MLA – NORTH AUSTRALIA PROGRAM

1998 Annual Reports of

Legume dominance and soil acidification

Sown pastures

and

Managing tropical woodlands to control exotic woody weeds

Reports presented to NAPIC

at Charters Towers 31st August 1998

Reports

Sown pastures (Brisbane 14 July 1998)

1. Legumes for clay soils (NAP3.103) - Bob Clem and Dick Jones
2. Back up legumes for stylos (DAQ.083) - Harry Bishop
3. The evaluation of selected shrub legumes under grazing cattle (CS.187) - Brian Palmer
4. Alternative delivery systems for the inoculation of new strains of stylo (CS.273) - Dick Date
5. Evaluation of grasses for heavy grazing (continuation of sites from project CS.185/DAQ.081)" - Ian Staples and Col Middleton
6. The reversion problem in shrubby stylo seed production – John Hopkinson
7. Elimination of unwanted introduced pasture plants – a discussion paper by Harry Bishop and John Hopkinson

Legume dominance and soil acidification (Mareeba – 21 July 1998)

8. Soil acidification research in the semi arid tropics (NAP3.218) – Andrew Noble
9. Potential constraints to the sustainability of legume based pasture systems in northern Australia and Thailand (ACIAR project) – Andrew Noble, S. Ruaysoongnern and Brian Palmer
10. Management of native pastures oversown with stylos (NAP3.224) – Deryk Cooksley and Mick Quirk
11. Communication of stylo management practices (NAP3.220) – Col Middleton

Grazing and Woodland Management (Emerald - 25 and 26 August 1998)

12. Managing tropical woodlands to control exotic woody weeds (NAP3.206) – A. Grice. (Tony Grice recently returned from overseas, so his paper was not included in the set of paers distributed for Emerald.

Legumes for Clay Soils

MRC Project No:	NAP3.103
Project Duration:	NAP2 - 01/07/92 - 30/06/96 NAP3 - 01/07/96 - 30/06/98
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Co-Investigators:	M J Conway, C R Esdale, T B Hilder, Kay Taylor, and T J Hall

Project Objectives:

By June 1998,

1. to develop and provide interim guidelines that will allow producers to successfully establish and manage *Desmanthus virgatus* and *Stylosanthes seabrana* pastures.

2. to quantify the liveweight gain from established *Desmanthus virgatus* demonstration areas.

3. to demonstrate the cost effectiveness of planting *Desmanthus virgatus* and *Stylosanthes seabrana* in a beef grazing enterprise.

4. to have sown 10,000 ha of *Desmanthus virgatus* in Queensland.

5. to identify the production and persistence of *Clitoria ternatea* cv. Milgarra, *Vigna trilobata, Macroptilium bracteatum* and *Macrotyloma daltonii* in clay soils.

Summary:

Tropical pasture legumes that could improve forage quality and animal performance on grazing land and maintain soil fertility in cropping soils were tested in a co-operative (QDPI, CSIRO, UQ, MRC) project. Studies from glasshouse experiments to grazing trails at sites on brigalow and downs soils in southern and central Queensland were undertaken.

Desmanthus and more recently Caatinga stylo have been successfully established with strong perennial grass and desmanthus has marginally improved liveweight gains of grazing stock.

Testing legumes "on farm" has confirmed the persistence and productivity of *Indigofera schimperi*, desmanthus and Caatinga stylo and demonstrated the value of Lablab, Milgarra butterfly pea and *Macroptilium bracteatum*.

Results of testing and experiences gained from understanding the establishment and nutritional requirements of legumes have been communicated by newsletters, displays and field days.

Report:

GUIDELINES FOR SOWING AND MANAGING DESMANTHUS AND CAATINGA STYLO AND QUANTIFYING ANIMAL LIVEWEIGHT GAIN.

Desmanthus grazing demonstrations

Desmanthus has been established by sowing with buffel grass (*Cenchrus ciliaris*) on brigalow clay soils at 2 "on property" sites at Wandoan and Middlemount, at Brigalow Research Station and with purple pigeon grass (*Setaria incrassata*) on a black earth at Brian Pastures.

Desmanthus has developed slowly at the 2 research station sites and the legume density and yield in the pasture is low in comparison with the other sites. Soil seed has increased to high levels, equivalent to 40 to 120 kg of seed per ha, which should ensure future seedling recruitment (Table 1). Stock graze all year at a stocking rate of 1 steer/2 ha except at Brian Pastures (1 weaner/ 1.2 ha). Liveweight gain on the *desmanthus* pastures at the 2 research station sites, which are the oldest established pastures, show an improvement over grass only pastures. At the "on property" sites there is no advantage to the *desmanthus* pastures but these are newer pastures and liveweight gain is high (over 200 kg/head/year).

Table 1. Pasture yield and composition, legume density, soil seed and steer liveweight gain for 1997/98 at the grazing sites.

		Brian Pastures	Brigalow	Wandoan	Middlemount
Liveweight Gain	- Grass	0.38	0.40	0.56	0.62
(kg/head/day)	- Grass + *Desmanthus*	0.47	0.43	0.55	0.63
Pasture Yield	- Grass	2459	5230	3784	3698
(kg/ha)	- Grass + *Desmanthus*	2288	4061	2750	3187
% *Desmanthus*		10	6	18	10
Legume Density plants/m^2 (seedlings/m^2)		1.7 (10.9)	4.0 (0.2)	21.1 (16.2)	6.4 (1.8)
Soil seed/m^2		1620	2040	3495	1170

Contribution of desmanthus to the diet

To estimate the proportion of grass and "non-grass" in the diet of grazing animals dung samples have been collected from the 4 sites over the last two years and the ratio of carbon isotopes measured. In these pastures desmanthus is the dominant "non-grass". Levels of desmanthus in the diet have been low at the two research stations, probably because of low desmanthus yields. At Wandoan, at least when the samples were taken, dietary levels of desmanthus were also low. This is surprising in view of the percentage of desmanthus in the pasture and the obvious grazing of desmanthus. Samples collected from Middlemount in autumn 1997 suggested that there was some 25% desmanthus in the diet.

Comparisons of legume quality

Quality of promising legume accessions was measured to see if there was a consistent ranking independent of site. Ten legumes were sampled at four sites (Arcadia Valley, Wandoan, Biloela and Mundubbera). The samples were taken of the last 15 cm of shoot during periods of active growth when there was little or no flowering. The 15 cm was selected to represent the "grazed layer". The samples were separated into leaf and stem. Samples from two sites were checked for any unusual concentrations of "other" elements. Acid detergent fibre was used as the key index of quality.

Quality of leaf was far higher than stem, with the mean stem ADF (38.3) being 62% higher than the mean leaf (23.6). This would suggest a difference of about 15 units of *in-vitro* digestibility (55 -70%). The % of leaf was consistently lowest in Seca and Unica stylo. The lowest leaf ADF levels were in all 3 desmanthus cultivars and Milgarra (18-20%) and the highest in Seca (30%). Seca also had the lowest N% in the leaf. Differences between quality of stem from the different accessions were still significant, but much smaller.

The main differences in "other" elements were in the far higher sodium level of Seca and *Indigofera schimperi*, about 10 times the levels in the other accessions, the higher calcium levels in *I. schimperi* and, to a lesser extent, the higher S levels in desmanthus.

These results linked with similar studies in "Back-up legumes for stylo" and in a dairy funded project on legumes for coastal pastures will give a wider picture of legume quality.

Inoculum and nutritional requirements of desmanthus

Although an effective strain of *Rhizobium* is commercially available, there was concern that it may not survive "dry" sowing under conditions where there is often a delay between sowing and the next "germinating" rains. In co-operation with the University of Queensland eight clay soils from southern and central Queensland were studied to see if there were native rhizobia that could form effective nodules with desmanthus. A pot trial showed that there were effective native rhizobia present in four soils. However, in four soils there was a response to inoculation and in two soils there were no nodules on the uninoculated controls. A field trial at four sites showed that inoculation improved first year growth at three sites and growth at one site in the second year. Based on these results inoculation is recommended but effective nodulation from native rhizobia is likely to occur.

Nutritional studies were conducted to investigate causes of desmanthus "yellowing". Pot trials on soils from Brian Pastures showed that desmanthus responded to applications of both sulphur and molybdenum. Following application of these nutrients to the desmanthus pasture there was a noticeable improvement in plant colour and vigour. In another trial 7 soils were tested for a range of nutrients. Responses to sulphur were obtained in 4. Suggested critical levels of soil and plant sulphur were determined. Follow-up assessments of the effect of sulphur are being made in the desmanthus plots in the "on-farm" field trials.

Nitrogen fixation by desmanthus

When clay soils are cultivated, nitrogen is mineralised. As newly sown legume plants will take up this soil N, rather than fix atmospheric nitrogen, it is possible that there will be some delay in fixation. Further, if there are no adapted native rhizobia there is a possibility that desmanthus may not be meeting the desired objective of improving soil nitrogen status.

The presence of effective fixation in legumes can be documented by analysis of the different ratios of nitrogen isotopes of the legumes and "non-fixing" plants. Hence, plant samples have been collected from the 4 grazing sites since 1996/97. Some samples are still to be analysed. All samples from Wandoan and Brigalow in 1996/97 and 1997/98 indicate the nitrogen in desmanthus is almost all derived from fixation. In the first samples collected in March and May 1997 from Middlemount, some 2 years after sowing, effectively all nitrogen was from soil mineral nitrogen. In the next sample (August 1997) one-third of the nitrogen was from fixation. It is anticipated that that it will now be similar to Wandoan and Brigalow with fixation being the main source of N.

Depth of sowing

Pot trials have shown that desmanthus should not be sown deeper than 3 cm. Legumes with larger seeds, such as siratro, were able to emerge from 5 cm depth.

Caatinga stylo demonstrations

Paddocks of 3.5 to 12 ha of *Stylosanthes seabrana* (cvv. Primar and Unica)/grass pastures have been established to demonstrate its grazing value at "on property" sites at Fernlees, Baralaba, Wallumbilla and Surat. There is also a buffel grass paddock adjacent to the stylo/buffel paddock at Baralaba.

Except at Fernlees, density of both cultivars has increased but legume yield is low with the best being 150 kg/ha (or 5% of pasture yield) at Baralaba (Table 2).

Table 2: Density of *Stylosanthes seabrana* at "on property" sites and pasture yield and liveweight gain at Baralaba.

Legume Density (plants/m^2)		Fernlees	Baralaba	Wallumbilla	Surat[1]	Surat[2]
Unica	1997	2.3	1.9	5.6	1.4	3.3
	1998	1.3	3.5	14.5	2.9	12.5
Primar	1997	2.3	3.3	7.5	0.9	4.7
	1998	2.3	4.9	27.5	1.5	16.5
Pasture Yield	grass	-	2275			
(kg/ha)	grass + stylo	-	2887	2500	-	2000
% stylo		-	5	-	-	-
Liveweight gain	grass	-	0.49	-	-	-
(kg/hd/day)	grass + stylo	-	0.54	-	-	-

"ON FARM" COMPARISONS OF GRAZING AND LEY LEGUMES.

A range of commercial and "best bet" experimental legumes were sown in 1994 at 5 sites (Clermont, Springsure, Biloela, Theodore and Wandoan) and in 1995 at 6 sites (Capella, Middlemount, Bauhinia Downs, Acadia Valley, Roma and Chinchilla. Bauhinia Downs was resown in 1996. Large plots (20m x 12m) were sown in 2 replicates into land prepared for cropping. Perennial grasses were oversown at all sites. Grazing has occurred at all sites usually in association with grazing crop stubbles but has been limited at some sites.

Establishment of legumes was satisfactory but more variable with smaller seeded legumes, desmanthus and stylo. In the year of sowing, lablab produced the most forage with yields from 1 - 5 t/ha, depending on soil moisture and rainfall. Yields of *Vigna trilobata* CPI 13671 and *Macroptilium bracteatum* CPI 27404 were also higher than longer term legumes. Lablab did not regenerate and although Vigna did emerge often in large numbers, second year yield was low. *M. bracteatum* yields were high in the second and third season but by 1998 had declined except at Biloela where it yielded 1 t/ha (5th year) and Bauhinia Downs 3 t/ha (3rd year).

Forage yields of *Glycine latifolia* varied between sites and seasons with high yields in 1998 only at Biloela (1 t/ha) and Acadia Valley (3 t/ha). The persistent and productive legumes were *Indigofera schimperi*, Milgarra butterfly pea, desmanthus, Caatinga stylo and Aztec (Table 3).

Indigofera produced high yields on both brigalow and downs soils. Seedling recruitment was initially slow but soil seed levels and seedling density are increasing.

Milgarra butterfly pea maintained high legume densities and high forage yields except at Wandoan, Roma and Chinchilla (brigalow soils at southern sites).

Desmanthus has generally grown better on the brigalow soils and Marc populations have been improved through seedling recruitments. Soil seed levels are extremely high for Marc but are lower for Bayamo and Uman suggesting their longer term survival may be at risk.

Table 3: Legume and seedling density, forage yield and soil seed levels of the most persistent and productive legumes in 1998.

	Downs			Brigalow		
	Legume density (plants/m^2)	Yield (kg/ha)	Soil Seed (/m^2)	Legume density (plants/m^2)	Yield (kg/ha)	Soil seed (/m^2)
Milgarra	13 (27)	2250	0	8 (4)	970	0
Marc	4 (1)	603	3910	17 (25)	627	24190
Bayamo	4 (3)	375	210	6 (8)	553	1740
Uman	2 (1)	341	0	3 (1)	232	890
I. schimperi	5 (2)	2675	4150	5 (3)	1065	2720
Aztec	4 (1)	569	30	3 (1)	729	210
Seca	1 (2)	64	-	1 (5)	136	-
Unica	32 (41)	1994	90	10 (10)	423	150

Caatinga stylo performance has been variable with high forage yields at downs sites and very high seedling recruitment (up to 110 seedlings/m^2) at Theodore. Soil seed reserves are low despite high seed production and seedling regeneration. This suggests that a high proportion of seed is soft and population maintenance is dependant on survival of seedlings.

Leucaena, sown in a sward, and Aztec had high yields at Acadia Valley and Biloela but, all legumes have grown well at these sites with deep, fertile soil and limited grazing.

Lucerne sown at some sites failed or yielded poorly except at Chinchilla in the first season.

SMALL PLOT TRIALS

These trials examined a much wider range of legume accessions than could be examined in the "on-farm" trials. Over 150 accessions were sown at 3 sites (Narayen, Brigalow and Emerald Research Stations) over 3 years (1992/93 to 1994/95).

Legumes for permanent pastures

The results again highlighted the superior long-term persistence of desmanthus, indigofera and Caatinga stylo. Indigofera was outstanding but although it was well grazed on some occasions there were others where it was not grazed. Two accessions of desmanthus (TQ90 and CPI 90750) show promise and could warrant more widespread testing if commercial experience show deficiencies in the three current cultivars. Although several accessions of Caatinga stylo have persisted, none shows any consistent advantages over Unica and Primar.

Legumes for ley pastures

No accessions outyielded lablab in year one, but several accessions, especially *M. bracteatum* showed promise for 2-3 year leys. Only one accession (CPI 27404) was widely sown in these trials, but another line (CPI 55769), sown in the last sowing at Narayen and also in evaluation trials of ley legumes funded by GRDC, is even more promising.

Annual medics

Annual medics can make a useful contribution to winter feed and soil nitrogen in years with good cool season rainfall. However, the occurrence of winter rain declines in central Queensland so to persist accessions must be able to maintain a seed bank through a run of dry years. A range of 17 medics was sown at Narayen, Jambin, Brigalow and Emerald in 1993. There was a good initial seed set at Narayen and Jambin, but there has been very little seed set since. Despite this, there was still good seedling emergence in autumn of this year at Narayen with 6 lines having over 50 seedlings per square metre.

COMMUNICATION ACHIEVEMENTS

Trials on 15 properties and 4 research stations from Roma to Middlemount has required a high level of cooperation between property owners and staff and research and extension officers. Many local groups such as the Brigalow Floodplain Management Group at Chinchilla, Landcare and Catchment Care groups have used sites for field days and discussion groups creating a very large network of producers, agri-business, extension and research personnel.

There have been 16 Legumes for Clay Soils newsletters produced and with a circulation of about 200 it has expanded the network of people interested in these legumes. It is anticipated that the group researching legumes for ley systems will continue to circulate the newsletter at the conclusion of the MRC funded project.

