material from Weipa in north Queensland and vegetatively-produced cuttings from selected areas at Howard Springs, the first hedge garden (HG) was established in March 2004. Additions have been made with coppice (stump re-growth) from some of the harvested trees at both harvest sites. There are now more than 560 individual plants in the HG which provide cuttings that can be propagated and deployed as rooted cuttings (RC) in clone tests at a number of sites. There are now nine clone tests at the Coastal Plains Horticulture Research Station (CPHRS), the Douglas Daly Research Farm, and the Katherine Research Station (KRS) and on commercial properties from Melville Island in the north to the Douglas/Daly region and Katherine in the south. The composition of the recently-established clone tests are outlined in Table 1.

Table 1. Summary of the composition of *Khaya senegalensis* clone tests

Test material x test sites – showing number of clones or number of seedlings	**CT* 1(g) GSL Melville Is. – 50 km north of Darwin (3 ramets/clone) planted January 07**	**CT 1(h) (NTT property 170 km south of Darwin (3-5 ramets/clone) planted March 07**	**CT 1(i) (GSL property 170km south of Darwin (3-5 ramets/clone) planted January 08**
Clones from OP** seedlings ex 11 of the 38 trees selected in 2003 in the NT plantings of the early 1970s at Gunn Pt and Howard Springs.	48 (includes many linking/common clones to CT 1a; and many links to CT 1b)	137 (includes many linking/common clones to CT 1a; and many links to CT 1b)	88 (includes many linking/common clones to CT 1a; and many links to CT 1b)
Clones from bulked seed ex Weipa, Qld selects	23	32	15
Clones ex NT wildlings	8	25	7
Other clones	2	3	0
Clone total per replicate	**81**	**197**	**110**
Seedlings from Ks 124 (ex seed Orchard)	40 per rep	10	0
Seedlings from Ks 129 (new infusion)	0	0	10
Seedlings ex Darwin street trees	39 per rep	33	0
Seedlings totals per replicate	**79**	**43**	**10**
Grand total plants per replicate	**160**	**240**	**120**

*CT = clone test; **OP = open pollinated

Results:

The first two clone tests established at CPHRS in early 2005, (reported in the 2004-05 and 2006-07 TAR) were measured at six months and 12 months for growth in height and branching. Any trees that showed extraordinary growth or form were also noted. The later measurements (the most recent in June 2008) have greatly extended the parameters measured to include, apart from height, diameter (DBH), apical dominance, bole length and stem straightness. This will provide a more accurate picture of how the trees are performing, keeping in mind that tall trees are not always productive trees. A snapshot of the best performing families (in terms of height growth, diameter and form) is shown below of clone test 1(a) and 1 (b) at CPHRS and 1(d) at KRS. The more recently established clone test trees on commercial properties were measured in July 2008 and indicate the growth of the average of the families deployed.

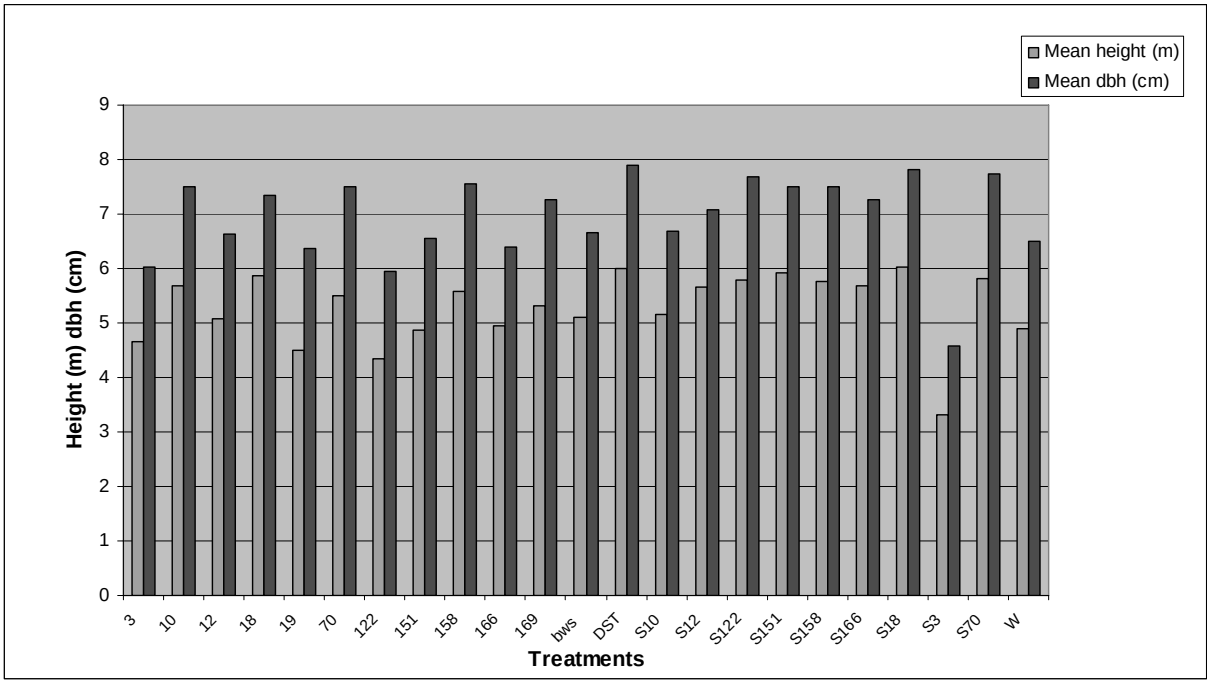

Figure 1. Height and diameter *of K. senegalensis* clone test 1(a) at 40 months

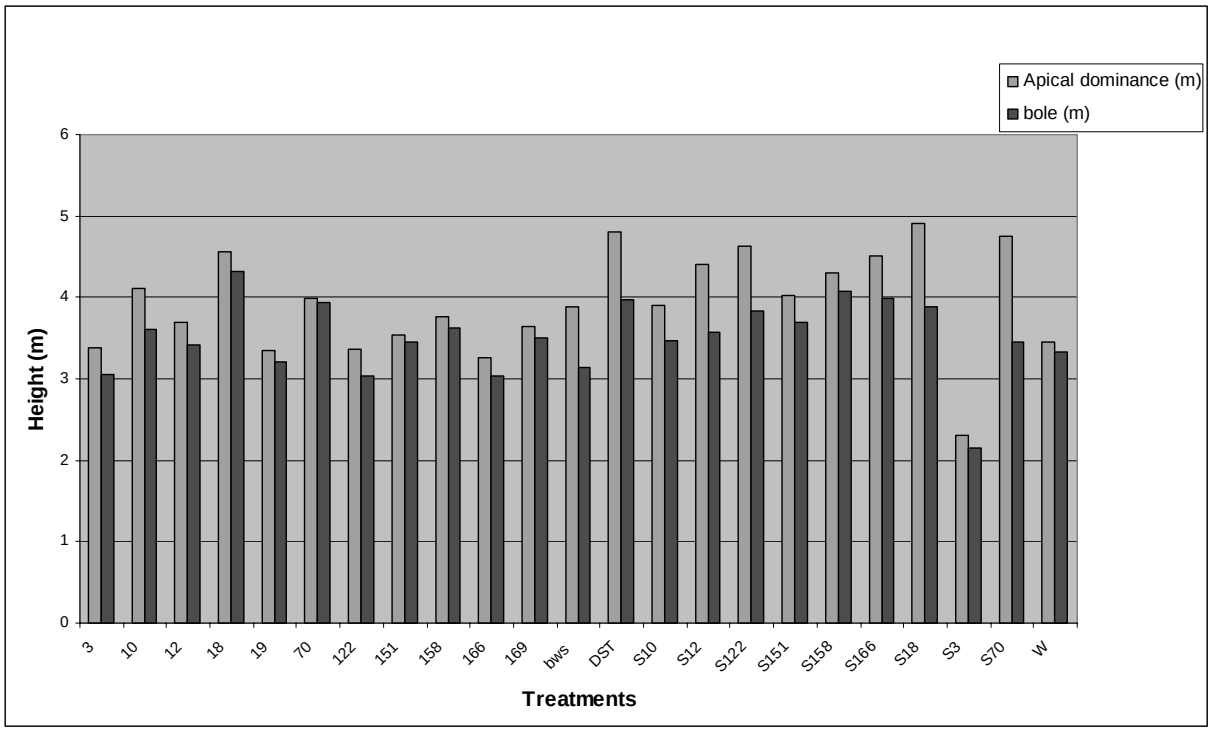

Figure 2. Apical dominance and bole length of *K. senegalensis* at clone test 1(a) at 40 months

The above figures summarise four parameters measured from the trees at 40 months of age at CPHRS. Within plots, there is considerable variability (as reported previously) between families of clonal material and seedlings. Previously the seedling treatments had superior growth. However, it now appears that the clonal material is equal to, if not better than, seedlings, especially in the seedling 3 treatments. The best of the clonal treatments at this stage are 10, 18, 70 and 158. The control treatment of Darwin street trees (largest number of individuals deployed) has the highest DBH growth and equal best for height growth. The form of the seedling treatments (except S3 and W) appears to be better than the clones at this site.

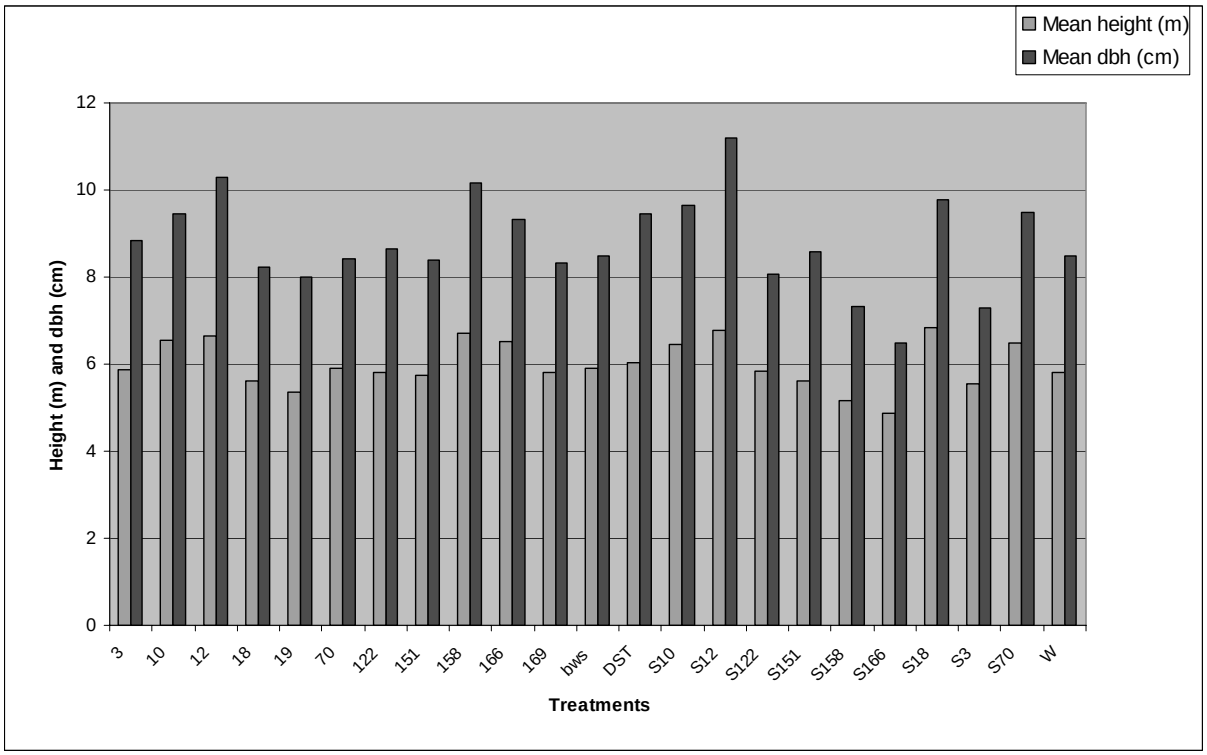

Figure 3. Height and diameter *of K. senegalensis* clone test 1(b) at 40 months

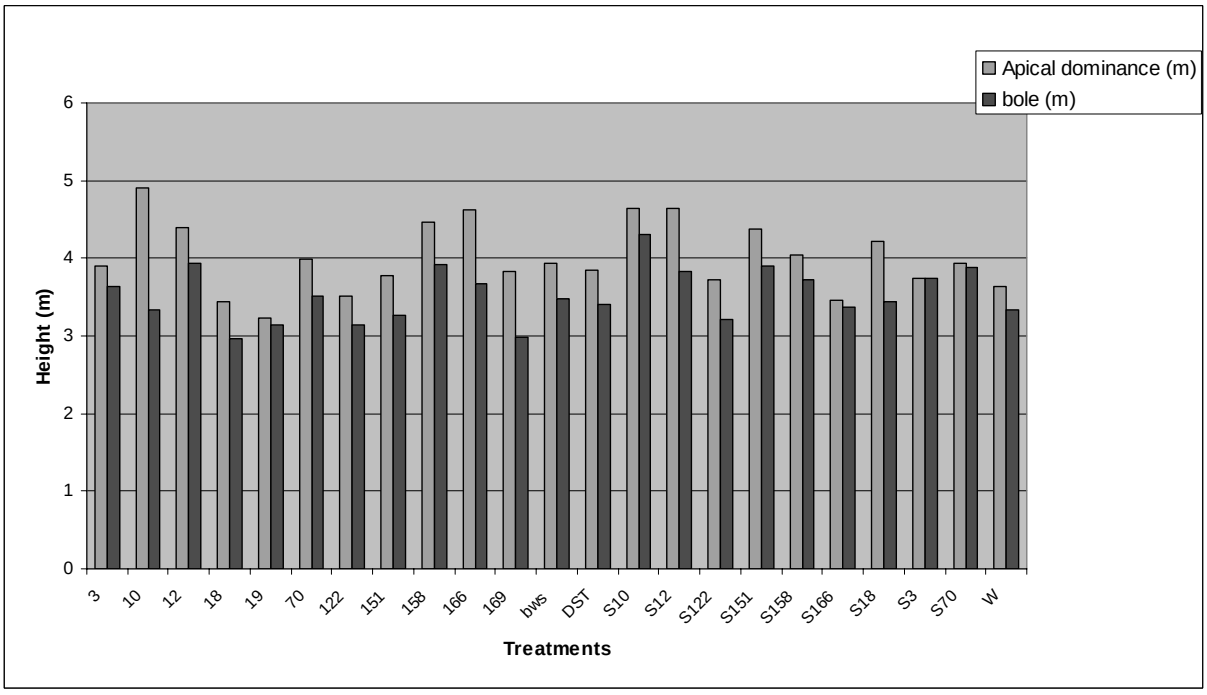

Figure 4. Apical dominance and bole length of *K. senegalensis* at clone test 1(b) at 40 months

The results of measurements from CT 1(b) indicate the clonal material and seedlings of family 12 are growing the best along with families 10 and 158. Again there is considerable variation between and within treatments. The best form as indicated in Figure 4 shows families 10, 12, 158 and 166 have the best trees.

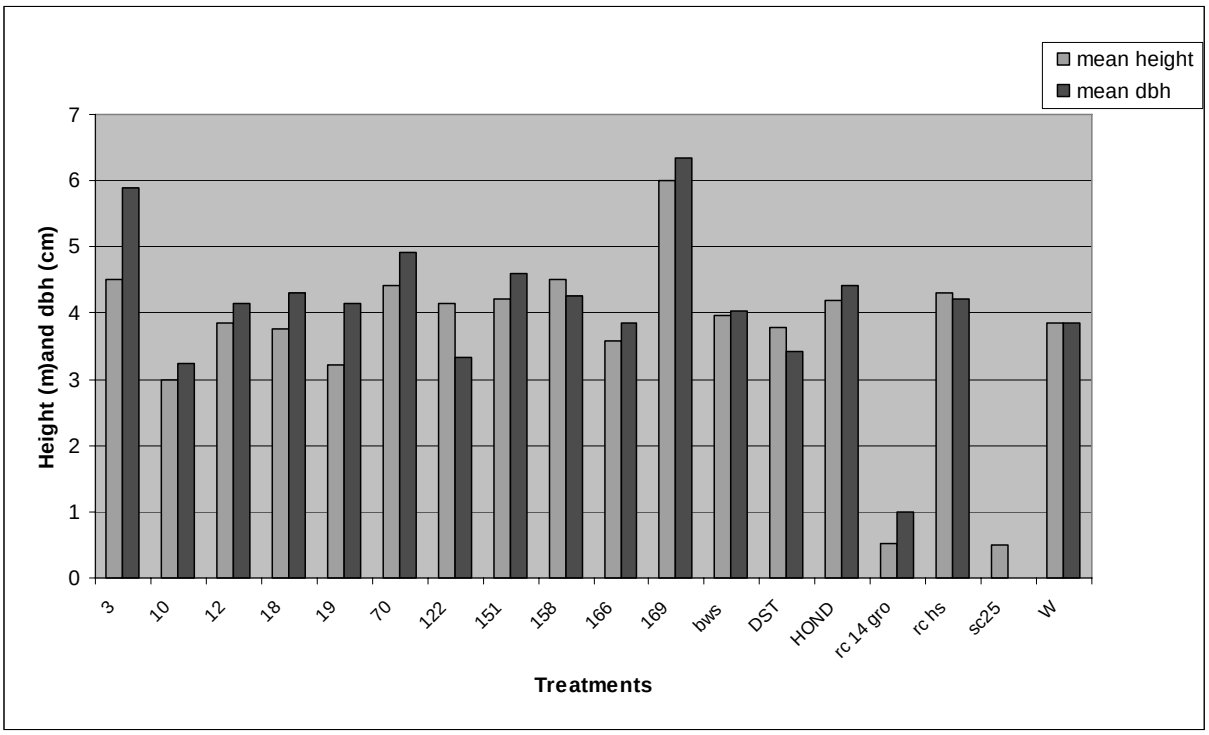

Figure 5. Height and DBH of *K. senegalensis* clone test 1(d) at 30 months

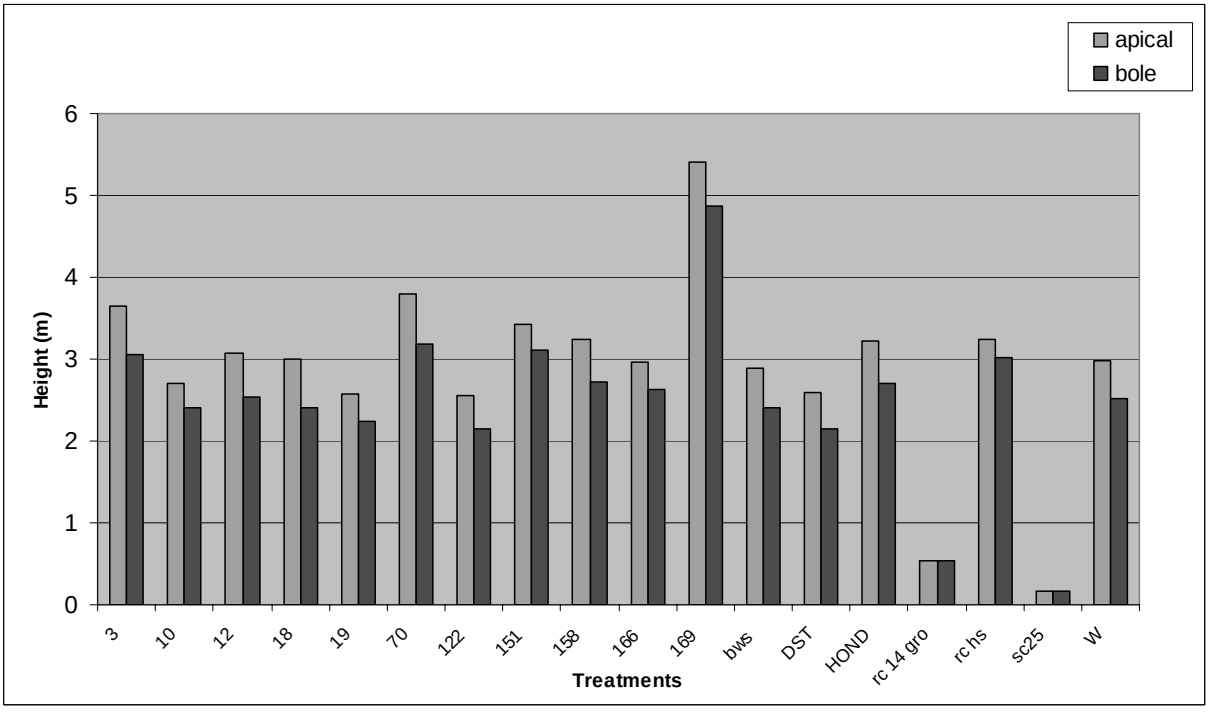

Figure 6. Apical dominance and bole length of *K. senegalensis* clone test 1(d) at 30 months

At Katherine, in the CT 1(d) the treatments of 3, 70 and 169 are showing the best growth and form although treatment 169 has low representation (n = 3). The results here show a very different trend from that seen at CPHRS. An expected difference between sites is showing variability of the family's adoption to a different set of conditions, such as soil, temperature and 'dry period'.

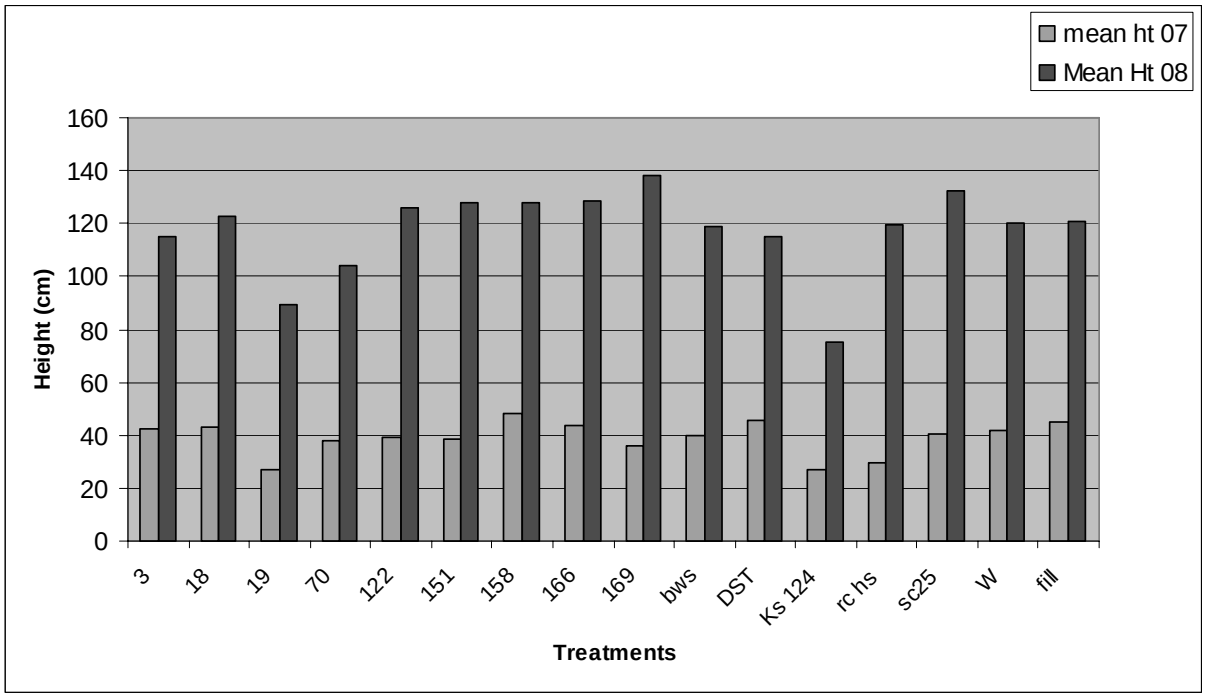

Figure 7. Height of *K. senegalensis*, clone test 1(g) at five and 17 months

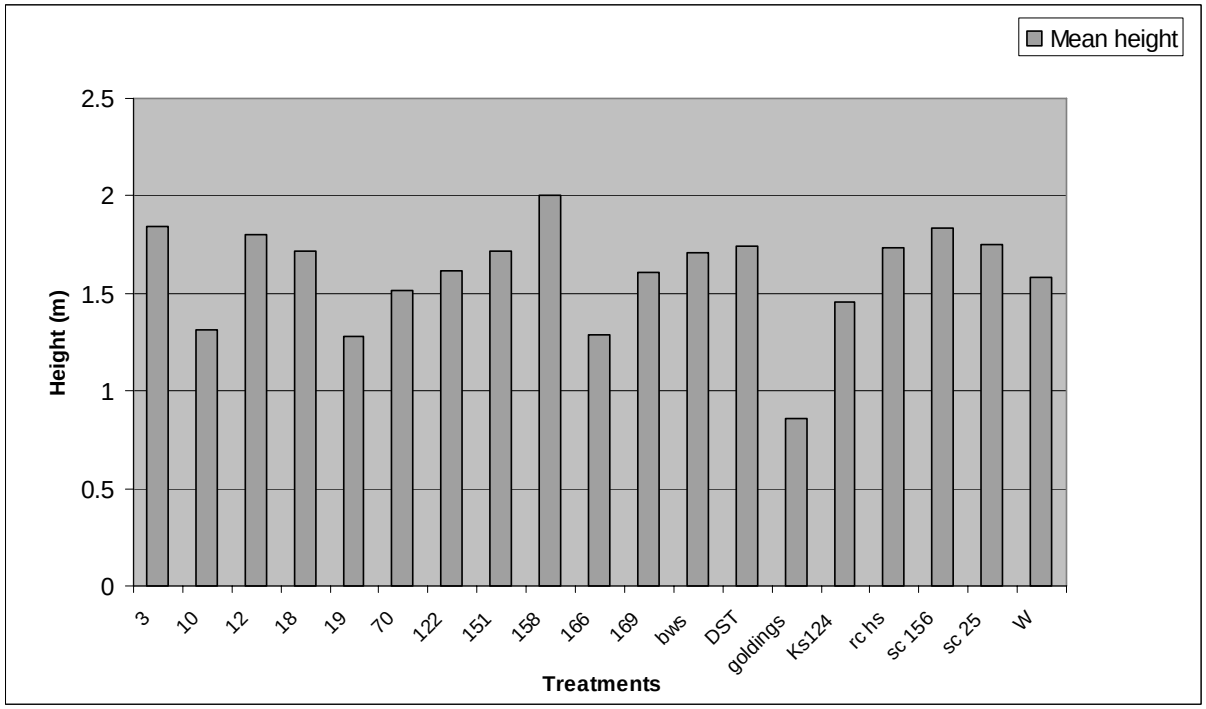

Figure 8. Height of *K. senegalensis* clone test 1(h) at 16 months

At clone tests 1(g) and 1(h) only height growth has been measured so far. At CT 1(g) on Melville Island, the trend seen at five month-old appears to be repeating at 17 months, with the clonal material appearing to grow better than the seedlings at that site.

At CT 1(h) at the Northern Tropical Timbers site in the Douglas /Daly area, only height growth has been measured and variation between treatments is very evident again with treatment 158 exhibiting the best growth.

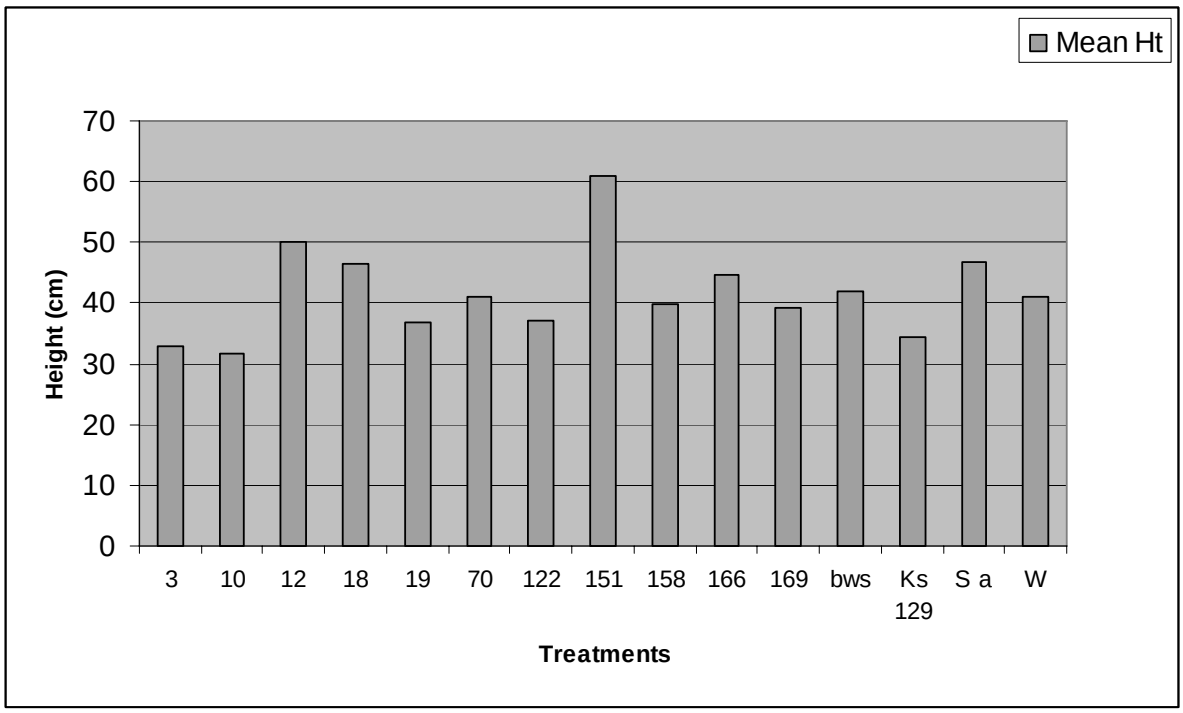

Figure 9. Height of *K. senegalensis* of clone test 1(i) at four months

The most recent clone test established is at the GSL property in the Douglas /Daly region which was planted in February 2008 and consists of six incomplete blocks (20 trees) per replication, and five replicates, giving a total of 600 trees in the trial.

As it was initiated recently, this trial does not allow firm conclusions to be made about the best genetic lines at this stage. The fact that only height was measured indicates that most trees had insufficient diameter growth to be recorded and there is large variability between the numbers representing each treatment.

Due to the inconsistencies within the hedge garden (source of cuttings) for propagation purposes there is not the same number of plants per treatment and for the rooted cuttings the range is from a low of three for entry 10 to a high of 53 for Weipa clonal material. The seedling component (controls) of ‘seedling A’ and ‘Ks 129’ have the highest with 150 and 167, respectively. The low representation of the rooted cutting component, especially from treatments ‘10’, ‘18’ and ‘169’ is a product of the low ‘rootability’ of some of the hedge garden families. This is being improved. Meanwhile, the low representation has required that many clone tests be established because of the variation and the high number of plants in the hedge garden to be tested. This was also an aim of the testing, to determine the suitability of clones to various sites so that some interaction between clones and environment can be evaluated and to better meet the requirements of commercial needs when assessing the suitability of genetic lines to a particular set of site conditions.

Seed orchards

The first general flowering followed by seed set occurred at the Howard Springs clonal seed orchard in 2007. In an effort to collect as much seed as possible, seed pods were bagged to retain seeds for collection when ripe. Table 2 shows the trees that flowered and also those that went on to produce seed.

Table 2. Tree performance details

Flowering clones in GRO and CCB		Update 070608		Flower observed	Seed pods
Clone No.	**Provenance and seed lot**	**Planted**	**Position**	**24- 2808 (X = yes)**	**0308**
4	Ghana d500	CCB	R6 T28	X	
5	Uganda S10053	GRO	R18 T5	X	yes
5	Uganda S10053	GRO	R24 T6	X	yes
5	Uganda S10053	GRO	R28 T3	X	
7	Senegal S10066	GRO	R21 T4	X	
8	New Caledonia D522	GRO	R1 T5	X	
9	New Caledonia D522	GRO	R0 T5	X	yes
11	New Caledonia D522	GRO	R21 T8	X	
11	New Caledonia D522	GRO	R23 T3	X	
13	Senegal S10066	GRO	R18 T1	X	
17	Senegal S10066	GRO	R23 T12	X	
20	Uganda S9620	GRO	R15 T5	X	yes
20	Uganda S9620	GRO	R28 T2	X	
21	Jos Nigeria D480	GRO	R15 T6	X	yes
25	Sudan S9687	GRO	R15 T1	X	
25	Sudan S9687	GRO	R4 T5	X	
27	Yola Nigeria D486	CCB	R7 T8	X	
27	Yola Nigeria D486	CCB	R8 T1	X	
27	Yola Nigeria D486	GRO	R25 T7	X	yes
30	New Caledonia D477	GRO	R24 T4	X	yes
30	New Caledonia D477	GRO	R29 T7	X	
32	Ghana d500	GRO	R28 T1	X	
33	Ivory Coast S10050	GRO	R13 T11	X	
33	Ivory Coast S10050	GRO	R17 T8	X	
33	Ivory Coast S10050	GRO	R30 T11	X	
33	Ivory Coast S10050	GRO	R5 T10	X	
36	Jos Nigeria D480	GRO	R19 T4	X	
37	Yola Nigeria D486	GRO	R26 T2	X	
50	Senegal D417	GRO	R26T7	query	yes
52	New Caledonia D487	GRO	R2 T3	X	yes
53	New Caledonia D487	GRO	R12 T2	X	
61	Yola Nigeria D486	GRO	R20 T8	X	
61	Yola Nigeria D486	GRO	R23 T11	X	yes
62	Yola Nigeria D486	GRO	R9 T3	X	yes
63	Ivory Coast S10050	GRO	R19 T2	X	yes
63	Ivory Coast S10050	GRO	R22 T11	X	yes
63	Ivory Coast S10050	GRO	R26 T10	X	yes
64	Ivory Coast S10050	GRO	R12 T6	X	
65	Jos Nigeria D480	GRO	R29 T3	X	
66	Jos Nigeria D480	GRO	R12 T9	X	yes
66	Jos Nigeria D480	GRO	R23 T2	X	
66	Jos Nigeria D480	GRO	R25 T10	X	

Flowering clones in GRO and CCB		Update 070608		Flower observed	Seed pods
Clone No.	**Provenance and seed lot**	**Planted**	**Position**	**24- 2808 (X = yes)**	**0308**
67	Sudan S9687	GRO	R24 T10	X	yes
73	Uganda D408	GRO	R22 T2	X	
74	Uganda D408	GRO	R25 T6	X	
77	Senegal S9392	GRO	R19 T12	X	YES
77	Senegal S9392	GRO	R26 T9	X	
77	Senegal S9392	GRO	R31 T11	X	
78	Togo D411	GRO	R10 T8	X	
78	Togo D411	GRO	R17 T6	X	yes
79	Togo D411	GRO	R27 T9	X	
83	Central Af Rep D391	GRO	R18 T7	X	
83	Central Af Rep D391	GRO	R22 T12	X	yes
83	Central Af Rep D391	GRO	R4 T6	X	yes
91	Central Af Rep D391	GRO	R10 T2	X	
92	Central Af Rep D391	CCB	R4 T14	X	
94	Uganda S9620	GRO	R12 T7	X	yes
94	Uganda S9620	GRO	R23 T7	X	yes
94	Uganda S9620	GRO	R3 T1	X	
96	Senegal S9392	GRO	R15 T10	X	
96	Senegal S9392	GRO	R22 T9	X	YES
102	Uganda D407	CCB	R6 T16	X	
102	Uganda D407	GRO	R14 T5	X	yes
102	Uganda D407	GRO	R21 T9	X	
102	Uganda D407	GRO	R26 T11	X	yes
102	Uganda D407	GRO	R30 T3	X	
103	Uganda D407	GRO	R22 T4	X	
104	Uganda D407	GRO	R10 T6	X	yes
104	Uganda D407	GRO	R30 T10	X	yes
107	Central Af Rep D391	CCB	R1 T10	X	
107	Central Af Rep D391	CCB	R2 T23	X	
107	Central Af Rep D391	GRO	R17 T11	X	yes
107	Central Af Rep D391	GRO	R6 T10	X	
113	Sudan S9368	GRO	R17 T1	X	yes
113	Sudan S9368	GRO	R8 T2	X	
116	Uganda D407	GRO	R17 T2	X	yes
116	Uganda D407	GRO	R5 T8	X	yes
118	Unknown Berrimah	GRO	R23 T9	X	
118	Unknown Berrimah	GRO	R27 T2	X	
119	Unknown Berrimah	GRO	R11 T4	X	yes
119	Unknown Berrimah	GRO	R9 T9	X	yes
121	Senegal D417	GRO	R19 T10	X	yes
121	Senegal D417	GRO	R5 T1	X	yes
124	Uganda S10053	GRO	R27T11	query	yes
124	Uganda S10053	GRO	R14 T2	X	

PROJECT: Scenario Planning for Sustainable Regional Development: Scenarios for a Different Future

Project Officers: M. Darcey and L. Doney

Division:	Plant Industries
Location:	NT
Keyword(s):	scenario planning, natural resource management, futures, land use

Objectives:

To test the use of scenario development as a tool for natural resource planning in the Northern Territory (NT).