Field days have always attracted interest. Displays of plants, posters and publications have been manned by project staff at Ag shows in Toowoomba, Bundaberg and Emerald, Meat Profit Days at Chinchilla and Emerald, Beef 97 and agricultural shows. Radio and newspaper coverage has been extensive. Fact sheets on the agronomy and management of desmanthus and butterfly pea have been produced and the Caatinga stylo sheet is in preparation.

Scientific posters and papers have been presented at the Tropical Pastures Conference, Australian Agronomy Conference and Australian Institute of Agriculture Science Seminars.

PLANS FOR 1998/99

1. Final measurements of medic soil seed levels to be completed at the 4 medic sites.

2. Small plots at the 3 research station sites will be terminated and the indigofera plots and any remaining in the old Narayen grazing trials will be sprayed.

3. Desmanthus and Caatinga stylo grazing demonstration sites will be maintained to:-
   - measure liveweight gain, yield and composition, legume density and soil seed.
   - allow isotope analyses of legume for N fixation and of dung for diet composition.

4. On farm legume sites will be progressively terminated. Sites will be returned to co-operators and some are likely to be cultivated. *Indigofera schimperi* has been sprayed.
   - Indigofera will be monitored and eradicated at all sites.
   - Isotope analyses are proposed on Caatinga stylo growing at selected sites.
   - At sites used for cropping it is proposed to measure crop yield and grain protein content from selected legume plots.

5. Management and funding arrangements for legume grazing trials at Brian Pastures, commenced in 1998 to complement this project, will be negotiated.

6. Economic analysis of using desmanthus, Caatinga stylo and Milgarra butterfly pea will be pursued. Better estimates should accrue from 3, 4 and 5 above.

7. Publication of the Caatinga stylo fact sheet will proceed and results from other studies will be progressed towards publication in journal and other media (brochures etc).

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MRC Project Annual Review Report – July 14, 1998

Project Title:	**Backup Legumes for Stylos (BULS)**
Project No.:	**DAQ.083 Duration: 01.07.92 to 30.06.98**
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NAP2 Project Objectives (01.07.92 to 30.06.96)

(i) By July 1995, to study and understand the general agronomy and ecology of three well adapted legume cultivars (particularly from *Aeschynomene* and *Chamaecrista* (*Cassia*) species) and develop commercial management practices to speed integration into the grazing industry.

(ii) By July 1995, to demonstrate the animal production potential of the three new cultivars.

(iii) By October 1995, to produce a minimum of 100 kg of seed of the three new cultivars.

(iv) By October 1995, to determine field nutritional requirements and responses and develop appropriate seed technology packages for each new cultivar.

(v) By June 1996, to release the three cultivars to complement and back-up currently used legume cultivars (particularly for the *Stylosanthes* species).

(vi) By June 1996, to select five now legumes for pre-release.

NAP3 Objectives (01.07.96 to 30.06.98)

(i) By July 1998, to provide sufficient agronomic details to the Queensland Herbage Plant Liaison Committee to allow for the release of *Aeschynomene brasiliana* CPI 92519 and at least one further *Chamaecrista rotundifolia* accession.

(ii) By July 1998, to select five new legumes for pre-release.

Project Summary

A network of 13 pasture legume adaptation sites, three liveweight gain sites and three phosphorus response sites was established across northern Australia from Gayndah in south-east Queensland to Katherine in the Northern Territory. Target soils were the lighter acid soils most suitable for stylo growth with target rainfall 650 to 1000 mm (26" to 40"). A total of 55 legumes was sown over the three summers, 1992/93, 1993/94 and 1994/95.

Four to six years' evaluation of 5 stylo and 50 non-stylo legumes, including 14 existing cultivars, has more clearly defined adaptation, performance and development options for existing and new pasture legumes and has progressed the application of sown pasture technologies in northern Australia. Below average and poorly distributed rainfall at most sites in the establishment years highlighted lines tolerant of harsh conditions. Animal production, objective 2, and field nutritional requirements, objective 4, were only partially achieved due to drought conditions. The two extra years of monitoring has clarified the status of pre-release lines and new and existing cultivars. The new *A. villosa* cultivars Reid and Kretschmer were marketed as a mixture called "Villomix" in 1997/98. *A. brasiliana* CPI 92519 continues to persist but palatability is a problem at some sites. The late flowering "Cassia" lines do not appear better adapted to climate or soil than Wynn and have similar palatability to Wynn. Adaptation and performance results have been presented at 14 "pasture walks" and four conferences, plus numerous press articles and radio talks. Guidelines for future management of on- farm evaluation sites are being developed in consultation with property owners

Results and achievements

1. Objectives NAP2 (i), (iii), (v) and NAP 3 (i)

This project contributed valuable information supporting the release of Reid and Kretschmer villose jointvetch (*Aeschynomene villosa*) for coastal speargrass communities receiving greater than 900 mm (36") rainfall. These cultivars have been commercialised under PBR and for the 1997/98 summer were retailed as "Villomix" at $12/kg.

Information packages for *Aeschynomene brasiliana* CPI 92519 and *Chamaecrista rotundifolia* CPI 85836/86172 are being prepared for the August 1998 Queensland Herbage Plant Liaison Committee (QHPLC) meeting. However these will be "non-release cases" with a recommendation that these accessions not be released but "lie in storage" for some future date when they may be needed.

A. brasiliana 92519 is well adapted to harsh conditions (next best to the stylos) but has a sticky exudate on the stems and leaves and at some sites has not been readily grazed. Although it is fairly well grazed at some sites no liveweight gain data are available due to drought in the first 3 years at the Mt Garnet grazing evaluation site. The 1997 QHPLC meeting requested that it be eradicated from all sites.

C. rotundifolia 85836/86172, although slower to establish than Wynn (probably due to higher hardseed content) now has equal or higher sward density, drymatter yield and soil seed reserves. Palatability is similar to Wynn and being higher yielding they have the capacity to "dominate" in native pasture situations. Again no comparative weight gain data (with Wynn) are available due to the grazing evaluation site being at Mt Garnet.

2. Objective NAP2 (ii)

The grazing evaluation sites for *A. brasiliana* and *C. rotundifolia* ("Sugarbag" and "Lamonds Lagoon"), Mt Garnet, experienced three years of drought and have been discontinued.

Reid and Kretschmer jointvetch are readily eaten by cattle but cattle weighings on two producer demonstrations near Gympie have been interrupted by periods of drought. In another producer demonstration near Mackay steer weight gain slightly favoured Glenn jointvetch (0.49 kg/day) over Lee jointvetch (0.45 kg/day) over a 600 day period stocked at 1.5 steers/ha.

3. Objective NAP2 (iv)

Response of Glenn, Lee and Reid to applied phosphorus, relative to seca stylo, has been documented but less information is available for *A. brasiliana* 92519. Glenn, Lee and Reid require higher soil phosphorus for optimum growth than does seca stylo but this also means the former have potential for greater yield, quality and digestibility in higher input situations. Soil analysis of evaluation sites in year six indicates that *A. brasiliana* 92519 is adapted to low soil phosphorus but no information was gained on its response to increasing P due to failure of the response trial at Mt Garnet due to 3 years of drought. Similarly no response data were obtained for *C. rotundifolia* 85836, 86172 or Wynn. Seed production packages for Reid and Kretschmer jointvetch have now been commercially tested and involve a combination of direct and suction harvesting. Although the stickiness of *A. brasiliana* 92519 causes some difficulties with seed harvesting, commercial seed production is possible with backup from suction harvesting. Seed production for "cassia" legumes poses no problem. The results of a herbicide tolerance/susceptibility screening trial conducted by Don Loch, Gympie, are currently being processed for use by commercial seed producers or for control of legumes in weed situations.

4. Objective NAP2 (vi) and NAP3 (ii)

A. histrix is very palatable with few environmental concerns and performance of the three late flowering pre-release lines (93599, 93636, 93638) has been sufficient to "flag" further evaluation of recent introductions which are earlier flowering. The earlier flowering *A. americana* 93624 has considerably better regeneration/persistence than Glenn at Miriam Vale and Gympie and a case will be submitted for pre-release pending further monitoring of its performance and investigation of co-marketing arrangements with commercial production of Glenn seed.

Good performance of *Desmanthus virgatus* lines at "Granite Vale", St Lawrence, indicates it is adapted to some duplex soils. Selections AC 10/AC 11 from naturalised desmanthus at Alligator Creek, Townsville (made by Bob Burt, then of CSIRO Davies Lab, Townsville) performed well in series 2 plantings at "Granite Vale", Narayen and Brian Pastures and series 3 at "Granite Vale", "Swans Lagoon" and Miriam Vale. CPI 37538 has persisted well at Brian Pastures, Narayen and Gympie but is a very small plant. These three accessions could be placed on pre-release to stimulate wider evaluation and discussion.

Additional results and achievements

Adaptation and production information on 14 current legume cultivars, including 5 stylos, has been updated by this project resulting in better management packages for, and greater use of and production from sown pastures in northern Australia. For example current stylo cultivars are being promoted and used more in the Northern Territory and in the southern speargrass zone. Aztec atro has persisted for four years at Eton Range, Sarina and Miriam Vale, and Glenn/Lee jointvetch "wax and wane" with rainfall but in certain situations make a valuable contribution. Bargoo jointvetch has proven a very persistent legume at Sarina, Gympie, Narayen and Brian Pastures. Seed production has been the main restraint to its commercial use. More recently introduced lines may overcome the pod shattering and anthracnose disease problems with Bargoo seed production. The adaptation of Wynn cassia is now better defined. Monitoring of soil seed reserves highlighted the relationship between seed set, seedling regeneration and legume persistence and the importance of management practices to encourage seed set.

Legume quality assessment of tip samples (%N, P and Acid Detergent Fibre) showed considerable variation between legumes and highlighted the productivity potential of certain legumes (Lee, Glenn, Villomix) due to their higher quality forage compared with that of Seca stylo.

Communication achievements

1. Communication with producer site owners/managers.

Evaluation sites have been established on 13 properties. Valuable information exchange occurs during site selection, establishment and ongoing management. Property owners/managers vary regarding interest and participation but most keep abreast of progress results during recording visits and phone calls. The "Glensfield" owner has increased his sown pasture development program over the past two summers sowing 250 ha to mixtures of legumes (and grasses) based on species performance at his Backup Legumes for Stylos (BULS) site. The owners of "Wadeleigh" and "Bethome", Bororen/Miriam Vale, have similarly developed areas based on performance at their sites. Seven properties volunteered demonstration sites for Reid and Kretschmer following an inspection of the BULS evaluation site by the Miriam Vale Rural Science and Landcare Society in May 1996. All properties were officially contacted at the end of year four about continued monitoring and were updated with a results summary for their site and for the overall project. All current properties will again be officially contacted on future management of their sites and updated with a six year result summary. On-site discussions have already occurred with most owners about management of un-released legumes.

2. Communication with wider rural and RD&E community.

Eleven producer "pasture walks" plus 3 inspections with producer/agri-business/RD&E interests have been organised. Many site owners and departmental collaborators have organised visits with neighbours and fellow workers. Four poster papers have been presented at conferences. Regular newspaper, newsletter and radio articles and talks have updated progress results. A fact sheet on "Villomix" and a BULS poster were prepared for the Emerald MRC Meat Profit Day.

3. Networking with RD&E people.

The interim final report lists 27 principal investigators/technical collaborators plus 5 research stations as involved in various aspects of the BULS project. These collaborators represented DPI, CSIRO, NT-DPI&F and James Cook University. Review and planning workshops in each of the first 3 years stimulated much interchange of ideas and techniques as well as progress reports.

A direct request to the Northern Australian Pasture Plant Evaluation Committee (NAPPEC), to assist with developing guidelines for future management of discontinued evaluation sites containing un-released legumes, led to one day of their 4 day 1998 field meeting being spent inspecting and discussing aspects of the BULS project. The 22 participants represented Queensland, NT and NSW Departments, Department of Environment, CSIRO, University of Queensland and the seed industry.

Plans for 1998/99

1. Write up and publish results

- 1.1 Release/non-release case on all pre-release lines (*A. brasiliana* 92519, *C. rotundifolia* 85836, 86172, *A. histrix* 93599, 93636, 93638) by August 1998.
- 1.2 Proposal to QHPLC to place *A. americana* 93624 and several *Desmanthus virgatus* lines on pre-release (by August 1998).
- 1.3 Commence proposed publications listed later in this report.
- 1.4 Final report on BULS project (by September 30, 1999).

2. Further develop and implement communication plan

- 2.1 Update or produce client/information fact sheets on the 14 legume cultivars in BULS for the DPI Internet Home Page and CD-ROM Prime Notes. Involve all relevant RD&E people and collaborate with Legumes for Clay Soils and PDS/PIRDS projects.
- 2.2 Facilitate more producer demonstration sites of "Villomix" along the Queensland coast in 1998/99, in cooperation with PBR licensee Southedge Seeds, Mareeba (John Rains), who has already put his own resources into promoting the new cultivars.

3. Develop and implement management guidelines for discontinued evaluation sites, in co-operation with owners of sites.

- 3.1 Develop and implement program of eradication for non-cultivar lines which are either -
  - requested by landowner to be removed
  - aggressive in regard to spread (potential environmental weed)
  - unpalatable
- 3.2 Clean-up of sites (remove fences, pegs, etc) where project is finished and no risk plants exist.
- 3.3 Containment of site (grazing and site management) to allow low risk continued monitoring of evaluation plots.

However a broader state-wide project encompassing all "recent" sown pasture evaluation work needs to be considerably resourced and implemented. This whole area of "responsible management" of species evaluation sites was a special agenda item at the April 1998 NAPPEC meeting in Mackay. The meeting decided to increase its focus and commitment to developing protocols for plant evaluation in relation to the ongoing implementation of The National Weed Strategy and DNR new Land Protection Bill legislation which targets environmental weeds. In the meantime a sub-project of BULS is currently being developed to handle eradication of non-cultivar "risk" legumes (item 3.1).

4. **Limited legume monitoring at selected sites.**

4.1 Depending on site owner requirements and outcome of site management guidelines some monitoring will continue, particularly of pre-release and promising lines (*A. americana* 93624, *A. histrix* 93599 and *D. virgatus* AC 10 and AC 11). Detailed soil profile description and analysis will be carried out on the "Granite Vale" (St Lawrence) site where desmanthus is well adapted, relative to a duplex soil site where desmanthus is poorly adapted.

4.2 Assist develop a plan to evaluate recently available *A. falcata* lines with better seed production characteristics than cv Bargoo and early maturing *A. histrix* lines as the lines on pre-release show good promise but are late seeding.

General Comments

1. Effectiveness of evaluation process

1.1 Drought and/or poorly distributed rainfall over the duration of this project, particularly in the establishment years, affected outcomes and made some results difficult to interpret. However supplementary irrigation would not seem an option.

1.2 Use of large number of sites had advantages (better cover of rainfall variability, better soil / vegetation type cover, contact with more producers and RD&E collaborators) and disadvantages (more seed required and more risk with any environmental weed types).

1.3 Use of large plots (50 m x 20 m in series 1 and 20 m x 5 m in series 2 and 3) gave credibility for producers, more success with species performance and allowed separate grazing of fenced site (series 1 sites were 4 ha or 10 acres in area).

1.4 Seed production of evaluation lines by the Walkamin Research Station team contributed greatly to the evaluation process.

2. MRC contract

Some contract wording is probably inappropriate. Using "Prepare a release case to QHPLC on three potential new cultivars by 1996" seems more appropriate than "By June 1996, to release three new cultivars". The former better fits established policy of QHPLC endorsement of new cultivars prior to their release.

Project "Publications"

1. Journal papers:

- Bielig, Leone M. (1997) Chromosome numbers in the forage legume genus *Aeschynomene* L. Sabrao-Journal 29(1):33-39.

2. Conference poster papers:

- Bishop, H.G. (1994). Finding backup legumes for stylos. Australian Rangeland Society 8th Biennial Conference, working papers p 175-176, Katherine, NT, June 21-23, 1994.
- Bishop, H.G., Bushell, J.J. and Hilder, T.B. (1996). Back-up legumes for stylos. Proceedings Fifth Tropical Pasture Conference, Atherton, Q'land, June 1995. In *Tropical Grasslands*, 30:153.
- Bishop, H.G., Cook, B.G., English, B.H., Bushell, J.J. and Hilder, T.B (1997). More *Aeschynomene* pasture legumes for the Tropics and Sub-tropics. Proceedings of XVIII International Grassland Congress, Volume 1, p 1-1, Canada, June 1997.
- Bishop, H.G., Hilder, T.B. and Bushell, J.J. (1997). Pasture yield and animal performance from *Aeschynomene americana* cultivars Glenn and Lee. Proceedings of XVIII International Grassland Congress, Vol 1 Canada, June 1997.

3. Reports:

- Bishop, H.G. (1996). Interim final report on project DAQ.083. Backup legumes for stylos. Report to MRC, October 1996
- Bishop, H.G and Hilder, T.B. (1996). *Aeschynomene* accessions evaluated in COPE plantings; in Development of new legumes and grasses for the cattle industry of Northern Australia, Final Report of MRC Projects CS 054/185 and DAQ 053/081 (compilers B.C Pengelly and I.B. Staples). Published by CSIRO and DPI, c/- CSIRO Cunningham Lab., St Lucia, Q 4067, p 155-165.
- Report to DPI by Leone M. Bielig, Dept of Botany and Tropical Agriculture, James Cook University. "Chromosome numbers in the legume *Aeschynomene* L."
- Report to QHPLC by H.G. Bishop and B.G. Cook (6 September 1995). "Proposal for release of *Aeschynomene villosa* CPI 91209 and 93621".
- Cook, B. and Bishop, H. New 1995 pasture releases – Reid and Kretschmer villose jointvetch MRC/NAP news, Issue 2 Autumn 1996.
- Villomix fact sheet, prepared for MRC Emerald Meat Profit Day, April 7, 1998.

4. Field days and pasture walks (handouts):

- "Wadeleigh" and "Bethome", Miriam Vale Rural Science and Landcare Society inspected the adaptation sites on 4 May 1994 (100 people) and 1 May 1996 (50 people) as part of half day district tours. Also attended their AGM field meeting on 6 December 1996 and visited evaluation sites on 7 December 1996 with 3 producers and John Rains of Southedge Seeds, Mareeba.
- "Granite Vale", St Lawrence. Inspected and discussed with the Marlborough Landcare group (30 people), 17 May 1995.
- "Sugarbag", Mt Garnet. Grazing evaluation inspected and discussed by 16 people from 7 properties following a "Best Practice" group meeting on 14 March 1996.
- "Sugarbag", Mt Garnet. Grazing evaluation of *A. brasiliana* CPI 92519 inspected and discussed with 60 people on the Atherton Tropical Grassland Conference Field Trip on 29 June 1996.
- "Tedlands", Mackay. Phosphorus response trial and Glenn/Lee grazing demonstration site inspected and discussed with 25 people on a DPI/Mackay Rural Production Society field day on 22 July 1994, and with 40 people on 8 June 1996.
- Cultivars of *A. villosa* (Reid and Kretschmer) in 5 year old plots at "Tedlands" were inspected by John Rains, Southedge Seeds, Mareeba, and John Hughes, Crokers/IAMA, Mackay, August 1996.
- "Glensfield", Sarina. Inspected by COPE/BULS/LCS workshop participants in October 1993 and October 1995. Also various student and DPI groups.
- "Glensfield", Sarina. Inspected by NAPPEC (20 members) and two producers on April 3, 1998.
- "Glensfield", Sarina. Inspected by 12 local producers and CQ DPI Rural Services Co-ordinator (Bob Miles) and Director-General (Roly Nieper) on 19/2/97.
- Katherine Research Station, NT. The BULS site was inspected by NAPPEC group in May 1994.

5. Proposed publications:

- Bishop, H.G. and Cook, B.G. (draft). Registration case for *Aeschynomene villosa* cvv Reid and Kretschmer. Register of Australian Herbage Plant Cultivars.
- Response of *Aeschynomene americana* cvv. Glenn, Lee and *A. villosa* cv Reid to rates of applied phosphorus. (in prep. – Rayment, G.E, Bishop, H.G., Bushell, J.J., Hilder, T.B. and Baker, D.).
- Tolerance/susceptibility of a range of tropical legumes to a range of herbicides (Loch, D.S. and Harvey, G.L. – data being tabulated).
- Adaptation and performance of a range of Tropical legumes in the 600 mm to 1000 mm rainfall zone of north-eastern Australia (Bishop *et al*).
  - (i) Yield and persistence in grazed swards.
  - (ii) Palatability and contribution to animal performance.
  - (iii) Legume-grass relationships; managing for stability.

CS.187: The Evaluation of Selected Shrub Legumes Under Grazing Cattle.

Duration: 1/1/92 to 30/6/99

Contact: Dr Brian Palmer, CSIRO, Division of Tropical Crops and Pastures

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PROJECT INVESTIGATORS:

Dr Brian Palmer (Coordinator)
Dr Ray Jones (Lansdown)
Dr Ross Gutteridge (Mt. Cotton)
Mr Deryk Cooksley - Dr B Palmer (Utchee Creek)
Mr Col Middleton (Rockhampton)
Dr John Hopkinson (Walkamin)
Mr Barry Lemcke (Douglas Daly)

Objectives: To evaluate the most promising shrub legumes for beef production in northern Australia.
Specifically to:

- Evaluate beef production under grazing shrub legume / grass pastures.
- Achieve a high enough daily liveweight gain to meet the emerging demand for younger more tender beef.
- Identify agronomically important properties of most promising shrub legumes.
- Build up seed reserves for commercial sowing.

Summary:

The project is collaborative between the MRC, CSIRO (Lansdown and Utchee Creek), University of Queensland (Mt. Cotton), DPI Queensland (Rockhampton, Utchee Creek and Walkamin) and DPI&F Northern Territory (Douglas Daly). The accessions planted at each location were as follows: At Lansdown *Calliandra calothyrsus* (CPI 115690) (2 areas), *Leucaena leucocephala* cv. Cunningham, *Leucaena diversifolia* (CPI33820), *Leucaena leucocephala* K636 (cv.Tarramba) and *Leucaena pallida* (CQ3439) with inter-row grass and a control of *Urochloa mosambicensis* cv. Nixon; at Utchee Creek *C. calothyrsus* (CPI115690) plus nitrogen fertilised *Brachiaria decumbens* (3 areas), *Arachis pintoi* cv. Amarillo sown with *Brachiaria decumbens* both with and without nitrogen fertiliser and a control of nitrogen fertilised Brachiaria; at Douglas Daly *C. calothyrsus* and *L. leucocephala* cv. Cunningham; at Rockhampton *Acacia boliviana* and at Mt Cotton *Tipuana tipu*, *Albizia chinensis*, *Leucaena pallida* and *Leucaena leucocephala* K636 with a control of *Brachiaria decumbens*.

Calliandra calothyrsus (CPI115690) was planted at both Walkamin and Kairi Research Stations for seed production areas. An area south of Mackay was planted to *C.calothyrsus* as an on-farm demonstration plot.

Sites at Lansdown, Utchee Creek and Walkamin are still viable. Other sites and the "On farm" evaluation have been terminated due to poor establishment and inadequate potential for feed supply and animal performance.

At Lansdown the Leucaena leucocephala accessions gave the best overall performance with DLWG for the first period in excess of 1.0 kg per day. This trial is to continue until June 1999 and should give a good comparison of *L. leucocephala* with psyllid tolerant shrub legumes. *Leucaena pallida* and Calliandra calothyrsus have not performed well the *L. pallida* not being grazed in the later period.

At Utchee Creek the inclusion of C. calothyrsus into the pasture system improved the DLWG by 0.06 kg/hd/day giving an annual advantage of approximately 142 kg liveweight per hectare. This site has been continued by the new owner and should run until November 1998. The recent measurements have shown little advantage for the *Calliandra* in what has been periods of more than adequate grass,

At Mt. Cotton the cattle performed best on the *L. leucocephala* cv. Tarramba. There were no differences between *Albizia chinensis*, *Tipuana tipu* and the grass control. The L. pallida in fact supported less production than the control.

At Walkamin Research Station 90 kg of high quality seed of C.calothyrsus has been produced.

Results
Mt COTTON

A 6.4 hectare site was selected at the University Farm at Mt Cotton. It was divided into eight 0.8ha blocks to which one of the following four treatments was allocated at random in two replications.

(1) *Albizia chinensis* plus signal grass (*Brachiaria decumbens*)
(2) *Leucaena leucocephala* K636 (Tarramba) plus signal grass
(3) *Tipuana* tipu plus signal grass
(4) Signal grass alone plus nitrogen fertiliser at 200 kg N/ha/year

Cattle Performance

Liveweight gain of the steers grazing the experimental paddocks has been divided into 4 periods. Period 1 (May - November 1994), period 2 (January - May 1995), period 3 (May - November 1995) and period 4 (March 1996 - March 1997). Period 1 runs from the commencement of grazing of the first draft of test animals until early November 1994 when all animals were removed from the trial because the total dry matter on offer in 5 of the 7 treatment paddocks fell below 800 kg/ha. All animals were grazed on a 4 ha spare area of B. decumbens until early January 1995 when feed on offer in all paddocks had regrown to exceed 1500 kg/ha. The first draft of test animals was replaced in May 1995 with a second draft which continued grazing until November 1995. A third draft of animals commenced grazing in March 1996.

The second replication of L. leucocephala K636 was not stocked in May 1994 because tree legume growth in half of this paddock was very poor and it was feared that grazing may destroy these plants.

In November 1994 the inferior rows of Leucaena in this paddock were resown but the resultant growth was still not sufficient to allow stocking in May 1995. This paddock remained ungrazed until March 1996 when the best half of paddock 1 and the best half of paddock 2 were fenced and grazed rotationally as one paddock.

In period 1 liveweight gain was highest for the Leucaena K636 paddock followed by Albizia. The Tipuana and control treatments produced similar liveweight gains (Table 1). In the next period K636 was still superior followed by Albizia and control which were similar. Liveweight from Tipuana in this period was significantly lower than all other treatments. In the third period May - November 1995, liveweight gain in all treatments decreased substantially particularly in the K636. This was quite a harsh period environmentally (cool and very dry) and although it was the same duration as period 1, productivity was quite low. The Albizia and control treatments were similar and the higher yield in the Albizia may have reflected the higher amount of tree leaf on offer at the start of this period compared to the other tree legume treatments. *Leucaena pallida* supported very poor animal performance during this final period. During the period from March 1996 – March 1997 only the Tarramba gave a measurable improvement over the grass control.

Table 1. Liveweight gain (kg/head/day) of steers grazing tree legume/signal grass associations in Southeast Queensland

Species	Liveweight gain (kg/head/day)			
	May-November 1994 (160 days)	**January-May 1995 (120 days)**	**May-November 1995 (167 days)**	**March 1996-March 1997 (348 days)**
Albizia chinensis	0.51	0.54	0.30	0.47
Tipuana tipu	0.42	0.35	0.19	0.52
L. leucocephala cv. Tarramba	0.53	0.60	0.17	0.67
L. pallida *	-	-	-	0.28
Control (Grass alone)	0.44	0.54	0.30	0.50

* L. pallida was grazed from March 1996 to October 1996 at a stocking rate of 3 animals/paddock.

LANSDOWN

Cattle Performance

Steer gains differed widely between treatments. For the first grazing period (35 days) *L. leucocephala* cultivars gave higher gains than the psyllid tolerant lines of *Leucaena* and *C. calothyrsus*. In the second (July 1996) grazing period (27 days) the liveweight gains from both the *L. pallida* and the *C. calothyrsus* were extremely poor. The *C. calothyrsus* leaf had in fact wilted on the plant which may in part account for the poor performance through a lowering of digestibility. For the third grazing period (March 1997) animals were grazed for 41 days after an adaptation period of 29 days, Daily live weight gains for all shrub legumes were in the order of 600g versus a grass control of 360g. In fact the highest gain was with *C. calothyrsus* (pdk 2) and the lowest with *L. leucocephala* cv. Cunningham. However, at this grazing all shrubs were preferentially grazed so that the shrubs never even attained a height of 1 m. This was unexpected as grass is usually preferred in the early wet season.

The average steer liveweight gains (g/day) on the animals periodically grazed the range of shrub legumes during 1996 and 1997 together with data for the period February to May 1998 is given in Table 1.

Steer liveweight gains (g/day) on shrub legumes		
Treatment	4 grazings 1996 -1997	1998 (Feb - May)
Cunningham	723	769
Tarramba	664	794
L. diversifolia	532	635
L.pallida	423	483
C. calothyrsus	410	513
Grass control	381	560

During the 1998 grazing animals performed poorly on Calliandra and *L. pallida* With little evidence of the latter being eaten.

UTCHEE CREEK

The trial site was made up of 6 two hectare paddocks all previously planted to *Brachiaria decumbens* (Brachiaria). Paddocks 1 and 5 had been planted to *Arachis pintoi* cv. Amarillo (Amarillo) in 1991 in rows 1.5 m apart and by 1994 the Armarillo had spread through the whole paddock area. In January 1993 one third of paddock 4 and the whole of paddocks 2 and 6 were sown to Calliandra on a 1 m row spacing and a 3 m row spacing respectively. Paddock 4 was clean cultivated and the seed bed well prepared. The seed was planted with a single row "Bandseeder"which applied 30 kg superphosphate per hectare below and to the side of the sown row and the sown strip sprayed with "Glyphosate" to control re-establishing grass and weeds.

Cattle performance

Ten weaners of average weight 168 kg (range 138 - 195) were allocated to each two hectare paddock on November 9th 1994 except for paddock 1 (Amarillo no nitrogen where a lighter stocking rate of eight weaners per paddock was used). All animals had been drenched for internal parasites, dipped and given a 'Compudose' implant. Insecticidal eartags were used to control buffalo fly. Animals were locked into the Calliandra for several periods to adapt the animals to this new feed. This process was done over a six to eight week period. After it was considered the animals were adapted, they were allowed free access to both the shrub legume and the grass. They appeared to regulate their intake by feeding Calliandra in the early morning and late afternoon while eating grass the remaining time.

Data are presented in Table 3 show the performance of the steers grazing the Calliandra, the Amarillo and the Brachiaria-nitrogen pastures. All measurements are taken after the adaptation period and begin 30th January 1995 and end 17th June 1996. Animals weights were recorded at approximately monthly intervals. The average Daily Liveweight Gain (kg/hd/day) [DLWG] for the base treatment Brachiaria-nitrogen and for Brachiaria-Amarillo were 0.44 and 0.42 respectively. This increased to 0.47 when both Amarillo and nitrogen were included.

Table 3. Animal performance of steers grazing at the Utchee Creek Site, from 30/1/1995 to 17/6/1996.

Treatment (paddock no.)	Average steer weight ± (SD) 30/1/95	Average DLWG(kg) [Monthly Range]	Average annual weightgain per steer (kg) ± (SD)
Amarillo + (1) Brachiaria (NO)	243 ± (22)	0.42 [0.00-0.68]	154 ± (26)
Calliandra(2) + Brachiaria (N)	214 ± (12)	0.51 [0.03-0.82]	188 ± (23)
Brachiaria (N) (3)	225 ± (11)	0.44 [0.12-0.80]	162 ± (13)
Calliandra(4) + Brachiaria (N)	207 ± (19)	0.52 [0.04-1.04]	187 ± (17)
Amarillo(5) + Brachiaria (N)	223 ± (16)	0.47 [0.12-0.89]	176 ± (27)
Calliandra(6) + Brachiaria (N)	225 ± (17)	0.48 [0.05-0.82]	172 ± (14)

When cattle had access to Calliandra and Brachiaria-Nitrogen the Daily Live Weight Gain increased to 0.50 kg. The differential increase over the Brachiaria -Nitrogen treatment was steady over the period of the measurements and gave annual advantage for Calliandra of 30 kg per animal or 150 kg liveweight per hectare. The estimate of daily liveweight gain for the first measurement period (February 1995) was the lowest recorded in each treatment, this may be due to the poor adaptation but is more likely due to the inordinately cloudy and rainy period During 1997 and early 1998 there has been adequate grass and no significant improvements were shown over the nitrogen fertilised Brachiaria.

WALKAMIN

A viable system for seed production of *Calliandra calothyrsus* has been developed and sufficient seed is now stored to meet any future requirements.