To describe possible futures for the Top End based on a range of scenarios using natural resource management (NRM) as the context.

To critically identify gaps in knowledge and assist in focusing research based on plausible and well thought out futures.

To include internal and external influences in the possible different futures to allow discussion of the impacts of those futures and strategies.

To broaden the thinking of workshop participants to define those futures and use them as "champions" of this type of thinking and the scenario planning technique in the NT.

Background:

Scenario planning has been used as a strategic planning tool by organisations and groups for many years. The methodology has not been used previously in the primary industry sector of the NT. The rapid change facing the sector called for alternative approaches to thinking about the future.

Four alternative views about how the future might unfold for the NT were developed at a series of four workshops between March and April 2008 by 25 residents of the NT.

The project was designed to test the value of scenario planning as a method for clarifying agricultural and natural resource managers' thinking and decision-making.

Method:

A public information forum was held to introduce concepts, to provide background and contextual information, resources and expert speakers to stimulate thought. The target audience included anyone with an interest in NRM issues and agribusiness development in the NT. Audience members were invited to nominate as participants in follow-on scenario development workshops.

Facilitated Workshop 1 to introduce scenario development concepts/processes, deliver presentations, gather baseline data and choose topics for scenario development.

Workshop 2 was facilitated to continue scenario development and prepare presentations for a final forum.

A public forum was organised to share scenarios/findings with a wider audience and to evaluate the project.

The key steps in developing the scenarios during the facilitated workshops for this project were as follows:

1. *Introduction to the participants*

Welcome, introduce the workshop and warm-up introductions for participants and got to know each other.

2. *Introduction to scenario planning*

Outlined the scenario process and approach, provided an overview of expectations and assumptions and discussed roles. Explained the nature of futures thinking and scenario planning to participants and invited questions.

3. *Historical timeline*

Input into the key events that have occurred and shaped the NT over the past to orient participants to the rate of change by developing a historical timeline of land use in the NT. Participants had a clear understanding of the process they were about to embark upon and of scenario planning, more generally.

4. *Present trends*

The Environmental Scanning Report was reviewed. Group discussion was facilitated, drawing on trends and present issues. The environmental scanning collated expert ideas and trends from a range of credible sources. The group discussed key future trends as identified in the trends paper and those known by experts, agriculturalists, and business and community members in the room.

5. *Underlying drivers of change*

Group activity designed to explore the underlying drivers of these trends was facilitated. Processes of cause and effect were explored; the polar ends of a trend were considered; deeper layers were looked for by asking ‘why?’

6. *Crossed-swords method for scenarios*

Two key drivers were identified as cross-swords to develop a two-by-two matrix. Each driver had credible outcomes (e.g. high, low) and the two drivers were themed differently (e.g. social, political, technological), so that the worlds created could be easily differentiated. Participants formed groups around these worlds (ensuring a diverse mix of views within each group) and began to answer some questions about what that world might look like given those driver constraints. Participants selected two sets of causes (drivers) of change and develop four to five future ‘worlds’ or scenarios of the NT by 2050.

7. *Scenario landscapes*

Participants were divided into their world groups and worked through questions in the scenario notes to ensure that all participants had taken on board the questions posed in the scenario notes. Groups were asked to do an illustration for their world that could be added to and notated during the day.

8. *Economics and society: how is land used in 2050?*

The groups worked through the economics and society matrix in each world group to outline key aspects of the society through a matrix.

9. *Future timeline*

The facilitators presented the trends outlined in the 'snapshot' paper and explained the process of documenting a timeline. The groups were divided into their four worlds with butcher paper to complete their timeline. Key inconsistencies were discussed and explored by the group; changes were made to the original scenarios and were recorded. The key moments in 'history' that led to the development of the 2050 world were identified

10. *Cross-testing plausibility*

The worlds were divided into pairs to query assumptions around common drivers. Each world group then reported back on its world and timeline to the whole group. Facilitators led the discussion to challenge key assumptions within each world's timeline and scenario. The whole group provided input and challenged inconsistencies.

11. *Scenario people*

Groups developed characters that could inhabit each world to imagine the motivations, characteristics, values and behaviours of people in each scenario world to enable the world to 'come alive'.

12. *Implications, opportunities and risks*

Participants were asked to discuss the key opportunities and risks for the NT of each scenario and the gaps in knowledge to encourage all groups to reflect on each scenario and the implications for the NT.

13. *Insights*

Participants were asked to discuss key insights and learning from the process and things to change next time. Participants were asked to provide evaluations.

14. *Presentation of scenarios and scenario process*

Each group presented its scenario in a creative and engaging way to share the scenarios and reflect on the scenario thinking process. Time was allowed for reflection on the process, evaluation and consideration of implications.

15. *Final report*

A final report was written to record all the information about scenarios and the recommended next steps.

Results:

The four scenarios offer a perspective about how the NT's future (roughly to 2050) might be different from the present and the past. They illustrate participants' concerns about the NT's ability to shape or create the future and how this might affect land use and natural resource management planning and practices. The four scenarios were:

Terratopia: In the first scenario a more sophisticated understanding of sustainability together with an emphasis on regional governance leads to late but effective intervention, attitudinal change and new ways of doing business.

Territory frontier: In the second scenario resource scarcity and ecosystem degradation coupled with late intervention lead to declines in population and the economy that catalyse a strong pioneering attitude amongst distributed small communities.

Prudential world: The third scenario describes a future where change has had limited consequences (few gains, few losses) causing Territorians to become complacent about the future. This complacency has diminished the NT's resilience (its capacity to cope with future shocks and surprises).

Beehive world: The fourth scenario describes centralised governance and a loss of political autonomy, enabling the NT to recover from a series of disasters. On the bright side, new industries emerge as a result of new ways of thinking about land use and biosecurity concerns.

PROJECT: Development of a Molecular Identification Test for *Cryptotermes* Species

Project Officers: L. Tran-Nguyen, M. Neal and B. M. Thistleton

Division:	Plant Industries
Location:	Darwin
Keyword(s):	biosecurity, dry-wood termite, DNA

Objective:

To develop a molecular diagnostic test to identify Cryptotermes species.

Background:

The dry wood termite (*Cryptotermes dudleyi* Banks (Isoptera: Kalotermitidae) was first detected in Darwin in 2003 in imported furniture. This species is closely related and morphologically similar to the native *C. secundus*. Dry wood termites are renowned for being the most invasive of all termites due to a combination of their life history, food sources and ease of transport by humans. The Australian horticulture and forestry industries, including those in the Northern Territory, are presently free of this and other dry wood termites which are present in countries to our immediate north. Fumigation of infested material is sufficient to eradicate the pests.

The increasing number of foreign fishing vessels that reach northern Australian waters has been well documented. This serves as a biosecurity issue because the likelihood of these vessels carrying pests is high. Identification of dry wood termites depends on locating the soldier termite. A characteristic feature of dry wood termite infestation is the presence of frass at infestation holes.

The availability of a molecular diagnostic test for these termites or their frass would aid identification of the pest termites and differentiate them from native species.

Method:

Dry wood termite samples were collected from mangroves around Darwin. The fresh samples together with termites preserved in alcohol were used for DNA extractions. Based on published literature, specific primers were selected and used to identify a particular termite gene using polymerase chain reaction (PCR) technology. This particular gene can be used to establish a DNA fingerprint for the termite species.

Comparisons of the DNA fingerprint will help identify the termite species of interest. The diagnostic test can potentially be extended to using frass DNA for termite identification, thereby bypassing the need to isolate the soldier termite.

Results:

Termites were sampled from mangroves at Channel Island and Buffalo Creek. These native termites known as *C. secundus* will be used as reference strains for optimising the molecular test and establishing a DNA fingerprint. To date, DNA extractions have been conducted from over twenty termite samples. Preliminary PCR tests were successful in detecting a mitochondrial termite gene from a number of termite samples. Frass DNA contains substances which inhibit the test and are currently being investigated.

PROJECT: Grapevine Leaf Rust – Incursion Risk Assessment and Improvement of PCR Diagnostics

Project Officers: A. Daly and L. Tran-Nguyen

Division:	Plant Industries
Location:	Darwin
Keyword(s):	grape disease, grapevine leaf rust

Objectives:

To investigate the possibility of a re-introduction of grapevine leaf rust to northern Australia by airstream transport of urediniospores.

To develop a real-time polymerase chain reaction (RT-PCR) test to identify the causal agent, Phakopsora euvitis.

To develop the capacity to identify P. euvitis in leaf tissue during the incubation period, when no symptoms are visible.

Background:

Grapevine leaf rust (GLR), which is caused by the fungus *P. euvitis*, is a serious disease of grapevines in Asia. It is wind-borne and has a high potential for spread. It can infect grapevines over a wide range of temperatures and there is a risk that if introduced, it could establish in most of Australia's viticulture areas.

GLR was discovered in Darwin on urban grapevines in July 2001. The disease had not previously occurred in Australia. The National Grapevine Leaf Rust Eradication Program was initiated and all diseased vines were located and removed. The program concluded successfully on 30 June 2007.

Research results have shown that susceptibility to *P. euvitis* is widespread in *Vitis* spp. All the major commercial cultivars are highly susceptible. New hosts of the disease were also discovered. Two local native grape species, *Ampelocissus acetosa* and *A. frutescens,* are also susceptible.

It remains unknown as to how GLR entered the Northern Territory in the first place. The disease is known to occur in East Timor and throughout Indonesia. These countries may be a source of air-borne inoculum of *P. euvitis*. Aerial dispersal of fungal pathogens between continents is known to occur and has received more

attention in recent times. However, the success of such dispersal depends on the ability of spores to survive the various environmental conditions during transport.

The industry provided strong support for further research to contain and manage future incursions. Funds were provided to study potential re-entry via air-borne inoculum and to improve detection methods by developing PCR assays that would expose the pathogen in healthy looking tissue.

To assess the risk of air-borne introduction of *P. euvitis*, it is necessary to forecast the height, direction, duration, frequency and timing of intercontinental movement of air systems. This can be done using air dispersion/transport modelling programs designed for predicting long distance dispersal of pollutant particles. It is also necessary to assess the mortality of urediniospores and the type of spore responsible for the spread of the disease during various conditions of travel. For spores to successfully traverse the Timor Sea from infested areas in Indonesia and East Timor, they must be able to survive for many hours or days at variable temperatures, relative humidity and solar irradiance.

Method:

Study 1: Investigate the possibility of re-introduction of GLR to northern Australia by air stream transport of urediniospores.

Air flow between SE Asia and northern Australia

The Bureau of Meteorology (BOM) in Darwin has been asked to model air movement associated with particular weather systems between East Timor and northern Australia. The direction, duration and frequency of air movement of hypothetical parcels of air during different times of the year at low, mid and high levels (100-1500 m) will be forecast. This will be done with the aid of a dispersion/transport model, HYSPLIT V. 4.7.

Urediniospore mortality

Experiments were conducted in May 2008 at the University of Gadjah Mada in Yogyakarta, Indonesia, where *P. euvitis* is endemic and widespread.

An experiment was conducted to determine the effect of solar radiation on the germination of urediniospores in the courtyard of the university by fencing a 3 m in diameter area with plastic (Figure 1) to protect spores from wind gusts.

A B

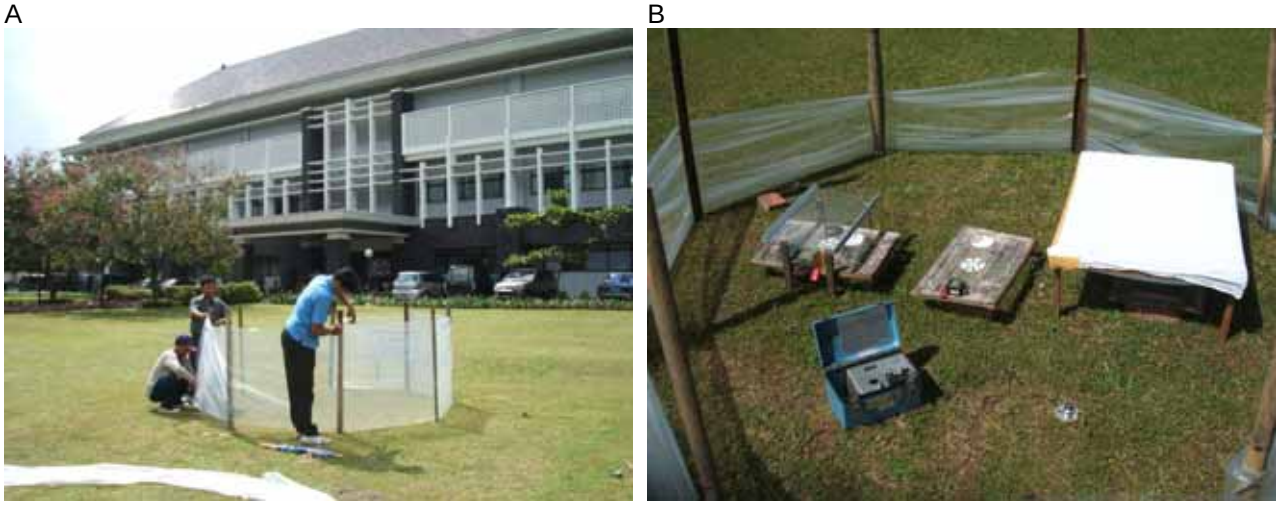

Figure 1. A. Installation of the experimental site B. Treatments and equipment (University of Gadjah Mada, Indonesia, May 2008)

Urediniospores were exposed to solar radiation in the experimental site for two consecutives days. On the day prior to exposure, a fresh set of infected leaves was harvested from local infected grapevines at around 10 a.m. when overnight due had dried. The leaves were kept at 5ºC overnight inside a sealed plastic bag. The following morning at 7.30 a.m. the urediniospores were gently tapped from the leaves onto sterile, 9-cm filter paper disks, which were placed in uncovered plastic Petri dishes. At 8 a.m. the Petri dishes were placed in the experimental site on wire grid platforms above the ground for allowing airflow. The spores on the filter paper disks were subjected to the following three treatments:

1. DS – exposure to global irradiance (Figure 2).

2. UV - exposure to solar radiation beneath an ultra-violet (UV) filter. The UV filter consisted of a trans-illuminator cover and a piece of PCR laboratory equipment, which blocked 99% of total UV radiation (Figure 3).

3. CH – exposure to diffuse solar radiation beneath four layers of cheesecloth (also known as Cotton crepe or Indian cotton) (shaded control). The light intensity beneath the cloth at midday with a clear sky was equivalent to that recorded previously at midday during full cumulonimbus cloud cover (Figure 4).

Figure 2. DS treatment: filter paper disks with urediniospores placed onto a wire grid platform and exposed to global irradiance

Figure 3. UV treatment: filter paper disks with urediniospores placed onto a wire grid platform and exposed to solar radiation beneath a UV filter

Figure 4. CH treatment: filter paper disks with urediniospores placed onto a wire grid platform and exposed to diffuse solar radiation beneath cheesecloth (shaded control)

One filter paper disk with urediniospores was used for each treatment. The disks were exposed to solar radiation for two days, from 8 a.m. to 4 p.m. The dishes were removed from the experimental site at the end of the first day, refrigerated at 5ºC overnight inside sealed plastic bags, and returned to the experimental site the following morning (second day of the experiment). After 0, 2, 4, 6 and 8 hours of exposure on the first day and 10, 12, 14 and 16 hours of cumulative exposure on the second day, a piece measuring approximately 2 x 5 cm was cut from the disks and placed on a Petri dish containing 20 g/L water agar, leaving a spore-print. The plates were incubated in darkness at 25ºC. Urediniospore germination was assessed after 24 and 48 hours. Each time the germination of 200 spores was assessed. Where no germination was evident, all urediniospores on the plates were viewed (2000-3000).

The light intensity (400-700 nm wavelength range measured in µmol S^{-1} m^{-2}) under the three treatments was recorded every hour using a LI-COR quantum sensor. Air temperature and relative humidity were recorded for each treatment every 15 minutes using Tiny Tag data loggers. Type and general duration of daily cloud cover was also noted.

The experiment was repeated five times over a nine-day period.

Study 2: Develop an RT-PCR test to identify the causal agent, Phakopsora euvitis.

The study was conducted at the University of Gadjah Mada, Yogyakarta, Indonesia where GLR is endemic. All bio-informatic analyses were conducted in Darwin. DNA from *P. euvitis* spores was obtained by scraping spores from infected grapevine leaves onto a microscope slide. The spores were mixed with a 20 µL Microlysis-Plus (Microzone Ltd) solution. The suspension was then placed in a PCR thermal cycler and subjected to the following treatments:

Step 1. 65 ºC for 15 min
Step 2. 96 ºC for 2 min
Step 3. 65 ºC for 4 min
Step 4. 96 ºC for 1 min
Step 5. 65 ºC for 1 min
Step 6. 96 ºC for 30 s
Step 7. 20 ºC hold.

The heat treatment allows the spore cells to be lysed and releases the *P. euvitis* DNA into the solution. The DNA can be used as reference standard in diagnostic PCR tests in Australia.

To develop a quantitative RT PCR assay for *Phakopsora euvitis,* a probe which specifically detects *P. euvitis* is required. DNA sequences of *P*. *euvitis* and other *Phakopsora* species were downloaded from GenBank (a DNA database freely available on the internet at http://www.ncbi.nlm.nih.gov/). These sequences were aligned to determine regions which were similar and different between the *Phakopsora* species.

Study 3: Develop the capacity to identify P. euvitis in leaf tissue, during the incubation period when no symptoms are visible.

The study was conducted at the University of Gadjah Mada, Yogyakarta, Indonesia where GLR is endemic. Leaves were sampled from 24 diseased and four non-diseased grapevines. Each leaf was assessed under a stereo-microscope to determine the presence and/or absence of spores prior to their selection for testing. A100 mg of tissue from each of 24 symptomatic and 22 symptom-less leaves (from the diseased vines) and the four healthy leaves was ground in 2 mL tubes using a sterile micropestle. Extraction of *P. euvitis* DNA from plant tissue was trialled using a commercially-available test kit (Qiagen DNeasy Plant mini kit) by following the manufacturer's instructions. The resulting total DNA (plant plus *P. euvitis*) solution was stored at -20 ºC until PCR testing.

The samples were subjected to a PCR test using NL1/NL4 primers which detects the D1/D2 region of the large subunit ribosomal DNA, a common fungal gene. If *Phakopsora* DNA is present, a PCR product 550 bp in size is observed. PCR parameters used were initial denaturation at 94 ºC for 10 min, followed by 40 cycles of denaturation at 94 ºC for 1 minute, annealing at 50 ºC for 1.5 minutes and extension at 72 ºC for 2 minutes then a final extension at 72 ºC for 10 minutes. The PCR products were visualised on a 1% agarose gel using gel electrophoresis.

To further characterise the gene, it was necessary to determine the DNA fingerprint and differentiate the *Phakopsora* DNA to species level. This was achieved by cutting the PCR product into pieces using three different restriction enzymes (*Alu* I, *Rsa* I and *Sau* 96I). The fragments were then separated on an 8% polyacrylamide gel and the unique DNA fingerprint was determined.

Results:

Study 1:

Air flow between SE Asia and northern Australia

Preliminary discussions with the Bureau of Meteorology in Darwin indicated it may be possible for "parcels" of air passing/leaving the southern side of East Timor at low altitude (10-1000 m) to maintain their trajectory, flowing all the way to Darwin within a short period of time (in a little over a day). This air-flow occurs during the northwest monsoon over the Timor Sea from December to March. If diseased grapevines are growing on the southern side of the island, spores could enter the air stream. Spore-laden parcels of air may then travel over Darwin at which time dry or wet (rainfall) deposition could occur.

An example of "tracked" air-flow from East Timor to Darwin using the Environmental Emergency Response version of HYSPLIT is shown in Figure 5.

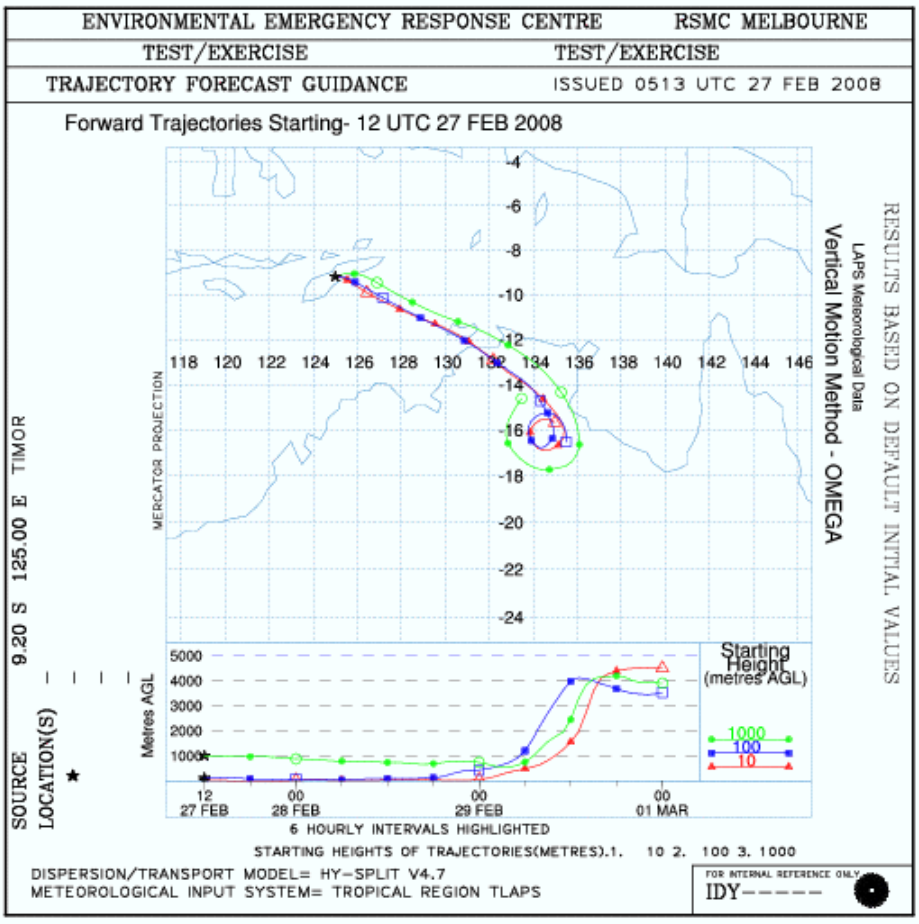

Figure 5. Computed forward trajectory of “parcels” of air from East Timor to Darwin on 27 February 2008 at starting elevations of 10 m (red triangles), 100 m (blue squares) and 1000 m (green circles) (Courtesy Bureau of Meteorology, 2008)

To understand more thoroughly the risk of air-borne introduction of *P. euvitis*, it will be necessary to forecast the height, direction, duration, frequency and timing of intercontinental movement of air systems to identify examples that could precipitate an introduction. This information can be coupled with experimental data on the mortality of urediniospores as influenced by environmental conditions similar to those experienced during transport. An analysis of historical data, aligning specific dates and circumstances with previous detections of the disease will also be considered.

Urediniospore mortality

Raw data of only three of the experiments is included here.

Whilst there were some brief periods of cloud cover (some low level cumulus cloud but mainly thin, high-level cirrus type cloud), the days during which the assessments took place were consistently clear and sunny. Urediniospore germination results are presented in Figures 6 and 7.

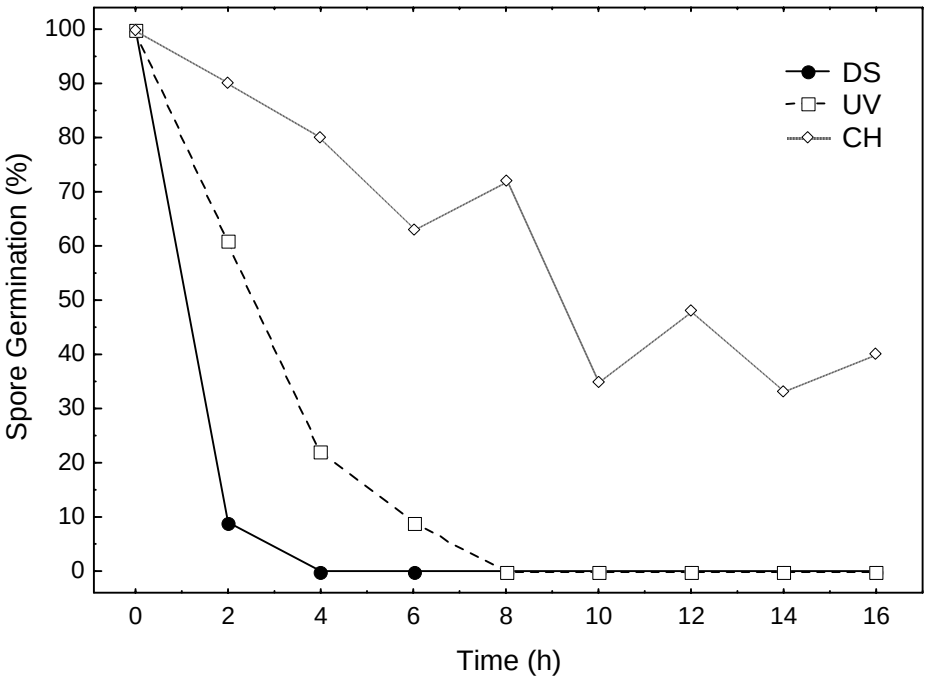

Figure 6. Relative germination percentage of urediniospores after incubation at 25 ºC for 24 hours on water agar following exposure over two days to global irradiance (DS), solar radiation minus UV (UV) and diffuse solar radiation (CH), sampled at 2 hour intervals Actual initial germinations were 46%, 48% and 44% for DS, UV and CH treatments, respectively.

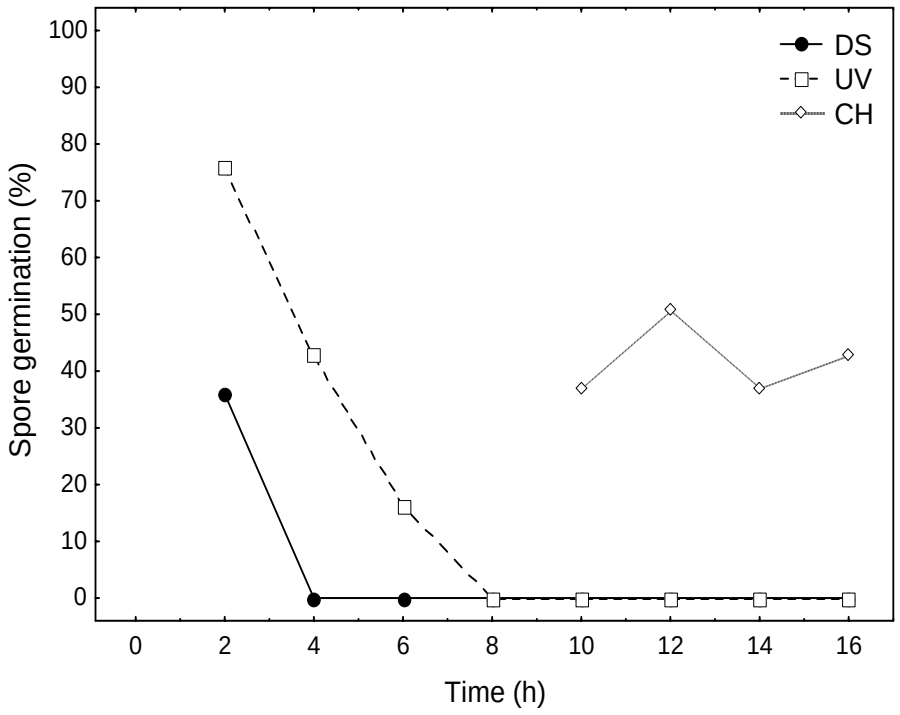

Figure 7. Relative germination percentage of urediniospores after incubation at 25 ºC for 48 hours on water agar following exposure over two days to global irradiance (DS), solar radiation minus UV (UV) and diffuse solar radiation (CH), sampled at 2 hour intervals

Exposure to global irradiance appeared to render the spores unviable after 4 hours (Figures 6 and 7). The absence of UV in the radiation reaching the urediniospores appeared to delay the loss of viability, with 43% of spores germinating after 4 hours exposure (Figure 7). Some germination still occurred after 6 hours exposure (Figures 6 and 7). In both these treatments, there was an obvious difference in the germination percentage after 24 (Fig. 6) and 48 hours of incubation (Figure 7), indicating that exposure to solar radiation can also cause dormancy. For all assessments of germination for DS and UV treatments, following 4 and 8 hours of exposure, respectively, all spores were viewed (due to there being no germination in the first 200 spores). A very small number of them (1-10 spores) were observed with highly abnormal germ tubes, being constricted, coiled and foreshortened.

Average temperatures during these treatments generally ranged between the mid 30 and 40 ºC for the duration of the exposure, reaching these levels within the first 2 hours (Figures 8 and 9). Peaks in excess of 50 °C did occur occasionally. Although the daily temperatures were similar for both treatments, the light intensity (400-700 nm wavelength range) of the UV treatment was consistently 15-20% lower. Relative humidity generally ranged between 35% and 65%.

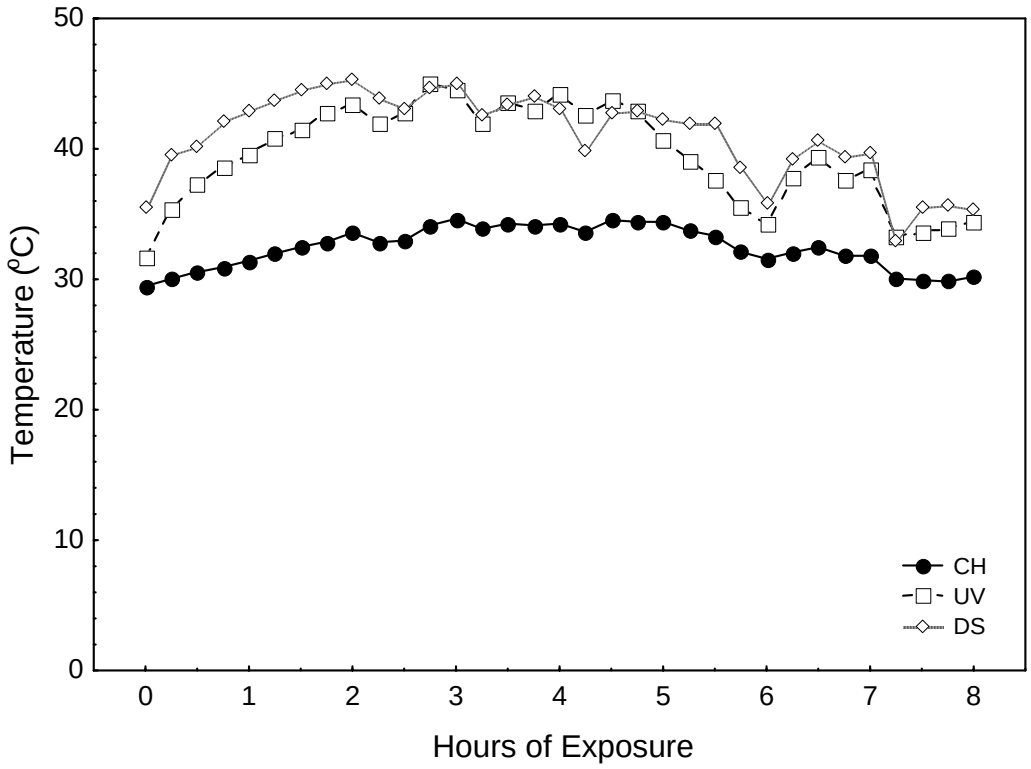

Figure 8. Average daily temperatures between 8 a.m. and 4 p.m. during the first day of exposure of urediniospores to global irradiance (DS), solar radiation minus UV (UV) and diffuse solar radiation (CH)

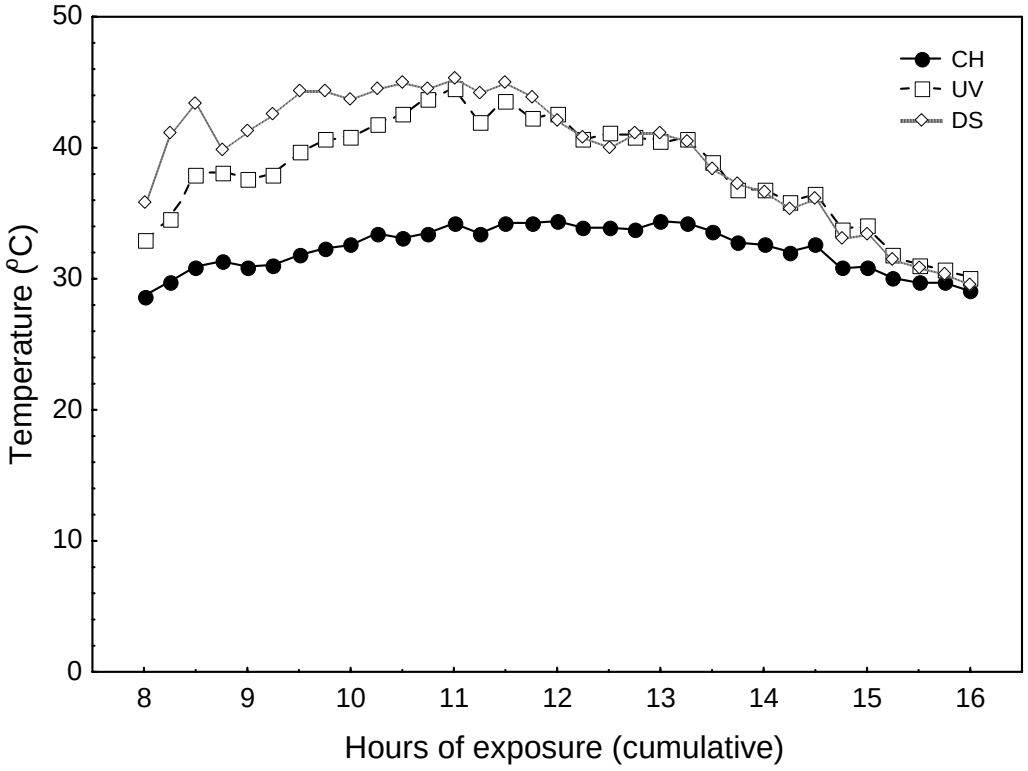

Figure 9. Average daily temperatures recorded between 8 a.m. and 4 p.m. during the second day of exposure of urediniospores to global irradiance (DS), solar radiation minus UV (UV) and diffuse solar radiation (CH)

When the spores were shaded, they maintained comparatively high viability, with 72% and 43% relative germination after 8 and 16 hours exposure, respectively (Figure 6). Recorded temperatures generally ranged in the low 30's, significantly milder than those recorded during the DS and UV treatments (Figures 8 and 9). Relative humidity generally ranged between 45% and 65%, which was a little more stable than for the DS and UV treatments. However, the morphology of spore germ tubes appeared abnormal when assessed on the second day of exposure as previously described for the DS and UV treatments. Also, there was a sharp decline in germination between the final first day assessment (8 hour) and the initial second day assessment (10 hour cumulative exposure). Further decline following exposure for 12, 14 and 16 hours did not occur. This may indicate an effect of the overnight storage on germination of spores.