DOUGLAS DALY

Two unsuccessful attempts were made to establish *Calliandra calothyrsus* at this site. The site has been discontinued.

ROCKHAMPTON

Acacia boliviana was established at the Raglan site, near Rockhampton. This site has however been discontinued and the site cleared. The material was of low palatability and was considered a potential woody weed of grazing lands.

"ON FARM" MACKAY

A site was planted but did not grow due to lack of rainfall and severe weed infestation.

FUTURE WORK 1998

It is considered desirable to continue the evaluation of Calliandra and the Leucaena spp at Lansdown for the next season and also to continue the site at Utchee Creek should also be continued as this is the only site with continuous grazing in the tropics.

Alternative Delivery Systems for the Inoculation of New Strains of Stylo

MRC Project No.: CS273

Project duration: 1/1/96 to 30/6/98

Final Report: 28/9/98

Principal Investigator: Dr R.A. Date
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Project Objectives:

i) To release suitable strains of root-nodule bacteria (RNB) that demonstrate effective nodulation of *S.* sp.aff. *S. scabra* (now known as Caatinga stylo - *Stylosanthes seabrana*).

ii) To identify alternative delivery systems for establishing effective strains of RNB in soil prior to sowing *S.* sp.aff. *S. scabra.*

Project Summary:

This project is allied to CS079/CS153 concerning the selection of new cultivars of stylosanthes from the *Stylosanthes hamata* and *S. seabrana* germplasm. Selection of effective nitrogen fixing strains of rhizobia became essential when it was demonstrated that the performance of *S. seabrana* was declining because field grown plants were not nodulating or fixing nitrogen. New strains of RNB collected in Brazil in 1994 (MRC separate funding) proved to be effective and persistent over a three year period. Strain CB3481 was released to industry for the 199798 growing season and additional effective and field competent strains have been identified.

"Dry" sowing small seeded legumes prior to the onset of seasonal rainfall is frequently the method of choice of producers in arable land situations. Soil surface temperatures under these conditions frequently exceed 50 °C for 4-6 hr/day and are lethal to rhizobia introduced on the seed. Experiments assessing alternative methods of delivery, indicate that introducing the rhizobia with the cereal crop grown in the season preceding the sowing of the legume may avoid the problem. Additional experience is required to confirm these indications.

The need to inoculate Caatinga stylo and the availability the selected strain of rhizobia have been publicised by newsletter and field day demonstrations.

Results:

Selection of Strains of RNB.

Two series of field trials were established. One in January 1995 to assess the then available strains of RNB and one in January 1996 to assess new strains from glasshouse soil-pot screening of new strains collected in Brazil in 1994. In each year experiments were established at the CSIRO field stations at Lansdown (solodic soil) and Narayen (Granite and Brigalow soils) and in a red earth soil near Roma ("Holyrood"). The experiments failed to establish on the Narayen Brigalow soil, but were successfully established and managed over three years at the other sites. Yield (plant dry weight) data and proportion of nodules formed by the test strains (Tables 1, 2 and 3) show that several strains produced 3-5 fold increases in plant dry weight, especially in the 2nd and 3rd growing seasons and that these strains accounted for the majority of nodules formed. Strain CB3481 was released to industry with the new cultivars Primar and Unica in 1997. Data from the trials sown in 1996 are incomplete. Serological typing of nodules has been delayed awaiting preparation of specific antisera for strain identification. Provided these strains form a high proportion of nodules in the third year. thus demonstrating long term persistence, they will be recommended as replacement strains for CB3481.

Alternative delivery of inoculum strains

Normal seed inoculation of *S. seabrana* is not a practical methodology for introducing these bacteria since the host plant is most often sown in mid-summer when soil is dry and near-surface temperatures exceed 40 and 50 °C for up to 8 hours per day. These temperatures are lethal to the RNB which survive only 1-3 days under such conditions. (Note: The experiments for selecting the new strains were completed using irrigation immediately after sowing to avoid this restriction).

Experiments established in January 1995 failed to provide satisfactory results since a non-field competent strain CB3480 was used (see Tables 1, 2 and 3). A new series of experiments was initiated in which the bacteria were introduced via inoculation and sowing of a cereal grain in May/June 1995 and over-sown (dry) with *S. seabrana* in January 1996. A non-inoculated cereal plot was included for comparison. Replicated trails were established at Narayen (Granite and Brigalow soils), Roma (red earth and 2 vertisol soils). using strain CB3546 (a sister isolate of CB3481). By this method it was anticipated that the RNB could establish in the soil and rhizosphere of the cereal and develop a sufficient population at a depth that would avoid the lethal temperatures of the summer period. Two treatments were superimposed on the inoculated and uninoculated cereal plots in January 1996. These were surface-sown inoculated seed of *S. seabrana* and surface sown *S. seabrana* with inoculated plastic beads drilled-in 10 cm below the surface.

There were no growth (plant dry weight) differences in samples taken in April/May 1996 nor were there many nodules. However, in April/May 1997 and 1998. there were nodules in samples from the plots sown originally with inoculated cereal. Also, there were dry weight differences in the two less fertile soil sites (Narayen Granite and Roma Holyrood). Serotyping of nodules is incomplete, however, it is anticipated that this will confirm the presence of the original inoculum strain, since no effective strains have been recorded from any of these sites in uninoculated control plots associated with the strain selection trials.

An extension of the project is requested to provide opportunity to 1) complete the serotyping of samples and 2) to extend the field plots for a further 12 months. Justification is based on the observation that the 1996/97 and 1997/98 growing seasons were unseasonally poor (dry) leading to significantly greater availablity of soil N. The positive response to pre-inoculating the soil via inoculation of cereal suggest that this method may provide producers with a practical way of avoiding the unfavourable condtions at normal sowing time.

Other Comments:

Soil pot work indicated that *S. seabrana* 1) is not nodulated effectively by native rhizobia, and 2) formation of nodules is very sensitive to available nitrogen, whereby the plant does not nodulate at all until the available N has been used. This observation explains Les Eyde's observations that plants were "turning yellow" and were not nodulated. The implications for introducing new RNB are that they need survive not only the dry high temperature establishment conditions but must survive 1 or 2 growing seasons as free living organisms until soil N levels decline. Data from the strain selection trials suggest that the strains have this capacity.

Papers, reports, media articles.

Date, R.A., Eyde, L.A. and Liu, C.J. (1996) *Stylosanthes* sp.aff. *S. scabra* - a potential new forage plant for northern Australia. Tropical Grasslands 30, 133.

Date, R.A. Demonstration of RNB strain selection plots and need for inoculation of *S.* sp.aff. *S. scabra*. CSIRO Tropical Agriculture Field Day, Lansdown Research Station, April 1997.

Stylos for better beef. (1996) Partridge, I, Middleton, C and Shaw, K. QDPI, Brisbane.

Legumes for Clay Soils Newsletters.

Table 1. Strain trial 1995. Proportion of nodules formed by inoculum strains

Holyrood

	<-----------%Nods------------->			
	CB3053	CB3480	CB3481	Control
Apr-95	11	0	100	0
Apr-96	34	1	72	2
Apr-97	0	0	75	0
Apr-98				

Narayen Granite

	CB3053	CB3480	CB3481	Control
Apr-95	25	1	44	0
Jan-96	39	8	96	1
May-97	78	0	98	0
Mar-98				

Lansdown

	CB3053	CB3480	CB3481	Control
May-95	31	0	47	0
Jan-96	81	25	86	0
May-96	na	34	81	0
May-97	na	na	59	31
Mar-98				

Table 2. Relative yield as % best treatment each year

Holyrood

	<-------Yield (% CB3481)---------->			
	CB3053	CB3480	CB3481	Control
Apr-95	94	57	100	101
Apr-96	29	29	100	31
Apr-97	na	na	100	21
Apr-98				

Narayen Granite

	CB3053	CB3480	CB3481	Control
Apr-95	<--Lost	to	wildlife	--->
Jan-96	54	61	100	25
May-97	30	8	100	6
Mar-98	22	na	100	32

Lansdown

	CB3053	CB3480	CB3481	Control
May-95	176	150	100	87
Jan-96	23	19	100	14
May-96	na	27	100	30
May-97	na	na	100	47
Mar-98				

Table 3. Strain trial 1996. Relative yield (% best treatment each year) and proportion of nodules ( ) formed by inoculum strains

Narayen granite

Strain	April 1996	April 1997	May 1998
2152	35		
3480	49		
3481	31	29 **(91)**	50
3483		41	
3486	100		
3488		41 **(97)**	67
3489	75	50	
3490			75
3494		59 **(96)**	100
3495	87	100 **(98)**	109
Control	57	34	12

Holyrood

Strain	April 1996	April 1997	May 1998
3480	100		
3481	100	77 **(63)**	78
3483		48	61
3488		54 **(40)**	78
3489		74	
3490			56
3494		44 **(96)**	56
3495		100 **(96)**	100
Control	75	37	33

Lansdown

Strain	April 1996	April 1997	May 1998
3480	67		
3481	90	61 **(87)**	80
3483		67	90
3489		61	
3490			113
3494			100
3495		100 **(96)**	100
Control	100		60

Table 4. Relative yield as % inoculated cereal crop for alternative methods of delivery of inoculum rhizobia.

Site	Year	Inoc cereal	Uninoc cereal
Roma "Holyrood"	1997	100	89
	1998	100	74
Roma "RRS"	1997	100	107
	1998	100	120
Roma "Banoona"	1997	na	na
	1998	100	112
Narayen Granite	1997	100	60
	1998	100	35
Narayen Brigalow	1997	na	na
	1998	100	101

Evaluation of grasses for heavy grazing

(I.B. Staples, QDPI, Mareeba, and C.H. Middleton, QDPI, Rockhampton)

This report is based on material presented in:

PENGELLY, B.C. and STAPLES, I.B. (1996). *Final Report of MRC Projects CS.054/185 and DAQ.053/081: Development of new legumes and grasses for the cattle industry of Northern Australia.* (CSIRO & QDPI, c/- CSIRO, St Lucia 4067)

and subsequent field assessments 1995/96 through 1997/98.

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Objective

To identify quality grasses capable of forming a persistent association with Seca stylo.

Summary and recommendations

Based on a range of grasses sown at three sites in the dry tropics of Queensland in 1991/92 through 1994/95, we have identified stoloniferous accessions in *Bothriochloa*, *Digitaria*, and *Urochloa*, which could make useful sown pasture grasses in association with stylos. Many buffel grass lines also performed well, but as these included the current cultivars we do not see great scope for improvement in this species in these environments. Some accessions with the tufted growth habit more typical of native grasses have also produced well and may be more environmentally acceptable than the stoloniferous forms, but the present evidence for their success and persistence in mixtures with stylos is tenuous.

Wider evaluation required While quality grasses which can help overcome the problem of stylo-dominant pastures are needed quickly, new material identified in these small plot evaluations requires testing on a broader scale, in terms of both area and environments, before recommending it for commercial use. Not only do we need to build confidence in users and their advisers, we also need to be sure the associations with stylos are truly stable. There is a moderate risk that some of these vigorous stoloniferous grasses may seriously hinder seedling regeneration of stylos, to the long term detriment of animal production from such pastures.

Grass establishment The problem of grass establishment in stylo pastures also needs addressing. Agronomic work is obviously needed on how best to sow into existing legume-dominant pasture for effective and economic establishment. This issue could also become a criterion for discriminating between otherwise similarly performing accessions. We did not address ease of establishment *per se* in this project—we concentrated on identifying productive, persistent material. Perhaps some trade-off of grass productivity for ease and reliability of establishment would be acceptable to achieve a commercially viable outcome?

Evaluation of grasses for heavy grazing*

(I.B. Staples, QDPI, Mareeba, and C.H. Middleton, QDPI, Rockhampton)

Introduction

One objective of the former MRC project CS.185/DAQ.081 was to identify quality grasses with the potential to grow in association with Seca shrubby stylo (*Stylosanthes scabra*) under the higher stocking rates achievable on pastures based on this hardy sown legume in the dry tropics of northern Australia. Commercial experience has shown that most tussock grasses, such as the majority of our native species, are incapable of withstanding these high stocking rates, resulting in potentially unstable legume dominant pastures within a few years. This report summarises the evaluation of stoloniferous and other introduced grasses which may be able to withstand such pressures as a consequence of their evolutionary backgrounds.

Methods

Representative lines from a selected range of genera and species were sown into one metre wide cultivated strips in existing shrubby stylo pasture at three sites in the dry tropics of central and north Queensland: Springmount near Mareeba, Lochwall near Charters Towers, and Galloway Plains near Calliope (Table 1). A new set of lines was sown each season 1991/92 through 1994/95 and selected commercially available cultivars were included for comparison. Plot size was 1 m by 5 m, with a border between strips to permit observation of natural spread into the background stylo pasture. Entries were replicated in two complete blocks and supplementary irrigation was used in an attempt to ensure establishment. The trial areas were open to grazing by cattle except during establishment and a brief period prior to data recording at the end of the growing season each year.

Each set was monitored for at least three years and performance was judged largely on the basis of persistence, yield, and spread; qualified by observations on seedling recruitment, palatability, phenology, and pests and diseases.

Table 1. Location and characteristics of the experimental sites

	Springmount	*Lochwall*[a]	*Galloway Plains*[b]
Latitude	17° 13' S	19° 51' S	24° 10' S
Longitude	145° 30' E	145° 53' E	150° 57' E
Altitude (m)	580	320	100
Annual rainfall (mm)	800	553	770
Soil type (Northcote)	Dr2.21	Gn2.22	Dy3.43
Climate (Papadakis)	4.20	4.2	4.42
Natural vegetation	Woodland	Woodland	Woodland
Actual vegetation	Woodland	Woodland	Grassland

[a] [b] The 1991/92 plantings were on similar country on nearby Toomba and Wycheproof respectively.

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* Based on the report:

PENGELLY, B.C. and STAPLES, I.B. (1996). *Final Report of MRC Projects CS.054/185 and DAQ.053/081: Development of new legumes and grasses for the cattle industry of Northern Australia.* (CSIRO & QDPI, c/- CSIRO, St Lucia 4067).

With additional observations in 1995/96 through 1997/98.

Results and discussion

Like much of the rest of Queensland, our experimental sites all suffered from periods of serious drought, including during the establishment year of all plantings. The Lochwall site was the worst affected and the surrounding paddock was destocked for much of the time, so the trial plots there were not grazed as consistently as we had intended. Supplementary irrigation proved essential to obtaining at least some establishment, but it could not entirely compensate for the combined effects of heat and low humidity on grass establishment in very low rainfall summers at Springmount and Lochwall. These problems may have eliminated material that could have established and survived otherwise. On the positive side, many lines did establish and were producing well after four to seven years. In some cases, such as Indian bluegrass (*Bothriochloa pertusa*) at Galloway Plains, the stands have improved with time.

1991/92 series

The entries in this set were lines of Indian bluegrass and buffel grass (*Cenchrus ciliaris*) with specific control lines cv. Medway and "Bowen" (Indian bluegrass) and cvv. American, Biloela, Gayndah and Molopo (buffel). Bisset creeping bluegrass (*B. insculpta*) and Nixon Sabi grass (*Urochloa mosambicensis*) were included as general controls.

In this season only, plantings were made at Wycheproof instead of Galloway Plains, and at Toomba instead of Lochwall. Establishment at Wycheproof was excellent, but at Toomba it was dismal. The only lines to establish and persist at Toomba were *B. pertusa* CPI 106629 and cvv. Bisset, Molopo, and Nixon. (In fact, Nixon later proved to be naturalised in the immediate locality.) The site was abandoned after three years when property fencing was realigned.

Wycheproof Lines were sown into an existing heavy stand of Seca under relatively heavy grazing pressure. All accessions persisted, with bluegrass performing better than the more nutrient demanding buffel which appears to be gradually declining. The former also suppressed Seca more (37% Seca content in the pasture versus 61% with buffel). Several new accessions of Indian bluegrass lines were similar to Medway; Bowen was less well eaten, had lower ground cover (more tufted habit) and was more prone to invasion by Seca; and CPI 104935B, 104642 and 106426 had good ground cover, spread, and legume balance, and were well grazed.

Springmount Bluegrass has not done as well as buffel under the more lenient grazing regime here, and they appear to be less well grazed during the dry season. Plot to plot variation is high in this natural woodland setting, so discrimination among fairly similarly performing material is difficult. The Indian bluegrass lines CPI 104642, 106426, and 104935B are the best of the new material, but are all performing similarly to Bowen. However, 106426 and 104935B are later flowering than Bowen, which could confer a quality advantage later in the season. Medway performed very poorly at Springmount.

Although buffel grass is persisting and yielding well at Springmount, and is better grazed than the bluegrasses, it is not spreading off the sown strips. This is a common experience with buffel on low phosphorus soils in the dry tropics. Furthermore, with the exception of Molopo, the present commercial cultivars are performing as well as any of the new material. Nixon Sabi grass has performed well, with excellent ground cover, but it seems to be declining gradually relative to the other species.

1992/93 series

The main genera sown in this set were *Dichanthium*, *Digitaria*, and *Urochloa*. Specific controls were Premier digit grass, Jarra finger grass, Floren Angleton grass, Petrie green panic, and Nixon Sabi grass (Saraji was included serendipitously as CPI 60128). General controls were Bowen and Medway Indian bluegrass, and American, Biloela and Gayndah buffel.

Galloway Plains As a group, Sabi grass performed very well and several lines were as good as or better than Nixon and Saraji: *U. mosambicensis* CPI 46876, 47167, 60151 and 60139, and *U. stolonifera* 47173 and 47178. CPI 46876 was outstanding. It has spread well beyond the sown strip and has kept Seca content down compared with adjoining native pasture.

The best lines of *Digitaria* species were *D. milanjiana* CPI 59787, 59761 and 59828. Premier produced well and was well eaten, but did not spread much. *D. swynnertonii* CPI 59715 also performed well. It was high yielding and well eaten, and resisted Seca invasion. Jarra (as CPI 59745) did not persist, though it performed reasonably well in the first three years.

Bowen and Medway performed very well, but Bowen was not as readily grazed as Medway. *Dichanthium* and *Panicum* species did not persist well except for *D. annulatum* CPI 50819 which was still yielding well after six years. The buffel grass control lines have also faded out.

Springmount The site was burnt out in late 1996, but most of the lines which had been doing well to that time survived the fire. Sabi grass lines and their relatives in *Urochloa* have mostly done well throughout the six years since planting. Several are as good as or better than Nixon: CPI 46876, 47167, 60139, 47122, 60123, 60127 and 47178. Of these, CPI 46876, 60123 and 47122 have been outstanding throughout. Saraji has died out.

Many *Digitaria* accessions are doing well. They have formed good swards, are highly palatable, and many are spreading into the adjoining undisturbed Seca pasture. In fact, we have some concern that they may be too competitive. In many cases they have formed pure swards in the planted strips, apparently preventing regeneration of both Seca and native grasses in these lightly cultivated areas.

Jarra has given good performance in recent years, but was slow to start compared with some other lines. All *D. milanjiana* lines except CPI 59777 have given good performance. Jarra has the advantage that it is more "obvious" due to its structure and leaf shape, which puts it into a higher comfort zone than lines with otherwise equivalent or even better performance. Of the other *Digitaria* species, *D. setivalva* CPI 59829 and *D. swynnertonii* CPI 59715 are now yielding well, and the former has been consistently fairly good over time. Premier has not done well.

Gayndah buffel is the best of the general controls and is still good; Biloela buffel started out the best, but is now barely mediocre; American buffel and Bowen Indian bluegrass are only fair; and Medway is insignificant. The *Dichanthium* lines under test all failed.

Lochwall All three buffel grass cultivars have given excellent performance, though they are now a bit yellow. Biloela has been consistently the best of them. Bowen and Medway were never much good here, and both appear to have died out.

Given their performance at Springmount, we had high hopes for *Digitaria* species, but they have been disappointing here. The best are *D. milanjiana* CPI 59761 and 59787. In the last three years *D. endlitchii* CPI 59817 has been building up in the sward [as it seems to be doing at Galloway Plains too] but it was poor earlier. Jarra and Premier have failed completely.

With a few exceptions, Sabi grass and relatives have been good at Lochwall. Nixon itself has done well, but other *U. mosambicensis* lines have been as good or better: CPI 46876, 47167, 60139 and 60151. The most consistently good of the *Urochloa* species has been *U. stolonifera* CPI 47178. Saraji has been insignificant.

1993/94 series

Most of this large set was made up of *Bothriochloa* and *Paspalum* accessions, with smaller groups of *Dichanthium*, *Ischaemum*, *Panicum* and *Schmidtia*. Specific controls were Bisset creeping bluegrass, Dawson and Medway Indian bluegrass, Petrie green panic, and Rodds Bay plicatulum. Four cultivars of Rhodes grass (*Chloris gayana*) were included to see how they would perform in the dry tropics; and American and Biloela buffel grass were again included as general controls. It was generally a fairly disappointing lot. *Paspalum* species failed throughout, as did the smaller group of *Ischaemum* lines.

Galloway Plains The best grass was *Bothriochloa insculpta* CPI 69517 which had high yield and spread, good ground cover, and was well eaten. CPI 125651 and 125652A had high yields, but less ground cover due to their tufted habit, and they were poorly eaten. *B. glabra* CPI 105854, 105909 and 105099 also yielded well but were not eaten as well as other species. Bisset and Dawson were both good in terms of yield, spread, and palatability. Medway grew well but was not eaten so well. Callide Rhodes grass gave consistently good yields too.

Springmount The most consistent performers throughout the full five years were the two buffel grass cultivars, American and Biloela. Surprisingly, the *Panicum* lines have done quite well in the past three years, especially cv. Natsuyutaka and CPI 60022. Performance of *Bothriochloa* species has been disappointing and inconsistent. The best are CPI 125652A and 125651. CPI 69517 has not done well here and Dawson and Medway are insignificant.

Lochwall Only Biloela buffel has performed consistently over time. Several *Bothriochloa* lines (including CPI 69517) established well, but were not recorded subsequently except for *B. insculpta* CPI 125652A and 125651. However, the native *B. bladhii* var. *bladhii* is often very vigorous over large parts of this site, which makes the identification and assessment of other bluegrasses very difficult.

Two lines of *Schmidtia pappophorides* (CPI 60087 and Q10092) are vigorous and spreading at Lochwall (especially the former). Both are present at Springmount too, but are not impressive there. This is not a genus we have had much previous experience with and, due to the sporadic grazing at Lochwall, we are not sure how palatable these lines are to cattle. They should be treated with caution until this can be clarified.

1994/95 series

This was a mixed set of eleven genera. Most interest centred on the ten accessions of *Cynodon* species, but they turned out to be total failures in practice. It is not known what caused the problem, but establishment of all ten lines was effectively nil.

Galloway Plains By far the best performances have been from *Bothriochloa pertusa* cv. Medway, and *B. insculpta* CPI 69517, cv. Bisset and CPI 125652A. *Iseilema* sp. CPI 106479 has also grown well and is very well eaten; and *Chrysopogon fulvus* CPI 106035 is persisting with reasonable yields.

Springmount Best lines are *Bothriochloa bladhii* CPI 104802A and *B. insculpta* CPI 69517. The present cultivars of these species, Swan and Bisset respectively, are insignificant. Other lines doing well or moderately well are *B. bladhii* CPI 52194, *B. glabra* CPI 108424, *Chrysopogon* sp. CPI 106689, and *Heteropogon contortus* CPI 106536 and Q25363.

Lochwall As in the previous series, the native bluegrass has seriously hindered assessment of other *Bothriochloa* lines. *B. insculpta* CPI 69517 and 125652A were both good initially but their current performance is obscured if, indeed, they are still present at all. Bisset is mediocre. With good regeneration of native spear grass in 1997/98, a similar problem has arisen in assessing the experimental *Heteropogon contortus* lines, but Q25363 had been doing well.

Several lines of *Chrysopogon fulvus* are now doing well, especially CPI 104958, 106035 and 105011. They are higher yielding than the native material, and appear to be better eaten; but they are probably equally unlikely to provide a balanced pasture in combination with Seca.

Summary

We have identified a number of accessions in the genera *Bothriochloa*, *Digitaria*, and *Urochloa*, which would make useful sown pasture grasses to grow in association with stylos (Table 2). A wide range of buffel grass lines also performed well, but so did the current cultivars of this species. Some accessions with the tufted growth habit more typical of native grasses have also produced well and may be more environmentally acceptable than stoloniferous forms, but the present evidence for their success in mixtures with stylos is tenuous.

Table 2. Best accessions in selected genera and species ranked within sites

Genus and species	Accession [a]	Rank within species at indicated site		
		Springmount	Lochwall	Galloway
Bothriochloa insculpta	69517	1	2	1
	125651	3	3	3
	125652A	2	1	2
Bothriochloa pertusa	104642	3	—	2
	104935B	2	—	1
	106426	1	—	3
Digitaria endlitchii	59817	—	1	1
Digitaria milanjiana	59761	4	1	3
	59786	1	—	1
	59787	3	2	2
	59789	2	—	4
Digitaria natalensis	59752	1	—	?
Digitaria setivalva	59829	1	—	?
Digitaria swynnertonii	59715	1	—	1
Urochloa mosambicensis	46876	1	1	1
	47167	2	2	2
	60139	3	4	4
	60151	4	3	3
Urochloa oligotricha	47122	2	—	2
	60123	1	2	1
	60127	3	1	3
Urochloa stolonifera	47178	1	1	1

[a] Commonwealth Plant Introduction (CPI) numbers

The Reversion Problem in Shrubby Stylo Seed Production

J M Hopkinson (DPI, Walkamin RS)

Summary

Reversion in shrubby stylo is a condition in which inflorescences revert to a form of vegetative growth part way through their maturation. It has been present at low frequencies in pastures and seed crops for some years, but in 1997 it caused serious seed yield depression to the point where it threatens the viability of seed production. It is believed to be caused by a phytoplasma (a microorganism intermediate between a bacterium and a virus) and to be transmitted by sucking insects. A task force from NT University and DPI and CSIRO in north Queensland has been accepted under the wing of the CRC for Tropical Plant Pathology and has begun an investigation designed to identify the cause of the condition and control its occurrence. Its members are seeking MRC support for the work

Background

In July 1997 commercial seed crops of shrubby stylo (*Stylosanthes scabra* cv. Seca and Siran) in north Queensland seemed to be on target for good yields. Growers were confident that they could live with the known enemies - *Botrytis, Sclerotinia, Sclerotium*, anthracnose, little-leaf, frost. Then, as so often happens, trouble came from the least expected quarter.

As crops matured it became increasingly evident that all was not well. Parts of plants, whole plants, in places seemingly whole plant populations, began to behave oddly. Instead of their inflorescences completing flowering, seed formation and seed ripening in the normal way, they began to return to vegetative development, but of an abnormal kind. Flowers and green seeds aborted. Primordial flower buds began to sprout, their individual parts - sepals, petals, ovaries - turning into leaf-like structures. Spike apical meristems, which normally cease to function after producing a number of flower buds, were reactivated, producing vegetative shoots. The normal proliferation of short spikes became an abnormal proliferation of weak, useless, elongating branches - the now-familiar "witch's brooms". Further seed formation ceased, and when this happened before the main seed crop had developed, as was most commonly the case, seed production and yield were dramatically reduced.

The consequence was seed yields of probably below half the expectation. This pushed seed prices up to perhaps 40% above what they would have been, which in turn led to buyer resistance and depressed sales. If the same thing happens to 1998 crops, the consequence will be the same. It will lead individual seed producers to decide that shrubby stylo seed production is unprofitable. They will then be unlikely to sow seed for 1999 crops. We are thus looking at the possibility of cessation of seed production of our most useful and widespread pasture legume for the dry tropics. We obviously have a problem on our hands, and we have not got long to find a solution to it before its effects become serious.

We called the condition *reversion* as it takes the form of a pathological reversion from the reproductive to the vegetative state, and this has become the familiar word in pasture circles. The term *phyllody*, used by pathologists to describe the same condition in other plants, might in retrospect have been a better choice, especially as they already use the word reversion for a somewhat different condition.

The causal agent

Early advice was that reversion was probably caused by a phytoplasma, and the likelihood has been reinforced by subsequent investigation. Phytoplasmas are a distinct group of pathogenic microorganisms different from either viruses or bacteria. They are described as somewhat like bacteria but without a cell wall. Their uniqueness has only relatively recently been recognised, they are still poorly understood, and their investigation remains a knowledge frontier. Little-leaf, so similar to stylo reversion, is a typical phytoplasma-induced condition. Reliance on techniques of molecular biology is necessary for positive detection and identification. Phytoplasmas in plants are only detected in phloem tissues, and only phloem-feeding insects are likely to transmit them. Phytoplasmas tend to have a wide host range, and are believed not to be seed-borne.

Similar symptoms are sometimes caused by viruses in other types of plant. The possibility of a virus causing reversion in stylo cannot wholly be dismissed but is at present considered unlikely by both virologists and phytoplasmologists. However, virus diseases of stylos also occur, and viruses are known to interact with phytoplasmas to increase the severity of symptoms. For this reason viruses must be taken into account in consideration of reversion.

The possibility exists that little-leaf and reversion are caused by the same phytoplasma. However, to reconcile it with the historical record, one must postulate some other change in circumstances, such as greater vector activity over the reproductive period than in earlier years

History of reversion

There is photographic evidence of reversion in shrubby stylo at Mareeba in 1990. It may be assumed to have been present for some years before that and is believed to have become progressively commoner. It certainly contributed to the withdrawal of Tully farmers from Seca seed production after 1996. Its occurrence in seed crops of stylo in inland districts (Lakeland and Mareeba) was, at most, uncommon before 1997, but by late 1997 it had seriously affected all seed crops. Once due attention was paid, it was also found to be widely distributed in shrubby stylo in pastures and on roadsides throughout much of northern and central Queensland. A more exact history of its build-up is impossible to reconstruct in retrospect

Action

Recognition that we had a problem brought together local seed industry members and relevant DPI and CSIRO staff in north Queensland to form a Mareeba-based coordinating group. Prior contact over the similar little-leaf condition with members of the NT University led us to seek their help, with an immediate positive response that resulted in the formation of the Stylo Reversion Group and the planning of a combined campaign to tackle the problem. The Group's plans were then accepted as a project under the CRC for Tropical Plant Pathology. This has provided a structural umbrella and a budget to get the investigation off the ground. It has also given us the opportunity to solicit the cooperation of virologists, entomologists, etc. to broaden the investigation. Donations by Southedge and Heritage Seeds of money for travel have eased the ever-present problems of distance between Darwin and Mareeba.

The joint investigation has two separate agenda. The NT University work, primarily done by a Ph.D. student Stephanie De La Rue and supervised by Karen Gibb, is a segment of a broad-based, long-term investigation of phytoplasmas as a whole - of their taxonomy, identification, distribution, host range, transmission, economic damage, genetics of resistance, etc. The overall investigation that Karen Gibb coordinates includes an ACIAR project with ramifications into a range of crops in various developing countries. Those of us in north Queensland - Raylee Trevorrow of CSIRO (based in Mareeba DPI), John Rains of Southedge Seeds, and myself - are urgently concerned with finding out how to control, or at least coexist with, reversion so as to be able to return to reliable economic production of shrubby stylo seed.

The two sets of agenda are complementary and mutually dependent, and the cooperative arrangement that they engender is working well. It is being extended to include virologists, though so far only in a monitoring and advisory role. The only real problem with the arrangement lies in the urgency of the need for an interim solution to our seed production problems. It means that we shall have to have a disease management strategy in place before we understand enough of the disease to formulate it reliably – an inevitably high-risk situation. Another concern is the lack of an available entomologist in north Queensland to parallel the other investigations with one of the transmission process.

Progress

With systematic testing being developed and conducted at NTU, the evidence inculpating phytoplasmas continues to accumulate. Plant parts with symptoms of reversion have generally tested positive for phytoplasma, and those without have generally not. Reversion has been observed primarily in shrubby stylo, regardless of cultivar or accession, to a very limited extent in *S. humilis, seabrana* and *hamata*, and not at all in *S. guianensis*. It occurs in legumes of other genera, including *Crotalaria goreensis* (Gambia pea), *Indigofera hirsuta, Aeschynomene americana* (joint-vetch); and in certain weeds of other families growing near infected areas of shrubby stylo (*Sida cordifolia; Mitracarpus hirtus).*

Meanwhile, in the Mareeba district, monitoring of the occurrence and spread of symptoms of reversion, both of shrubby stylo seed crops and generally, and of leaf-hopper populations, has begun. In addition CSIRO is recording occurrence of symptoms in breeding lines and accessions of shrubby stylo sown as part of an investigation of resistance to anthracnose, in order to learn something of the possibilities of obtaining resistance to the reversion organism.