In general, urediniospores of *P. euvitis* were very sensitive to environmental conditions once they were detached from diseased grapevine leaves. The high mortality of spores when exposed to global irradiance may have been a result of the high temperatures they experienced as well as the deleterious effects of the sunlight. Also, the smaller reduction in germination under the UV filter when compared with the DS treatment, may be partly due to the 15-20% reduction in the recorded light intensity as well as the absence of the UV portion of the spectrum (wavelengths < 400 nm).

Following these studies, there is evidence to show that the ability of *P. euvitis* inoculum to remain viable during intercontinental travel probably depends on cloud cover during the daylight hours. However, the observed morphology of the spores following exposure poses questions about their ability to infect once they come in contact with a grapevine. They appear to suffer damage to the DNA which is likely to severely hamper or eliminate their pathogenicity. Further studies are warranted to test their pathogenicity by bioassay following exposure and to determine their mortality at high temperatures (similar to those recorded during the trial) in the absence of solar radiation.

Study 2:

This component of the research relies on many factors. These include the successful extraction of *P. euvitis* DNA from grapevine leaf samples and spores, amplification of specific genetic markers and sequence analysis. *P. euvitis* DNA was successfully extracted from urediniospores and the 550 bp D1/D2 segment of the large subunit ribosomal DNA was amplified in the PCR test (Figure 10).

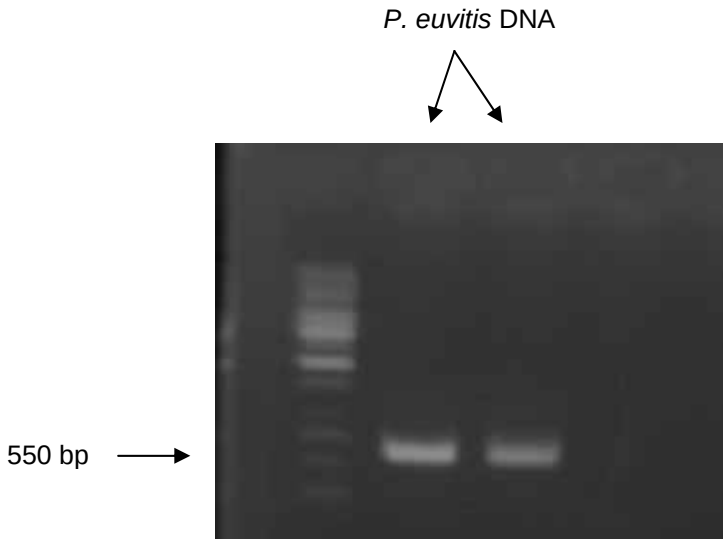

Figure 10. PCR test targeting the 550 bp D1/D2 region of the large subunit ribosomal DNA from *P. euvitis* urediniospores

The large subunit of the ribosomal DNA sequences from *Phakopsora* sp. were aligned to determine potential areas where a specific probe to detect *P. euvitis* DNA could be designed. However, the ribosomal DNA sequences available indicate very high levels of similarities between the *Phakopsora* sp. This increases the difficulty of a specific probe to target only *P. euvitis*.

As a result, the diagnostic test for GLR may rely on amplification of the D1/D2 region which will determine the presence of *Phakopsora* sp. DNA. Further differentiation to species level can be conducted using restriction fragment length polymorphism (RFLP) which provides a DNA fingerprint unique to each species.

Study 3:

DNA was successfully extracted from symptomatic and symptom-less grapevine leaf samples as well as urediniospores. Preliminary results show that the target gene was amplified from diseased samples, *P. euvitis* urediniospores and some symptom-less leaves (Table 1). An extra product, 1 kb in size, was also detected and this is currently undergoing sequence analyses (Figure 11).

Table 1. Amplification of fungal DNA from symptomatic and symptom-less leaf samples and *P. euvitis* spores collected from GLR-infected vines growing in Yogyakarta, Indonesia (May 2008)

Sample No.	Source	Sample Location	Symptom	NL1/NL4 PCR
S1A	Grapevine	Rajawali St Catur Tunggal Depok Sleman Yogyakarta	Symptom-less	550 bp, 1 kb
S1D	Grapevine	Rajawali St Catur Tunggal Depok Sleman Yogyakarta	Grapevine leaf rust	550 bp
S2A	Grapevine	4 Ringgodani St Catur Tunggal Depok Sleman Yogyakarta	Symptom-less	550 bp, 1 kb
S2D	Grapevine	4 Ringgodani St Catur Tunggal Depok Sleman Yogyakarta	Grapevine leaf rust	550 bp
S3A	Grapevine	1 Mawar St Catur Tunggal Depok Sleman Yogyakarta	Symptom-less	550 bp, 1 kb
S3D	Grapevine	1 Mawar St Catur Tunggal Depok Sleman Yogyakarta	Grapevine leaf rust	550 bp, 1 kb
S4A	Grapevine	Anggajaya Condong Catur Depok Sleman Yogyakarta	Symptom-less	550 bp, 1 kb
S4D	Grapevine	Anggajaya Condong Catur Depok Sleman Yogyakarta	Grapevine leaf rust	550 bp, 1 kb
S5A	Grapevine	Mundgur St Condong Catur Depok Sleman Yogyakarta	Symptom-less	550 bp
S5D	Grapevine	Mundgur St Condong Catur Depok Sleman Yogyakarta	Grapevine leaf rust	550 bp, 1 kb
S6A	Grapevine	Mundgur St Condong Catur Depok Sleman Yogyakarta	Symptom-less	550 bp, 1 kb
S6D	Grapevine	Mundgur St Condong Catur Depok Sleman Yogyakarta	Grapevine leaf rust	550 bp
S7A	Grapevine	Wates St Km 10 Sleman Yogyakarta	Symptom--less	550 bp, 1 kb
S7D	Grapevine	Wates St Km 10 Sleman Yogyakarta	Grapevine leaf rust	550 bp
S8A	Grapevine	Wates St Km 10 Sleman Yogyakarta	Symptom-less	1 kb
S8D	Grapevine	Wates St Km 10 Sleman Yogyakarta	Grapevine leaf rust	550 bp
S9A	Grapevine	Wates St Km 10 Sleman Yogyakarta	Symptom-less	550 bp, 1 kb
S9D	Grapevine	Wates St Km 10 Sleman Yogyakarta	Grapevine leaf rust	Negative
S10A	Grapevine	Wates St Km 4.5 Sleman Yogyakarta	Symptom-less	1 kb
S10D	Grapevine	Wates St Km 4.5 Sleman Yogyakarta	Grapevine leaf rust	550 bp
S11A	Grapevine	NASA House Ringroad St Sleman Yogyakarta	Symptom-less	550 bp, 1 kb
S11D	Grapevine	NASA House Ringroad St Sleman Yogyakarta	Grapevine leaf rust	550 bp
S12A	Grapevine	West Ringroad St Sleman Yogyakarta	Symptom-less	Negative
S12D	Grapevine	West Ringroad St Sleman Yogyakarta	Grapevine leaf rust	550 bp
S13A	Grapevine	Manwkan Plasakuning Ngaglik Sleman Yogyakarta	Symptom-less	Negative
S13D	Grapevine	Manwkan Plasakuning Ngaglik Sleman Yogyakarta	Grapevine leaf rust	550 bp
S14H	Grapevine	Blotan Wedomartani Ngemplah Sleman Yogyakarta	'Healthy'	Negative
S15A	Grapevine	Garuda Gejayan Depok Sleman Yogyakarta	Symptom-less	550 bp
S15D	Grapevine	Garuda Gejayan Depok Sleman Yogyakarta	Grapevine leaf rust	550 bp
S16 Atypical	Grapevine	Christanti Juwangen Kalasan, Yogyakarta	Leaf spots	550 bp
S16D	Grapevine	Christanti Juwangen Kalasan, Yogyakarta	No rust	550 bp
S17H	Grapevine	Wahyudi Juwangen Kalasan, Yogyakarta	'Healthy'	550 bp
S18H	Grapevine	Umbulharjo Yogyakarta	'Healthy'	550 bp
S19H	Grapevine	Umbulharjo Yogyakarta	'Healthy'	Negative
S20A	Grapevine	Umbulharjo Yogyakarta	Symptom-less	1 kb
S20D	Grapevine	Umbulharjo Yogyakarta	Grapevine leaf rust	1 kb
S21A	Grapevine	Umbulharjo Yogyakarta	Symptom-less	1 kb
S21D	Grapevine	Umbulharjo Yogyakarta	Grapevine leaf rust	Negative
S22A	Grapevine	Umbulharjo Yogyakarta	Symptom-less	1 kb
S22D	Grapevine	Umbulharjo Yogyakarta	Grapevine leaf rust	550 bp
S23A	Grapevine	Banteng Estate, Yogyakarta	Symptom-less	1 kb
S23D	Grapevine	Banteng Estate, Yogyakarta	Grapevine leaf rust	550 bp
S24A	Grapevine	Banteng Utama, Yogyakarta	Symptom-less	500 bp, 1 kb
S24D	Grapevine	Banteng Utama, Yogyakarta	Grapevine leaf rust	1 kb
S25A	Grapevine	Banteng 3, Yogyakarta	Symptom-less	Negative
S25D	Grapevine	Banteng 3, Yogyakarta	Grapevine leaf rust	1 kb
S26A	Grapevine	Jambon Estate, Yogyakarta	Symptom-less	550 bp, 1 kb
S26D	Grapevine	Jambon Estate, Yogyakarta	Grapevine leaf rust	550 bp
S27A	Grapevine	Kriecak, Yogyakarta	Symptom-less	Negative
S27D	Grapevine	Kriecak, Yogyakarta	Grapevine leaf rust	Negative
P. euvitis	Spores	Rajawali St Catur Tunggal Depok Sleman Yogyakarta	Grapevine leaf rust	550 bp

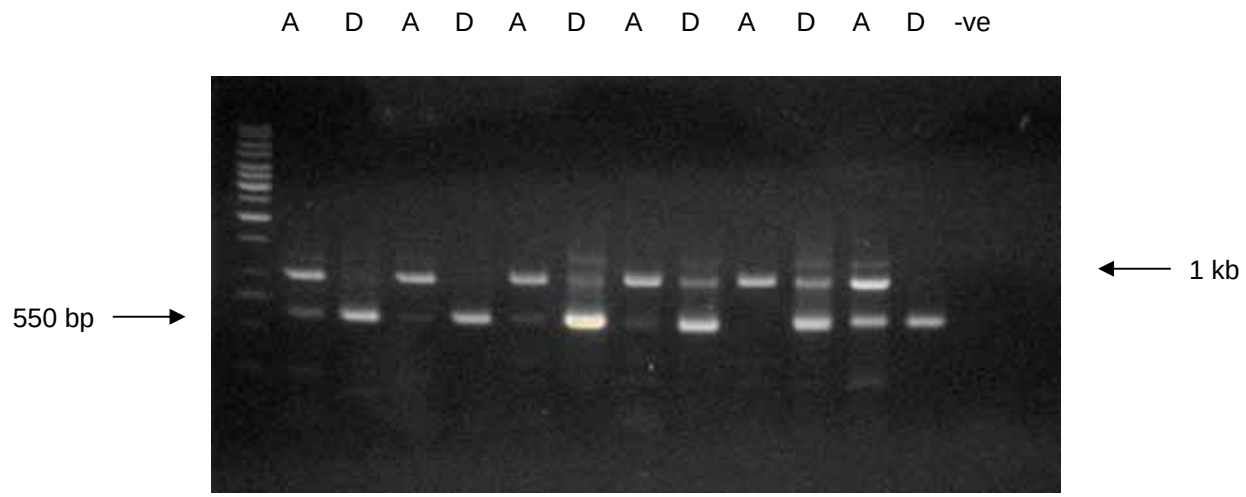

Figure 11. NL1/NL4 PCR results for symptomatic (D) and symptom-less (A) grapevine leaf samples

Two bands are observed in most samples. The targeted *Phakopsora* sp. gene is 550 bp. Sterile distilled water was used as the PCR negative control (-ve).

The samples were also subjected to restriction fragment length polymorphism to ascertain a unique DNA fingerprint (Figure 12). Confirmation of the fungal pathogen will require sequencing and bio-informatic analysis.

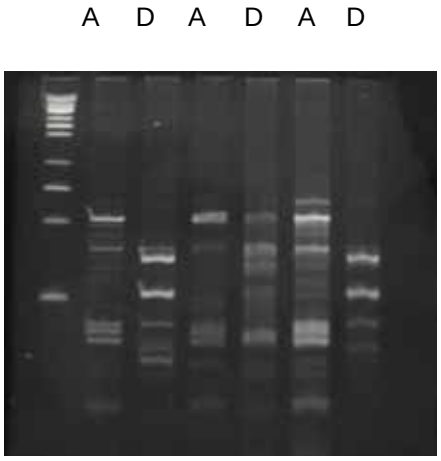

Figure 12. DNA fingerprint of the D1/D2 region of ribosomal DNA of *P. euvitis* extracted from symptomatic and symptom-less grapevine leaf samples, generated using the restriction enzyme, Alu I

Preliminary results thus far indicate that amplification of the target *P. euvitis* gene from symptom-less grapevine leaves was successful. The D1/D2 region PCR followed by RFLP using three restriction enzymes can be potentially used for a GLR diagnostic PCR test. Future studies will involve implementing the GLR diagnostic test in Darwin. This will include the retesting of Indonesian samples plus DNA extracted from dried diseased grapevine and fresh healthy grapevine samples collected from the Darwin region. This will ensure the test is applicable to both fresh and dried samples. The test will also require validation from another diagnostic laboratory.

Acknowledgements

The authors acknowledge funding by the Grape and Wine Research and Development Corporation and the support provided by the University of Gadjah Mada, Indonesia, Professors Siti Subandiyah and Christianti Sumardiyono and their staff.

PROJECT: Biology and Pest Management of the Spiralling Whitefly

Project Officers: D. Chin, H. Brown, L. Zhang, M. Neal and B. Thistleton

Division:	Plant Industries
Location:	NT
Keyword(s):	spiralling whitefly, *Aleurodicus dispersus*, *Encarsia*, wasp parasite, biological control

Objectives:

To monitor the distribution of the spiralling whitefly.

To release the parasitic wasp Encarsia for biological control.

Background:

Distribution

The spiralling whitefly (*Aleurodicus disperses)* is native to the Caribbean region and Central America. The pest is also found in southern Florida, the West Indies, South America, Africa, the Canary Islands, Hawaii, the Maldives, many of the South Pacific Island countries, Taiwan, India, Sri Lanka, Papua New Guinea, South East Asia and Torres Strait. In Australia, this pest is established in coastal Queensland from Mackay to Cape York and was first detected in Darwin in March 2006. The spiralling whitefly has now been recorded from many localities in Darwin, Palmerston, and nearby rural areas including Howard Springs, Virginia, Bees Creek, Noonamah, Humpty Doo, Girraween, Berry Springs, Wagait Beach (Cox Peninsula), Adelaide River and Batchelor. It has not been detected in Jabiru, Nhulunbuy, Katherine or Alice Springs.

Appearance

The spiralling whitefly is a small sap-sucking insect which is related to mealy bugs and aphids. To the naked eye, the adults look like very small moths and have a body length of about 2 mm. The wings of adults are plain white or occasionally have pale or dark spots on the forewings. Eggs are elliptical and yellow to tan in colour, 0.3 mm long and are laid singly at right angles to the leaf veins and associated with irregularly spiralling deposits of white flocculent wax. The spiralling effect is usually on the underside of leaves but in heavy infestations, the spirals may also be seen on the upper surface of leaves as well as on fruit and non plant material. The first stage of the larva is mobile but the later immature stages are sedentary and have an oval disc-shaped soft body that is light green in colour with characteristic waxy tufts. The final immature stage is the pupa which is about 1 mm in length and has glass-like rods of wax along the sides of the body.

The coconut whitefly (*Aleurodicus destructor)* is a local species that resembles the spiralling whitefly. Differences between the two species cannot be seen with the naked eye and require identification by a specialist.

Figure 1. A spiralling whitefly adult

Figure 2. Spiral pattern formed during egg laying

Life cycle

At a temperature range of 20°C to 39°C, development from egg to adult takes 34 to 38 days (eggs 9 -11 days, 1st instar larvae 6 -7 days, second instar 4-5 days, third instar 5-7 days and fourth instar larva (pupa) 10-11 days). Under laboratory conditions the adult can live for up to 39 days.

Symptoms and damage

The spiralling whitefly attacks a large range of plants including vegetables, fruit trees, ornamentals, native plants and weeds. Some common hosts that it has been found on in the Darwin area include acalypha, a local weed called *Euphorbia heterophylla* (sometimes referred to as “milkweed”), chillies, capsicum, bauhinia, sweet potato, guava, pawpaw, poinsettia, banana, tomato, heliconia, eggplant, mulberry, frangipani and ground orchids. The spiralling whitefly will also deposit eggs on non-hosts.

The whitefly produces honeydew, which may provide a substrate for the growth of sooty mould which interferes with photosynthesis. In heavy infestations, feeding damage may cause leaf drop or reduced yield in crops. The wet season weather is less favourable to the whitefly, when it will generally be found in low numbers. Higher populations are more common during the favourable weather conditions of the dry season.

Figure 3. Spiralling whitefly larvae

Figure 4. A spiralling whitefly on an acalypha leaf

Pest management

The whitefly is able to build up resistance to most chemical pesticides and should not be treated with them. Spraying with chemicals also destroys natural enemies or biological control agents that have been released. Potassium soap such as Natrasoap® or Neemtech potassium soap® with added spray oil may assist in managing populations on host plants. Note that other potassium soap products may also be effective.

Examples of spray oils include Eco oil®, DC tron plus®, Spraytech oil®, Synertrol Hort oil® or any other suitable horticultural spray oil. In home gardens, cooking oils, such as canola or other vegetable oils, are also suitable. It is important to spray both sides of leaves to runoff and repeat every three days until controlled is achieved. The spray solution may cause leaf burn to sensitive plants. The best time to apply sprays is in the early morning or late afternoon.

Suggested spray rates: Natrasoap 20 mL/L + spray oil 2 mL/L or Neemtech 30 mL/L + spray oil 2 mL/L.

Note: The recommended rate of spray listed above is for canola and other vegetable cooking oils. If you are using a horticultural spray oil, follow instructions on the container.

Biological control with the Encarsia wasp parasite

Shortly after the spiralling whitefly was detected in March 2006, the Department introduced a microscopic wasp parasite called *Encarsia* sp. from Cairns supplied by QDPI&F to assist in its management. The wasp parasite is 0.1 mm long and is harmless to humans. *Encarsia* is now established in many localities in Darwin, Palmerston and the rural area and has been observed to reduce spiralling whitefly numbers in several areas. The Department has continued to monitor and promote the establishment of *Encarsia* in all major suburbs and rural areas where the whitefly has been detected. The wasp will spread naturally to nearby areas after it has been released and will take between one and six months to establish at a new site depending on the suitability of the vegetation and how well the garden is maintained. In general, *Encarsia* is more likely to establish quickly and control the spiralling whitefly if the garden is well maintained and has plenty of shade.

Up to August 2008, the spiralling whitefly was detected in the Darwin suburbs of Alawa, Anula, Berrimah, Brinkin, Coconut Grove, Darwin City, Fannie Bay, Karama, Jingili, Knuckey's Lagoon, Leanyer, Woodleigh Gardens, Malak, Nakara, Nightcliff, North Lakes, Parap, Stuart Park, Wagaman, Wanguri, Wulagi, Tiwi and 11 Mile. It was detected in the Palmerston suburbs of Bakewell, Driver, Durack, Gray, Gunn, Marlow Lagoon, Moulden, Woodroffe and Roseberry. In rural areas it was detected in Bees Creek, Howard Springs, Humpty Doo, McMinns Lagoon, Virginia, Wagait Beach Cox Peninsula and Batchelor.

The wasp parasite was released in about 100 sites in the Darwin, Palmerston and rural areas and it is now spreading naturally. *Encarsia* has now established in the Darwin suburbs of Alawa, Anula, Berrimah, Brinkin, Darwin City, Coconut Grove, Fannie Bay, Jingili, Karama, Knuckeys Lagoon, Leanyer, Malak, Moil, Nakara, North Lakes, Rapid Creek, Stuart Park, Wagaman, Wanguri, Wulagi and Tiwi. In Palmerston suburbs, it is now established in Bakewell, Driver, Gray, Marlow Lagoon, Moulden, Woodroffe and Roseberry. In the rural area it is established in Bees Creek, Howard Springs, Humpty Doo and Batchelor.

Figure 5. *Encarsia* wasp parasite (0.1 mm in length)

Figure 6. Spiralling whitefly larvae parasitised by *Encarsia*

The Department supplies the *Encarsia* wasp only to new areas where the spiralling whitefly has been detected and to all commercial horticultural properties that have been affected, but not to Darwin and Palmerston suburbs where the wasp has already been released and is spreading naturally.

Quarantine restrictions

Plants and fruit exported interstate may require specific treatments as well as an inspection by a Quarantine inspector to comply with the Interstate Certification Assurance agreements. Similarly, plants moving within the Territory from an infested to a clean area may need treatment to prevent the spread of the pest. More information is available from NT Quarantine and at www.ntqs.nt.gov.au. New legislation is being developed to highlight public responsibility to prevent the spread of plant pests and diseases.

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www.cabicompendium.org

PROJECT: Coastal Plains Research Farm

Project Officers: Research Farm Managers and Staff

Division:	Plant Industries
Location:	Darwin
Keyword(s):	Coastal Plains Research Farm, horticulture, forestry

Objective:

To provide land and infrastructure to DRDPIFR staff to conduct research, demonstration and extension projects in horticulture and forestry suitable for the Top End of the Northern Territory.

Background:

The Farm is located at Middle Point near Fogg Dam in the Darwin rural area and conducts horticultural research on 140 hectares. It has national significance as a site for tropical horticultural research, with a role for testing new tropical fruit and vegetable crops.

Annual highlights

- Strategy development and progress of the genetic improvement of African mahogany in the Northern Territory and the establishment of a series of clone tests on other Research Farms.
- Potentially suitable bio-fuel crop identification for NT farmers for producing bio-diesel and/or ethanol.
- Integrated tropical passion fruit production systems (ACIAR project SMAR/2007/203) project to extend vine life and select improved clones.
- A tropical germplasm collection at the Farm consists of exotics such as cupuacu, cocoa, sapodilla, pitaya, ornamentals and bamboo varieties,
- Banana tropical race 4 panama disease management.
- Mango malformation disease trial; Koch's postulates research in a quarantine screen house.
- Carrot evaluation trial for South Pacific Seed.
- Strickland hay production on 8 ha.
- Healthy soil awareness workshop for NTHA, CDU and Ausveg. Forty growers attended.
- CDU used the facility to conduct courses; Freshcare provided a course for Vietnamese growers; Smart Train chemical course was provided for reaccredidation.
- Japanese research crew from the Division of Electrical and Information Engineering Osaka University set up lightning monitoring sensors on the Farm for the wet season.
- The University of Sydney conducted research on the effect of lungworm parasites on cane toads and native frogs.

PROJECT: Ti Tree Research Farm

Project Officers: Research Farm Managers and Staff

Division:	Plant Industries
Location:	Alice Springs
Keyword(s):	citrus, lemon, mandarin, Queensland fruit fly

Objective:

To provide land and infrastructure to enable RDPIFR staff to conduct research, demonstration and extension projects for the local Ti Tree horticultural industry.

Description:

Ti Tree Research Farm is about 8 ha in size and is located 190 km north of Alice Springs, on the Stuart Highway. It is situated in the Ti Tree Farms area which consists of eight properties of various sizes totaling 200 ha. The research farm is used mainly for horticulture research, as a venue for grower meetings and as a training facility for indigenous economic development.

Annual highlights

Citrus trial

Evaluation is conducted for of lemon, orange and mandarin scion/rootstock combinations and staff training is provided.

The eradication of the Queensland fruit fly (QFF)

QFF was first detected in early March 2006. As the Ti Tree farms region used to be a QFF-free area, every measure was taken to eradicate the pest. All host fruit was stripped and buried. It was sprayed with Chlorpyrifos. Malathion and protein baits were also applied on a weekly basis and supplementary traps were put in place to monitor the progress of the eradication program. The program was successful and area freedom was reinstated. However, several QFF were detected in early February 2007.

Indigenous economic development

A number of crops are being grown for training purposes with the assistance of the apprentice and staff. The workers take home fresh fruit and vegetables to the community. This training is useful for the Anmatjere people to obtain skills and employment in the industry.

Best practice grape block

Work has continued on establishing a 1-ha best practice grape block containing three scion/rootstock combinations. It is a joint project between industry and the Department. The purpose is to demonstrate best practice techniques to both industry and trainees as well as provide training.

Mango planting

Sixty mango trees of three different scion/rootstock combinations have been grown.

ANIMAL INDUSTRIES

Animal industries projects conduct applied research in controlled trials to discover solutions to problems that affect productivity and profitability of the industry and, where possible, to protect the environment and human health.

PROJECT: Breeding to Suit Future Market Opportunities: Tuli x Brahman, F1 Belmont Red x Brahman, and Brahman Cattle

Project Officers: R. Golding and K. McCosker

Division:	Animal Industries
Location:	Katherine
Keyword(s):	sustainable land management, research, breeding herd

Objective:

To determine the relative mature size of young Tuli x Brahman, F1 Belmont red x Brahman and Brahman cattle by June 2009.

Background:

This project is needed to consolidate the Northern Territory's position as a major supplier to the SE Asian beef market. The project may also potentially provide alternative options to NT beef cattle producers by increasing market flexibility and possibly reducing reliance on the live export trade.

Method:

Ten steers of each genotype will be selected and introduced to feedlot conditions in late 2008. Animal weight, hip height and P8 fat depth will be measured until the animals average a P8 of 10 mm fat depth.

PROJECT: Increasing the Market Share of NT Livestock Exports

Project Officers: D. Ffoulkes and B. Lemcke

Division:	Animal Industries
Location:	Darwin
Keyword(s):	cattle, buffalo, nutrition, husbandry, breeding, slaughter, processing, food safety, best practice, training

Objective:

To supports new and existing markets for NT pastoral and livestock export industries by providing technical assistance to importing countries.

Background:

The Livestock Exports Development (LED) program provides technical support to governments and industry sectors of importing countries to strengthen trading links and increase the market share of NT livestock exports. Technical assistance is provided in the form of feasibility studies, advice and training in best practice management of imported cattle.

The program is focused on providing technical support for offshore livestock industry development projects that are likely to seek imports of cattle and buffalo from Northern Australia. From mid-2007, there were projects ongoing in Malaysian Borneo (Sabah and Sarawak) and technical support was provided to feedlot operators in Indonesia and the Philippines.

Method:

A Memorandum of Cooperation (MOC) between this department and the Department of Veterinary Services and Animal Industries (DOVSAI), Sabah, Malaysia, concerning cattle industry development and trade was signed by the respective ministers in February 2005. A working group representing each department meets annually to review collaborative activities aimed at capacity building of DOVSAI staff in tropical beef production, animal disease diagnostics and abattoir management.

The Sarawak beef development support project was initiated in early 2007 as part of a collaborative effort by Meat & Livestock Australia (MLA) and the Australian Brahman Breeders' Association to assist the Sarawak Department of Agriculture (DOA) to establish a breeding herd to supply quality, locally-bred and adapted Brahman bulls to cattle herds raised under oil palm. The outputs provided by DRDPIFR are training in breeder herd management and development of herd management plans for the DOA Karabungan Livestock Centre, 75 km from Miri, which will be evaluated over a period of 18 months.

SE Asian importers who are clients of the NT Livestock Export Association also receive technical support from DRDPIFR's LED program in collaboration with MLA. This is expected to enhance commercial relations between Territory cattle traders and SE Asian markets.

Results:

Sabah

The cattle industry development program received a serious blow when the Sabah Meat Technology Centre (SMTC) was almost completely destroyed by fire in September 2007. A portable abattoir was quickly constructed to enable slaughter and processing to continue. In November 2007, an economic study on different beef production systems using imported cattle was conducted by DRDPIFR. The study looked at the Korban model, cattle under oil palm, a vertically integrated feedlot operation, imported slaughter cattle and TenderBuff. All the systems studied were found to be profitable with more than 25% returns on current prices. The main risks were increases in landed prices of imported stock and/or feed costs, particularly palm kernel cake which was in growing demand for the export market. It was recommended that the Sabah Government continue to support and coordinate importations of Australian cattle for producers, particularly for the markets that are associated with Islamic festivals (Ffoulkes 2007).

The project officer also visited the Bundu grazing reserve to evaluate the potential for TenderBuff production. A major concern was that the area was prone to flooding; moreover, high returns from improved management practices would need to be clearly demonstrated to farmers before they are likely to change from their traditional production system.

The MOC expired in February 2008; however, further collaborative activities will continue on a project-by-project basis. In February 2008, two Sabah officers attended a Breed Leader course in Katherine. Sabah government farms will be evaluated later in the year.

From July 2007 to June 2008, exports of livestock to Sabah included 1397 beef cattle, 292 buffalo and 5428 goats.

Sarawak

Following the development of herd management plans for the Karabungan Livestock Centre in June (Ffoulkes and Lemcke 2007) a project officer visited the Centre in November 2007 to appraise the progress of the action plan. Delays in repairing and procuring equipment together with budget constraints had delayed substantial progress and it was agreed that the six-monthly evaluation of the breeder herd should be postponed until March 2008.

In March 2008, a project officer conducted a herd evaluation at the Livestock Centre and found that very little progress had been made on agreed actions for improving herd management. A new action plan was therefore developed requiring monthly reporting. The project officer also visited the Buffalo Centre near Lawas, where he found some worrying management issues. Details of the visit to the Livestock and Buffalo Centres can be found in the visit report (Lemcke 2008). The next evaluation is due to take place in October 2008.

Technical support for SE Asian importers

In February 2008, three Indonesian feedlots were evaluated near Medan, in Sumatra and one in Pampanga near Manila, in the Philippines. The management of the Indonesian feedlots was well advanced as the operations were based on well-established feedlots in West Java and Lampung. The Philippines feedlot, however, will need to improve its operations as there was little understanding of management requirements and standard procedures for running a feedlot. Returns to feed costs were estimated to be 37% and 26% for the Medan and Pampanga operations, respectively, reflecting higher feed costs and lower market prices for the latter (Ffoulkes 2008).

All the feedlot managers were interested in low stress stock handling and it was recommended that this visit be followed up with a training course on feedlot management, including nutrition and stock handling.

References

Ffoulkes, D. (2007). Comparative Economic Studies of Downstream Beef Cattle Production Systems in Sabah using Imported Australian Commercial Brahman Cattle. Visit Report (28 Oct-2 Nov 2007).

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Ffoulkes, D. and Lemcke, B. (2007). Northern Territory Government and Meat & Livestock Australia Sarawak Beef Development Support Program. Visit Report (June 2007).

Lemcke, B. (2008). Northern Territory Government and Meat & Livestock Australia Sarawak Beef Development Support Program. Visit Report (April 2008).

PROJECT: Improving Herd Profitability

Project Officer: R. Golding

Division:	Animal Industries
Location:	Katherine
Keyword(s):	cattle, steers, gross margin

Objectives:

To determine the costs and returns of each management package in terms of gross margin per animal equivalent (AE) after interest.

To calculate the production differences between each management package in terms of kg of calf weaned per 100 kg of cow mated.

To calculate the differences in labour requirements between management packages in terms of full time equivalents

To achieve the stated objectives and report on them by December 2008.

Background:

In 1990 the best bet management package was formulated for Kidman Springs, Victoria River Research Station, which has been described in previous Technical Annual Reports.

The adoption of the package has greatly improved the performance of the herd at Kidman Springs. Mortality rates declined from 12% to less than 2% and weaning rates increased from 50% to over 80%. With the ever-increasing cost price squeeze, pastoralists have requested a study to improve or maintain performance with reduced input costs.

The improved profit package made changes to five of the best bet management practices: modifying stocking rates, reducing bull percentages, reducing supplementation costs, varying minimum weaning weight and keeping aged cows longer.

Method:

- Using one paddock at Kidman Springs based on the improved profit package.
- Using two control paddocks at Kidman Springs, one with higher and one with lower nutrition, based on the best bet package.
- Using a commercial paddock, 'Rifts Yard' on Victoria River Downs based on the improved profit package.

The improved profit project commenced in May 2003 and data collection was scheduled for completion by October 2007. Data collection from the commercial scale paddock was completed at the second round in 2006.

Results:

Analysis of the Kidman Springs data has begun and some preliminary results are outlined. A more comprehensive report will be presented by December 2008.

Table 1. Breeder performance

Treatment	Annual mean breeder live-weight (kg)			Annual mean breeder BCS*			Annual BHE* (kg/AE mated)		
	LW*	± s.e.	Sig	LW	± s.e.	Sig	LW	± s.e.	Sig
Control	444.42	2.19	ns						
IHP	445.26	1.92							

*BCS = Body condition score (1-9). *LW = Live-weight

*BHE = Breeding herd efficiency (kg of weaner weaned / kg breeder mated in the previous 12 months).