The future

The provisional model is one of a pathogenic phytoplasma affecting primarily shrubby stylo, transmitted by a leaf hopper, and with a range of alternative hosts that may, along with perennial plants of shrubby stylo surviving either in pastures or as roadside volunteers, provide a reservoir of new infection early each season. The investigation of the background science of this will continue for at least three years at NTU. Meanwhile, in NQ, the NTU effort will continue to be supported, and at the same time means of avoiding severe reversion will be sought. Suggested avoidance strategies include shifts to isolated areas for seed production, crop management to bring seeding forward to an earlier part of the season, extension of crop hygiene, and leaf hopper control. Further effort will be needed to recruit an entomologist to put substantial effort into the epidemiology of the condition. Visitors from CSIRO DTA in Brisbane have recently raised the possibility of their investigating prospects for control of reversion through plant breeding.

Acknowledgement

This report summarises information obtained through the combined effort of all members of the Stylo Reversion Group.

Elimination of unwanted introduced pasture plants

a discussion paper by Harry Bishop and John Hopkinson

1. An inevitable undesirable by-product of pasture plant introduction is the persistence of unreleased accessions as potential weeds. The research program must now accept the responsibility for having to get rid of these plants and for ongoing management of discontinued evaluation sites. This acceptance has resulted through professional "duty of care", shifts in community perceptions about introduced plants and pending legislation. The most difficult task is to define which plants are undesirable and unwanted and to make the categorical decision to "remove" them. The obligation falls on the research program:
   - wherever the original owner of the land wants them eliminated:
   - wherever there is good reason for us to see a real risk of the plants becoming weeds.

2. Responsibly introduced plants run the risk of becoming weeds
   - where they are both well-adapted and unpalatable to stock,
   - where they are well adapted in places where stock are excluded, regardless of palatability.

3. Most plants that have passed through formal evaluation show their weed potential before they get beyond the boundaries of evaluation sites and research stations. While their distribution is still so restricted, it is realistic to expect to be able to eradicate them. This is where we are concentrating our attention.

4. The intention is not only to eliminate unwanted plants, but also to develop effective strategies for future elimination and management of sites. We aim to develop a process that can be put in place quickly and effectively as problems arise. The Northern Australian Pasture Plant Evaluation Committee (NAPPEC) is also addressing the situation of potential weeds from plant introduction activities and the April 1998 meeting at Mackay registered its commitment to further assist with developing protocols for pasture plant evaluation (minutes of NAPPEC meeting at Mackay, April 1 to 4, 1998).

5. The strategy developed for BULS is:
   - 5.1 Document all evaluation sites (past and present) sown with non-cultivar legumes. Use the QPASTURES data base as a record of site locations and performance of accessions sown.
   - 5.2 Survey each site for unwanted "risk" accessions and document area and spread, inside plots and away from plots.
   - 5.3 Eradicate "risk" accessions using herbicide recommendations from Don Loch's BULS herbicide trial plus various management procedures applicable to that site.
   - 5.4 Develop guidelines for future management of site in co-operation with landowner.
   - 5.5 Record/document methods/chemicals/management used and results achieved so that effective procedures can be developed and refined.

6. Currently Harry Bishop is coordinating a state-wide eradication activity (under the umbrella of the BULS project) on unwanted plants sown in the BULS and some associated projects. All target plants are legumes, and the particular problem that legumes present is their production of hard seed, which places a time-scale of many years on the process before there is real certainty of success. Current activities are being funded from a BULS carry-over balance. The aim is to initiate a new and wider ranging project for the purpose of " Responsible management of discontinued sown pasture evaluation sites". **Funds are being sought to initiate this project.**

7. 1998/99 Work plan
   7.1 Bob Walker is responsible for off-station eradication in north Queensland, mainly of *Aeschynomene brasiliana* and *Indogofera schimperi*. Specific target sites include Burlington, Wrotham Park, Sugarbag and Lamond's Lagoon.
   7.2 John Hopkinson has taken responsibility for continuing attempts at eradication of *Acacia angustissima* on Walkamin Research Station with the support of John Hardy (Station Manager).
   7.3 Terry Hilder is responsible for "on-farm" eradication of *A. brasiliana* at "Swans Lagoon" Research Station, "Sorrell Hills", Duaringa, and "Wadeleigh", Miriam Vale. Plans for "Narrabri", Gympie, Brian Pastures Research Station Gayndah and Narayen Research Station Mundubbera are the responsibility of Bruce Cook, John Mullaly and Cam McDonald respectively. Other discontinued sites to be monitored are "Braceborough", Charters Towers, "Stillwater", Daly Waters, and Katherine Research Station.
   7.4 These collaborators will record and report details of activities and help develop a process for future use.

8. A specific management plan has been developed for the DPI Swans Lagoon Research Station, Millaroo, via Ayr, where the BULS evaluation site is adjacent to native pasture paddocks used for breeder herd management trials. The aim is to contain and eliminate invasive sown legumes including Wynn and Seca from this site and with the cooperation of the Station Manager will be a good test of possible elimination techniques.

Guidelines for current management of "Swans Lagoon"BULS project site.

8.1 Remove stock and shut the gate (site already fenced) – April 1998.

8.2 Spray well adapted non-release legumes with herbicides, preferably pre-flowering. Mix of dicamba - "Banvel 200" (at 1 ml/L) and metsulfuron methyl - "Ally", "Brush-off" (at 1.5g/20 L, with wetting agent) Total chemical cost $12.50/ha) – April 1998.

8.3 Burn site summer 1998/99 after first storms to kill some adult plants, soften seed, increase germination and make site more accessible to spraying. (Cost of fire breaks, equipment and team?)

8.4 Oversow site with 5 kg/ha of Bowen pertusa seed after burn, site already invaded with Bowen bluegrass. (Cost at $15/kg for 6 ha = $450).

8.5 Spray legumes with above herbicides in early wet season – 1998/99.

8.6 Apply urea at 100 kg/ha to whole site (6 ha x 100 kg = 0.6 tonne = $ 250, plus appln costs). Apply another 100 kg/ha urea to individual plots of *A. brasiliana* 93592 and 92519, *Chamaecrista rotundifolia* 86172, 93094 and Wynn and *C. pilosa* 57503 ((5 x 0.1 ha x 2 reps) = 1 ha) – after early storms.

8.7 If accessible, check site in mid March 1999 and spot spray listed legumes.

8.8 Burn site early summer 1999/2000.

8.9 Spray legumes early wet season 1999/2000.

8.10 Apply urea at 100 kg/ha to site, and an extra 100 kg/ha to problem legume plots.

8.11 Review situation in early summer 2000/2001 and if legumes are still persisting continue above operations as resources permit.

8.12 Total **product** cost for 6 ha Year 1 = $855.00, Year 2 = $385.00.

Sustainability of *Stylosanthes* based pasture systems in northern Australia: Managing soil acidity

Project title: Sustainability of *Stylosanthes* based pasture systems in northern Australia: Managing soil acidity.

MRC Project No. NAP3.218

Project duration: 1 July, 1997 - 30 June, 2001.

Due date for milestone report: 30 June, 1998.

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Project objectives:

1. Establish permanent monitoring sites throughout northern Australia to assess long-term soil fertility and moisture trends under *Stylosanthes* and native pasture systems. Insight into the impact of these grazing systems on the soil resource base will assist in the development of sustainable beef production strategies.
2. Develop a soil acidity risk assessment map for the Dalrymple Shire at a level that will assist resource managers in identifying areas most vulnerable to accelerated acidification. In addition, a simple field based tool-kit will be developed to assess soils for their sensitivity to accelerated soil acidification.
3. Evaluate the impact of different *Stylosanthes* management strategies implemented at Springmount, Mareeba, on the rate of acidification. This will facilitate the development of management strategies to minimise *Stylosanthes* dominance in improved pastures.
4. Conduct greenhouse and laboratory studies to ascertain the tolerance of grass and *Stylosanthes* species to acid soil infertility and assess the impact of ash produced after burning as an acid soil ameliorant.
5. Quantify the mineral nitrogen dynamics under a *Stylosanthes* dominant pasture in order to assess the contribution of nitrate leaching to acidification. Using published data attempt to establish a total nitrogen budget for pastures with and without *Stylosanthes*.
6. Develop a comprehensive communication plan in conjunction with QDPI which will facilitate awareness amongst producers of the possible negative impacts of *Stylosanthes* dominant pastures on the soil resource base and to suggest management strategies to minimise these negative impacts

Project summary:

Land degradation issues are assuming greater importance in northern Australian beef grazing systems. In this respect, the aims of this project are to evaluate the long-term impact of accelerated acidification due to the introduction of *Stylosanthes* based pasture systems on mechanisms associated with this problem and the development of strategies to minimise this risk.

Whilst the project is still in its infancy there are a number of activities that have been initiated over the last 12 months. Several permanent monitoring sites have been established and at two of these sites soil moisture and rainfall monitoring equipment have been installed. Analysis of soil samples has been completed on some of these sites.

At one of the permanent monitoring sites (Thalanga) root profile distribution patterns were mapped for a native pasture and *Stylosanthes* dominant systems. Distinct differences in root distribution under the two systems were observed with *Stylosanthes* roots being more prolific at depth when compared to the native pasture. It is suggested that these differences in rooting patterns may in part account for the higher tree mortality observed on the *Stylosanthes* site.

Another activity includes the validation of a pedotransfer function to predict the pH buffering capacity of soils and its subsequent use in the development of a soil acidification risk map for the Dalrymple Shire. A significant outcome from this mapping exercise is that large areas of the Shire, are potentially predisposed to rapid acidification if *Stylosanthes* dominance does occur. A field tool kit for the determination of potential risk of acidification is proposed which is based on a measurement of soil pH and texture. The estimated time to reach a soil pH of 5.0 can then be read off from a table. Details of the structure and rationale behind the tool kit are presented as an attachment.

A rapid screening technique based on root elongation has been validated and tested on a range of *Stylosanthes* accessions. Preliminary results indicate that the accessions tested are highly intolerant of acid soil infertility and it is speculated that continued soil acidification will result in poor legume seedling recruitment with a corresponding decline in vegetation cover. Continued screening of *Stylosanthes* and grass species are currently being undertaken.

Considerable effort has gone into communicating results and making producers aware of potential problems associated with legume dominance. This has been facilitated through field days, research articles, popular articles and video features. This has been achieved through collaboration with Col Middleton, QDPI (Project NAP3.22.).

Results and achievements in addressing agreed objectives

Objective 1

Progress has been made in the establishment of permanent monitoring sites. With the prolonged wet season and associated logistical problems only 2 of the 4 permanent soil moisture and rainfall monitoring sites have been established. During the dry season continued establishment of monitoring sites will be undertaken. The 2 sites established are at Lansdown and Thalanga. Soil samples and site characterisation has been completed at both sites and the regular downloading of dataloggers has been routinely undertaken on a 3 monthly basis. At the Thalanga site, neutron moisture tubes have also been inserted in the native pasture and *Stylosanthes* dominant pasture to monitor water uptake from depths down to 2 m. In addition to the soil moisture monitoring activities on this site, an estimation of the root distribution characteristics of the two production systems was undertaken using the methodology of Nicoullaud *et al.* (1994). Whilst comprehensive analysis of the data is still being undertaken, there is clear evidence of difference in the rooting patterns between the two production systems (Figure 1). The root distribution under *Stylosanthes* appears to be deeper and more extensive than under the native pasture. The greater root proliferation observed under *Stylosanthes* may account for the significantly higher tree mortality observed on this site through competition for water.

Objective 2

The development of an acidity risk map for the Dalrymple Shire has progressed with the validation of a pedotransfer function and the production of a risk map for the Shire. The validation of the pedotransfer function was undertaken using archival soil samples collected from the Shire that are in storage at CSIRO Land and Water, Townsville. Thirty one surface soils were selected based on their dominance within the Shire and subjected to laboratory determinations of pH buffer capacity using a methodology previously outlined by Noble *et al.* (1997). A highly significant linear regression was observed between measured and predicted pH buffering with no significant deviation from the 1:1 line (Figure 2). For each of the soil associations within the Dalrymple Land Resource data base, a pH buffer capacity was assigned based on mean characteristics for that association. A map of Shire was produced indicating the potential risk of acidification based on the number of years required to reach a base pH of 5.5 in water and a nett annual input of 3.5 kmol H^+/ha.yr (Figure 3). The map excludes areas with mean annual rainfall of less than 500 mm as these areas are deemed to be unsuitable for Stylos production. In the initial development of this map it was proposed that soil P could be used as one of the variables in the overall structure of the risk map. However, on statistical evaluation of the data set within a soil association the variability was too high for P to be a meaningful predictor. Consequently, the risk map is based on rainfall and pH buffering capacity.

An attempt has been made in developing a field based tool kit for the assessment of acidity risk. This tool kit is based on the measurement of soil pH using a field electronic pH meter and the determination of field based texture. Using a table system, the number of years that it would take for the soil pH to drop to a value of pH 5.0 in water is estimated. A complete discussion and outline of the method and rationale is presented in Appendix 1.

Objective 3.

Soil sampling of the Springmount site at Mareeba is to be undertaken in August 1998 for the assessment of the impact of various *Stylosanthes* management systems on rates of soil acidification.

Objective 4.

The development of a rapid technique to assess the sensitivity of *Stylosanthes* and grass species to soil acidification has been undertaken. This involves evaluating root elongation over a 7 day period for seedlings grown in an acid soil that that has been ameliorated with $Ca(OH)_2$. In the development of this rapid bioassay technique the wheat varieties Egret and Carazinho where used model as plants since these varieties have been screened for their tolerance and sensitivity to acid soil infertility.

The soil used in this study has a pH 4.62 and an acid saturation of 66%. The effects of remediation of acidity are clearly shown with respect to Egret whilst in the case of Carazinho there was no significant response to lime application (Figure 4a). From these results it has been concluded that the soil used in this screening process is adequately acid to illicit a response. Continued screening of *Stylosanthes* varieties is currently being undertaken, the results of which are presented in Figure 4. It is clearly evident that all of the *Stylosanthes* varieties tested to date have shown significant responsiveness of lime additions. In addition, root elongation in the unamended treatments is extremely poor suggesting that the species tested are highly sensitive to acidity. It is probable that under severe acidification there will be a decline in annual recruit. This could significantly impact on productivity. Similar bioassay tests have been attempted using different grass species. However, to date there has been problems associated with germination of seed. This matter is currently being investigated. A pot trial to assess the growth and productivity of selected grass and *Stylosanthes* varieties will be established this winter.

Objective 5.

In an effort to understand the nitrogen dynamics under a *Stylosanthes* dominant and sown pasture (*Urochloa mosambicenis*) pasture, a series of Teflon soil solution sampling cups was installed at a site at Landsdown. Eight samplers were installed on each site at 2 depth intervals namely 25 and 60 cm. These samplers when placed under vacuum extract the soil solution when conditions permit and allow one to determine the composition of the solution. Samplers were installed in January 1998 and soil solutions extracted on the 3/02/98, 13/03/98 and 20/05/98. Samples are currently being analysed for mineral nitrogen. Leaf litter traps have been installed on each of the sites to determine the amount of leaf senescence that does occur over the dry season and the nitrogen content of this material.

Objective 6.

Over the past 12 months significant progress has been made in the area of communicating the problems associated with accelerated soil acidification under *Stylosanthes* dominant pastures. This activity is associated with Project NAP3.22 "Communication of stylo management practices" coordinated by Col Middleton of QDPI. Over the reporting period field days on the properties Thalanga and Strathbogie were attended and presentations made on the potential problems associated with legume dominant pasture systems with respect to soil acidification and land degradation. In addition, presentations to research scientist visiting Davies Laboratory from India, China and Thailand have been made on the subject of accelerated soil acidification under legume based pasture systems. In cooperation with DPI and other CSIRO Divisions articles on 'Managing Stylo Pastures for Sustainable Production' and 'Soil Acidification: A Potential Threat to Legume Based Pasture Systems' have been produced for graziers and extension officers respectively. As a means of outlining the problem of acidification to graziers at field days a poster has been produced in collaboration with Col Middleton. A video feature on stylos was produced for the program Cross Country and an article on the problem of *Stylosanthes* dominance appeared in the Spring issue of NAP News 1997. Research articles have been written for Australian Journal of Experimental Agriculture and the National Soil Acidity Meetings. A complete list of articles is attached below.