Table 2. Pregnancy and lactation

Treatment	Annual mean weaning rate (%)			Annual mean pre-weaning ADG* (kg)			Annual mean weaning weight (kg)		
	LW	± s.e.	Sig	LW	± s.e.	Sig	LW	± s.e.	Sig
Control				0.67	0.02	ns	183.0	± 2.5	ns
IHP				0.64	0.02		185.6	± 2.6	

*ADG = Average daily gain

Relative planes of nutrition

- Faecal NIRS

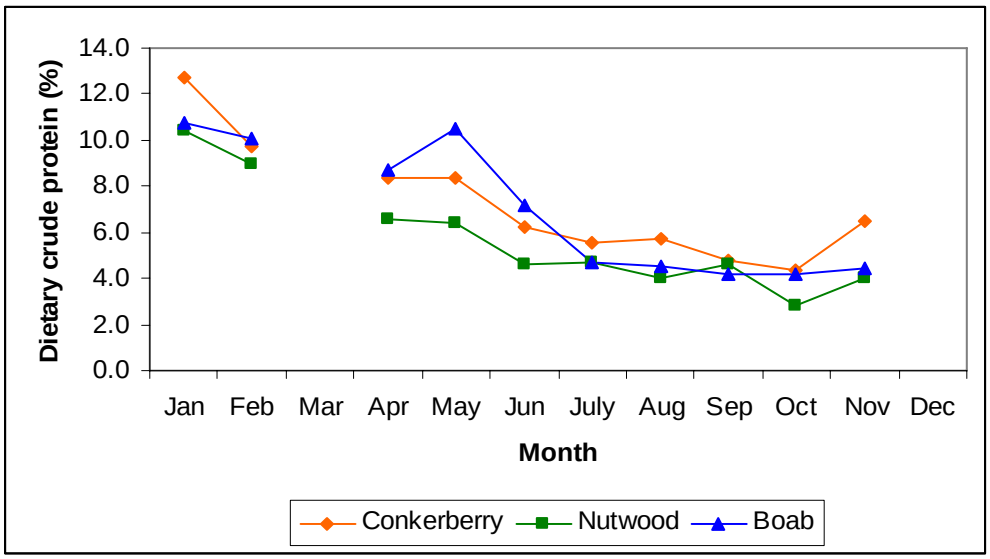


Figure 1. The 2003–07 mean predicted dietary crude protein content (%) of pasture (using faecal NIRS analysis) consumed by breeder herds grazing in Boab, Coolibah, Nutwood and Supplejack paddocks, Victoria River Research Station

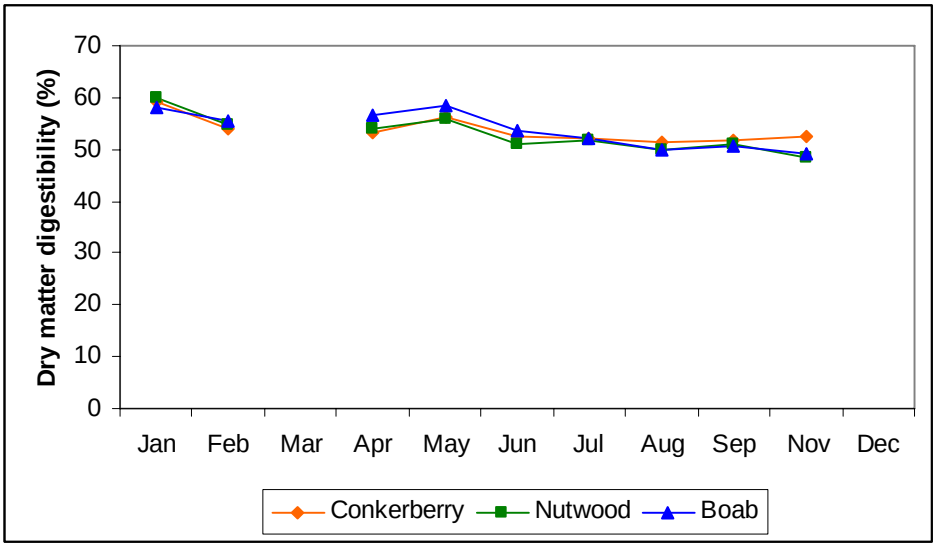


Figure 2. The 2003–07 mean predicted dry matter digestibility (%) of pasture (using faecal NIRS analysis) consumed by breeder herds grazing in Boab, Coolibah, Nutwood and Supplejack paddocks, Victoria River Research Station

- Indicator steers

Indicator steer results showed no significant difference in yearly growth between paddocks for the years 2003, 2004 and 2006. In 2005, steers in the control paddock (Nutwood) showed significantly higher growth than those in the treatment paddock (Conkerberry).

PROJECT: Industry Initiatives to Improve Heifer Performance in the NT

Project Officers: T. Schatz, S. Leigo (Alice Springs region) and H. James (Barkly region)

Division:	Animal Industries
Location:	NT
Keyword(s):	cattle, heifer fertility, commercial properties

Objectives:

To determine current levels of fertility in heifers on commercial properties throughout the NT.

To investigate current heifer management practices and determine why some management strategies are not widely adopted.

To demonstrate the best practice heifer management system in each region and determine the production that can be achieved by adopting that system.

To prepare a best practice manual for heifer management.

Background:

The research in this project is conducted entirely on commercial properties, which decide through producer groups (the Katherine Pastoral Industry Advisory Committee, the Barkly Region Advisory Committee and the Alice Springs Pastoral Industry Advisory Committee) what is studied.

A survey was conducted in 2004 to determine current levels of heifer fertility in each region and how the animals are commonly managed (see *The NT Pastoral Industry Survey* by Oxley et al. 2006). Copies are available from DRDPIFR Publications. The actual performance of heifers was then measured on 14 commercial cattle properties. The findings were published in *The Australian Journal of Experimental Agriculture* **48:** 940-944 (Schatz, T. J, and Hearnden, M.N. 2008) titled 'Heifer fertility on commercial cattle properties in the Northern Territory'. A summary of the findings is shown in Table 1.

Table 1. Performance of heifers on NT commercial cattle properties

Property location	Breed	Maiden heifer pregnancy rate (%)	1st lactation heifer pregnancy rate (%)	1st lactation heifer avg. wt. at WR1 (kg)	1st lactation heifer calf loss (%)
VRD (N)	Bra	59 2005	4 2006	306 May	24
	Bra	65 2006	5 2007	314 Apr	34
VRD (S)[1]	Bra & Bra X	72 2005	17 2006		15
VRD (E)	Bra	84 2003	14 2004	312 Apr	12
VRD (C)	Bra	84 2005	1 2006	256 May	14
Sturt Plateau	Bra & Bra X	53 2007 (5)	30 2007	294 Jul	25
Barkly (N)	Bra & Bra X	85 2005	3 2006	309 Aug	32
Barkly (NW)	Santa		7 2005 (6)	316 Aug	
Barkly (C) [1, 2]	Composite	86 2006	88 2007	494 May	10
Barkly (E)[3]	Composite		76 2007	421 Aug	30
	Santa		68 2007	416 Aug	39
Barkly (SW)	Santa		21 2005	321 May	35
Alice Sp. (N)	Shorthorn	84 2005			
Alice Sp. (N)	Santa	88 2007			
Alice Sp. (S)	Angus	81 2004	17 2005	322 Jun	4
	Angus	77 2005	16 2006	313 Apr	12
VRD (C)[4]	Bra	90 2006	39 2007	365 May	8

[1] These two herds were control mated for thee months (all the other herds were continuously mated).

[2] This is a stud herd.

[3] Two groups of heifers (of different genotypes in separate paddocks) were recorded on this property.

[4] This was an extensively managed herd on Victoria River Research Station (VRRS).

[5] Heifers were mated at the end of the year in which they were weaned and so were almost a year younger at first mating than is normal for maiden heifers in the NT.

[6] Drier than average conditions were experienced in this year resulting in performance that is lower than normal on this property.

[7] Calving occurred throughout the year although there was a peak during these months.

Only heifers that conceived before their calves had been weaned were included in calculating the first lactation heifer pregnancy rate. VRD = Victoria River District, Barkly = Barkly Tableland, Alice Sp. = Alice Springs district, C = central, N = north, S = south, E = East, W = west, Bra = Brahman, Bra X = Brahman cross, Santa = Santa Gertrudis. The year and month in which the measurements were recorded are shown in superscript.

Most research is conducted at demonstration sites on commercial properties in the VRD (Newry) and Alice Springs region (Tieyon). The work is due to finish in 2009. The findings from the demonstration sites are presented at field days. Copies of reports from the field days are available from Tim Schatz (tim.schatz@nt.gov.au or (08) 89992332). A field day was held at Newry and the following findings were presented:

1. Conception rates in maiden and first calf heifers were strongly influenced by weight and body condition. First calf heifer re-conception rates were low at Newry due to the light weight of heifers between calving and weaning, as they are on many properties across the NT (see Table 1). Most heifers were in too poor a condition to resume cycling before weaning and it was not until the following wet season that their condition picked up enough for them to re-conceive. Those heifers that did re-conceive were heavier on average than those that did not.

2. Calf losses in first calf heifers were high (26% overall). High rates of calf losses were found to be very common on many NT cattle properties (see Table 1). Where heifers had successfully raised their first calves, calf losses in the following calving were lower than in heifers that lost their first calves (17% compared to 29%). Calf losses were highest in heifers that calved between October and December (the hottest months when pasture quality is worst).

3. An experiment was conducted to determine whether vitamin A deficiency was a major cause of the high calf losses, as it was found during drought in western Queensland and on the Barkly Tableland. One group of heifers which were more than four months pregnant in September 2007 was given a single injection of Vitamec ADE (vitamin A supplement) and another (control) was not. There was no significant difference in calf mortality between the groups.

4. A single vaccination of maiden heifers against vibriosis before their first joining increased conception rates by 11% during the first round muster after joining. The benefit was reduced by the second round muster, indicating that there was a higher proportion of late pregnancies in heifers that were not vaccinated. Late conceptions are not desirable as such heifers will calve and lactate in the dry season. This is likely to reduce their chances of re-conception and increase the likelihood that they and/or their calves will die. Their progeny are also likely to have lower weaning weights and may take an extra year to reach turn-off weight.

5. Loss rates of EID (NLIS) tags were 0.6% after 18 months, 3.5% after 30 months and 10.9% after 42 months. However, it should be noted that most of the tags that fell off had not been positioned correctly in the ear and that very few tags that had been put in the right place fell out.

A best practise manual on heifer management will be produced at the end of the project in 2009.

PROJECT: Understanding and Improving Heifer Fertility in the NT

Project Officer: T. Schatz

Division:	Animal Industries
Location:	Katherine
Keyword(s):	cattle, heifer fertility

Objectives:

To determine the relationship between body weight/condition and conception rates for the first two joinings of Brahman heifers (joined first as yearlings and as two-year olds) in northern Australia.

To produce simple charts showing the conception rates that can be expected from mating heifers at different weights/conditions at their first two joinings.

To determine the effect of a range of target weights in heifers on subsequent fertility achievable under high and low input management systems in different pastoral zones of the NT and its cost.

Background:

The low re-mating conception rates in lactating first calf heifers has long been recognised as the biggest area of inefficiency in northern Australian breeding herds. The main reason for this is that the condition of

first calf heifers often slips while they are lactating and still growing at the same time. As a result they do not resume cycling shortly after calving.

This project attempts to establish the exact relationship between body weight (and/or condition) and re-mating conception rates for Brahman heifers during their first two joinings in northern Australia. From the results it will be possible to produce a simple chart showing the conception rates that would be expected from mating first calf heifers at different weights. This would allow producers to determine the most cost-effective way to manage replacement breeders.

Note: The term “yearling” here describes heifers that were joined at the end of the year in which they were weaned. Some heifers were purchased from continuously-mated herds and so may have been slightly older than 12 months at joining.

Method:

The method has been described in detail in previous Technical Annual Reports.

Summary

Each year at least 100 maiden Brahman heifers are joined for the first time at two years of age at VRRS and as yearlings at DDRF. At both sites, heifers that are pregnant with their first calf are split into two treatment groups. One group (control) grazes pasture as normal in the pre-calving dry season, while the other (high nutrition) group is managed to gain an extra 50 kg before calving. This provides heifers with a range of weights/body conditions at their second joining. The data from this joining (over several years) will allow the generation of a model that predicts the pregnancy rates likely from mating lactating first calf heifers at a range of pre-calving weights, P8 fat depth and condition scores. From the model, a simple chart can be produced showing the conception rates that would be expected from mating first calf heifers at different weights. The data from the project can also be used to produce similar charts for maiden heifers (mated first as yearlings and as two year olds).

Results:

DDRF first joined as yearlings

The results from yearling mating of three-year groups of heifers are now available. While conception rates in yearling high grade Brahman heifers increase with increasing joining weights (Figure 1), their fertility is not high enough at that age to justify the expense of transporting them from other regions of the NT for yearling mating. Table 1 shows the pregnancy rates achieved in each year group. The data suggests that high grade Brahman heifers are just too late-maturing to achieve good results from mating as yearlings.

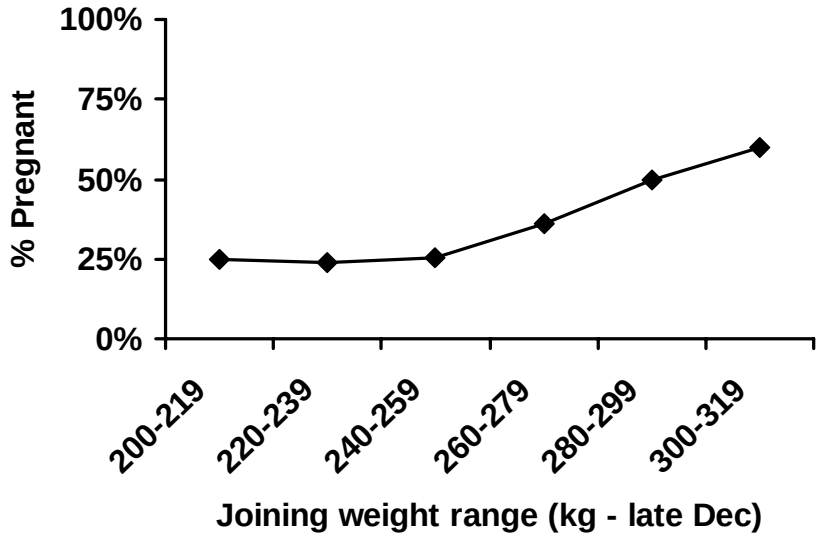


Figure 1. The effect of joining weight in mid December on conception rates of yearling Brahman heifers (three-year groups; n = 300)

Table 1. Conception rates and joining weight data for each year group of heifers that were joined as yearlings

Year weaned	Pregnant (%)	Average joining wt (kg)
2004	27*	259
2005	36	252
2006	36	264

*Note that the 2004 heifers were from a control mated herd and so were slightly younger on average than the heifers from the other year groups which came from continuously-mated herds. The heifers from the continuously-mated herds were all weaned at the 1st round but some that had been branded as small calves at the 2nd round the previous year and were put back with their mothers, were slightly older.

First calf heifers at DDRF

Data from three-year groups is now available and a fourth year group will calve over the coming wet season which will increase the number of heifers in the study. Information on the effects of weight and fatness on re-conception rates in lactating first calf heifers will be presented next year when all the data has been collected.

VRRS first joined at two years of age

Data from the first joining is available for three-year groups of heifers.

Figure 2 shows the large effect of joining weight recorded in October/November on conception rates of heifers joined first at two years of age at VRRS. Conception rates increased with joining weight until they plateau after a pre-joining weight of 300-319 kg.

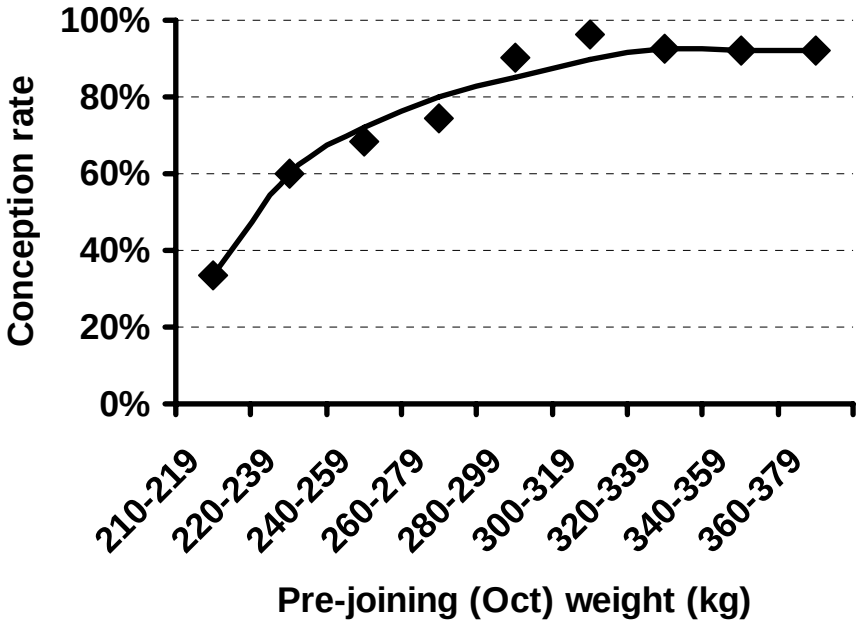


Figure 2. The effect of joining weight on conception rate at VRRS (three years combined data)

The effect of fat depth on conception rates at the maiden joining was very strong with conception rates increasing until they reach 100% at 5 mm (see Figure 3).

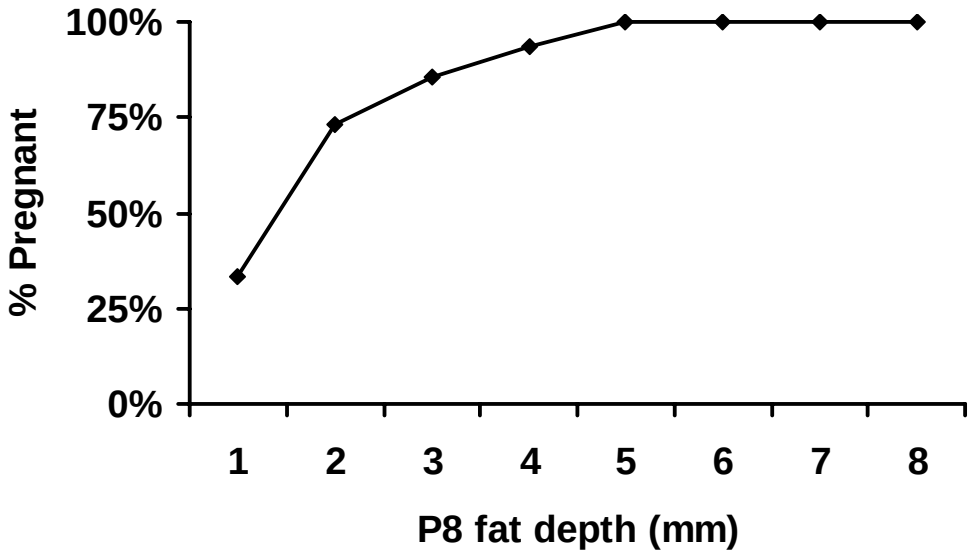


Figure 3. The effect of pre-joining fat depth on conception rates in maiden two year old heifers (data combined for both years; n = 177)

First calf heifer data from two-year groups at VRRS is now available. The third year group is due to calve in the coming wet season.

Following their first joining, pregnant heifers are allocated to either a high nutrition (HN) or low nutrition (LN) group. Each group grazes in a similar paddock with access to dry lick mineral supplement but the HN group also is given some protein and energy supplement in troughs in their paddock during the dry season until the season breaks.

It was not possible to measure the increased weight gain due to protein feeding as feeding continued after the date on which the pre-calving weight was recorded. As a result, the difference between the control and HN groups would have continued to increase until feeding stopped at the break in the season.

In 2006-07 the HN group was fed AustAsia HiPro pellets (28% CP) at 2.27 kg/animal/day (or 0.58% of average body weight) from 17-07-2006 to 18-12-2006 (154 days). Feeding continued longer than expected due to the late start of the wet season.

Re-conception rates were 43% higher in the HN group at 82% than in the control group which achieved 39%. However, despite the extra calves, the strategy actually lost money (-$7.90 per heifer fed) due to the extended time that the pellets were fed because of the late arrival of the wet season. To break even, feeding should have been reduced by nine days. Assuming weaners were valued at $315 each, i.e. $1.75/kg x 180 kg and pellets cost $410 per tonne).

In 2007-08 the HN group was fed copra meal (22% CP) at 1.62 kg/animal/day (0.4% average body weight) from 30-07-2007 to 16-11-2007 (109 days).

At the time their calves were weaned (May 2008), the HN group weighed 15 kg heavier on average than the control group and their re-conception rates were 63% compared to 54% in the control group, a difference of at 9%. The profit (excluding the cost of labour for feeding) from this feeding strategy was $63.27 per heifer fed (assuming the weaners are valued at $315 each and the cost of copra meal was $605 per tonne).

The effect of weight on conception rates in first calf heifers

As with maiden heifers, re-conception rates in first calf heifers are strongly affected by the weight and condition (fatness) of the heifers during the joining period (see Figures 4, 5 and 6). HN (protein and energy supplementation) also seemed to have a positive effect on re-conception rates in excess of what was expected from just its effect of increasing weight/condition.

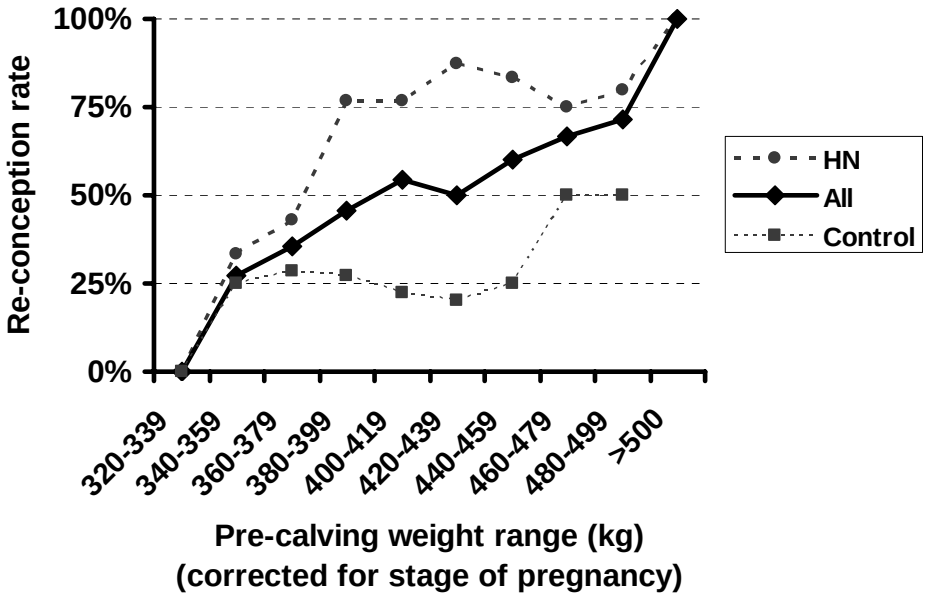


Figure 4. The effect of pre-calving weight (corrected for stage of pregnancy) on re-conception rates in first calf heifers (HN = high nutrition, All = all data)

The complicating factor in establishing the relationship between weight and conception rates in first calf heifers is that it is difficult to record a weight at joining as mustering heifers around calving is likely to lead to increased calf losses. As a result weights recorded prior to calving (Figure 4) and at weaning (Figure 5) are used.

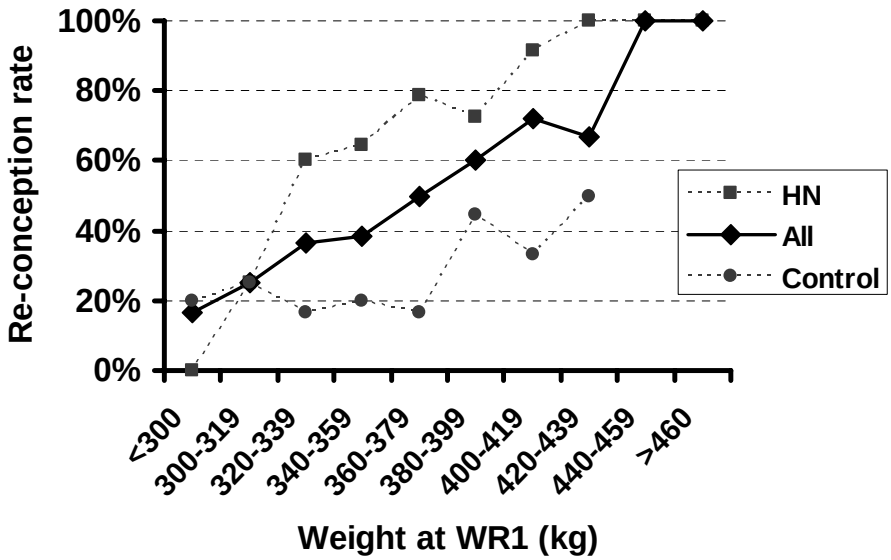


Figure 5. The effect of weight at WR1 on re-conception rates in first calf heifers

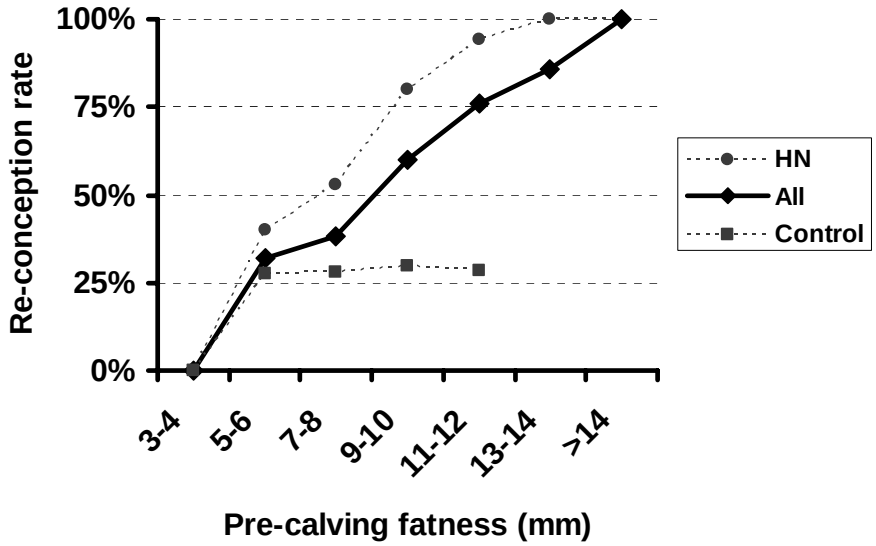


Figure 6. The effect of pre-calving fatness on re-conception rates in first calf heifers

PROJECT: Northern Australian Beef Fertility Project – Cash Cow

Project Officers: **M. McGowan[1], S. Jephcott[2], J. Morton[1], N. Perkins[3], G. Fordyce[4], B. Burns[4], B. Hill[4], K. Prayaga[5], D. Poppi[1] and K. McCosker[6]**

[1]The University of Queensland, School of Veterinary Science; [2]Chinchilla Veterinary Services; [3]Ausvet, Toowoomba; [4]QDPI&F; [5]CSIRO and [6]DRDPIFR

Division: Animal Industries

Location: Katherine

Keyword(s): beef cattle, perinatal losses

Objectives:

To define reproductive performance in a selected population of northern Australian commercial properties (study population) over three consecutive years using a range of measures.

To establish outcome measures for monitoring and comparing the reproductive performance of breeding 'mobs' and properties in northern Australia.

To define typical and achievable performance using the above measures in the study population.

To estimate variation in reproductive performance at the animal, 'mob', property and region level.

To identify causes of variation in the reproductive performance between animals, 'mobs', properties and regions.

To quantify the proportion of variation explained by identified risk factors.

To identify those risk factors which explain the greatest amount of the variation between 'mobs', properties and regions.

To develop a cost-benefit framework to estimate the economics of changing the major mob-level factors affecting reproductive performance.

To recommend a cost-benefit study to assess the impact on production of changing well-defined inputs and management practices that affect key risk factors.

To recommend extension priorities for changing well-defined inputs and management practices that affect key risk factors.

To recommend research priorities for inputs and management practices that affect key risk factors for which the impacts are not well defined.

To recommend the feasibility of establishing strategic ongoing reproductive performance monitoring 'systems' to enable the longitudinal evaluation of the impact of implemented changes in management practices and inputs.

Background:

A recently completed MLA-funded project (Fordyce et al. 2006) concluded that if northern beef cattle producers achieved breeding mob pregnancy rates of 65% per cycle and perinatal losses of less than 10%, the direct benefits to their businesses could be about $15m per year. No systematic study has been conducted of the reproductive performance of breeding herds in northern Australia or of the factors affecting performance. However, there have been a number of case studies and producer surveys which, although providing some very useful data, are limited in their application to the industry as a whole. Further, the current lack of a common 'language' to describe performance of breeding mobs prevents accurate comparisons between mobs, properties and regions.

The causes of sub-optimal reproductive performance in northern Australian beef herds are multi-factorial. However, although our knowledge of specific causes of lower than expected/predicted performance has improved considerably, quantification of the contribution of each to the overall performance of breeding mobs and herds is lacking. The latter information is critical to enable producers to be able to focus management changes and investment on those factors which have been shown to be contributing most to mob/herd reproductive outcomes. This information is also needed to guide investment by research funding agencies. For example, if 75% of the difference between mobs/herds can be explained by known factors, then investment should target technology transfer or development of improved approaches to manage these factors. However, if only 30% of the difference can be explained, then investment should target further research to define the causes and factors associated with sub-optimal performance.

Over the past 25 years there have been considerable improvements in nutritional and herd management practices in northern Australia, which have resulted in an improvement of 15% in branding rates. Fordyce et al. (2006) found that the established pregnancy rates per cycle ranged from 40% to 70% in a sample of commercial and research station herds, indicating some herds were achieving physiological targets of performance. However, the economic benefits of improved conception rates can only be realised if there are minimal losses in the period between confirmed pregnancy and weaning. Data from case studies conducted in northern Australia indicates that losses during the period between confirmed pregnancy and weaning in heifer herds was 15% to 20%. Losses of 5% to 10% are not uncommon in cow herds. Although in some cases the causes of these losses have been determined, the relative contribution of each cause to overall loss at an industry level *has not* been defined. A recent study by Brown et al. (2002) found that only 79.2% of Brahman heifers (n=207) on a pastoral company property on the Barkly Tableland successfully raised a calf, with 63% of the losses being perinatal, primarily due to dystocia, mismothering and unknown causes. Even where appropriate, good quality foetal and maternal samples have been submitted for comprehensive pathological and microbiological investigations, a definitive diagnosis of the cause of perinatal mortality could only be obtained in about 50% of cases. The Cash Cow project will use epidemiological analyses to identify the risk factors significantly associated with perinatal mortality. The findings will then be used to design studies to determine the causes of the unexplained losses.

The planning and design of this proposed project has relied on the findings of the following MLA-funded projects:

- North Australia Beef Producer survey 1990 – O'Rourke, Winks and Kelly (1992).
- Minimising pregnancy failure and calf loss – Fordyce, Burns and Holroyd (2006).
- Improved diagnosis of reproductive disease in cattle – Lew et al. (2006).
- The impact of infectious disease on beef cattle reproduction – Kirkland et al. (2008).

PROJECT: NT Live-weight Gain Project

Project Officer: S. Streeter

Division:	Animal Industries
Location:	Barkly
Keyword(s):	beef cattle; live-weight gain

Objectives:

To analyse data from the Beef CRC herds and stud herds from two major pastoral companies in northern Australia to determine the amount of live-weight gain variation in growing animals that can be attributed to genetic and environmental influences.

To identify and quantify the drivers of live-weight gain variation within and between ten study mobs in the Northern Territory.

To identify the influence of other difficult-to-measure causal factors such as foraging behaviour, parasites and some disease factors from a series of smaller-scale nested experiments.

To determine the potential differences in feed efficiency factors between high and low growth animals at the Katherine Research Station.

To develop a practical analytical toolkit and determine data requirements for investigating and identifying the drivers of live-weight gain in individual herds.

To develop strategies that can be identified by using an analytical toolkit to reduce the number of poor performing animals and increase average herd performance.

Background:

It is proposed that for the NT and many other extensive areas of northern Australia, the most cost-effective way to improve live-weight gain would be to address the huge variation in performance within the herd, rather than to focus on the performance of the leading animals. In many cases, the limiting factor for growth of the best performing animals appears to be the digestibility of their base diet and any major change to that would be expensive. Measurements in extensively managed herds in the NT show extremely wide variations in rates of live-weight gain even in herds with no obvious breed differences. This variation presents an opportunity for significant improvement.

As a way of estimating the potential financial return of this investigation, a model was devised that estimated a narrower spread of live-weight gain in the herds by improving growth rate in poor performing animals. From this it is suggested that an average increase in live-weight gain across the herd of 13.3% would be achievable, which would be worth $22 per animal at current prices.

Method:

The project consists of three experimental phases.

1. Desktop study – analysis of Beef CRC and NT industry stud data.

2. Field study – investigation of causal factors affecting live-weight gain on 10 commercial NT herds (Barkly and Katherine regions).

3. Nested studies – Research Station pen trials to investigate feed efficiency and other difficult to measure factors that contribute to live-weight gain variation the extensive environment in Phase 2.

Go/no go point

At the moment, this project is under review by MLA and an external review panel. The AusVet report and the proposed methodology of the field study will be considered to meet the proposed project objectives.

Results:

The analysis of the Beef CRC and industry stud data was completed in May 2008 by a consultant. The results of this report will guide the final design of the field study. A major conclusion of this report is that there appears to be sufficient variance in live-weight gain due to some broad effects such as property of origin. A reasonable amount of unexplained variance suggests that there is scope for measuring additional explanatory variables in a detailed field study.

Sire DNA samples were collected from allocated paddocks on three stations in a second-round muster in 2007 for the 2008-09 round of the field study. Two of the three stations failed to produce sufficient male weaners from those paddocks in the first-round muster in 2008 to continue in the project. Manbulloo remains the sole property in the 2008-09 round of the field study. Weaning and post-weaning observations have been collected from the trial steers on this station. Sire DNA samples were collected in the first-round muster in 2008 from allocated paddocks on the 2009-10 enrolled stations of Lakefield, Mainoru, Camfield, Hayfield and Walhallow.

This project is funded by MLA.

PROJECT: Northern Livestock Transporters Short Course

Project Officer: T. Cowley

Division:	Animal Industries
Location:	Katherine
Keyword(s):	cattle transport, training, livestock, course, animal welfare, stock handling, trucks

Objectives:

To develop, conduct and evaluate a practical interactive training course for truck drivers in the northern beef industry to focus on improving animal welfare during long-haul land transport and decreasing losses during transport.

To prepare hard copy and electronic versions of lesson plans, facilitator notes and course materials (including video footage) for use in training courses throughout northern Australia.

Background:

It is becoming increasingly hard to recruit and retain livestock transport drivers. Current livestock drivers are often relatively inexperienced in transporting and handling livestock. Training has typically occurred on the job, with few formal training courses available. The decreasing number of experienced drivers to teach new staff coupled with a shortage of drivers means that there is an even greater need for training. Currently inexperienced drivers are expected to carry out duties in which they are not trained.

Truck drivers are also a very visible part of the red meat supply chain as the public can easily observe the conditions under which cattle are transported. Animal welfare groups are an increasing threat to the pastoral industry, running increasingly sophisticated campaigns and targeting long distance transport of livestock.

It is therefore imperative that drivers are educated to take the best care possible of travelling livestock when they usually experience increased stress.

Method:

1. Determine topic lists and technical information through consultation with:
    - transport companies and drivers in Queensland and the NT;
    - NTCA, KPIAC, BRAC and producers in Queensland and the NT;
    - MLA experts on animal welfare and husbandry;
    - recognised experts in the field of livestock handling to tailor a stock handling DVD presentation for truck drivers;
    - Charles Darwin University;
    - other developers of driver training courses;
    - DRDPIFR Biosecurity and Product Integrity Section and stock inspectors from QDPI&F.

2. Film and edit a DVD presentation encompassing a summary of stock handling and OH&S considerations and precautions that are difficult to stage in practical demonstrations.

3. Develop draft versions of lesson plans, facilitator notes and course materials.

4. Run a pilot course (no cost to participants).

5. Review and revise course materials in consultation with previously mentioned stakeholders.

6. Promote and organise the final course.

7. Print course materials.

8. Run the final course on a cost recovery fee basis.

9. Analyse feedback from course participants, debrief all involved parties and revise materials if necessary.

10. Submit a final report. This will include recommendations for a model for the future delivery of the course.

Results:

The pilot course was conducted at Berrimah Farm on 31 January. It was attended by six drivers from two road transport companies, five operations managers from depots in the NT and Queensland, and a producer representative.

An evaluation indicated that all participants rated the course as highly relevant, well facilitated and it significantly increased their technical knowledge. All participants said they would recommend the course to drivers. Extreme weather conditions did not allow the courses to be held according to plan. They have now been postponed to September and December. The final course materials were submitted to MLA by the deadline of June 2008.

Activities to promote the course included:

- An overview presentation of the course at the Queensland Livestock Transporters Association.
- A presentation at Kidman Springs.
- An article in MLA's Feedback magazine which has received significant interest from potential attendees of the course from across Queensland and the Pilbara/Kimberley area as well as the Dalby Agricultural College.

PROJECT: Productivity Consequences of Incorporating Tropically-adapted Taurus Breeds into a Breeding Herd in the Victoria River District

Project Officers: R. Golding and K. McCosker

Division: Animal Industries

Location: Katherine

Keyword(s): beef cattle, Belmont, Tuli

Objectives:

To determine by 2011the relative breeding herd efficiency (kg calf weaned per 100 kg of cow mated and AE) of adult F1 Belmont Red x Brahman and F1 Tuli x Brahman, relative to purebred Brahman.

To determine the mature size of F1 Belmont Red x Brahman and F1 Tuli x Brahman.

Background:

Feedback from SE Asian feedlots in the early 1990s indicated that there was an increasing problem with over-fattening at the completion of the feeding phase in young Brahman cattle sourced from northern Australia. SE Asian feedlots usually supply beef to local 'wet' markets, which have a low value for fat and consider it a less-desirable component of the carcase.

A way to combat the problem of over-fattening is to include later-maturing genes. However, history shows that animals containing a high proportion of later-maturing genes are not productive in northern Australia. Therefore, to investigate the productivity of breeders containing later-maturing genes, Belmont red and Tuli breeds were introduced into a Brahman breeding herd at Victoria River Research Station (VRRS).

Method:

Location

The breeder herds are grazing in 'Boab', 'Coolibah', 'Nutwood' and 'Supplejack' paddocks at VRRS.

Table 1. Paddock allocation

Paddock	AEs	Breeders	Bulls
Boab	55	40 Bra	2 Bra
Coolibah	120	43 F1 Belm red x Bra 43 Tuli x Bra	4 Bra
Nutwood	64	46 Bra	2 Bra
Supplejack	118	43 F1 Belm red x Bra 43 Tul x Bra	4 Bra

Breeding herd

The breeding herds are being managed under a modified best bet management system using a stocking rate that has been calculated from the long-term median pasture growth and estimated safe utilisation rates.

The breeding herds are processed twice yearly, usually in May and October and data is collected for pregnancy and lactation status and empty live-weight. The condition of the animal is visually assessed at processing and assigned a score against a nine point system. Breeders are culled on barrenness (empty and non-lactating), temperament, injury or age (10 years). The breeders are continuously mated at 4% to annually fertility-tested bulls. Bulls are culled for sub-fertility based on a BBSE score, injury, or temperament or being with the herd for two years. A two-year maximum joining ensures a breed effect rather than a bull effect. All animals are vaccinated against C & D botulism strains during May and a booster vibriosis vaccination is given to bulls in October.

At processing, the progeny are mothered-up to determine parentage and bulls are identified using DNA sampling. The calves are tagged and weighed. A weaning weight of 100 kg is used for both weaning rounds across all years. They are branded and are left whole until after weaning and are then transported to Douglas Daly Research Farm.

Heifers are selected at two years of age based on temperament, live-weight of 280 kg or over and general appearance. Heifers are mated in January each year and are run separately until they wean their first calf.

Supplementation

All animals are supplemented all year round. During the dry season, a loose supplement consisting of 20%–30% urea, 20% kynophos, 10% sulphate of ammonia and 40–50% salt is used. A loose wet season mix consisting of 35% kynophos, 10% sulphate of ammonia and 55% salt is used across the wet season. These mixes were distributed weekly at about 100 g of supplement per animal per day.

Paddock differences

In order to highlight any differences between paddocks, indicator steers are included with each breeder herd and monthly faecal samples are collected for each paddock.

- Indicator steers: Ten steers of similar genotype, age and weight were included in each paddock annually in May and were replaced in May the following year. The inter-paddock difference in average live-weight gain was used as an indicator of paddock quality.
- Faecal samples: Faecal samples were collected monthly from various locations in each paddock. A bulked sample representing each paddock was then analysed using NIRS technology for faecal nitrogen, dietary crude protein and dry matter digestibility.

Results:

- In 2006-07 all breeding females were stratified for age, pregnancy, lactation and live-weight. They were then introduced to the trial paddocks. This is considered a preliminary year for the trial.
- Data from weaning round 1 2008 has been summarised below. Further data and more indicative results will be available after the second weaning in October 2008.

Breeder live-weights

Table 2. Mean breeder live-weights at mustering

Genotype	Paddock	Muster	Mean breeder live-weight (kg)	Overall mean breeder live-weight (kg)
Brahman	Boab	Weaner round 1 2008	485.58	489.20
	Nutwood		492.82	
F1 Belmont Red x Brahman	Coolibah	Weaner round 1 2008	491.12	478.52
	Supplejack		465.91	
Tuli x Brahman	Coolibah	Weaner round 1 2008	427.50	416.11
	Supplejack		404.71	

Weaning weight

Table 3. Mean weaner live-weights at mustering, using a 100 kg weaning weight

Genotype	Paddock	Muster	Mean weaner weight (kg)		Female mean weaner weight (kg)		Male mean weaner weight (kg)	
Brahman	Boab	Wnr Rnd 1 2008	171.6	198.1	159.8	188.9	179.0	204.8
	Nutwood		224.6		218.0		230.6	
F1 Belmont Red x Brahman	Coolibah	Wnr Rnd 1 2008	220.0	209.1	214.6	210.6	233.5	213.3
	Supplejack		198.3		206.7		193.2	
Tuli x Brahman	Coolibah	Wnr Rnd 1 2008	192.4	205.8	189.7	211.3	198.0	196.5
	Supplejack		219.1		232.9		195.0	

Paddock differences

- Faecal NIRS Analysis

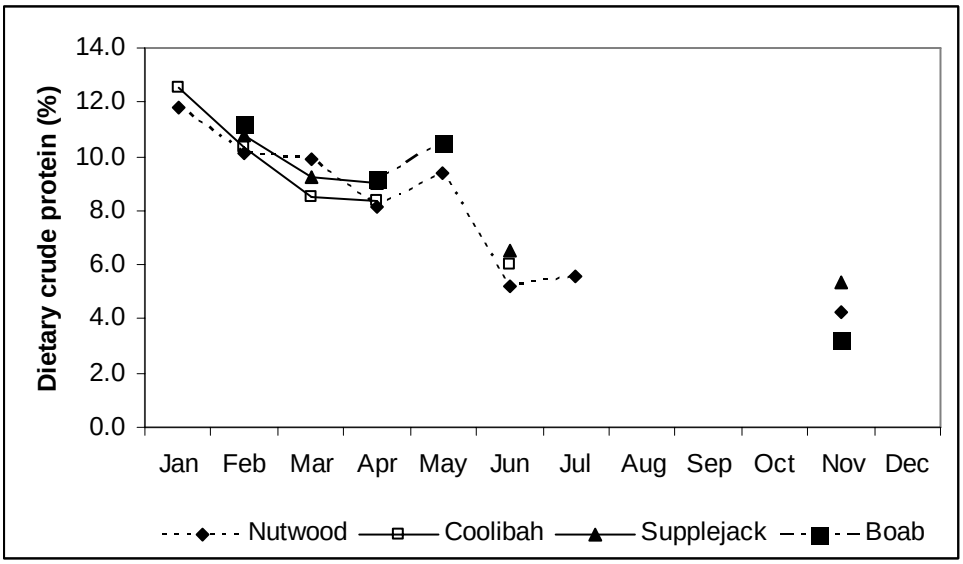


Figure 1. The 2007–08 mean predicted dietary crude protein content (%) of pasture (using faecal NIRS analysis) consumed by breeder herds grazing in Boab, Coolibah, Nutwood and Supplejack paddocks, VRRS

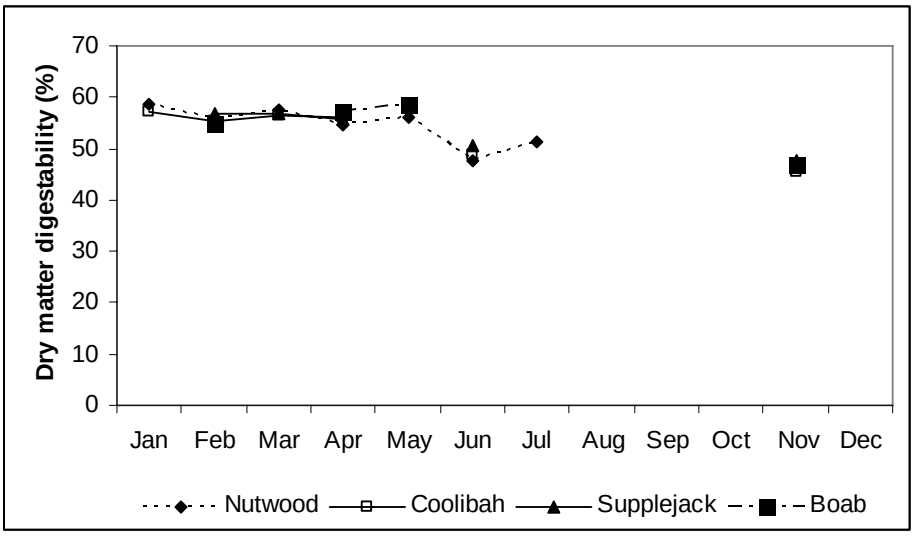


Figure 2. The 2007–08 mean predicted dry matter digestibility (%) of pasture (using faecal NIRS analysis) consumed by breeder herds grazing in Boab, Coolibah, Nutwood and Supplejack paddocks, VRRS

Indicator steers

Table 4. Indicator steer live-weights

Paddock	Average LWG (kg) dry season 2007	Average LWG (kg) wet season 2007–08	Average LWG (kg) year 2007–2008
Boab	14.85	126.78	139.94
Coolibah	19.30	130.44	149.19
Nutwood	23.80	132.22	155.17
Supplejack	30.65	113.75	144.40

Key points:

- Tuli x Brahman breeders were lighter than the F1 Belmont red x Brahman and pure Brahman breeders at weaner round 1 2008.
- There was no obvious difference in weaning weights between any of the breeds.
- NIRS and indicator steer results showed the paddocks were similar in nutrition.

PROJECT: Evaluation of Rapid Molecular Detection and Characterisation Systems for Surveillance of Arboviruses Circulating in Northern Australia

Project Officers: L. Melville, R. Weir and S. Walsh

Division:	Animal Industries
Location:	NT
Keyword(s):	surveillance, biosecurity, arbovirus

Objectives:

To develop and evaluate micro-arrays for the rapid identification – serotyping and topo-typing (identifying the geographical origin) - of arboviruses isolated by Berrimah Veterinary Laboratories (BVL) as part of the National Arbovirus Monitoring Program (NAMP).

To use global virus characterisation arrays and polymerase chain reaction (PCR) select suppressive subtractive hybridization for the rapid and full characterisation of a selection of existing and new isolates that remain uncharacterised by conventional approaches.

Background:

BVL is the key centre for monitoring arbovirus activity in the Northern Territory. Surveillance is undertaken by virus isolation and serological testing. Viruses isolated in the program (up to several hundred per year) are characterized by classical virological techniques of cell culture, electron microscopy and sero-typing. There is a critical need to increase the speed with which viruses isolated in NAMP and from clinical disease in livestock and wildlife are characterized and to fully characterize viruses which remain unidentified by currently-available classical virology techniques.

Method:

1. Design and print sero-typing/topo-typing array for characterisation of viruses circulating in northern Australia.

2. Evaluate arrays with known viruses, and evaluate arrays for use in the rapid characterisation of isolates made in ongoing NAMP surveillance at BVL.

3. Add newly-characterised viruses to the array, and evaluate for ongoing application to surveillance programs.

4. Test ~ 20 unknown isolates on the global virus characterisation array and ~ 20 unknown viruses using preliminary PCR-select suppressive subtractive hybridization.

5. Select a sample of unknown viruses for full genome sequencing. Retrospectively screen previous years' isolates by PCR to identify further unknown viruses.

6. Complete sequencing of unknown viruses and use for threat assessment and inclusion on modified arrays for routing use.

Results:

Design and printing of sero-typing/topo-typing array for characterisation of viruses circulating in northern Australia

The first iteration of arrays for use in this project has been completed in collaboration with Columbia University. The oligo-nucleotides for the arrays have been purchased and the first batch of arrays has been printed. Dr. Philippa Jack from the Australian Animal Health Laboratories (AAHL) visited Columbia University in July 2005 to test the arrays for hybridisation with one agent. The results were encouraging.

Testing of ~20 unknown isolates on the global virus characterisation array

BVL has prepared RNA and cDNA from 15 novel agents. This material was shipped to Columbia University. Ten unknown virus isolates, two known controls and an uninfected cell culture control subjected to microarray analysis by Columbia University have now been completed. The two knowns were submitted blinded and were correctly identified. 7/10 unknowns yielded one virus related to Sindbis (Western Australian type), orbiviruses related to a Chinese isolate, Yunnan virus EHDV-2 (Ibaraki virus), and novel orbiviruses related to, but often very distinct from ,currently known orbiviruses.

Discussions with Dr. Ian Lipkin indicated agreement for the AB CRC project to access the new panpathogen arrays available from Columbia University. Negotiations are currently underway to do so and to access additional oligonucleotide designs for the subarrays to be used for virus characteristion at Berrimah.

Additional RNA samples from two unknown viruses have been prepared and sent to Columbia University collaborators to enable further 454 sequencing runs to finalise the full genome sequences. A joint publication describing the utility of the arrays and elution of nucleic acid from the arrays and sequencing of this for the identification of novel viruses has been published.

Suppressive subtraction hybridization on ~20 unknowns

The PCR select technology has been successfully transferred to Berrimah. The M genome segment of an uncharacterised Bunyavirus has been completely sequenced except for the very ends of the segment. The L (polymerase) genome fragment has been completely sequenced. The S and M genome fragments have been partially sequenced and continuing sequencing is in progress.

Preliminary analysis indicates that this virus – provisional name “Buffalo Creek Virus” - is distantly related to La Crosse virus of USA origin. This virus is known to be involved in human disease in the USA. An NT uncharacterised Rhabdovirus is currently being subjected to PCR select analysis.

Two PhD student projects have proceeded. One project has completed the high quality genome sequence of a rhabdovirus _Wongabel_ except for the 3’ and 5’ ends. Preliminary analysis reveals unique genome arrangements with additional genes of undefined relationships and function. The sequence of the genome ends are currently being sought. A thesis chapter and a draft manuscript are being prepared. The second project has completed two genome fragment sequences from two unique orbiviruses not previously reported in Australia. The first is related to Yunnan virus – a Chinese orbivirus and the second is unique and distantly related to known orbiviruses.

We have developed a strategy based on the PCR select method and a newly developed high throughput sequencing process – 454 sequencing – by which we believe we could obtain simultaneously sequence 30 to 50 novel viruses at one time. Three Rhabdoviruses were subjected to this technique. From this we obtained two near complete genomic sequences and one partial genomic sequence. This has demonstrated the potential for this approach – pooled subtraction and high throughput sequencing – to provide near complete genome sequences from a number of viruses at once.

Evaluation of arrays with known viruses and evaluation of arrays for use in the rapid characterisation of isolates made in ongoing NAMP surveillance at BVL

Ten know and frequently isolated viruses obtained during NAMP were sent to AAHL. The coded samples were processed on the sub-arrays for presumptive identification. So far two viruses have been completed and both have been identified at the genus level i.e. bunyavirus and Ibaraki (EHDV). The results to date suggest that this approach will provide presumptive genus level identification of the common viruses being isolated in NAMP.

Summary

Partial or complete genomic sequence has now been obtained from five Rhabdo-viruses, two Bunya-viruses and four orbi-viruses. Serological testing of wildlife and livestock has identified important species in the maintenance of these viruses. The development of 454 high throughput sequencing has identified a strategy to simultaneously sequence 30 to 50 viruses.

Testing of 10 unknown viruses on the global virus arrays at Columbia University showed novel orbi-viruses related to, but very distinct from, known orbi-viruses. Testing of 10 known and frequently isolated viruses on arrays at AAHL identified half to the genus level. Further evaluation is needed before arrays can be used on a routine basis.

The lack of relevant sequence data on Genebank has inhibited comparison with known arboviruses. Full genome sequence is required for numerous named Australian arbo-viruses to assist the adoption of PCR and arrays to NAMP and similar programs.

PROJECT: Investigating the Epidemiology of Chlamydia in Farmed Crocodiles

Project Officers: I. Jerrett, N. Elliott and L. Tran-Nguyen

Division:	Animal Industries
Location:	NT
Keyword(s):	biosecurity, chlamydia

Objectives:

To gain an understanding of the epidemiology of chlamydial infection in farmed crocodiles.

To formulate targeted infection control measures to minimise the occurrence and impact of the eye and throat disease associated with chlamydial infection.

Background:

The farmed crocodile industry has remained relatively free in recent years of diseases capable of causing high levels of losses in well-managed operations. However, in 2006 a conjunctivitis and pharyngitis syndrome not previously seen in the industry caused massive mortality in hatchling estuarine crocodiles on two farms. Laboratory testing at the time of the outbreaks implicated chlamydial infection as the likely cause of the disease. Knowledge of the epidemiology of an infectious agent in a population is critical in establishing effective disease prevention and control measures. The relatively recent availability of molecular techniques for detection and characterisation of chlamydia allows sensitive widespread screening of animals for infection. The techniques also allow the use of extracted DNA to classify strains of chlamydia from crocodiles and compare them with strains found in other animal hosts.

Method:

Two published PCR methods for detecting DNA of all species in the family Chlamydiaceae were established and optimised at the Berrimah Veterinary Laboratories (BVL). A method based on the 16S rRNA gene was used to identify infected animals or eggs by testing of swabs. The PCR product of a representative subgroup of positive samples was then sequenced to confirm that the amplicon was in fact chlamydial DNA and to provide data on strain identification. The same subgroup of positive samples was tested by the second PCR method based on the OMP2 chlamydial gene to provide a different segment of chlamydial DNA for analysis. This OMP2 gene segment was used as a second method for identifying the species/strain by DNA sequencing and by a restriction fragment length polymorphism (RFLP) technique.

Conjunctival and/or pharyngeal swabs were obtained from the following groups of farmed estuarine crocodiles: i) animals with eye and throat lesions submitted to BVL for necropsy ii) random hatchlings one to 120 days of age from two farms and iii) random yearling and grower animals one to three years of age from six farms across northern Australia and animals from a seventh farm experiencing an outbreak of conjunctivitis in yearling and grower groups. Swabs were also taken from embryonated eggs collected in the wild and from the conjunctiva and cloaca of trapped wild crocodiles. Prevalence rates were determined in healthy and sick animals and were compared within and between groups and farms.

Results:

Reservoirs of chlamydial infection exist in apparently normal animals on all crocodile farms studied. Chlamydial infection is also present in clinically normal wild crocodiles. Sequencing of the OMP2 gene indicates strains of chlamydia in the eyes and pharynxes of crocodiles on different farms across northern Australia are virtually identical. Gene sequencing and RFLP testing indicate that the crocodile strains constitute a new species of *Chlamydophila* which has not been recorded in other animal hosts.

Embryos and hatchlings less than 40 days of age are generally free of chlamydial infection. Infection commonly establishes in hatchlings at 40 to 120 days of age. In all age groups chlamydial infection tends to be concentrated in certain pens with some pens of animals remaining virtually free of infection. In the hatchling population mild eye and throat disease occurred only in pens with chlamydia-infected animals. However, on an individual animal basis there was no significant correlation between chlamydial infection and clinical signs.

The prevalence of chlamydial infection in the yearling and grower groups varies widely between farms. Conjunctivitis and/or pharyngitis of mild to moderate severity occurred in some yearling or grower groups on three of seven farms in the study but lesions did not correlate with chlamydial infection either on a group basis or on an individual animal basis. A high prevalence of chlamydial infection was, however, found in animals of all ages submitted to the laboratory with severe eye and throat lesions.

On the basis of the above findings, it is considered important that managers on all crocodile farms ensure that biosecurity plans are in place and focus on minimising exposure of young hatchlings to infection from older animals. Since the likelihood of infection of hatchlings is high, stresses on this group need to be minimised to avoid mild or sub clinical infection developing into serious potentially fatal disease.

Eye or throat disease of mild to moderate severity in randomly sampled animals often could not be attributed to chlamydial infection. This suggests another agent or multiple agents may be involved in the development of conjunctivitis-pharyngitis. Further research is required to determine the role of other agents, particularly viruses, in the development of clinical eye and throat disease.

PROJECT: Genetic and Reproductive Improvements in Australian Water Buffalo

Project Officers: B. Lemcke, E Cox, A. Turner (NTAB), G. Jayawardhana and BHF Staff

Division:	Animal Industries
Location:	Darwin
Keyword(s):	buffalo, breeding, artificial insemination, genetic analysis, buffalo register

Objectives:

To develop an artificial insemination (AI) synchronization method to improve outcomes.

To establish a database for the Australian buffalo industry.

To analyse the genetics of the swamp buffalo from historical data held by DRDPIFR.

Background:

DRDPIFR conducted a four-year RIRDC project (DNT 33A) from 2003 to 2007.A final report was submitted in 2008.

Method:

As suitable buffalo became available, drugs were used to synchronize the onset of oestrus in them for fixed time inseminations. Semen has been available from Italy and locally to use for producing suitable genetic lines. This is necessary due to the limited number of initial imports of breeding stock from the US in 1994 and later. Northern Territory and interstate producers with suitable stock and facilities participated in this project. So far DRDPIFR at Beatrice Hill Farm (BHF), Shaw River Buffalo Dairy, Yambuk Victoria and the Australian Dairy Buffalo Company (ADBC) in Millaa Millaa North Queensland have participated in the AI project.

The Agricultural Business Research Institute (ABRI) at the University of New England provided technical advice, genetic analysis and registry facilities for this project. Data from the current riverine and crossbreeding herd and from the swamp herd of the1980s and 1990s at BHF was submitted and analysed.

Results:

AI trials

Over the four-year period, 12 rounds of AI were conducted on 248 buffalo, producing 67 calves. The most successful round achieved a calving rate of 41.7%. Three different methods were used with variations in timing. They were Ovsynch, CIDRs and Cue-Mates. Ovsynch was the most used because of the widespread reporting in the literature of its success. It was found that with few exceptions, heifers were quite difficult to inseminate successfully and many of the early trials had large proportions of heifers. The introduction of the AI pistolette into the uterus was very time-consuming, to say the least and often impossible to navigate the cervix successfully. Many management factors were found that influenced the success rate, including:

- good quality frozen semen;
- good cow condition to reduce the likelihood of anoestrus;
- good handling facilities;
- a rising plane of nutrition;
- favourable weather conditions;
- stock with quiet temperament and stock handlers with good handling skills;
- good heat detection ability;
- appropriate synchronizing methods;
- skilled and experienced (quick) inseminators to reduce stress;
- timing of AI in relation to ovulation.

Generation of register/database

ABRI was commissioned to set up a database for the buffalo industry in Australia, which includes a register that covers meat and dairy breeds available in Australia and also makes the Breedplan® system for cattle available to buffalo producers to enable them to identify and breed from animals with superior genes for particular objectively-measured production traits. A secure remote access terminal database has been set up at DRDPIFR for recording stock information, which will allow for the electronic transfer of data from all breeders. The register will also be available on-line for interaction between members and purchasers of stock. Other countries can access the service, particularly those that import our stock, as the pedigree information is already on the database. There is an annual fee for members and an entry fee for registered calves.

Analysis of past and current buffalo research data

Due to a disruption from an outbreak of TB in the mid 1990s in which parental linkages to future stock were lost, the calculation of genetic heritability of various traits could not be accurately assessed. Another three years' data has to be added for riverine animals, which could be helpful. Insufficient records were available of animals with a known history to allow calculations. Sufficient records can be achieved over the medium term if BHF and other producers continue to submit animal production data to the database.

Maintenance of industry contact

The ABIC Buffalo News kept industry members informed of progress. The senior author attended both the 7th and 8th World Buffalo Congresses in Manila in 2004 and in Caserta, Italy in 2007. He also attended a pre-Congress course on cheese-making, particularly mozzarella. He took a wide-ranging tour of the Italian buffalo dairy industry from south to north, culminating at the 62nd International Dairy Cattle Show in Milan, which was a highlight of the 8th Congress.

PROJECT: Enhancing Productivity Improvements in the Water Buffalo Industry

Project Officers: B. Lemcke, E. Cox, A. Turner, M. Humphries and BHF Staff

Division:	Animal Industries
Location:	Darwin
Keyword(s):	buffalo, breeding, artificial insemination, genetic analysis, buffalo register

Objectives:

To continue to provide information on buffalo production in Australia to enable the Industry to prosper in the future.

Background:

DRDPIFR conducted a four-year RIRDC project (DNT 33A), between 2003 and 2007. RIRDC has approved funding for the next four years to continue the work.

Method:

This project has several objectives:

1. To continue to develop artificial insemination (AI) synchronisation methods to achieve 50% conception rates from a single insemination.
2. To establish benchmark tenderness values for TenderBuff of various age/weight ranges.
3. To determine the quality factors in buffalo milk that set it apart from cow's milk so as to attract consumers.
4. To continue subsidising milk testing at the Millaa Millaa dairy to collect dairy production data in a commercial herd.
5. To encourage registration of producer herds in Australia.
6. To monitor feedlot performance of crossbred river buffalo overseas to compare it with that of swamp buffalo.
7. To prepare a "Best Practice Manual for Water Buffalo in Australia" for publication.

As suitable females become available, drugs are used to synchronise the onset of oestrus for fixed time inseminations. Semen is purchased from Italy and locally to produce suitable genetic lines to improve productivity traits for both meat and milk. AI is necessary because of the limited number of imported breeding stock from the US. NT and interstate producers can participate in this project if they have suitable stock and facilities.

Feed conversion efficiencies between crossbred and swamp buffalo will be conducted in a local trial and in overseas feedlots to demonstrate to our customers the value of the crossbred for meat production.

Milk testing and characterisation of buffalo milk quality will be conducted to enhance marketing of buffalo dairy products.

Producers will be encouraged to participate in registration and Breedplan facilities that have been prepared for the industry

If abattoir facilities become available in the NT, further development of TenderBuff will be conducted to explore meat tenderness relationships for different weight/age ranges.

Results:

Three AI rounds were carried out at BHF in January, March and June 2008. Then a bull was used after the last round. Ultrasound tests showed that 20 out of 26 animals responded after three rounds. DNA tests will be needed to confirm parentage when the calves are born in 2009. Cue-Mates and Ovsynch were used in the March and June rounds with mixed results: 4/8 for Ovsynch and 0/8 for Cue-Mates in March and in June 4/6 for Cue-Mates and 2/6 for Ovsynch.

Seven milk tests were conducted in 2007-08 on the herd at Millaa Millaa.

PROJECT: Riverine Buffalo and Crossbreeding

Project Officers: B. Lemcke, E. Cox, L. Huth, A. Turner (NTAB), G. Jayawardhana and BHF Staff

Division:	Animal Industries
Location:	Darwin
Keyword(s):	buffalo breeding

Objectives:

To determine the merits of crossbreeding and upgrading to riverine buffalo for the NT buffalo industry.

To distribute suitable progeny from the program to industry for breeding or to supply TenderBuff.

To demonstrate sustainable buffalo production systems.

Background:

The NT Buffalo Industry Council for long wished to upgrade the Australian swamp buffalo by crossbreeding with imported riverine buffalo. Two riverine bulls were imported in 1994, followed over the next three years by four heifers and two more bulls. Two of the heifers were purchased by a private producer and were left at Beatrice Hill Farm (BHF) for mating. A crossbreeding program was started and progeny performance has continued to be monitored. Some young animals are also sent to supply the TenderBuff market. The purebred number has now reached 75 at BHF, with a steady increase in breeder and bull numbers. Two of the original four imported bulls are still used.

The aim is to expedite the production of purebred riverine buffalo in two ways: (i) by using purebred cows to increase numbers from within the herd, and (ii) by crossbreeding with swamp buffalo and then backcrossing to purebred through ¾. ⅞ and 15⁄16 generations back to purebred riverine.

It is expected that this project will identify all suitable mixtures of the two breeds for local meat production, for live export for slaughter and for dairy production in Australia and overseas.

A four-year cooperative agreement was finalised in early 2007with the Australian Dairy Buffalo Company in Millaa Millaa, north Queensland, to record quantitative and qualitative data on the milk producing potential of the various crosses compared with pure riverine buffalo. Most of the company's stock is from the BHF herd. The dairy supplies milk to the Vanella Cheese Factory in Cairns, which is producing mozzarella, fetta, buffalino, yoghurt, and other products through its own factory and shops.

BHF has also supplied stock in 2004, 2005 and 2008 to a dairy farmer in Maleny, Queensland. The farmer now supplies milk to the local Maleny Cheese Factory, which started marketing a new range of buffalo cheese and yoghurt.

Method:

All DRDPIFR animals are produced at BHF. Half-bred cows and heifers are mated to "OJ", the bull imported from the US, to produce ¾ calves. Locally-bred bull 5775 sired the ⅞ calf group while a half-Italian AI-produced bull 5796, sired all the 15⁄16 calves. Hillary, another bull imported from the US, has been used to produce F1 calves from swamp cows. There are enough Italian sires now to allow for a departure from this plan. So in the 2008 mating period, more bulls were used in order to broaden the genetic mix (see Table 1).

Table 1. The 2008 mating plan

Cow group	**Bull(s) used**
Swamp	OJ
F1	5775
3/4	Hillary
7/8	5861 (2 year-old. bull)
15/16	5858 and 5859*
River	AI only (3 rounds) then 2 bulls in after last round in June 2008 - 5860 and 5861*
All heifers	5858 and 5859* (2 year-old. bulls)

* Where groups have been multi-sire mated, DNA testing will be used to determine parentage.

In 2007 and 2008 all heifers were mated continuously instead of entering the cow group with controlled mating. This allows for earlier calving in heifers at two years of age, instead of at three years. Bulls were used as AI is more difficult in heifers yet they are well grown as yearlings to cope with pregnancy. If allowed until two years of age before mating, they become heavier and over-fatness may become an issue.

Some semen of Italian milking buffalo was imported. Semen from six Italian bulls has been used in AI projects. Some of the purebred cows and some crossbreds have been inseminated with the Italian semen and others have been inseminated with semen from "Bill".

Results:

Table 2. The composition of riverine, swamp and crossbred buffalo groups at BHF in June 2008

	Imported bulls	Local bred bulls	Breeder cows	Yearling bulls	Yearling heifers	Male calves live	Female calves live	Calf mortality	Total
Purebred riverine	2	11	33	9	8	8	4	0	75
Swamp			25						25
F1			37		11	11	4	0	63
3/4			34		2	14	9	3	59
7/8			33		6	18	10	2	67
15/16			7		5	9	7	0	28
Total	2	11	169	9	32	60	34	5	317

Table 3. Calving results for 2007-08 and pregnancy diagnosis (July 2008) for next season's calves

Breeder group	Calves born/cows mated = Calving rate (%) 07-08 calves	No. pregnant June 2008/ cows mated Jan 2008	Pregnancy (%)	No. preg+wet cows/ total wet cows = (%) wet cows pregnant
Swamp cows	15 / 26 = 57.7	16 / 23	69.6	8/15 = 53
F1 cows	26 / 38 = 68.4	25 / 37	67.6	13/22 = 59
¾ cows	30 / 34 = 88.2	27/ 33	81.8	21/27 = 78
7/8 cows	16 / 25 = 64.0	22 / 28	78.6	7/12 = 58
15/16 cows	2 / 2 = 100	5 / 7	71.4	2/2 = 100
Riverine cows	All calves weaned in 12- 07 prior to AI	20 / 26 3 AI rounds in Jan/Mar/Jun 08	76.9	No lactating cows at AI
All two year heifers	22 / 25 = 88%			
Yearling heifers		20 / 30	67.0%	
Total	111 /150 = 74%	115 / 184	62.5%	51/78 = 65.4%

Calf mortality dropped markedly this year back to a reasonable level of 5%, in contrast to 12.8% and 8% in the previous two years.

Pregnancy rates have improved slightly with a much better result in the swamp cow group in particular, than in previous years. Wet cow pregnancy rate has improved slightly this year. The slight drop in total herd numbers reflects exported of heifers.

The purebred riverine breeders were weaned in December 2007 and three rounds of AI were carried out in January, March and June 2008. Provisionally there are 20 pregnant heifers out of 26 after three rounds. However, DNA testing will be conducted to confirm this. The desire to maximize AI in this group has caused a lengthening of calving intervals due to the need to build up body condition and to coincide with the best seasonal conception time, which is the wet season to early dry season.

We now have enough bulls due to the AI program to be able to service all of the crossbred breeder groups with different genetic material which was not been possible until this year.

The 7/8 cow group also improved their pregnancy rate after a poor showing last year. Two-year-old bulls were used and despite the appearance of some early social problems with the older cows, the mating performance was satisfactory by the end of the season.