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Plans for the coming year

The establishment of further permanent monitoring sites and the installation of a further 2 soil moisture monitoring sites will be undertaken over the next 12 months. Continued monitoring of soil solution nitrate and nitrogen flux will be undertaken on the Lansdown site. It is anticipated that greenhouse studies on the productivity of selected legume and grass species will be completed by the end of 1998.

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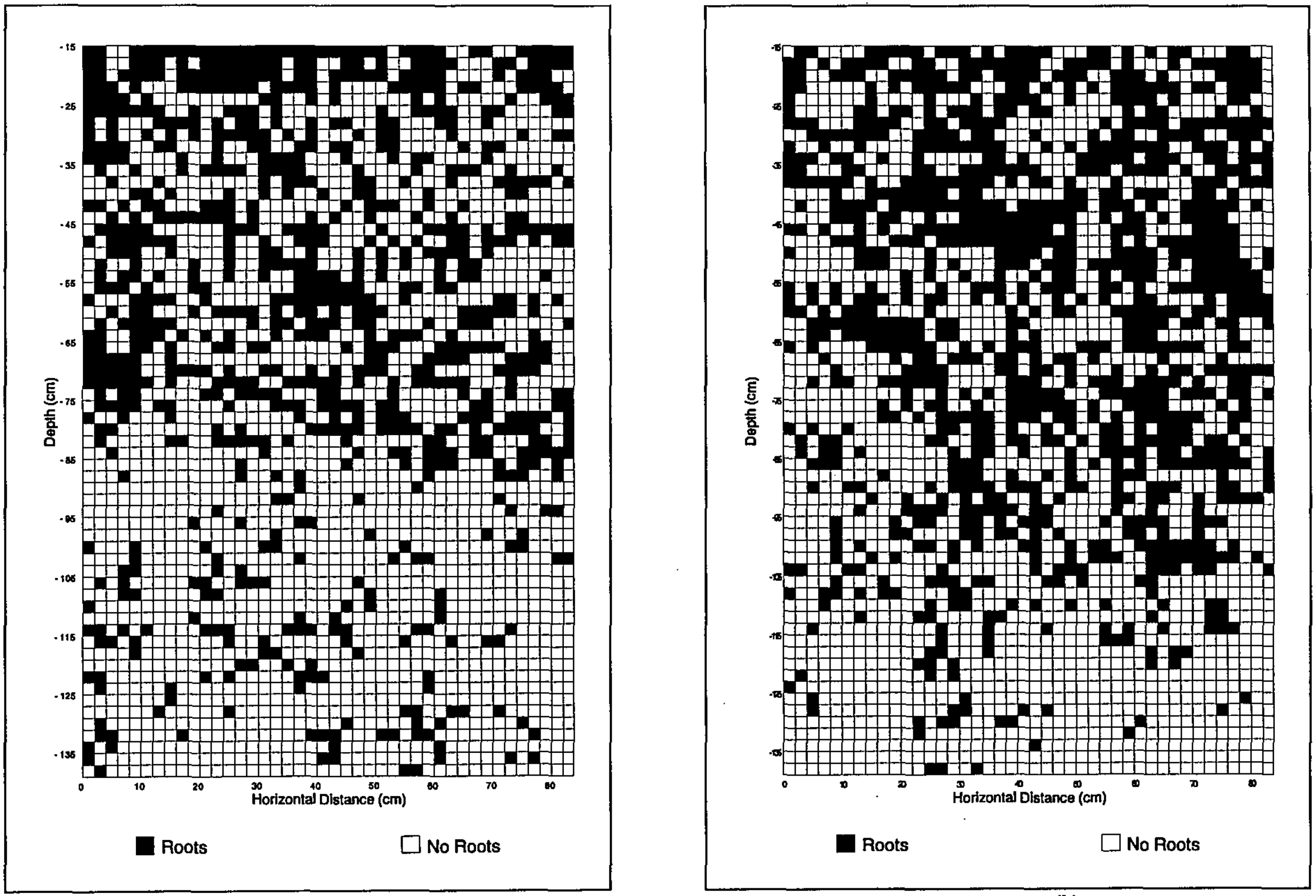

(a) (b)

Figure 1. Root profile distributions for (a) native grass lands and (b) *Stylosanthes* dominant pasture at Thalanga on a yellow brown earth with significant soft plinthic to indurate layers at depth.

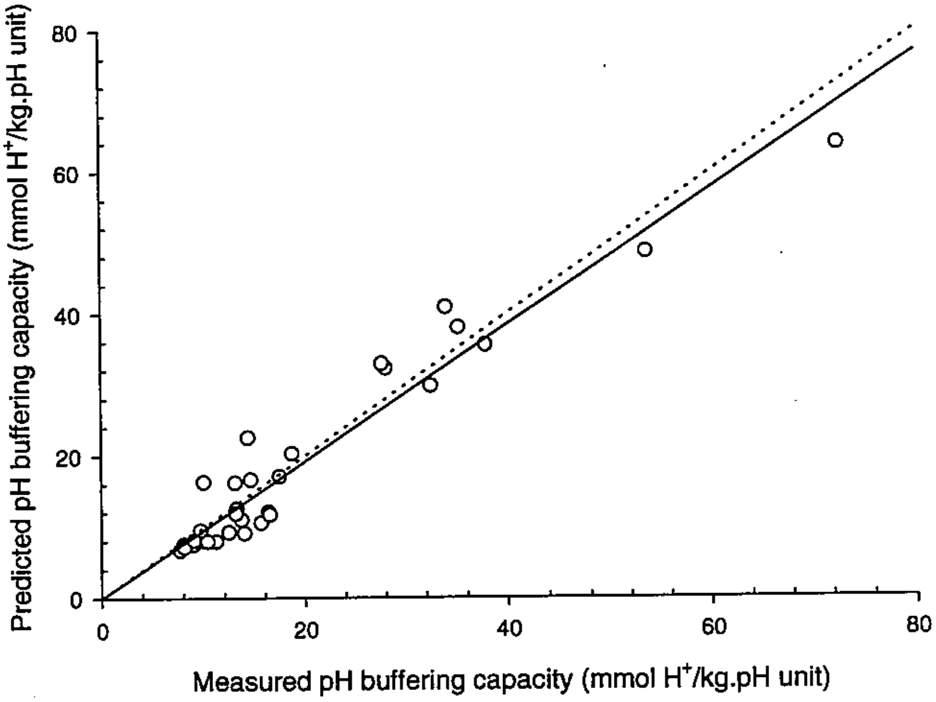

Figure 2. Validation of predicted pH buffering capacity against measured values for 31 surface soil samples from the Dalrymple Shire. The dotted line represents the 1:1 relationship between the two parameters. Equation for the solid line forcing the intercept through zero is: $y = 0.960(\pm 0.028)x$; $r^2 = 0.928$; $n = 31$.

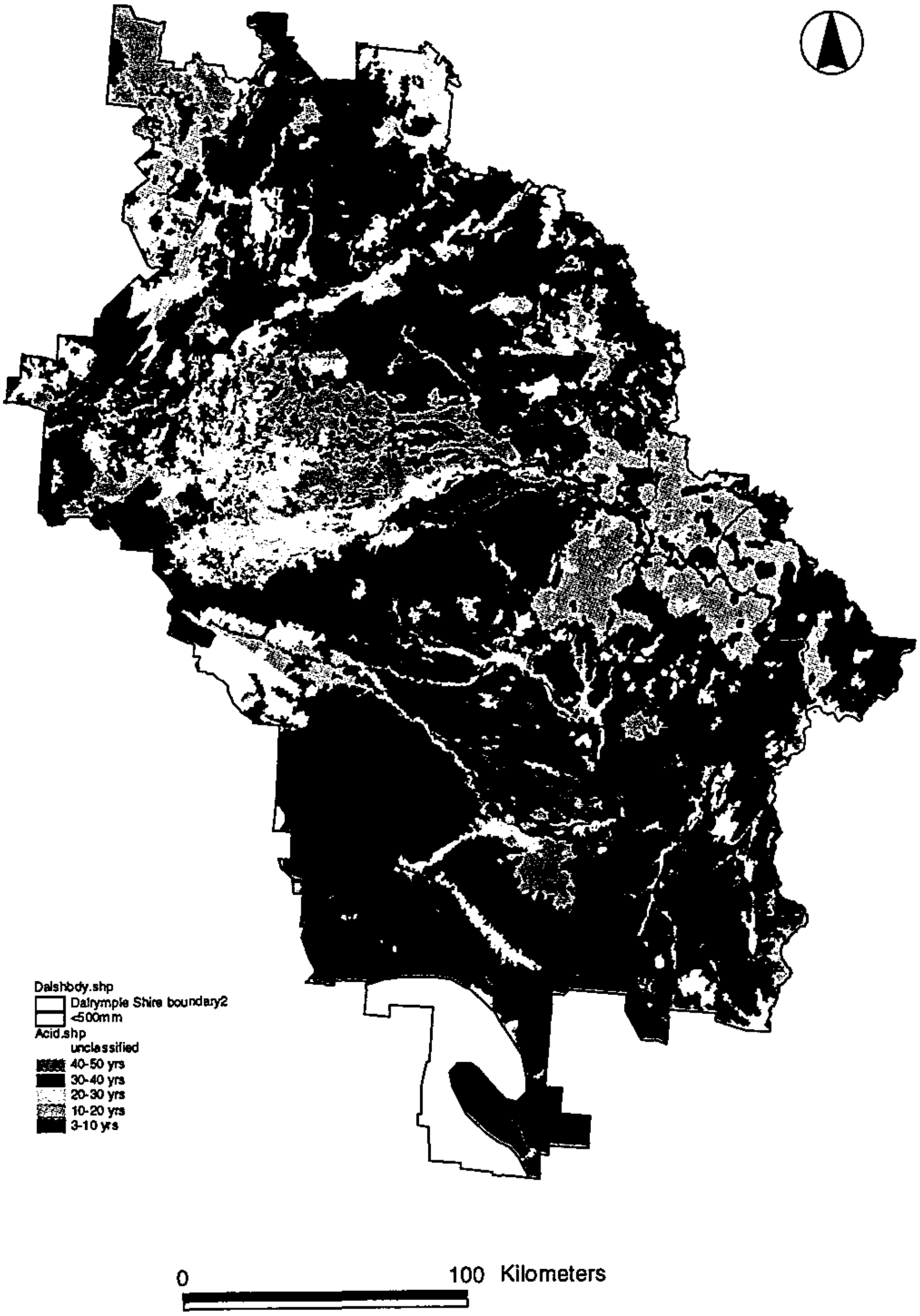

Figure 3. Acidification risk map for the Dalrymple Shire based on the time required for the soil pH to decline to 5.5.

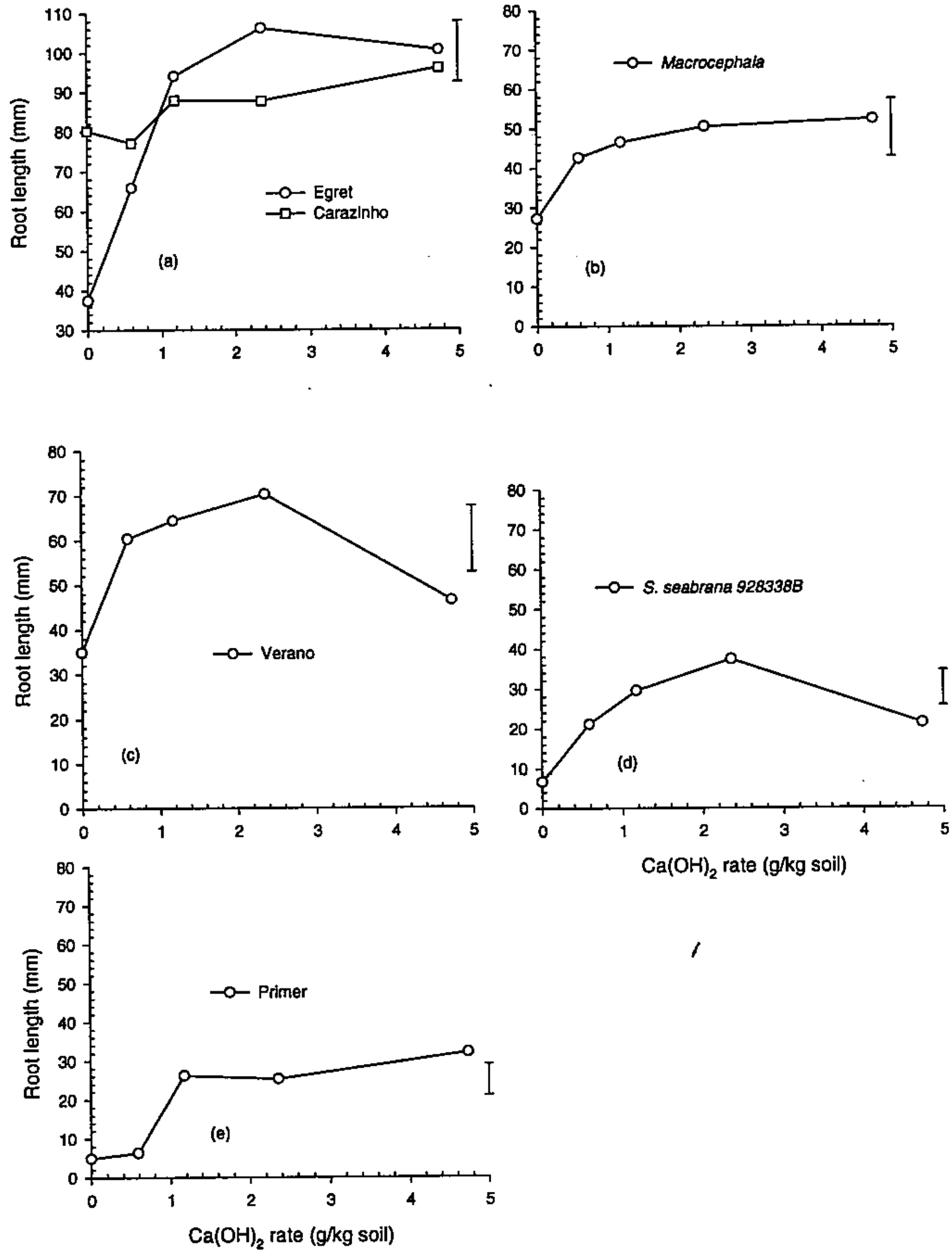

Figure 4. Root elongation in the presence of lime in (a) the wheat varieties Egret and Carazinho, and *Stylosanthes* varieties/species (b) *S. macrocephela*, (c) Verano, (d) *S. seabrana* 92838B and (e) Primer. Vertical bars represent the LSD between treatments at $P<0.05$.

Appendix 1

Draft of a field based test to estimate pH buffer capacity and acidity risk.

The test is designed for use by either graziers or extension personnel and focuses on the establishment of a risk index which is a measure of the number of years for the soil to reach a base pH of 5.0 in water. There are two stages in the process, namely collection of soil samples and preparation, measurement of pH, an estimation of the texture characteristics of the soil and finally, using pH and texture, an assessment of acidification risk.

Collection and preparation of soil samples:

1. Take a clean bucket into the paddock and collect surface soil samples (0-15 cm) using a soil auger or spade.
2. Collect samples randomly from a minimum of 5 locations in the paddock that exhibit uniform soil characteristics and place them in the bucket.
3. Spread the soil in a thin layer on a clean plastic sheet taking care to break up clods. Allow the soils to air dried, which may take several days.
4. Mix the soil thoroughly once it is dry making sure there are no clods.

Measuring the soil pH:

If you cannot borrow a pH meter you might consider purchasing one. There are a number of hand held pH meters that are on the market, which cost approximately $100. Check with the retailer before purchasing. It must be remembered that these are electronic pieces of equipment and must be handled, operated and stored with care. Note the pH meter requires calibration before use.