A milestone event for the herd this year was the birth of the first six purebred riverine buffalo calves produced through the five generation backcrossing route. It is 13 years since the first crossbred calves were born at Berrimah Farm from the first imported US riverine bulls. The rapid speed of this process is due in part to the shorter generation interval of the riverine and its crosses

Sales

A further two consignments of 38 heifers and three bulls went to Melbourne quarantine for shipment to New Zealand in December 2007 and February 2008. Three of the heifers were from a private herd. Two purebred Italian semen bulls were also bought from two Top End producers. Two heifers were not able to travel to New Zealand due to tick fever reactions. The sales obtained very favourable prices compared with breeder stock sold for non-dairy purposes. Two other shipments from interstate to New Zealand occurred since the three shipments from the NT in the past two years. It is not possible at the moment to supply enough heifers to meet overseas demand.

It is hoped that a buffalo dairy will be established in the Top End within a year after the first local cows were recently machine-milked in the Darwin rural area. The long term viability of buffalo dairying in the Top End is being assessed. The experience at Millaa Millaa suggests that buffalo dairying is feasible in the Top End provided there is proper feeding. The advantage of using buffalo is their ability to produce milk without needing large quantities of concentrates and supplements.

PROJECT: TenderBuff Development and Supply

Project Officers: B. Lemcke, E. Cox, L. Huth and BHF Staff

Division:	Animal Industries
Location:	Darwin
Keyword(s):	buffalo, TenderBuff

Objectives:

To supply animals and promote and implement the TenderBuff quality assurance program for local and interstate markets.

To ensure a continuous supply of TenderBuff in the Northern Territory.

Background:

The TenderBuff program was started to provide higher returns to buffalo producers whose animal numbers were quite small post the BTEC program. TenderBuff was seen as a reasonable substitute for eye fillet from feral animals going to the restaurant trade. It was also an opportunity to supply a much wider range of high quality cuts.

DRDPIFR conducted the project with the NT Buffalo Industry Council to assure quality through branding carcases at the abattoir. The producer received $3.10/kg hot standard carcase weight (HSCW). The carcase must meet five specifications to receive the TenderBuff strip brand.

TenderBuff has less cholesterol and fat than beef. These two factors can be used for positive marketing of the product as an alternative red meat. As riverine cross buffalo grow much faster than swamp buffalo, they can be turned-off at a much younger age and should therefore produce more tender meat.

The latest problem to affect local TenderBuff production was the closure of Litchfield Abattoir in March 2007. There is no alternative abattoir in the NT at present with the necessary facilities on a year-round basis.

This has forced all currently produced animals to be sent live to overseas markets, mainly in Indonesia, at a lower price.

Method:

The current TenderBuff specifications are:

- 150-300 kg HSCW.
- 3-12 mm fat at p8 site.
- No permanent teeth.
- Electrically stimulated carcase.
- Muscle pH below 5.8 after 18 hours.

Results:

Two groups of nine animals each were sent to Oenpelli (Gunbalanya Meat Supply) to supply meat for the NTBIC Darwin Show stalls in 2007 and 2008. Only one other shipment of cull cows and two TenderBuff animals was made to Gunbalanya in December 2007. Unfortunately, this abattoir does not have sufficient rail height to hang a full side or the equipment to do electrical stimulation of carcases. It is also isolated during the wet season, which prevents slaughter all year round unless animals are brought in before the wet season. It also has few areas for wet season grazing.

PROJECT: 21st Century Pastoralism

Project Officer: A. Bubb

Division:	Animal Industries
Location:	Alice Springs
Keyword(s):	desert pastoral enterprises

Objectives:

To provide research, development and extension services to commercial pastoral producers in the Alice Springs region and the broader desert regions of Australia as a component of the Desert Knowledge Cooperative Research Centre.

To increase the economic opportunities associated with desert pastoralism by developing unique enterprise models, economic development systems and pastoral management systems that provide tangible benefits to producers.

Background:

The project aims to increase the economic viability of desert pastoral enterprises. It is analysing the cost benefit of labour saving devices including telemetry systems and creating exciting new remote livestock management systems. The WaterSmart project evaluated commercially-available products for delivering and monitoring stock water. Participatory evaluation of Aboriginal pastoral programs was conducted in 2007-08.

The cattle and country project completed evaluations of the Kimberly indigenous management support service and the indigenous pastoral program. It also reviewed indigenous participation in the northern beef industry for Meat and Livestock Australia (MLA) and the Indigenous Land Corporation.

Method:

The cost of bore runs has been assessed at the three stations and telemetry systems have been installed on them.

A beef cattle automatic drafter was added to the walk-over weighing prototype at Napperby Station in September. The automatic drafter utilises the electronic individual animal identification tags to collect data and make drafting decisions. The system is solar-powered.

The testing of live video feeds was completed using the Sparse Ad Hoc Networks for Deserts at Napperby in March and was linked to the Remote Livestock Management System.

Evaluations of the Kimberly indigenous management support service and the indigenous pastoral program were completed. Reviews were conducted of indigenous participation in the northern beef industry for MLA and the Indigenous Land Corporation.

Results:

The telemetry systems evaluated in the utilising technology and WaterSmart projects generated significant savings for the properties involved, reducing the cost of monitoring and maintaining stock water by 30% to

50%. The investments in new technologies ranged between $30 000 and $70 000 and had a cost recovery period of six to 24months.

The second prototype remote livestock management system is being developed and evaluated at Napperby Station. During initial testing, 93% of animals were drafted correctly by the automated system.

The Sparse Ad hoc Networks for Deserts was demonstrated at the Napperby field day and was capable of broadcasting live video footage over 2 km. The development and testing of the system continued to improve the reliability and stability of the network.

The evaluation findings were presented to the Indigenous Land Corporation in two individual reports. The indigenous pastoral employment review identified the lack of a clearly-defined career pathway as the greatest impediment to long term Aboriginal employment in the pastoral industry.

PROJECT: Seasonal Burning of Mitchell Grassland on the Barkly Tableland

Project Officer: C. Materne

Division:	Animal Industries
Location:	Barkly
Keyword(s):	Mitchell grassland, seasonal burning, rangeland management

Objectives:

To measure the impact of low intensity, early dry season fires and high intensity, late dry season fires on Mitchell grasslands and woody plant species in Buchanan paddock on Alexandria station.

To demonstrate the application of prescribed burning in the extensively grazed Mitchell grasslands of Buchanan paddock.

Background:

Understanding the relationship between fire and Mitchell grasslands has been overlooked in the past due to a view that “Mitchell grasslands are too valuable as a pasture to be burnt” (Thackway et al. 2007). However, more recent observations by station managers and naturalists of Mitchell grassland recovery after wildfires have stimulated curiosity as to whether seasonal fire is needed to maintain Mitchell grasslands in good condition on the Barkly Tableland. Scanlan (1980) found that burning under low soil moisture conditions followed by low rainfall was detrimental to the pasture of Mitchell grasslands. Phelps & Bates (1996) demonstrated the benefit of spring fire as a tool for managing the undesirable feather-top wiregrass *(Aristida latifolia)* in Mitchell grasslands of the intensively-grazed areas of Queensland by sheep. This trial attempts to better understand the importance of seasonal prescribed burning as a management tool for Mitchell grasslands under continuous grazing and its effect on cattle production on the Barkly Tableland.

Method:

The trial was conducted on Alexandria Downs Station between 2001 and 2004. The trial site is dominated by barley Mitchell grass (*Astrebla pectinata)* and *w*eeping Mitchell grass (*A. elymoides).* It is in the sub-tropical (distinctively dry winter) grassland climate zone and has a median financial year rainfall of 350 mm. The

effects of early and late-dry-season burning on native trees and shrubs, pasture dynamics, cattle diet quality and grazing characteristics were investigated using a randomised three plot (25 ha each) block design with four replications in a paddock under conservative continuous grazing. Tree and shrub data was collected prior to the trial. Information on pasture yield, species composition and cover was collected from 50 x 1 m^2 quadrats on four parallel transects each 400 m long. Pasture quality data was collected using the 'grab sampling' technique (Ash and McIvor 1995) and was analysed using wet chemistry methods. Cattle diet was analysed using NIRS on a paddock scale, replicated twice. Repeated measures ANOVA was used to test the interaction effect of treatment and time. *Post priori* comparisons were used to test for differences between treatments within different time periods.

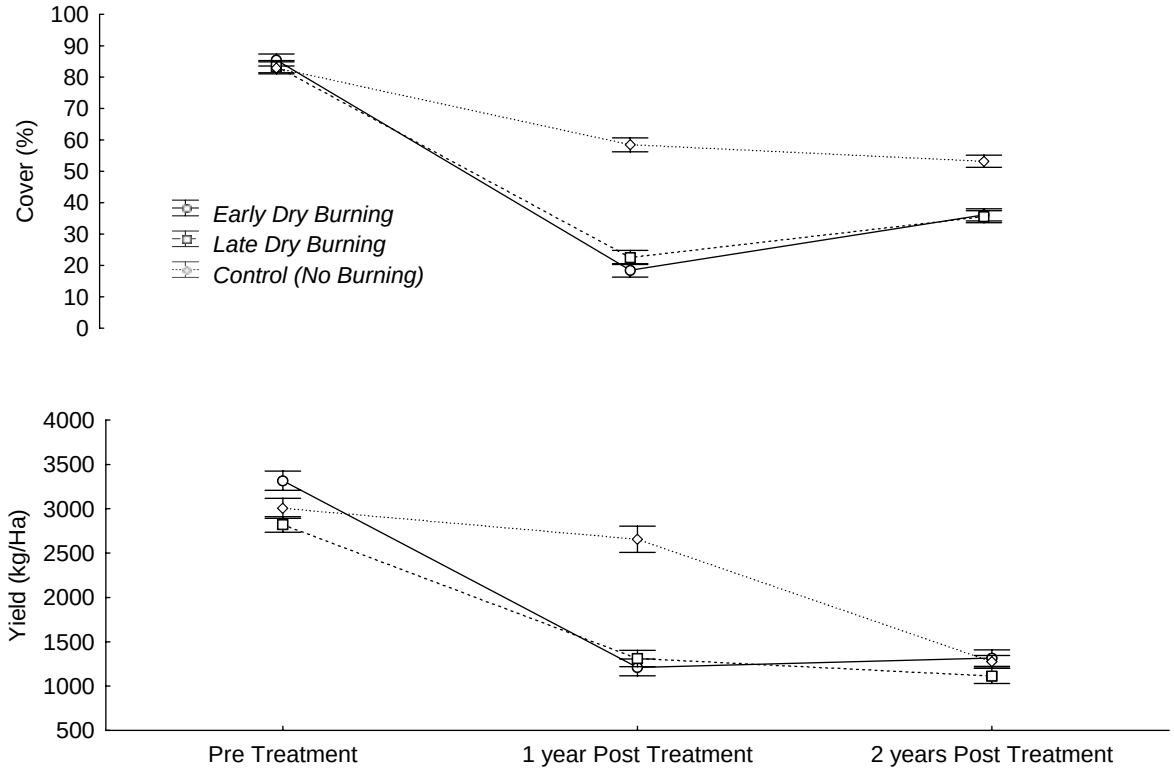
Results:

The financial year rainfall total during the trial was close to the median of 350 mm, although it became increasingly drier as the trial progressed. This followed consecutive above average seasons (top decile) in 1999-2000 and 2000-01.

In all treatment areas cover and yield (Figures 1 and 2) progressively declined over the trial period due to the decreasing seasonal rainfall ($F_{2, 40}$=206, P<0.001, and $F_{2, 40}$=316, P<0.001 respectively). Although no significant difference in cover ($F_{1, 20}$=0.35; p=0.55) or yield ($F_{1, 20}$=0.0; p=0.99) was recorded between the two seasonal burning treatments, burning itself significantly reduced both cover ($F_{1, 20}$= 78.3; p<0.0001) and yield ($F_{1, 20}$=35.9; p<0.0001) following the first growing season. Yield recovered but cover was still lower in burned plots after the second growing season ($F_{1, 20}$=0.13; p=0.72, $F_{1, 20}$=11.1, P<0.01, respectively).

Flora species richness was largely influenced by seasonal response ($F_{2, 40}$=171.6; p<0.001). However, fire significantly increased species richness following the first growing season ($F_{1, 20}$=7.8; p=0.01) (Figure 3). There was no significant difference between the two seasonal burning treatments after one year ($F_{1, 20}$=0.4; p=.05). The effect of fire on flora richness disappeared after two growing seasons.

Woody plant death rates increased following the burning treatments and were greatest under the late-dry-season burns (Figure 4). Considerable re-sprouting did occur following burning, but consecutive drier than average years caused more deaths following the second year. The height of surviving woody vegetation was reduced on average by about 40% regardless of the burning season (Figure 5).



Figures 1 and 2. Seasonal burning effect on ground cover and pasture yield under grazing, with 95% confidence limits (measured in April)

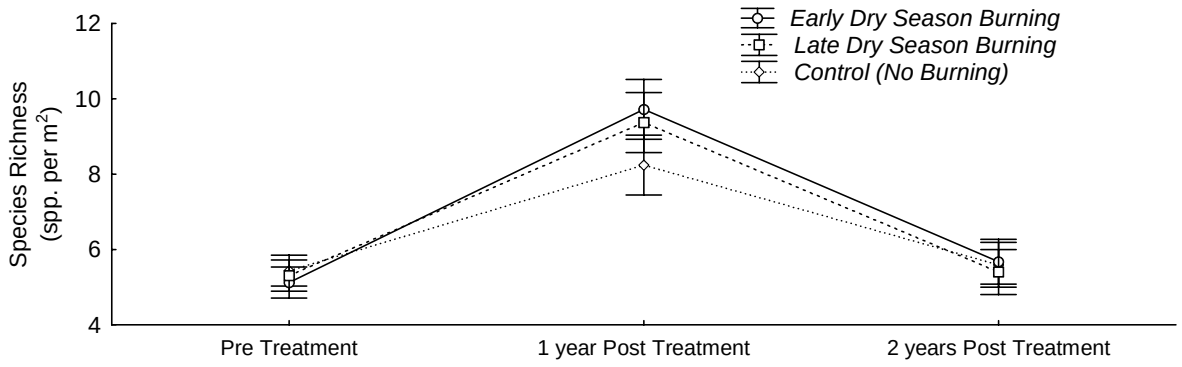
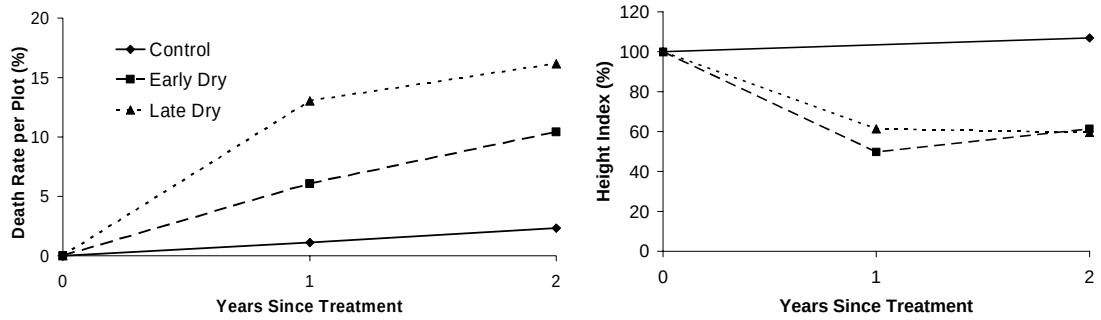


Figure 3. The effect of seasonal burning on species richness within a 1 m area over time with 95% confidence intervals (measured in April)



Figures 4 and 5. Woody vegetation death rate and height under different seasonal burning regimes

In all treatments, cattle activity increased over the trial period (Figure 6) due to the decreasing seasonal rainfall ($F_{2, 40}$=124.9, P<0.001). Burning further significantly increased cattle activity ($F_{1, 20}$=6.7; p=0.01) over at least two dry seasons. Short-term improvements in Mitchell grass feed quality over the first growing season were found following fire (Figures 7, 9 and 10). However NIRS sampling (Figure 8) indicated the effect on diet was relatively small and only at the beginning of the growing season before the annual grasses and forbs germinated.

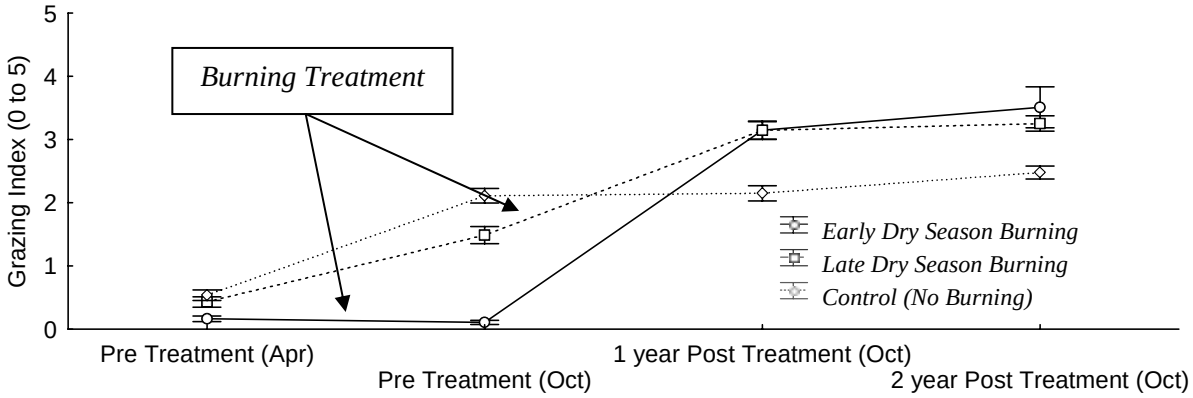
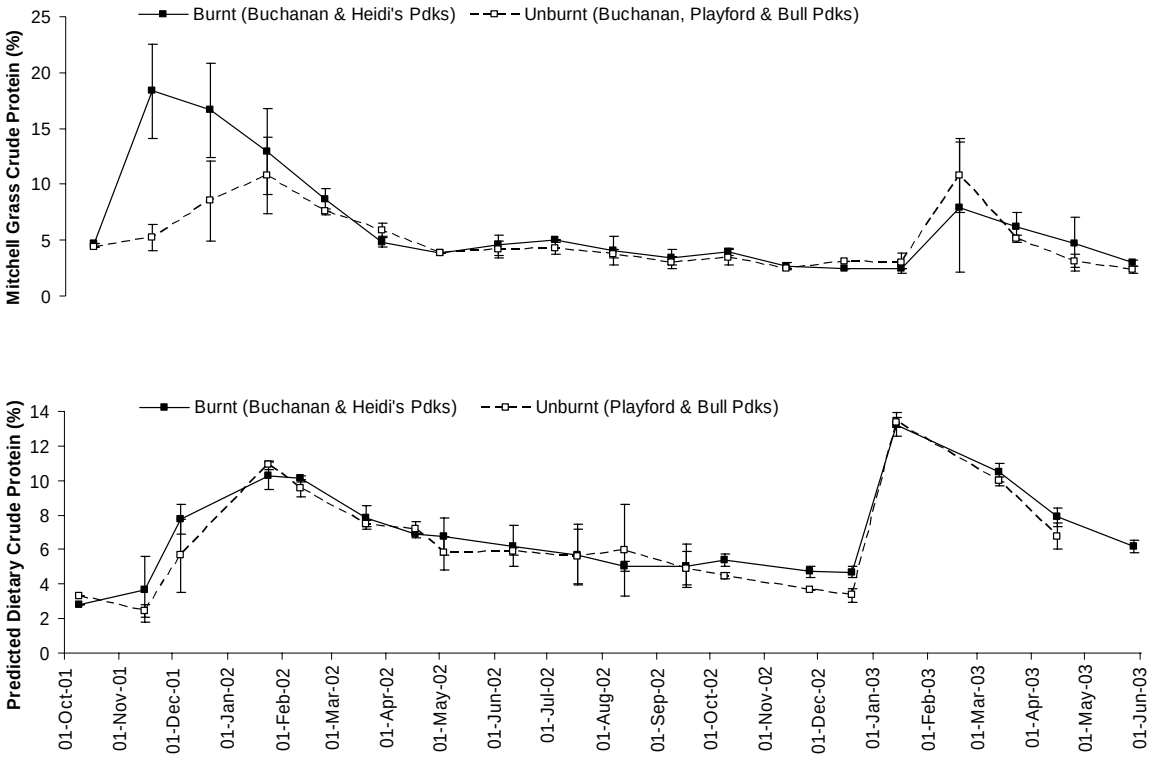


Figure 6. The effect of seasonal burning on cattle grazing activity, with 95% confidence limits



Figures 7 and 8. Crude protein content of late-dry-season burnt and unburnt Mitchell grass (*Astrebla pectinata* and *A. elymoides*) from grab sampling analysis using dry chemical methodology and the predicted cattle diet quality from dung samples (NIRS analysis), with 95% confidence limits

Figures 9 and 10. Rank pasture pre-burning in December and in late January after burning and rain

Discussion

The greatest pasture management risk with prescribed burning in Mitchell grasslands in more arid areas is a lack of follow-up rain and the resulting short-term feed loss and production (Daubenmire 1968 and Scanlan 1980). However, dry matter differences between the burnt and unburnt plots in drier seasons appear to be due to carry-over feed in the unburnt plots, rather than a lack of seasonal growth from the burnt plots. Following the second consecutive below average growing season, no difference was identified in the available feed between the burnt and unburnt sites, similar to Scanlan's (1983) findings even though the

burnt areas remained auxiliary tiller free. With adequate rainfall Scanlan (1980) found these grasslands can recover rapidly within one growing season supporting the observations in this study.

Following fire, Mitchell grassland cover appears to require three growing seasons to recover. These findings are similar to those of Dyer et al. (2003) in the higher rainfall Victoria River District of the NT. Cover is considered an important land condition indicator (Materne 2005 and Chilcott et al. 2007). However, personal observations, supported by Scanlan (1983), suggest the cover change was dominated by the litter component and not the more stable Mitchell grass basal area, and hence is not considered an indicator of declining land condition. This reduced litter cover is likely to have contributed to increased species richness by removing its suppressive tendencies.

Even though many woody species in the trial area are considered to be relatively fire tolerant re-emerging plants, fire still had a significant effect on survival and height.

Although short-term negative impacts were recorded following fire in Mitchell grassland on the Barkly Tableland, the results of this trial indicate that these grasslands are resilient to fire and conservative stocking, even under less than favourable growing conditions. Late-dry season burning has the potential to improve production and can be a useful cost-effective management tool for the removal of rank pasture, reducing tree and shrub cover and influencing cattle movement and short-term diet quality.

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PROJECT: Developing Sustainable Carrying Capacities in the NT

Project Officers: C. Smith and R. Cowley (Sturt Plateau), R. Allan (Barkly) and A. Kain (Alice Springs)

Division:	Animal Industries
Location:	NT
Keyword(s):	carrying capacity

Objectives:

To develop methods to objectively assess carrying capacity including calibration of pasture growth models for the Sturt Plateau in the Barkly region and in the Alice Springs region.

To develop methods to evaluate carrying capacity to enable pastoralists to make informed decisions on seasonal and long-term stocking rates.

Background:

There is potential in the NT cattle industry to increase production through subdivision and intensification of land use. However, land intensification in other states has sometimes led to unviable small blocks and extensive land degradation due to an over-optimistic assessment of land capability. To facilitate sustainable development of the NT cattle industry, it is therefore imperative that there be an objective and transparent method for estimating carrying capacity, particularly where properties are being subdivided.

This project will calibrate the GRASP model to facilitate estimation of sustainable carrying capacities in important grazing pasture types of the NT such as the Barkly, Sturt Plateau and Alice regions. The GRASP model is calibrated through the collection of pasture, soil and meteorological data from small exclosures called SWIFTSYND sites. These exclosures have been set up on areas that represent different land systems and vegetation types in order to obtain a broad viewpoint across the region.

Monitoring events (harvests) are conducted at four times throughout the year except for the Alice region where harvests are conducted every two months. The timing of harvests depends on seasonal conditions. At each harvest, pasture, soil and rainfall data is collected from the sites.

Method:

Alice Springs

Six sites were constructed on four stations and on the Old Man Plains Research Station (OMPRS) during 2004-05. They represented the following land systems: Alcoota (Alcoota Station), Ebenezer (Mt Ebenezer Station), Muller (OPRS), Outounya (Umbeara Station), Renners (Deep Well Station) and Sandover (Alcoota Station). Harvests are undertaken when the predominant annual grasses have begun seeding (about 10-14 days after rain).

Two sites have enough data to calibrate GRASP, the remaining sites are ongoing.

Barkly

Twelve monitoring sites have been constructed in the Barkly region. The sites are located at Alexandria, Beetaloo, Benmara, Brunette Downs, Helen Springs, Newcastle Waters, Rockhampton Downs and Walhallow Stations. The land systems represented include Barkly, Creswell, Pollyarra, Pollyarra/Creswell and Wonorah/Barkly1 land systems.

Harvest of the remaining four sites is due to finish in October 2008.

Sturt Plateau

There are currently 10 SWIFTSYND sites located around the Sturt Plateau on five different land systems. The selected land systems are Banjo, Larrimah, Sturt, Bulwaddy and Elsey. Together, these land systems represent 71% of the total Sturt Plateau region.

Two sites (Gorrie Station, Larrimah land system and West Elsey Station, Elsey land system) have been completed. The remaining sites are due for the eighth and final harvest in October 2007.

All sites have been completed.

Results:

A two week workshop in August 2008 will begin the calibration of completed SWIFTSYND sites, with training of Katherine and Alice Springs staff. This will allow an independent NT processing of the remainder of the sites as they are completed.

Alice Springs

Two sites have eight harvests, although bulk density is still to be collected and preliminary calibration of sites will then be done. The final calibration will be done following the collection of bulk density site data.

Barkly

Finished sites will be calibrated in 2008 following data collation.

Sturt Plateau

All sites will be calibrated in 2008.

GRASP parameter sets will be used in GLM courses.

PROJECT: Emissions Management Strategies for Pastoral Production in the Northern Territory

Project Officer: D. Ffoulkes

Division:	Animal Industries
Location:	NT
Keyword(s):	pastoral operations, greenhouse gases, emissions, abatement, best practice, training

Objective:

To develop strategies for mitigation (abatement) of greenhouse gas emissions on pastoral properties that can potentially deliver environmental and financial benefits to the enterprise.

Background:

As pressure grows in Australia for action on climate change, a wide array of adaptation and mitigation options are being developed to reduce vulnerability to projected climate change and variability. This project focuses on the early integration of mitigation measures into pastoral operations in the NT in order to understand the processes involved and the benefits to the enterprise and environment.

Method:

1. Undertake capacity building in greenhouse gas emissions management principles and delivery of relevant information to the pastoral industry in the form of Factsheets and newsletter articles.

2. Establish producer demonstration sites to monitor greenhouse gas emissions and measure cost benefits of abatement strategies.

3. Develop and publish best practice emissions management strategies for the NT pastoral industry.

Results:

The project officer attended a two-day training course in New Zealand on Fundamentals of Carbon and Emissions Management as part of the capacity building component of the project.

Three Factsheets were published on the DRDPIFR website (see References below).

- Factsheet 1: NT Pastoral Industry and Climate Change Overview
- Factsheet 2: Sources of Greenhouse Gas Emissions from the NT Pastoral Industry
- Factsheet 3: Reducing Greenhouse Gas Emissions from the NT Pastoral Industry

PROJECT: Short Duration Grazing Demonstration

Project Officers: P. O'Brien, P. Shotton, S. Reed and DDRF Staff

Division:	Animal Industries
Location:	Katherine
Keyword(s):	cattle, grazing systems

Objective:

To monitor a rotational cattle grazing system on introduced pastures to determine the benefits to soil health, plant composition and cattle performance compared with traditional grazing systems.

Background:

The basic objective of short duration grazing (SDG) is to divide the pasture grazing area into a series of smaller paddocks where cattle are rotated from paddock to paddock, spending from one to five days in each paddock. This allows cattle to continually graze quality feed, allows more even grazing distribution and allows pasture to rest before being grazed again.

Advocates of cell grazing/SDG expect an improvement in pasture and paddock condition to increase carrying capacity. As input prices and overheads continue to rise, NT producers are keen to find out if SDG can help increase their returns through increased animal weight gains or carrying capacity.

Method:

Sixteen paddocks of 2, 4 and 6 hectares each were used to rotationally graze year-round. Brahman cross yearling heifers remain in the demonstration until December and are then replaced with another group of yearling heifers.

Paddocks 2, 5 and 17 were selected as controls where heifers are set stocked at the same rate as in the SDG paddocks and are continuously grazed.

At the commencement of the trial all paddocks received 50 kg/ha Generator® pasture fertiliser in December 2005 and were sprayed with herbicides (Amine® 24-D and/or Brush-off®) to control various broadleaf weeds, particularly Senna (*Senna obtusifolia*), Hyptis (*Hyptis suaveolens*), Sida spp. (*Sida*) and Caltrop (*Tribulus terrestris*).

The paddocks were stocked at 1.5 animals/ha in the wet season and reduced to 1 animal/ha in June. From June 2005 supplementary lick blocks were supplied ad lib to all animals: Uramol® in the dry season and Phosrite® in the wet season.

Data collection

Plant composition in each paddock was assessed in December 2005, 2006, 2007 and 2008 to determine pasture yield and to monitor changes in desirable and non-desirable plant species.

All cattle movements and grazing days are recorded on a grazing chart. Cattle are weighed at the start of the grazing year (December) and then about every eight weeks thereafter, to monitor live-weight changes and cattle health.

Results:

In the first year (2005/06) the annual live-weight gain (LWG) was 125 kg/animal (0.34 kg/day) for the cell heifers compared to 90 kg/animal (0.25 kg/day) for the control group. Wet season gains were 0.39 kg/animal/day for the cell heifers and 0.36 kg/animal/day for the control heifers, with the dry season gains being 0.55 kg/animal/day for the cell heifers and 0.47 kg/animal/day for the control heifers.

In the second year (2006/07) a fire burned the first seven paddocks, including Paddocks 2 and 5 in the control group, which left only paddock 17 in the control group for the remainder of the year. Due to the fire, the stocking rate was reduced to one animal/ha. Prior to the fire, the wet season gains were 0.37 kg/animal/day for the cell group and 0.5 kg/animal/day for the control group. Dry season gains were 0.17 kg/animal/day (range 0.006 to 0.31 kg/animal/day) for the cell group and 0.08 kg/animal/day (range 0.006 to 0.12 kg/animal/day) for the control group. Annual LWG was 0.26 kg/animal/day (range 0.06 to 0.36 kg/animal/day) in the cells and 0.3 kg/animal/day (range 0.21 to 0.37 kg/animal/day) in the control group (paddock 17).

Replacement heifers on 24/12/07 had an average weight of 181 kg (range 111 kg to 244 kg). By 18/04/08 the average LWG was 0.3 kg/animal/day in the control paddocks (0.1 to 0.4 kg/h/d range) and 0.2 kg/animal/day in the cell group (0.1 to 0.4 kg/animal/day range).

Table 1. LWG in the groups (kg/animal/day)

	Dec 05 to April 2006	**April 06 to Dec 2006**	**Dec 2006 to May 07**	**May 07 to Dec 2007**	**Dec 07 to April 08**
Cell	0.39	0.34	0.37	0.26	0.20
Control	0.36	0.25	0.50	0.30*	0.30

Note: * Control Paddock 17 only

Plant composition and pasture yield varied throughout each paddock. Total plant biomass in each paddock ranged between 5 and 8.5 tons/ha in May 2007 and between 3.5 and 8 tons/ha in April 2008. The lower yield was due mainly to flooding of some of the lower paddocks in February 2008.

Sabi (*Urochloa mosambicensis*) remains the dominant grass species with summer and other grasses increasing in some paddocks. In most paddocks, there was an increase in Cavalcade yield over the past two years and an increase of broadleaf weeds, mainly Senna and Sida, in all paddocks.

Statistical analysis

Means of quadrat yields from four groups were analysed for three paddock comparisons using an ANOVA model to assess yields repeated in time (May values for 2006, 2007 and 2008).

Paddocks that were compared:

- Paddock 2 v Paddock 3
- Paddock 5 v Paddock 6
- Paddock 16 vs. Paddock 17.

Groups in each comparison were:

- Sabi grass
- All other grasses
- All legumes
- All broadleaf weeds.

The source of variation was undertaken for each comparison. This test assesses the overall paddock effect (paddock means across all years), the overall year effect (year means across both paddocks) and the interaction effect of paddock in each year (year*paddock).

The comparison between Paddocks 2 (set stocked) and 3 found both were declining in sabi grass yield; however, Paddock 3 had higher yields (statistical difference in paddocks P=0.0098).

Paddock 2 was also increasing more in other grasses and broadleaf weeds (Figure 1).

Table 2. Sabi ANOVA Paddock 2 vs. Paddock 3

Effect	SS	df	MS	F	P
Paddock	16545792	1	16545792	13.8193	0.0098
Error(Paddock)	7183788	6	1197298		
Year	8775932	2	4387966	3.3755	0.0687
Year*Paddock	2393309	2	1196655	0.9205	0.4247
Error(Y*P)	15599246	12	1299937		

The comparison between Paddocks 5 (set stocked) and 6 found both had low sabi grass yields (Paddock 5 had a higher mean yield in 2007; however, it reduced again in 2008) and a high mean yield of other grasses. Paddock 6 had the least amount of sabi grass and the most of other grass. Broadleaf weeds have been increasing in both paddocks at similar rates (Figure 1).

The comparison between paddocks 17 (set stocked) and 16 found both had similar sabi grass and other grass yields. The trend in both paddocks was a lower yield of sabi grass in 2005 than in the previous year and slightly more other grasses. Both paddocks have more broadleaf weeds. Broadleaf weed increased much more in Paddock 17in 2008 (Figure 1).

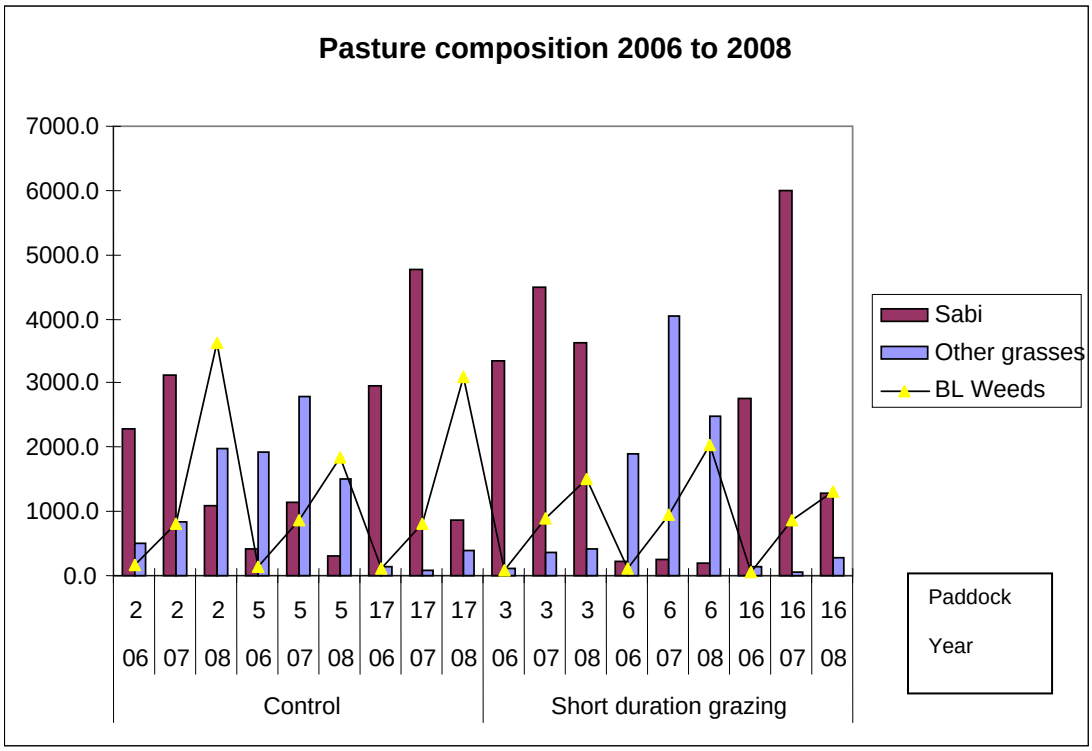


Figure 1. Comparison of desirable grass, other grasses and broadleaf weeds (kg/ha)

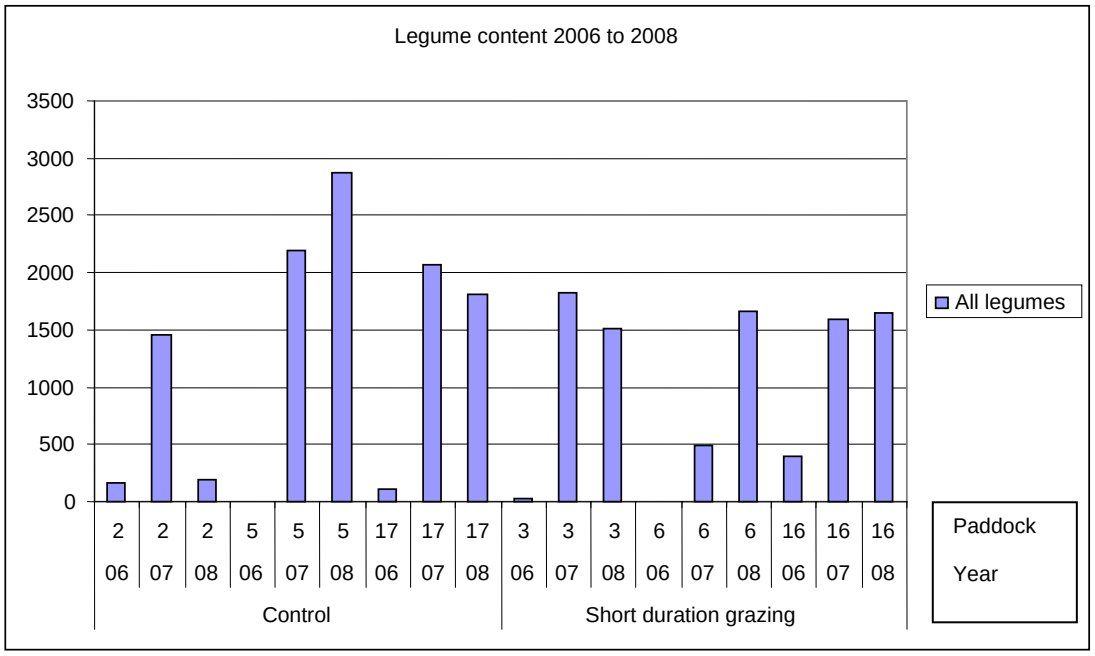


Figure 2. Legume yield in comparison paddocks over three years

Discussion:

At this stage the management of short duration grazing and the non-spraying management of the trial area are not controlling the broadleaf weed invasion. The increase in legume plants (Figure 2), particularly Cavalcade, could be due to favourable climatic conditions and the non-herbicide management.

Wallabies have influenced grazing pressure in some areas of the trial, particularly in Paddocks 1, 2 (control) and 3. The high rainfall in February 2008 caused flooding in the lower paddocks (Paddocks 9 to 14) reducing the biomass yield in considerably. Fires in July 2007 burnt Paddocks 1 to 7 and they were not grazed again until January 2008. The paddocks recovered well during the wet season with biomass yield and plant composition not appearing to have changed substantially due to the fire.

The comparison of cattle LWG between the set stocked and rotationally-grazed paddocks varies slightly over the two and half years, with no evidence of marked differences at this stage.

PROJECT: Pasture Species Evaluation under Grazing at DDRF

Project Officers: B. Lemcke, P. Shotton and DDRF Staff

Division:	Animal Industries
Location:	Katherine
Keyword(s):	improved pasture, pasture grass, pasture legume, cattle grazing, Douglas Daly Research Farm

Objectives:

To evaluate improved pasture species and mixtures under a continuous grazing regime on Blain soil at Douglas Daly Research Farm (DDRF).

To determine their persistence, productivity and contribution to the weight gain performance of cattle.

To make pasture management recommendations for Top End livestock producers

Background:

Promising pasture species and mixtures are evaluated under grazing by cattle at DDRF to determine their long-term potential in the Douglas Daly and other Top End regions.

Method:

Pastures are grazed in 4-ha paddocks by six Brahman weaner steers per paddock (1.5 animals/ha). However, to monitor the long-term effects of heavy stocking rates on these productive leucaena/buffel and buffel pastures, Paddocks 39 and 49 had four extra animals to increase stocking rate to 2.5 animals/ha. Steers are allotted to paddocks in June/July (post-weaning) and remain in the grazing trial until the following June (almost 12 months).

Paddocks are top-dressed annually with a phosphorus-based fertiliser. This year, Pasture Generator® (NPKS 0:16:0:20) was ground spread on the paddocks at 50 kg/ha. During the wet season, various measures to control weeds were undertaken where required, such as spot-spraying to control broadleaf weeds. Some grass-only paddocks are boom-sprayed with Starane®/2, 4-D or 2, 4-D/Brush Off ® mixtures if broadleaf weeds become prominent. A 2 x 50 kg split application of urea was made to paddock 532 to substitute wet season blocks.

The animals were supplemented ad-lib with Uramol® blocks during the dry season and Phosrite® blocks in the wet season. Intake was recorded monthly. Only in paddock 532 where urea had been applied, cattle did not receive wet season blocks.

The cattle were weighed monthly, given a condition score and their P8 (rump) fat was measured from January onwards until the end of the grazing season in June 2008.

Pasture composition and yield were assessed twice during the year, first in the early wet season in December 2007 and post-wet season in May 2008.

Paddock 39 was divided into two and grazing is rotated monthly to allow leucaena to recover leaves on a regular basis.

As an extension to a 12-month evaluation trial in 2006 titled”Monitoring the consumption of companion pasture legumes with improved grass species using near infrared reflectance spectroscopy”, a collaborative project between QDPI&F and DRDPIFR commenced in August 2007 to investigate further the consumption of pasture legumes, dietary crude protein, digestibility and faecal N concentration of each group of animals sampled.

Results:

Table 1. Mean cattle live-weight gains in each paddock (kg/animal)

Paddock No.	Pasture type	July 07-Nov 07 (mid-late dry)	Nov 07 - April 08 (wet season)	April 08-June 08 (early dry)	Total July 07-June 08
39	Buffel/leucaena (split paddock-heavier stocking))	29.2	125.4	20.3	174.9
40	Nunbank buffel	1.3	95.5	11.2	107.9
41	Tully (*B. humidicola*)	10.6	71.2	8.0	89.8
42	Wynn cassia/Jarra	24.3	133.7	11.0	169.0
43	Forage sorghum /legumes Signal*grass –planted Dec 2007	6.3*	*	*	*
44	Pangola	16.8	141.8	13.3	172.0
45	Pangola/leucaena	31.8	141.2	27.7	200.7
46	Sabi	26.4	97.8	13.7	137.9
47	Jarra	22.5	127.7	9.3	159.5
48	Sabi/leucaena	27.9	137.3	19.2	184.4
49	Buffel/tall variety (heavier stocking)	9.0	118.7	11.8	139.5
50	Buffel/legumes	27.5	127.2	23.0	177.7
51	Strickland/Wynn	24.4	141.3	18.7	184.4
52	Arnhem/Oolloo	4.3	109.7	4.5	118.4
531	Buffel/sabi/ WS blocks	22.3	141.8	13.7	177.8
532	Buffel/sabi (100 kg urea)	26.6	103.2	10.2	139.9
533	Buffel/sabi/Wynn	10.1	127.8	19.7	157.6
534	Leucaena/buffel/sabi	26.3	128.8	25.0	180.2
535	Buffel / Oolloo	5.8	138.5	26.2	170.5
All paddocks	Mean live-weight change	20.3	122.8	14.6	157.7

*Paddock 43 was only stocked during the dry season and replanted with signal grass.

Table 2. Mean cattle live-weight gain (LWG) for the previous nine years (kg)

Year	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
LWG/ animal	187.7	176.1	173.0	173.1	176.5	168.0	205.9	137.6	157.7

There was a slight increase in average LWG per animal this year compared with last year but it was still the second lowest result in the last 10 years. Stocking rate was the same as last year, but in both years it was 20% higher than in previous years, except for Paddock 49 which had 2.5 animals/ha. This was the second year of 2.5 animals/ha in the leucaena/buffel Paddock 39.

The seasonal rainfall for each year was markedly different, with 1846 mm (119 rain days) in 2005-06, 1127 mm (76 rain days) in 2006-07 and 1984.8 mm (96 days) in 2007-08. Despite the higher rainfall in 2007-08, there were fewer rain days and 2005-06 had higher falls in the October-November and April (a much longer green season). It would appear that total rainfall is less important than season length on LWG in cattle.

The patterns of previous years were again apparent. Animals in grass/leucaena paddocks performed best; in grass/legume paddocks they performed less well; in grass alone paddocks, they performed poorly.

Table 3. Cattle LWG performance in different pastures (kg/animals)

Year	Mean LWG all leucaena / grass paddocks	Mean LWG all legume / grass paddocks (excluding leucaena)	Mean LWG all grass-only paddocks
2005-06	235.0 l	204.8 l	193.8
2006-07	158.3	150.5	119.8
2007-08	185.0 l	171.8 l	137.9 l

Pasture composition and total yield were assessed in December 2007 and May 2008 using Botanal®.

Table 4 shows the total average biomass yield of each paddock and the proportion of the main grass species, all other grass species, all legumes and all broad leaf weeds.

Table 4. Paddock details

Paddock	Main grass (%)	Other grasses (%)	Legumes (%)	Broadleaf weeds (%)	Total biomass yield May 2008 (kg/ha)
535	74.4	4.6	16	4.9	7,741
534	70.9	13.2	7.6	8.4	8,151
533	81	2.6	14.8	1.7	7,860
532	88.4	1	9.7	0.9	7,418
531	85.7	7	4.9	2.2	5,282
52	92.3	2.9	3.8	0.9	6,591
51	78.2	1.4	20.4	0.1	7,252
50	81.6	2.7	11.6	4.1	8,927
49	93.1	4.5	1	1.4	5,253
48	83.8	1.6	10.2	4.3	8,765
47	92.4	2.7	2.2	2.6	4,580
46	92.5	6.4	0.2	0.9	5,008
45	91.5	0.3	6.8	1.7	9,768
44	88	11.4	0.5	0.1	7,067
43	70.1	25.8	1.6	2.1	6,087
42	68.1	1	30.6	0.2	8,104
41	85.4	0.4	12.4	1.8	6,489
40	80.9	10.6	5.2	3.3	6,720
39	81.3	4.4	10.6	3.7	9,694

The 2007–08 wet season was well above average in total rainfall with 1984 mm, and with above average falls in most months. The number of rain days was 96, which is above station average.

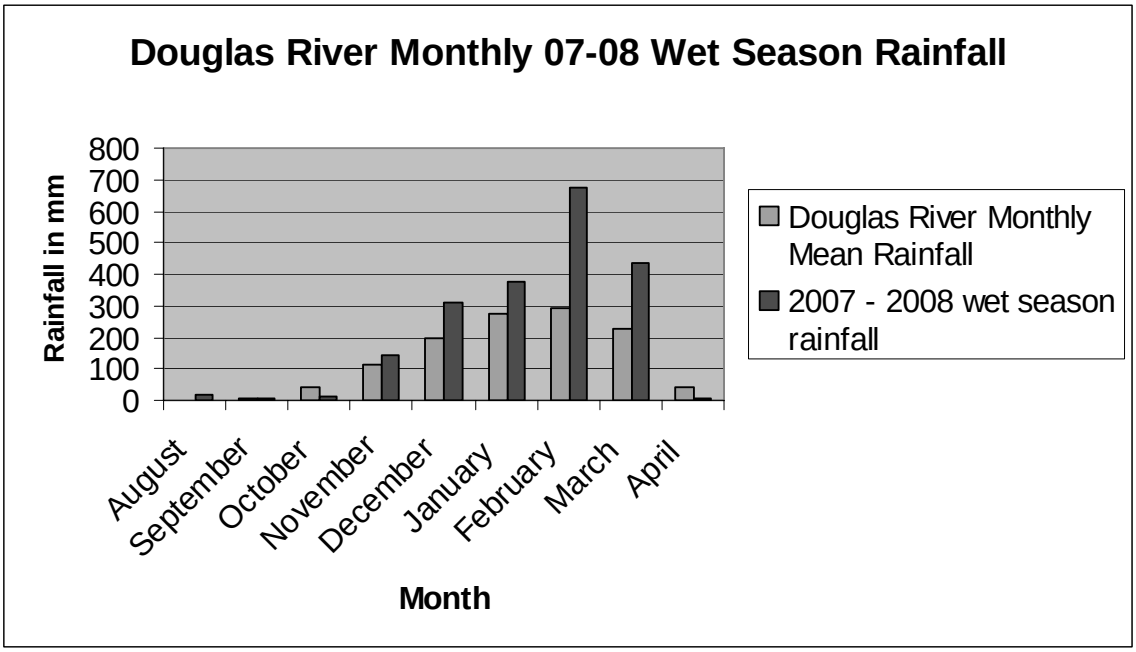


Figure 1. Rainfall for Douglas River during the 2007-08 wet season

Other observations

Cattle performed poorly again on Tully and Nunbank buffel grass, both of which were very poor in comparison to other grasses. The 2007-08 LWG on Tully was 20% lower than on Nunbank, which was 28% lower than on sabi.

Animals on Jarra/Wynn outperformed those on Jarra-only as would be expected; both groups showed a lower performance than on Strickland/Wynn.

The second year of higher stocking on paddock 39 did not seem to cause a further reduction in LWG performance in compared with last year's performance. The ratios are still similar so the higher weight gains achieved this year reflect seasonal effects.

Block consumption

Uramol® was provided in all paddocks from 03/07/07 to 08/11/07. Phosrite® was provided from 08/11/07 to 24/06/08 except for Paddock 532.

Table 5. Block consumption rates

Paddock No.	Variety/species	Dry season Uramol® consumption (137 days) (g/animal/day)	Wet season Phosrite® consumption (226 days) (g/animal/day)
39	Buffel/leucaena (5 full length rows)	58	77
40	Nunbank buffel	49	88
41	Tully (*B. humidicola*)	86	31
42	Wynn cassia/Jarra	71	97
43	Forage Sorghum/legumes/ Signal	Not stocked for full period	Not stocked for most of period
44	Pangola	49	27
45	Pangola/leucaena	42	12
46	Sabi	104	63
47	Jarra	103	93
48	Sabi/leucaena	73	79
49	Buffel (tall variety) Double stocking rate	55	80
50	Buffel/legumes	62	117
51	Strickland/Wynn	78	105
52	Arnhem/Oolloo	89	55
531	Buffel/sabi/blocks	83	104
532	Buffel/sabi/Urea	52	Not supplied
533	Buffel/sabi/Wynn	63	171
534	Leucaena/buffel/sabi	67	79
535	Buffel/Oolloo	62	103
All paddocks		69	94

Consumption rates compared with last year were lower for Uramol® (down 4 g/animal/day) and higher for Phosrite® (up 22 g/animal/day). Over 10 years, it is at the lowest end of the range for Uramol (range 69-134 g) and mid range for Phosrite (range 72-119 g). Group consumption was very variable between paddocks. It was very low in pangola and Tully paddocks and was highest in buffel and Strickland paddocks.

The comparison between performance on nitrogen-fertilised buffel grass and wet season blocks has shown that LWG was higher in block-fed animals. The yearly difference in the first year was 23 kg LWG/animal in favour of the block-fed group (Paddock 531 compared with Paddock 532). In the second year, the difference was less at 10 kg LWG/animal. In the third year, the difference was 8.1 kg/animal in favour of the urea-fed group. Last year when no urea was fed, there was a 16 kg advantage in the block fed group. However, this year there was a massive difference in wet season weight gain of 42 kg in favour of the block-fed group. This was consistent over all cattle in the two groups.

PROJECT: Pasture Species Evaluation under Grazing at Douglas Daly Research Farm: Buffel/Legumes

Project Officers: P. Shotton, B. Lemcke and DDRF Staff

Division:	Animal Industries
Location:	Katherine
Keyword(s):	cattle, improved pasture species, nutrition, sustainability, grazing, Douglas Day Research Farm

Objective:

To monitor the value of a companion pasture legume with buffel grass in terms of nitrogen (N) availability, pasture quality, quantity and persistence of legume species.

Background:

Buffel grass is a commonly used improved pasture in the Top End, mainly south of, and including, the Douglas-Daly region. As established buffel grass pasture tends to grow in clumps, a favourable legume companion species would be beneficial to help utilise the area between buffel plants and provide N to the grass to improve quality and increase yield. Higher protein in the diet of cattle from the legume would be an additional benefit. The legume also would help to reduce potential weeds between grass clumps.

The project follows a non-grazed plot trial of 1996-1998 that evaluated the benefits of six tropical pasture legume species as companions to buffel grass (see Technote 110).

Method:

On 6 January 2000, five pasture legume species were planted in a 4-ha paddock (Paddock 50) at Douglas Daly Research Farm. The legumes were Wynn cassia *(Chamaechrista rotundifolia),* Verano stylo *(Stylosanthes hamata),* Oolloo *(Centrosema brasilianum),* Maldonado *(Macroptilium gracile)* and Milgara blue pea *(Clitoria ternatea).* The legume treatments and control (buffel only (*Cenchrus ciliaris)*) were randomized and replicated four times with a plot size of 12 m x 130 m.

In December each year 50 kg/ha of Goldphos 20® or equivalent fertiliser was applied.

The area was left non-grazed in the first wet season to allow legumes to set seed. The paddock was grazed over the 12-month period by five Brahman weaner steers (1.25 animals/ha) which were weighed, condition scored and, after December, tested for fat depth (P8) every 28 days. Steers were put in at the end of June each year and were changed over every 12 months. The practice in 2004-05 and 2005-06 differed slightly by altering the breed of steers to a mixture of Brahman, Composites and Droughtmaster. In 2006-07 animal numbers were increased to six (1.5 animals/ha).

The animals were supplemented with Uramol® blocks during the dry season and Phosrite® blocks during the wet season.

Prior to planting, broadleaf weeds were controlled by using Starane® as a post-planting/pre-emergent herbicide in January 2000. Some hand-weeding and spot-spraying were carried out for broadleaf weeds, mainly spiny head sida *(Sida acuta)* Flannel weed *(Sida cordifolia)*, Hyptis *(Hyptis suaveolens)* and Senna (*Cassia obtusifolia)*.

Pasture composition and yield were assessed twice each year in December and May using Botanal®.

Results:

During the first two seasons, all legumes established well. The most prolific were Milgara blue pea, Oolloo and Maldonado. Wynn cassia and Verano stylo were less prolific than the twining legumes. Verano, Wynn and blue pea seeded well while Oolloo and Maldonado seeded poorly. However, all legumes seeded down well in the second year. Results from the April 2001 Botanal® harvest indicated the greater the legume content, the higher was the overall yield, although grass yields in the Oolloo treatments were lower, indicating the Oolloo legume was competing with buffel grass.

Results of the 2002-03 plant composition check found the proportion of legumes decreased with only Oolloo showing signs of sustaining a grass/legume mix (Figure 1). Very few legumes were present during the 2003-04 wet season. However, the following season (2004-05) Oolloo, Verano and Wynn treatments increased in legume content, particularly Wynn and Oolloo. In 2005-06 DDRF received 1846 mm of rain, which encouraged strong growth in the legumes. In the following two years, very few Maldonado or Milgara plants were found. Oolloo accounted for over 10% of the total biomass in the 2006–07 season. However, less than 1% was found the following year. Wynn continues to produce reasonable amounts of legume biomass (6% and 9% total paddock biomass) and is spreading outside the original plots. Verano continues to produce a lower proportion of legume biomass yearly.

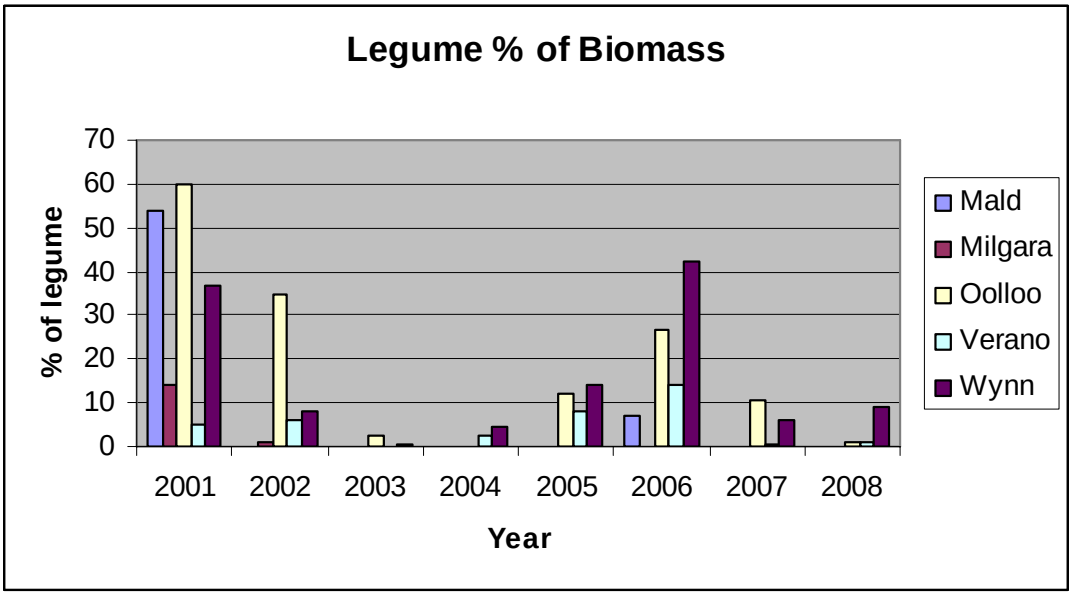


Figure 1. Legume proportions in Paddock 50

Plant analysis results suggest that the higher the proportion of legume content, the higher is the N in the companion buffel grass. This could be visibly seen throughout the wet season and early dry season when plants in the Oolloo treatment appeared dark green and buffel grass flowered earlier, creating a denser stand of pasture.

The average 12-month live-weight gain was similar to last year but lower compared with previous years (see Table 1). This may have been due mainly to the increased stocking rate, seasonal effects and varying legume percentages.

Table 1. Mean cattle yearly LWG

Year	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Average weight gain (kg)	208	176	190	168	203	173	170

Hard-seediness, climatic conditions, insect pests and palatability of legumes have long-term effects on the pasture mix. Different management techniques of the pasture such as non-grazing to allow seed to set every second or third year, will improve sustainability of pasture legumes. A limitation of this trial was that the animals could selectively graze plants of preference, which could result in over-grazing and depletion of some legumes, allowing the less palatable to survive or dominate. The promising performance of Oolloo as a companion legume in buffel grass has led to further production monitoring in Paddock 535 where the legume was introduced in December 2002 into an existing buffel grass paddock.

The pasture composition surveys carried out in the last three years found no Milgara in any of the treatment areas.

Buffel grass remains the dominant plant species with all other grasses accounting for 2.4%, the introduced legumes 11.6% and broadleaf weeds just over 4% (including *Sida acuta* at 3%).

PROJECT: Rangeland Grazing Strategies for Economic Improvement and Resource Sustainability

Project Officers: A. Kain and C. Materne

Division: Animal Industries

Location: Alice Springs

Keyword(s): grazing strategies, rotation grazing, spelling

Objective:

To develop industry-acknowledged best practice guidelines for grazing strategies in Central Australia to incorporate spelling to contribute to improved economic viability and resource sustainability.

Background:

Best practice guidelines for Central Australian spell grazing strategies

Over the past decade, the ongoing cost-price squeeze has forced pastoralists to use their land more efficiently. There is widespread interest in spelling practices, which can potentially increase and sustain production without damaging natural resources. However, the potential has not been fully documented, particularly at a practical whole-of-property/business scale. Recently, Heytesbury Beef established a major commercial trial of intensified land use in the tropical savannah regions of the VRD, at Pigeon Hole Station.

Another project is being established in the southwest rangelands of Western Australia to monitor the effects of various practices by pastoralists at the property level. In Queensland, a new Meat and Livestock Australia project is exploring the environmental and economic benefits and costs of different grazing systems, particularly cell grazing. Thus existing trials encompass summer and winter-dominant rainfall regions of the rangelands but do not cover the seasonal and more variable sector of the rangelands from western NSW and south western Queensland through Central Australia to the Murchison in WA.

The major benefits of spell grazing practices are likely to be:

1. Opportunities to spell country at critical times for pasture regeneration.

2. Closer observation of the condition of the country for the benefit of both quality stock production and resource sustainability.

3. Better drought preparedness.

Potential risks of spell grazing include:

1. Capital costs of setting up a more intensively-fenced and watered system.

2. Errors of judgment in leaving stock on country for too long, but offset by damaging less area in a single time period, probably riskier in regions with a more variable climate or fragile soils.

3. Lack of access to markets at critical times.

Method:

There are three grazing trials in Central Australia. Two of them are at pastoral properties at Mt Riddock and Idracowra Stations, and the third is at Old Man Plains Research Station (OMPRS). The trials at Mt Riddock Station and OMPRS are continuing. The Idracowra Station trial was discontinued due to the sale of the property.

At Mt Riddock, steers are grazed through an eight paddock rotation. Pastures are monitored pre- and post-grazing. Cattle are weighed at the beginning and end of their time in the rotation and are also weighed periodically throughout the rotation. Animal grazing and behaviour is recorded using a defoliation index and cattle activity index. The defoliation index is a qualitative measurement of yield that has been removed. Cattle activity is a qualitative assessment of activity within a quadrat. Activity is described by hoof prints or manure. One or two hoof prints are given a score of one. Where hoof prints or manure cover all of the non-vegetated area of a quadrat, a score of three is given.

At Idracowra, breeders were run in a 500 km^2 paddock that is watered via a moveable trough along a 30 km pipeline. The trough is moved approximately once a week, depending on seasonal conditions and type of country. Pastures were monitored pre- and post-grazing. Breeders were weighed and pregnancy tested at the beginning of their time in the paddock until May 2006.

The OMPRS strategy will consist of four paddocks that allow for annual summer spelling of the calcareous grasslands and biannual summer spelling of the mulga sand plains. Pastures are monitored pre- and post-grazing.

Results:

Idracowra report abstract

The trial at Idracowra Station, 180 km south-south-west of Alice Springs incorporated rest from grazing by moving a water point through the paddock. The hypothesis was that as pastures became remote from water they would be spelled from grazing without the need for fences. The moving water treatment was compared with continuously-grazed watering points. Both the treatment and control paddocks are dominated by native pastures.

The study aimed to test the hypothesis that it is possible to train cattle to move around a paddock by shifting a water point. The study also intended to test the hypothesis that rotational grazing will result in more even utilisation of pasture, maintain land condition and improve animal productivity. Unfortunately, one year after the trial began, it was terminated. Whilst there is no data available to support the hypotheses, there was anecdotal information of interest. The manager found that most of the herd could manage to follow the watering point if it was only moved 500 m at a time and that whilst cattle were grazing less favoured country immediately adjacent to the watering point, opportunistic observations noted that they were still walking in excess of 5 km to access more favoured pastures. One of the most important elements to arise from this trial is the comparison of actual stocking rates with forage budget recommendations. While the manager felt that the cattle on the moving water pipeline were performing better than those in the continuously-grazed system, this may have been attributable to the lower stocking rate of the treatment compared with the control.

The moving water principle still deserves to be trialled in Central Australia but realistic and safe estimates of carrying capacity are required in order to accurately assess the economic return that such a system is likely to generate in the long term.

Mt Riddock report abstract

There has been widespread industry interest in spelling practices, which promise increased production without damaging natural resources, or sustained production that allows recovery of natural resources. The benefits of rotational grazing in the semi-arid rangelands have been little documented. It is therefore difficult for managers to adopt them. The trial at Mt Riddock Station, 200 km north-east of Alice Springs, compares an eight paddock rotation by steers, with a continuously-grazed paddock. Both the treatment and control paddocks are dominated by the introduced perennial buffel grass (*Cenchrus ciliaris*). The study was to test the hypotheses that rotational grazing will increase carrying capacity, result in more even utilisation of pasture, improve or maintain land condition, increase species diversity, reduce fire risk and frequency and increase average daily weight gain in steers. Given that the trial had only been operating for two years at the time of reporting, there is little conclusive evidence to support these hypotheses. Early results suggest that rotational grazing has the potential to improve evenness of use across a pasture. Land condition did not improve under either treatment. Species diversity declined under rotational grazing whilst remaining stable under continuous grazing. Fire risk and steer performance were difficult to assess due to the methodology used and the relatively short time of assessment. It is also difficult to draw sound conclusions in this trial as the paddocks differed by far more than just grazing duration and rest. Factors such as stocking rate and distance to water are likely to be large contributors to the results.

It is worth noting that the managers felt that the rotational grazing strategy was producing good results with regard to steer performance although they feel that it will take some years before the true impact on the pastures is understood. This is typically the case in Central Australia where seasonal conditions can significantly influence the length of time before impacts on natural resources are understood. They find the rotational grazing strategy easy to implement and are very keen to continue with the existing strategy and to also extend it to other parts of the property.

OMPRS report abstract

The trial at OMPRS, 50 km south-west of Alice Springs, compares a four paddock rotation with a continuously-grazed paddock using breeder herds. Both the treatment and control paddocks are dominated by native pastures of mulga (*Acacia aneura*) over woollybutt (*Eragrostis eriopoda*) and kerosene grass (*Aristida holathera*) and oat grass (*Enneapogon avenaceus*) pastures. The four paddock rotation was designed to allow herd management activities to be incorporated into paddock moves and was based on the Resource Consulting Services design.

The study tests the hypotheses that rotational grazing will improve the quality and quantity of available pasture, improve land condition and therefore animal productivity, and reduce risks associated with a variable climate. Cattle in the rotation performed slightly better than the control group in average cow weight and branding percent. Pregnancy status was similar in both groups.

PROJECT: Managing Grazing by Alternating Watering Points

Project Officer: H. James

Division:	Pastoral Production
Location:	Barkly
Keyword(s):	cattle, pasture, grazing management, grazing systems, watering points

Objective:

To reduce grazing pressure by spreading animals more evenly in a paddock.

Background:

The project attempts to establish a grazing management strategy for cattle without increasing fencing in the extensive production systems of the Barkly region of the NT. Cattle grazing behaviour was manipulated by having only one of five watering points in a paddock operating at any one time during the dry season, from April to November. A control paddock operated in the traditional way. Extensive pasture and cattle data was collected from the Rockhampton Downs Station site, which indicated that cattle performance was reduced initially by alternating watering points, although pasture composition was improved. Preliminary results and observations indicate that managing cattle by using alternating watering points is possible within the extensive grazing systems of the Barkly region. This project was able to demonstrate the increases in perennial grass species gained through the alternating watering system.

Method:

A 530 km^2 paddock was divided into two paddocks. There were 880 animals in the control paddock traditionally-managed in a continuous grazing system. All watering points in the control paddock were operational at all times and grazing was not controlled. The experimental paddock operated under an alternating watering system. The 730 animals in the experimental paddock were moved around by having only one of five watering points operating at any one time.

New watering points were created by turning off existing troughs at bores and pumping the water to new troughs about 4 km away in areas traditionally not grazed. Cattle were kept on one watering point for six

weeks, which allowed for each watering point area to be grazed once during an average dry season. During the wet season when surface water was present, grazing was not controlled.

The pasture was monitored using an intensive double sampling method at the beginning and end of the dry season. All transects originated at watering points and extended to a distance of 3 km at new watering points and 5 km at existing watering points. Sampling occurred at 250 m intervals within 2 km of the watering point and then at 500 m intervals when further than 2 km from the watering point.

Cattle weights, pregnancy status and weaner weights were recorded in May. A management diary was kept to evaluate the impact of the grazing system on overall station operations, allowing for a greater understanding of its impact.

Results:

Holding the cattle at watering points proved difficult in 2004 but was resolved in 2005 and 2006 through the persistence of management. Greater influence over the areas of the paddock that were grazed was achieved by investing time in modifying cattle behaviour and training livestock to respond to the changes in watering locations. This investment in training the cattle and developing more watering points allowed for savings in time and money during mustering, by having cattle closer to yards thus reducing the need for helicopters.

Preliminary analysis suggested there was an increase in perennial grass species within traditional sacrifice zones, which represents an improvement in pasture composition. Increases in perennial grasses offer more feed towards the end of the dry season, increasing the overall carrying capacity of the paddock.

The alternating watering point method has been shown to be a profitable change from the traditional grazing system.

PROJECT: Identifying Optimum Levels of Pasture Utilisation at Pigeonhole and Mt Sanford

Project Officers: R. Cowley, K. McDonald, C. Smith and T. Cowley

Division:	Animal Industries
Location:	Katherine
Keyword(s):	cattle production, pasture utilisation, Pigeonhole, Mt Sanford

Objective:

To identify the optimal levels of pasture utilisation

Background:

A 1997 survey of 134 paddocks in the Victoria River Downs (VRD) found paddock stocking rates averaged 11 AE/km^{2,} ranging from 5 to 35 AE/km^2. About 40% of paddocks were stocked with less than 10 AE/km^2. Based on modelled pasture growth, 11AE/km^2 is equivalent to 25% utilisation on red and 15% utilisation on black soils in a median rainfall year. At the time of the survey however, this represented utilisation rates of just 13% on black soil or 21% utilisation on red soil. A study of utilisation rates in the VRD in 2006 found that average rates of utilisation were 16%.

However, while average utilisation rates were low to moderate, paddock sizes were large and 40% of the VRD is more than 4 km from water, resulting in areas close to water being overgrazed, while those far from water being under-grazed. Cattle producers in the region recognise the potential for further development and in a recent survey in the Katherine region, producers estimated that carrying capacity could be increased by 25% in the next five years and 42% in the next 10 years with current development plans; 80% of producers had immediate plans to develop more water points and subdivide paddocks.

Prior to this study, there was little local information on sustainable carrying capacity of the region. This study will provide objective estimates of sustainable utilisation and facilitate infrastructure development based on realistic production capacity estimates, which will hopefully avoid the over-development of the rangeland that has occurred in the eastern savannas.

Method:

There were two sites where utilisation was tested.

At the research level (Mt Sanford) utilisation was trialled between 2001 and 2006. Paddocks were stocked for six years at six utilisation rates ranging between 12% and 43% in paddocks 4 to 12 km².

At the commercial level (Pigeonhole), paddocks were stocked for five years at five utilisation rates ranging between 15% and 44% in paddocks 20 to 22 km². The trial was completed in October 2007.

At both sites animal numbers were adjusted each May according to the amount of pasture available to achieve the target utilisation rate for the paddock (Table 1).

Table 1. Stocking rates and utilisation

Mt Sanford		**Pigeonhole**	
Average utilisation rate (%)	**Average stocking rate (AE / km²)**	**Average utilisation rate (%)**	**Average stocking rate(AE / km²)**
12	12	15	12
19	17	20	16
21	18	25	18
28	22	30	20
36	27	44	24
43	38		

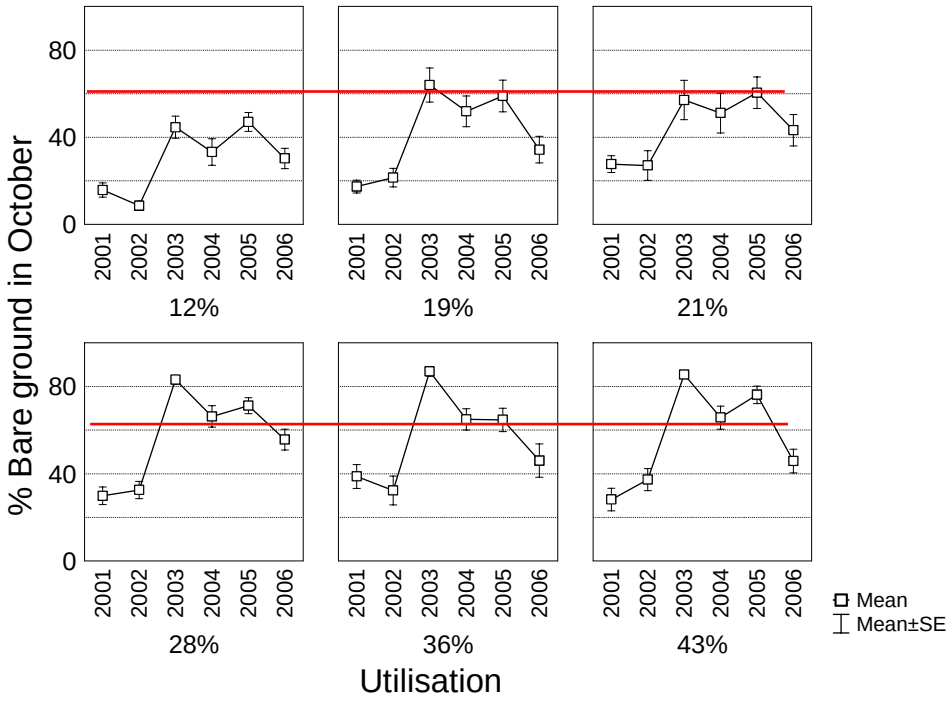
Results:

Utilisation at Mt Sanford (research level) between 2001 and 2006

Land condition and biodiversity

Above 21%

- Bare ground levels in October were unsustainable (more than 60%) (Figure 1)
- Bird abundance declined
- Some palatable plant species declined.



Values above 60% bare ground are above the red line, and occured at utilisation rates of 28% to 43% from 2003 to 2005.

Figure 1. The effect of utilisation on the proportion of the ground becoming bare during October at Mt Sanford between 2001 and2006

Animal production

Above 21% utilisation:

- Individual weight gain was reduced by 10 kg
- Breeders took 1.5 months longer to re-conceive
- Weaning rate was nearly 10% lower.

Animal production per area was highest at the highest utilisation rates, on average, but it was much more variable through time, as animals took longer to get over dry periods at higher utilisations (Figure 2).

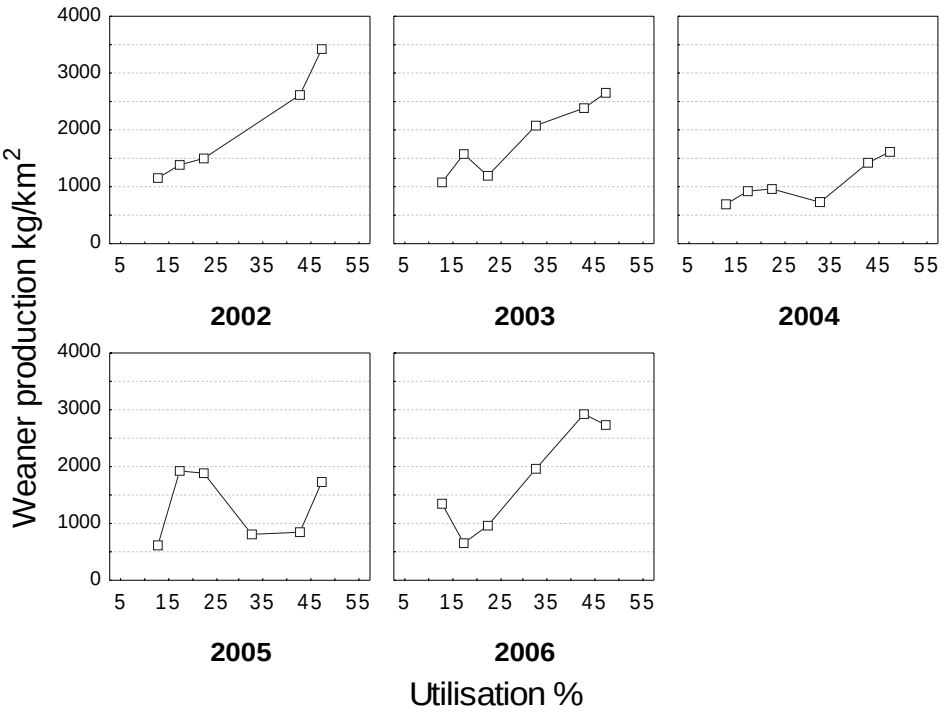


Figure 2. Weaner production per unit area through time at Mt Sanford

Utilisation at Pigeonhole (commercial level) between 2003 and 2007

Unlike in the Mt Sanford trial, there were large fires at the Pigeonhole site during the trial. They occurred in different paddocks at different times. The effect of fires on vegetation and hence animal production through removal of poor quality dry forage, often overrides other treatment and sometimes seasonal effects.

There was no effect of utilisation on land condition through time at Pigeonhole.

Initially there was little effect of the utilisation rate on weight gains, partly because of the overriding effect of fire in some paddocks. However, since 2006 there was less influence of fire and treatment effects were discernible as consistently higher weight gains were achieved in the lower utilisation paddocks (Figure 3). The effect was greatest during the wet season.

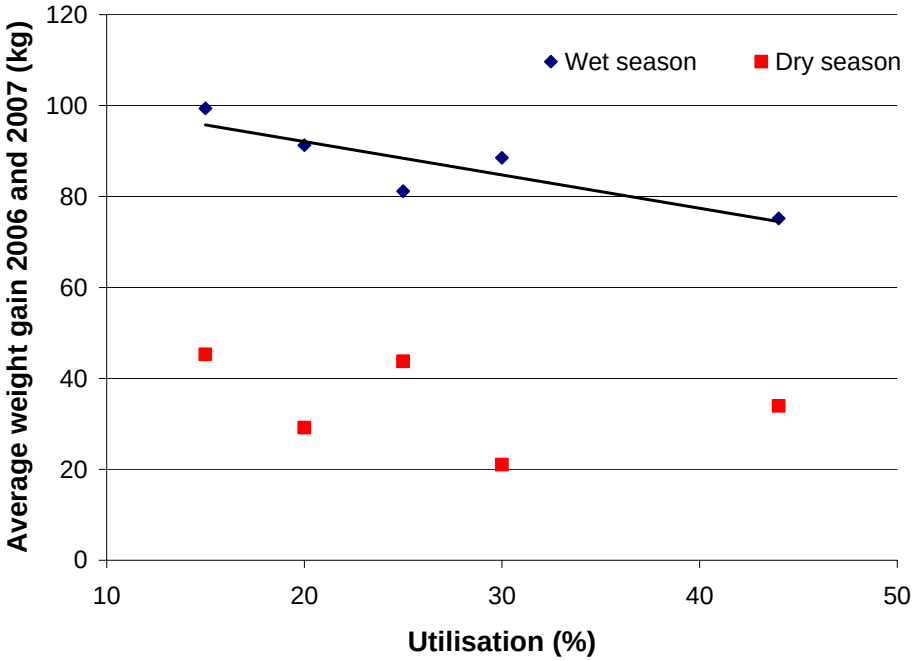


Figure 3. The effect of utilisation on weight gain of indicator steers at Pigeonhole in 2006 and 2007

The effect of utilisation on branding percentage varied through time. In 2004, branding percentage was highest at lower utilisations. This pattern disappeared in 2005 and 2006 after fire in some of the paddocks in 2005 started to have a greater effect on animal production. At high utilisation rates, there are large fluctuations in branding percentage through time (Figure 4).

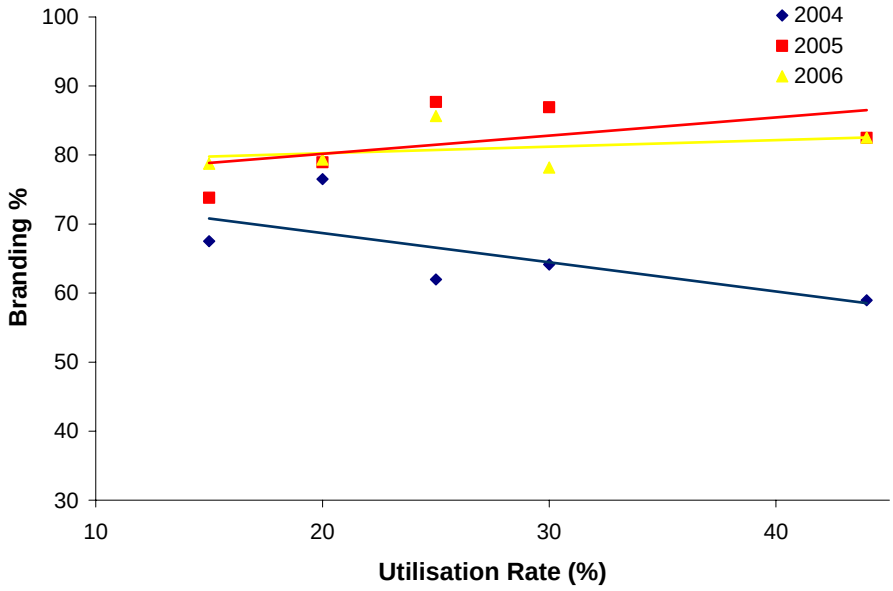


Figure 4. The effect of utilisation rate on branding through time at Pigeonhole Station

Conclusions

Large paddocks may already have *average* utilisation rates at around 20%; but where water is sparsely distributed; *actual* utilisation around water is likely to be much higher, and very low beyond 3 km from water (see Leigh Hunt's paper recommending maximum distance to water of 2.5 km for even-grazing distribution). By adding watering points to large sparely watered paddocks, *actual* utilisation may decrease by making utilisation more even across the landscape and can provide significant animal production gains.

Future research

The regional implications of the trial recommendations are being investigated. They include the potential for future development in the northern NT and how that may affect infrastructure, staffing, cattle turnoff and the NT economy.

Recommendations

20% utilisation is the magic number.

On red soils, utilisation may be lower. DRDPIFR currently recommends 15% utilisation on red soils, as these land types are less resilient.

Producers looking for development opportunities should analyse current utilisation rates to identify potential gains in animal production and land condition for infrastructure development.

The MLA Grazing Land Management course run by DRDPIFR can assist producers to identify their current utilisation rates and to plan property development and management strategies for sustainable improvements in animal production and land condition.

PROJECT: Enterprise Planning for Economic, Environmental and Social Outcomes

Project Officer: S. White

Division:	Pastoral
Location:	NT
Keyword(s):	property planning, benchmarking

Objective:

To develop, promote and deliver a tailored program to assist primary producers in the pastoral, agricultural and horticultural sectors of the NT to critically analyse their enterprises within a triple bottom line context and identify business, personal and NRM goals and directions and take action to achieve them.

Background:

This project was developed to meet the property management planning targets set in the NT Integrated Natural Resource Management Plan and the accompanying Regional Investment Strategy.

Method:

The methods outlined in the original project application involved reviewing and updating an existing planning framework and the production of a toolkit for planning, creating demand for planning activities, delivery of workshops and one on one meetings and collation of existing planning activities across industry at the commencement and completion of the project.

An application for project variation was submitted to the Natural Resource Management Board, which was approved.

The scope of the new project includes the following:

1. Develop benchmarks for all areas of the primary production business so producers can assess themselves against them and use them for planning and decision-making activities

2. Deliver a toolkit of resources and outline their relevance to the primary production business.

3. Document case studies of producers who were previously involved in planning activities

4. Deliver a benchmarking and planning process to pilot properties with an emphasis on how the business is performing now, identifying strengths and weaknesses, and potential areas for change and then plan for them.

Results:

Benchmarks have been developed in consultation with experts in the fields of human resources, profitability and natural resource management in a primary production business context.

A toolkit of resources has been delivered in the form of the FrontGate website, which is designed to give NT primary producers access to a range of information and services that will assist them in their business. The available tools and resources are categorised under three main headings in the business: people, natural resource management and profitability. They can be searched by key word or browsing the tools listed by subject area.

Case studies of producers who were previously involved in planning activities have been published. The case studies detail the benefits to those involved and the outcomes of the planning activities chosen.

The pilot property benchmarking and planning process has not been delivered yet.

PROJECT: Weather Recording for Douglas River

Project Officers: P. Shotton, T. McComish and the Bureau of Meteorology

Division:	Animal Industries
Location:	Katherine
Keyword(s):	weather recording

Objective:

To record and maintain daily weather information for the DDRF manual and automatic weather station.

Background:

Weather plays a vital role in farm productivity and is also a vital component of research trials.

Method:

Manual meteorological observations are conducted of pan evaporation, minimum and maximum temperatures and rainfall.

The automatic weather station records wind run, wind speed, gusts and direction, wet and dry bulb temperatures for humidity and dew point, minimum and maximum temperatures, rainfall amount, intensity, soil temperature and moisture and barometric pressure.

Results:

All past DDRF weather information is available through the Bureau of Meteorology. See Table 1 for monthly historical weather data and Table 2 for details of 2007.

Total rainfall for the 2007-08 wet season was 1974 mm over 96 rain days. This was well above average rainfall of 1208 mm over 86 rain days.

Most months had above average rainfall. February had the highest, receiving 673 mm over 27 rain days.

Table 1. Douglas River monthly historical weather data

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp (°C)	33.9	32.7	33.9	34.9	33.1	31.5	31.7	33.6	36.5	37	36.9	34.9
Highest daily max temp (°C)	39.2	37.1	37.6	38.5	38.4	36.6	36.6	38.7	40.6	42.6	41.5	40.7
Mean daily minimum temperature (°C)	23.9	23.9	22.9	20.8	16.9	13.9	13	15.1	19.1	22.4	23.4	23.8
Lowest daily min temp °(C)	19.5	19.5	11.6	10	5.5	4	2	2.5	4.5	11.5	14.2	16.4
Mean 9a.m. air temp. (°C)	27.6	26.9	27.2	26.8	24.1	21.4	20.7	23	26.9	28.8	29.2	28.5
Mean 9a.m. relative humidity (%)	83	87	83	73	61	56	57	59	64	67	71	78
Mean 3p.m. relative humidity (%)	62	68	56	41	34	29	29	26	25	34	41	56
Mean monthly rainfall (mm)	275.4	292.8	226.1	41.5	8.4	3	3.4	0.8	4.6	38.7	114.7	198.7
Mean number of rain days	17.7	18.4	15.1	4.7	1.2	0.2	0.3	0.2	0.9	4.2	9.9	13.7
Highest monthly rainfall (mm)	786.6	572	636.4	229	96.8	86.8	47.7	8.4	37.6	124.8	241.6	515.6
Lowest monthly rainfall (mm)	106.3	77.4	63.4	0	0	0	0	0	0	0	30.4	30
Highest recorded daily rainfall (mm)	194.6	206.4	155	73	52.8	40.1	41.8	8.4	37.2	93.5	98	113
Highest recorded wind gust (km/h)	59.4	59.4	64.8	51.8	53.6	51.8	50	50	50	48.2	66.6	70.2
Mean daily open pan evaporation (mm)	5.6	5.2	5.3	6	6.4	6.2	6.4	7.2	7.7	7.6	6.8	6.1

Table 2. Monthly details for 2007

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Highest monthly temp (ºC)	36.7	37.4	34.6	36.1	37.7	33.1	34.2	36.2	39.4	40.3	38.8	38.7
Lowest monthly temp (ºC)	23.3	22.3	22.4	15.1	13.9	3.7	4	8.3	6.4	13.3	21.9	21.8
Mean 3p.m. relative humidity (%)	64	57	66	36	35	32	23	25	19	27	44	58
Mean 9a.m. relative humidity	84	86	88	74	73	52	60	60	62	65	71	80
Mean daily maximum temp (ºC)	33.8	35	32.5	34.6	34.9	28.4	30.7	32.6	37	38.6	36.9	34.8
Mean daily minimum temp (ºC)	24.8	23.8	23.9	20.3	19.8	14.6	10.6	14.2	17.3	22.5	23.6	24.2
Number of days with rain	17	16	25	1	2	2	0	2	1	3	8	18
Total monthly rainfall (mm)	196.2	144.8	359.6	0.6	13.8	4.6	0	21.4	6.4	10.6	149.8	308.8
Average pan evaporation (mm)	3.4	4.5	3.5	5.5	5.1	5.6	6.1	7.1	7.5	6.9	6.8	5.1

PROJECT: Research and Demonstration Farms Management

Project Officers: Research Farm Managers and Staff

Division:	Plant and Animal Industries
Location:	NT
Keyword(s):	Research Farms

Objective:

To enable the Primary Industry Group to conduct innovative research and provide alternative forms of delivery to industry to facilitate economic development.

Overview:

The Research Farms provide facilities that enable researchers to conduct trials under secure, managed, conditions. They are also regional centres for staff and industry to interact to develop “best practice” production systems. Berrimah Farm (BF) in Darwin, the Katherine Research Station (KRS), and the Arid Zone Research Institute (AZRI) in Alice Springs are also Regional Headquarters for the Department.

The Research and Demonstration Farms based in regional areas include Beatrice Hill Farm (BHF) and Coastal Plains Research Farm (CPRF), both located at Middle Point in the Darwin rural area; Douglas Daly Research Farm in the Douglas Daly Region; Victoria River Research Station, in the VRD; Ti Tree Research Farm, at Ti Tree; and Old Man Plains Research Station (OMPRS) at Alice Springs.

During the year reviews were conducted for Ti Tree, AZRI and OMPRS in Central Australia, and for BF, BHF, CPRF and KRS in the Top End.

Following the review, the Government announced plans to develop BF land for a new housing sub-division.

PROJECT: Berrimah Farm

Project Officers: Research Farm Managers and Staff

Division:	Animal Industries
Location:	Darwin
Keyword(s):	Berrimah Farm, cattle, horticulture

Objective:

To provide land, infrastructure and laboratories for the DRDPIFR Primary Industries Group to conduct research, development and extension programs for primary industries in the Northern Territory.

Background:

Berrimah Farm is the headquarters for DRDPIFR, accommodating 200 primary industry and fisheries staff.

The Farm complex consists of:

- The area which provides staff with office and laboratory accommodation, and a work base for operational service program delivery.
- Land for trials on grazing, fruit production and agro-forestry.

Annual highlights

- Production of 180 tonnes of good quality pangola hay for use at Beatrice Hill Farm, Victoria River Research Station and Old Man Plains Research Station.
- A small cattle herd sentinel animals is kept for virology and the national arbovirus monitoring program.
- Animals are provided for the maternal antibody project for Virology.
- The stockyards were used to demonstrate procedures for the National Livestock Identification Scheme to industry.
- The Farm provides a base and workshop facilities for farm machinery and trucks for the transport of heavy machinery and stock around all research farms.

PROJECT: Arid Zone Research Institute and the Old Man Plains Research Station

Project Officers: Research Farm Managers and Staff

Division:	Plant and Animal Industries
Location:	Alice Springs
Keyword(s):	grazing, AZRI, Old Man Plains

Objective:

To provide land, livestock, and infrastructure to enable RDPIFR staff to conduct research, demonstration and extension projects for the pastoral and horticultural industries in Central Australia.

Background:

The Departmental headquarters for the southern region of the Northern Territory is located at the Arid Zone Research Institute (AZRI), 10 km south of Alice Springs. The Old Man Plains Research Station is a further 10 km south on the Stuart Highway. The total area of the two research stations is 557.5 km². AZRI provides the pastoral industry in arid areas sound advice on long term viability while preserving diversity of the rangeland ecosystems.

Annual highlights

Current projects

- Grazing systems partnerships (four paddock rotation trial funded by NHT).
- GRASP pasture growth model collaboration.
- Sentinel animals for virology and the National Arbovirus Monitoring Program).
- Breeding program developed for Droughtmaster herd (artificial insemination and controlled breeding).
- Reducing the impact on weaner weight gain (in partnership with MLA).

Best practice demonstrations

- Active demonstration of the benefits of forage budgeting and rotational rest grazing.
- Firebreak maintenance using plough technology and grader.
- Rehabilitation of degraded land (fenceline and pipeline location and construction).
- Fencing to land type for better grazing land management.
- Water development for stock distribution purposes.

PROJECT: Beatrice Hill Farm

Project Officers: Research Farm Managers and Staff

Division:	Animal Industries
Location:	Darwin
Keyword(s):	Beatrice Hill Farm, buffalo

Objective:

To provide land, livestock and infrastructure to DRDPIFR staff to conduct research, demonstration and extension programs for cattle and buffalo production suitable for the coastal floodplains across the Top End of the Northern Territory.

Background:

The Farm consists of 2600 ha, 60 km south of Darwin on the Arnhem highway. It was established in the late 1950s and is used primarily to support buffalo research. Because it is adjacent to the Adelaide River, approximately 80% of it is floodplain. Very high pasture yields are achieved in ponded areas during the dry season

Annual highlights

- The buffalo breeding herd project monitored the performance of various riverine/ swamp buffalo crosses.
- Riverine buffalo were sent to Queensland and New Zealand.
- The Tenderbuff project provided a set of quality control measures to guarantee good quality buffalo meat for the domestic market. Animals graze flooded pasture during the dry season to ensure year round turnoff.
- The buffalo herd is used in a RIRDC project to improve artificial insemination.
- A sentinel herd is kept on the farm for the Virology Section as part of the national arbovirus monitoring program.
- Provided pasture for surplus stock from other research farms until they were ready for sale.
- About 180 tonnes of hay was produced.
- The stockyards were used for demonstrating the National Livestock Identification Scheme.

PROJECT: The Douglas Daly Research Farm

Project Officers: Research Farm Managers and Staff

Division:	Animal Industries
Location:	Katherine
Keyword(s):	cattle, crops, Douglas Daly Research Farm

Objective:

To conduct research, demonstration and extension programs for mixed farming production systems for the Katherine, Daly Basin and Top End of the NT.

The Douglas Daly Research Farm (DDRF) is a 3100-ha farm located 220 km southwest of Darwin in the Douglas Daly Region. It has about 2000 ha of sown tropical perennials pasture. Beef cattle production is the main focus for research. It has 40 ha of centre pivot irrigation for peanut and fodder research. The farm also conducts trials and demonstrations on suitable dry land field crops.

DDRF received 1933 mm of rain in the 2007-08 wet season (the average is 1208 mm). The first substantial rain fell around September. February Was very wet. However, the rain was gone by the end of March which resulted in a long dry season.

Current/ongoing trials and demonstrations

- Improved pasture species and the importance of legumes were evaluated.
- Multi-bred composite cattle were assessed.
- Improvement of Brahman herd fertility continued.
- Heifer fertility improvement and assessment continued, emphasising the importance of nutrition preconception.
- Assessment of short duration grazing on pasture composition, soil health and cattle performance.
- Irrigation assessment on 15 ha of peanut.
- Irrigated hay trials for export including lucerne, Rhodes grass and oats.
- Production of commercial Cavalcade hay on 24 ha.
- Establishment of 20 hectares of leucaena.
- Peanuts seed production on 15 ha.
- Gamba grass eradication trial and reestablishment of 40 ha of sabi grass.
- Hosted an industry field day in March for 100 producers and industry representatives.
- Provided facilities for various industry group meetings, including DRMAC, NTCA, NTAgA.
- Accommodated various university and government environmental research groups.

PROJECT: Katherine Research Station

Project Officers: Research Farm Managers and Staff

Division:	Plant and Animal Industries
Location:	Katherine
Keyword(s):	livestock, agro-forestry, sunflower, linseed, soybeans

Objective:

To provide land, livestock, and infrastructure to enable RDPIFR staff to conduct research, demonstration and extension projects for the pastoral, mixed farming, horticultural and forestry production industries of the Katherine region.

Background:

Located on the outskirts of Katherine, the Katherine Research Station (KRS) consists of 1240 ha and is the headquarters for the Department in the Katherine region. KRS staff maintain centre pivot, lateral move and trickle irrigation systems, a dedicated horticulture research area and improved pasture for beef cattle production. Underground water usage is monitored as part of the irrigation program. An area of 2650 ha has been agisted from CPC of the adjacent "Manbulloo Station" where 300 breeders are run to produce female crossbred Senepol for breeder genotype comparison projects at VRRS.

Annual highlights

Bio-fuels

- Investigating dry season irrigated crops such as maize, pongamia, sunflower, linseed, soybeans, cassava and African palm oil for bio diesel or ethanol production.

African mahogany clone test

- A 1-ha mahogany orchard was established to benchmark clones to identify trees with straight stems and minimum branching, which will be used for commercial propagation.

Livestock production

- A sentinel cattle herd is run on the farm for virology work for the National Arbovirus Monitoring Program.
- Irrigated maize was produced on 13 ha for use in the feed lot.

Hay production

- A total of 150 tonnes grass hay, 24 tonnes of lucerne hay and 20 tonnes of forage ‘Mega Sweet’ hay was produced.

Extension

- Three livestock movement management courses and two advanced livestock movement management courses were conducted.

PROJECT: Victoria River Research Station

Project Officers: Research Farm Managers and Staff

Division:	Animal Industries
Location:	Katherine
Keyword(s):	fire, native pasture, Brahman, Victoria River Research Station

Objective:

To provide land, livestock, and infrastructure to enable DRDPIFR staff to conduct research, demonstration and extension projects for the pastoral industry.

Background:

Victoria River Research Station (VRRS) is located in the Victoria River District (VRD) and is approximately 314 km² in area. It is managed as a breeding farm for supplying young animals to the Douglas Daly Research Farm following weaning. Currently 800 breeders are stocked at VRRS.

VRRS received 901mm rain in the 2007-08 wet season, most of which fell in February. The average is 630 mm.

Annual highlights

Current/ongoing trials and demonstrations

Native pasture management

- The use of fire in the VRD to control woody vegetation [Shruburn].

Grazing management

- Pasture sustainability, long term carrying capacity.

Herd management

- Improved breeder herd profitability, NIRS sampling.
- Multi-breed composites, assessment and Brahman improvement.

- Understanding and improving heifer fertility.
- Braham control herd.

Future markets

- Productivity consequences of incorporating tropically adapted Taurus breeds in a breeding herd in the VRD [Senepol, Belmont, Tuli].

Virology

- Sentinel herd monitoring - NAMP sampling.

Other highlights

- A major producer field day was held at the Station in August 2008.
- NLIS workshop was conducted.
- Several interstate and overseas producers were hosted.
- Support the Native Bustard Survey.

PUBLICATIONS, CONFERENCE PAPERS AND PRESENTATIONS

Scientific Journal/Proceeding Publications

Bishop, E. J., Shilton, C., Benedict, S., Kung, F., Gilbert, G. L., Gal, D., Godoy, D., Spratt, B. G. and Currie, B. J. (2007). Necrotising fasciitis in captive juvenile *Crocodylus porosus* caused by *Streptococcus agalactiae*: an outbreak and review of the animal and human literature. *Epidemiology and Infection* **135:** 1248-1255.

Bourhy, H., Gubala, A., Weir, R., Boyle, D. (2007). Unassigned animal rhabdoviruses (Rhabdoviridae). *In 'Encyclopaedia of Virology'*. (B. Mahy and M. Van Regenmortel Eds.), Elsevier: Oxford UK.

Brown, G. P., Shilton, C., Phillips, B. L. and Shine, R. (2007). Invasion can be bad for you: spinal arthritis in invasive cane toads. *Proceedings of the National Academy of Science.* U.S.A. **104:** (45) 17698-17700.

Cowled, C., Melville, L., Weir, L., Walsh, S., Hyatt, A., Van Driel, R., Davis, S., Gubala. A., and Boyle, D. (2007). Genetic and epidemiological characterisation of middle point orbivirus, a novel virus isolated from sentinel cattle in northern Australia. *Journal of General Virology* **88:** 3413-3422.

Crossland, M., Brown, G. P., Shilton, C. and Shine, R. (2008). Mass mortality of native anuran tadpoles in tropical Australia due to the invasive cane toad (*Bufo marinus*). *Biological Conservation*. In press.

Jenkins, T., Jones, S., Lee, C., Forschler, B., Chen, Z., Lopez-Martinez G., Gallagher, N., Brown, G., Neal, M., Thistleton, B. and Kleinschmidt, S. (2007). Phylogeography illuminates maternal origins of exotic *Coptotermes gestroi* (Isoptera: Rhinotermitidae). *Molecular Phylogenetics and Evolution* **42:** 612–621

McTaggart, A. R., Shivas, R. G., Liberato, J. R., Wright, J. G. and Braun, U. (2008). More cercosporoid hyphomycetes from some South Pacific island countries. *Australasian Plant Pathology*, **37:** 392—395.

Schatz, T. J. and Hearnden, M. N. (2008). Heifer fertility on commercial cattle properties in the Northern Territory. *Australian Journal of Experimental Agriculture* **48:** 940-944.

Shilton, C. M., Brown, G. P., Benedict, S. and Shine, R. (2008). Spinal arthropathy associated with *Ochrobactrum anthropi* in free-ranging cane toads (*Chaunus* [*Bufo*] *marinus*) in Australia. *Veterinary Pathology* **45:** (1) 85-94.

Tran-Nguyen, L. T., Kube, M., Schneider, B., Reinhardt, R. and Gibb. K. S. (2008). Comparative genome analysis of "Candidatus Phytoplasma australiense" (subgroup tuf-Australia I; rp-A) and "Ca. Phytoplasma asteris" strains OY-M and AY-WB. *Journal of Bacteriology*. **190:** (11) 3979-3991.

Tran-Nguyen, L. T., Kube, M., Schneider, B., Reinhardt, R. and Gibb. K. S. (2007). An overview of the genome sequence of *Candidatus* Phytoplasma australiense - Australian strain. *Bulletin of Insectology*. **60:** (2) 111-112.

Other Publications/Presentations

Brown, H., Chin, D. and Thistleton, B.M. (2008). Entomology staff poster.

Brown, H., and Chin, D. (2007). Mango IPM posters.

Brown, H, and Chin, D. (2007). The spiralling whitefly poster.

Brown, H. and Smith, E. S. C. (2008). Mango leafhopper Factsheet.

Burnup, C., Thistleton, B. M. and Liberato, J. (2008). Tomato and maize pest and disease field guide for East Timor.

Chin, D. and Brown, H. (2008). Longicorn borers in fruit trees Factsheet.

Chin, D., Neal, M. and Brown, H. (2008). The effect of dimpling bug and thrips on mango fruit in Katherine. Mango IPM workshop, Katherine.

Chin, D., Brown, H., Zhang, L., Neal, M., Thistleton, B. M. and Smith, E. S. C. (2007). Biology and pest management of the spiralling whitefly Factsheet.

Chin, D., Brown, H. and Neal, M. (2007). Mango IPM from panicle to packing shed. *Diagnostic Services Day Out*.

Chin, D. and Neal, M. (2007). Mango flower insects and their effect on fruit quality in the Northern Territory. IPM workshop, Katherine.

Cunnington, J.H., Watson, A., Liberato, J. R. and Jones, R. H. (2008). First record of powdery mildew on carrots in Australia. *Australasian Plant Disease Notes*, 3: 38-41.

Hennesy, C., Schulz, G., Hore, G. West, S. Daly, A. and Smith, E. S. C. (2007). Eradication of grapevine leaf rust from the Northern Territory. *Australian and New Zealand Grape & Winemaker* 524:55.

Hoult, M. (2007). Integrated passionfruit production in South Sulawesi and the Northern Territory. International Finance Corporation/World Bank passionfruit (Markisa) workshop – 'supply and demand'. Makassar, Sulawesi.

Khan, M. S. A. and Conde B. D. (2008). Severe oedema on pumpkin fruit in Katherine. *Australasian Plant Disease Notes* 3: 50.

Khan, M. S. A., and Renfree, D. (2007). Oedema on pumpkin fruit in Katherine. *Katherine Rural Review* 284.

Khan, M. S. A., and Conde, B. (2007). Citrus dry root rot and wood rotting fungi in Katherine. *Katherine Rural Review* 285.

Liberato, J. R., Ray, J. D. and Gunua, T. (2008). *Puccinia heliconiae* on *Heliconia* sp. in Papua New Guinea. *Australasian Plant Disease Notes* 3: (In press).

Marcsik, D. (2008). New ginger cut-flowers. *Australia Flower Industry Magazine* No. 16.

McLennan, A. (2008). Predatory mite investigations in melons. *Katherine Rural Review*.

Reilly, D. F., Robertson, R. M., Nikles, D. G., Robson, K and Lee, D. J. (2007). Testing and breeding forest trees for plantations in the Northern Territory. RIRDC Publication No. 07/113a.

Smith, E.S.C. (2008). Mango seed weevil, *Sternochetus mangiferae* Factsheet.

Thistleton, B. M. and Neal, M. (2007). PNG *Mastotermes* survey. *Garrards Pest Review*.

Thistleton, B. M. (2008). Pest management presentations, East Timor. AusAID funded workshop.

Thistleton, B. M. (2007-08). Training and mentoring of ASEAN countries in workshops held in Indonesia, Vietnam and Thailand for mango pest list development under the AADCP Plant Health Capacity project.

Thistleton, B. M. and Neal, M. (2007). Safer termite control in Territory crops. *Diagnostic Services Day Out*.

Tran-Nguyen, L. (2007). PCR research on dry wood termites. *Diagnostic Services Day Out*.

Tran-Nguyen, L. (2007). “An overview of the genome sequence of *Candidatus* Phytoplasma australiense – Australian strain”. - International phyto-plasmology working group conference in Italy.

Tran-Nguyen, L. (2007). “Promoting Darwin for the joint international conference “Asia Conference on Plant Pathology” Yogyakarta, Indonesia.

Walduck, G. and Daly, A. (2007). Identification of banana varieties with resistance to Fusarium wilt Tropical Race 4. Report to Horticulture Australia Limited, Project No. FR00043.

Zhang, L. (2008). Spider mites diagnostic scholarship report. Office of the Chief Plant Protection Officer, Department of Agriculture, Fisheries and Forestry.

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