Measuring pH

1. For each of your surface soil samples weigh out 100g of soil into a clean 600 ml glass jar with lid.
2. Measure out 500 ml of <u>rainwater</u> or <u>distilled</u> water to give a 1:5 soil solution ratio. Place the lid on top of the jar and shake gently for 1 minute and then allow to stand for 2 hours.
3. After this time lapse, measure the pH of the soil suspension with a calibrated pH meter. Stir the suspension with the meter for a while and then wait 20-30 seconds for the meter reading to stabilise and record this value. Wash the glass bulb of the meter with rainwater or distilled water before and after each measurement.
4. Note this reading is referred to the pH in water. Sometimes pH is measured in a solution of calcium chloride. This lowers the reading by between 0.5 and 1.2 of a pH unit.

Estimating field soil texture

Soils mostly consist of particles of different size. The main classes being clay (<0.002 mm), silt (0.002 - 0.5 mm) and sand (0.5 - 2 mm). The word texture is used to indicate the relative amounts of these various sized units. An estimate of the field texture of a soil can be ascertained by the behaviour of a small handful of soil when moistened and kneaded into a ball and then pressed out between thumb and forefinger. The following method can be used:

- Take a sample of soil sufficient to fit comfortably into the palm of the hand.

- Moisten the soil with water, a little at a time, and knead until the ball of soil, so formed, just fails to stick to the fingers.
- Add more soil or water to attain this condition. This approximates the field moisture capacity of the soil.
- Continue kneading and moistening until there is no apparent change in the soil ball. The soil ball, or *bolus*, is now ready for moulding.
- Field texture grades may be defined by the by the behaviour of the moist bolus as set out in Table 1.

Field Texture Grade	Behaviour of moist bolus	Approximate clay content (%)
Sand	Little or no coherence; cannot be moulded; single grains adhere to fingers.	Less than 10
Loamy sand	Slight coherence; a 'sausage' can just be formed when the bolus is rolled between hand palms	10-15
Sandy loam	Slight coherence; a 'sausage' will form which will bend slightly before cracking	15-20
Sandy clay loam	Soil contains sufficient clay to be distinctly sticky when moist; the 'sausage' will bend readily before cracking; sand fraction is still obvious.	20-30
Sandy clay	The soil contains enough clay to allow the 'sausage' to be nearly bent in a circle.	30-55
Clay	The 'sausage' can be bent into a full circle.	Greater than 55

Using the soil pH that has been measured and the approximate field texture, an estimate of the number of years that it would take for the soil to drop to pH 5.0 in water is given in Table 2. Note it is assumed in the calculation of this time period that the annual input of acid is 2.5 kmol H^+/ha/yr (mean acid input of *Stylosanthes* dominant pastures), the soil bulk density is 1500 kg/m^3 and the soil depth is 15 cm.

Table 2. Estimates of the number of years for the soil to fall to a pH of 5.00.

Soil pH_w	Field texture class					
	Sand	Loamy sand	Sandy loam	Sandy clay loam	Sandy clay	Clay
5.5	3.7	4.6	5.4	7.6	13.7	15.2
5.6	4.5	5.5	6.5	9.1	16.5	18.3
5.7	5.3	6.5	7.6	10.7	19.2	21.3
5.8	6.0	7.4	8.6	12.2	21.9	24.4
5.9	6.7	8.3	9.7	13.7	24.7	27.4
6.0	7.5	9.2	10.8	15.2	27.5	30.5
6.1	8.2	10.1	11.9	16.7	30.2	33.5
6.2	8.9	11.1	13.0	18.2	32.9	36.6
6.3	9.7	11.9	14.1	19.8	35.7	39.6
6.4	10.5	12.9	15.1	21.3	38.5	42.6
6.5	11.2	13.8	16.3	22.8	41.2	45.7
6.6	11.9	14.7	17.3	24.4	43.9	48.8
6.7	12.7	15.7	18.4	25.9	46.7	51.8
6.8	13.5	16.6	19.5	27.4	49.5	54.9
6.9	14.2	17.5	20.6	28.9	52.2	57.9
7.0	14.9	18.4	21.7	30.5	55.0	60.9
7.1	15.7	19.3	22.8	32.0	57.7	64.0
7.2	16.4	20.3	23.9	33.5	60.5	67.1
7.3	17.2	21.1	24.9	35.0	63.2	70.1
7.4	17.9	22.1	26.0	36.6	66.0	73.2
7.5	18.7	23.0	27.1	38.1	68.7	76.2

Rationale behind the development of a field based test to assess risk of accelerated acidification on a paddock scale.

The previously discussed draft field based method for assessing risk (ie. number of years for the pH to fall to 5.0) is based on the determination of the field texture to which a pH buffer capacity is assigned. The assigned pH buffering capacity associated with each of the field texture classes was established using the Dalrymple Shire Land Resource data set. For each of the surface soils within a field texture class (based on laboratory determination of particle size distribution) the pH buffering capacity was calculated using the following equation:

$$pHBC = 6.28 - 0.11\, clay\% + 3.71\, OC\% - 0.16\, silt\% + 0.03 silt\% * clay\% \quad (1)$$

where pHBC has the units mmol H^+/kg.pH unit and OC is the organic carbon content of the soil. The pH buffering capacity for each of the texture classes was then subjected to statistical analysis, the results of which are presented in Table 3.

Table 3. Basic statistical analysis of pH buffer capacity for each of the field based texture classes for surface soil samples from the Dalrymple Shire Land Resource data base.

Parameter			Texture class			
	Sand	Loamy sand	Sandy loam	Sandy clay loam	Sandy clay	Clay
			pH buffer capacity			
Mean	8.31	10.25	12.06	16.93	30.55	33.88
Standard error	0.17	0.38	0.62	1.57	1.79	2.97
Median	8.11	9.75	11.25	15.33	29.59	31.48
Standard deviation	1.37	2.26	3.13	7.03	9.85	8.90
Minium	6.37	7.39	8.08	7.94	9.65	25.44
Maximum	13.61	16.61	20.03	39.31	49.38	53.95
Number of samples	60	35	25	20	30	9

It will be noted from Table 3 that range of pH buffering capacities values becomes larger as the clay content increases. This is due in part to greater range in clay contents assigned to each class as one moves from a sand clay loam to a clay (Table 1).

Using the mean values for pH buffering capacity for each of the field texture classes the amount of time taken for the pH to fall to 5.0 is calculated using the following equation:

$$T = [(pH_i - 5.0) \times pHBC \times BD \times V]/NAAR \quad (2)$$

where T is time in years; pH_i is the measured soil pH; pHBC is mean pH buffering capacity of the field texture class (kmol H^+/kg. PH unit); BD is soil bulk density (1500 kg/m^3); V is volume of soil in depth of 0.15 m; and NAAR is nett acid addition rate (kmol H^+/ha. year) which is assumed to be 2.5 kmol H^+/ha. year.

Potential constraints to the sustainability of legume based pasture systems in northern Australia and Thailand

Project Number: 96/196

A. D. Noble, S. Ruaysoongnern and B. Palmer

Progress Report
June 1998

General note

This document has been prepared as a general note on the progress to date on this ACIAR funded project. The document contains sections where information is still being collected and is therefore incomplete. The results to date have been divided into two sections based on distinct activities within the project.

Field based assessment of soil acidification under *Stylosanthes* based production systems in Northeast Thailand.

Background

A major constraint to animal production in northern Australia and Northeast Thailand is an inadequate supply of high quality feed throughout the year. Low quality pastures during the cool/dry season severely restrict animal performance. In order to rectify this shortcoming the inclusion of the shrub legume (*Stylosanthes scabra*; *S. hamata*) has been shown to be an ideal low cost method of improving the quality and dietary value of these pastures (Miller *et al.*, 1988, 1991). In this respect the introduction of these shrub legumes has had a significant impact on the profitability of the beef industry in north Australia. However, increasing use of *Stylosanthes spp.* in northern Australia (c. 1.2 million ha) and Northeast Thailand (c. 10 000 ha) with accompanying management practices, such as fertilisers and supplements, improved cattle breeds and increased stocking rates has not been without associated problems with respect to land degradation (McIvor *et al.*, 1996).

Surveys of long-term grazing trials with *Stylosanthes* in northern Australia have shown that significant acidification has occurred under *Stylosanthes* dominant pastures when compare to native grass systems (Noble *et al.*, 1997). In an extension of this work, a survey of several long-term *Stylosanthes* seed production systems was undertaken in Northeast Thailand to ascertain whether the same trends observed in northern Australia were occurring elsewhere where *Stylosanthes* has been introduced.

Methods and materials

A preliminary evaluation of acidification under *Stylosanthes* based pasture systems was undertaken by Dr Sawaeng Ruaysoongnern in order to ascertain whether accelerated acidification had occurred under *Stylosanthes* production systems and to identify sites for more intensive sampling. In the preliminary assessment, paired sites were selected and a single set of samples were collected to 100 cm at 10 cm intervals. Electrical conductivity, and pH in a 1:5 soil solution ratio was measured in both water and 0.01 *M* $CaCl_2$. From this initial broad based approach, five potential sites were selected to go forward into a more intensive sampling exercise undertaken in March 1998 (Table 1).

Table 1. Soil pH_s values measured on selected sites in a preliminary investigation into soil acidification under *Stylosanthes* based pasture systems in Northeast Thailand.

Depth (cm)	Nampong T3/1		Nampong T3/2		Satuk T2		Satuk T6		Korat T7	
	Control	Stylo	Control	Stylo	Control	Stylo	Control	Stylo	Control	Stylo
0 - 10	5.57	4.03	4.03	4.15	4.54	3.74	3.70	3.74	3.80	3.93
10 - 20	5.22	3.81	3.85	3.93	4.01	3.58	4.64	3.48	3.90	3.84
20 - 30	4.45	3.84	3.85	3.99	3.70	3.54	4.61	3.46	4.27	3.84
30 - 40	4.24	3.77	3.91	4.03	3.72	3.45	4.19	3.49	4.07	3.87
40 - 50	4.19	3.71	3.88	4.04	3.53	3.44	5.57	3.57	3.85	3.80
50 - 60	3.98	3.73	3.89	3.76	3.55	3.54	5.06	3.59	3.76	3.75
60 - 70	3.93	3.78	4.04	3.76	3.56	3.52	5.54	3.56	3.94	3.72
70 - 80	3.80	3.85	3.92	3.72	3.68	3.54	5.11	3.79	4.42	3.78
80 - 90	3.73	3.88	4.03	3.71	3.68	3.56	4.33	3.76	5.70	3.82
90 - 100	3.73	3.86	3.93	3.73	3.68	3.57	3.74	3.72	6.19	3.89
Mean	4.28	3.85	3.93	3.88	3.76	3.54	4.65	3.61	4.39	3.82

The 5 sites selected to go forward to a more intensive assessment were all seed production systems situated in Northeast Thailand (Table 2). This type of production system represent the most extreme case of *Stylosanthes* dominance and therefore the most susceptible to accelerated acidification. In order to assess changes in soil pH, a paired area approach was used to estimate the effect of *Stylosanthes* pasture on rates of soil acidification. The selection of sites was based on the following criteria: (1) the existence of a grass/crop dominated production system in close proximity to a *Stylosanthes* the seed production area of known history; (2) a well defined boundary (ie road or bund) separating the two production areas; (3) the same soil type in both areas; and (4) little topographical difference (ie slope) between the two areas. Samples were taken at five points in each area along a transect at right angles to the boundary separating the two areas. Sampling points were 2.5 m apart and at each point an auger hole was dug with samples being taken at 10 cm depth intervals to a depth 100cm.

Table 2. Selected soil properties and details of sites used in comprehensive sampling undertaken in March 1998.

Site No	Location	Local soil series	USDA classification	Age of plots	Acidification zone (cm)	Net acidification rate (kmol H^+/ha.year)
1	Nontun 48Q 0256913 UTM 1807082			(10)	20	1.90
2.	Chodyai 48Q 025 3597 UTM 180 2824			9	100	4.03
3.	M3 48Q03240 95 UTM 1785137			10	80	1.15
4.	Khon Kaen University					
5.	Sakon					

Samples were air dried and sieved to pass a 2 mm mesh before pH was measured in both water (pH_w) and 0.01 *M* $CaCl_2$ (pH_s) using 1:5 soil:solution. The pH_s measurements are presented in preference pH_w because dilute salt solution assists in reducing seasonal effects due to variations in soil solution salt concentrations.

An estimation of the pH buffering capacity (pH_{BC}), for 3 of the sites was made on composite samples from each depth interval for both the *Stylosanthes* and control areas. The methodology used differed from that previously used by Noble *et al.* (1997) since this method required an incubation period of 7 days. In this study buffering curves for each of the depth intervals and sites were produced using the methodology of Bruce *et al.* (1985) which is very similar to that of Aitken and Moody (1994) used previously. In this case the incubation period was only 22 hr. A modification to the Bruce *et al.*, (1985) was introduced in that 0.25 mL chloroform was added to the solutions to prevent microbial activity since in an earlier study in evaluating the method it was found that the final pH after 22 hr was significantly lower where chloroform was omitted (data not presented). The entire data set used to construct buffer curves for the samples from Thailand analysed at the Townsville laboratory are presented in Appendix 1.

Estimation of net acid addition rate

The net acid addition rate (NAAR, kmol H^+/ha.yr) to the *Stylosanthes* based pasture area was calculated relative to the adjacent control area at each site for each depth interval using the following equation:

$$NAAR = [(pH_C - pH_S) \times pH_{BC} \times BD \times V]/T \quad (1)$$

where the subscript C and S refer to the control and *Stylosanthes* areas respectively; pH_{BC} is the mean pH buffering capacity (kmol H^+/kg soil. pH unit) of the control and *Stylosanthes* areas; BD is soil bulk density (kg/m^3); V is the soil volume in the depth interval under consideration (m^3/ha); and T is time (years) since the establishment of the *Stylosanthes* pasture. The net acid addition due to the introduction of *Stylosanthes* was estimated from the sum of all depth intervals where there was a difference in pH_s between the two sites.

Statistical analysis

In order to avoid auto-correlation with depth in the profile, statistical analysis was carried out for each site x depth combination, thereby testing for any effect due to the contrast between the *Stylosanthes* and control areas for that particular depth interval. The statistical package Genstat5 was used in all analyses.

Results

The pH_s results from the preliminary assessment of sites are presented in Table 1. Whilst a rigorous statistical assessment of changes in pH due to acid addition is not possible due to the lack of replication, the data clearly shows that the mean profile pH_s under the *Stylosanthes* based production systems was lower than that of the control. A distinct characteristic of sites sampled in this preliminary survey was the very low pH values recorded throughout the entire sampling depth.

The location, soil classification, annual rainfall and site history for the 5 sites included in the comprehensive assessment are presented in Table 2. The soils were of a sandy to sandy loam texture and were dominated by fine sands and silt with only a slight increase in clay content with depth. These soils are massive when dry with extremely high bulk densities. The pH values under the *Stylosanthes* dominant production systems were significantly ($P<0.05$) more acid than under the adjacent control area in all 5 sites presented in Figure 1. The extent of acidification ranged from significant measurable changes in pH that were confined to the top 20 cm (site 3) to what may be termed severe subsurface acidification extending to over 90 cm (Figure 1). It is of note that the pH_s were extreme and would indicate severe acidification. Under these conditions one would expect the exchange complex to be dominated by Al^{3+} with very low levels of base saturation.

The pH buffering capacities for selected sites (sites 1, 2 and 3) were extremely low throughout the entire soil profile (Table 3). This is in part due to the low clay content and organic carbon. An estimation of the NAAR was undertaken assuming an average bulk density of the soil of 1.5 g/cm^3 and the length of time under *Stylosanthes* as outlined in Table 2. The acidification rates ranged from 1.15 (site 3) to 4.03 (site 2) kmol H^+/ha.year (Table 2).

Table 3. Soil pH buffer capacities as determined on bulked samples from the control treatments.

Depth	Site		
(cm)	1	2 (mmol H^+/kg.pH unit)	
0-10	4.88	5.44	5.26
10-20	6.15	4.43	6.12
20-30	3.00	5.08	5.90
30-40	2.91	6.28	6.24
40-50	2.91	8.63	6.09
50-60	2.73	21.00	8.42
60-70	2.84	12.94	6.63
70-80	3.85	13.74	6.23
80-90	4.33	12.80	7.47
90-100	4.55	11.79	7.05

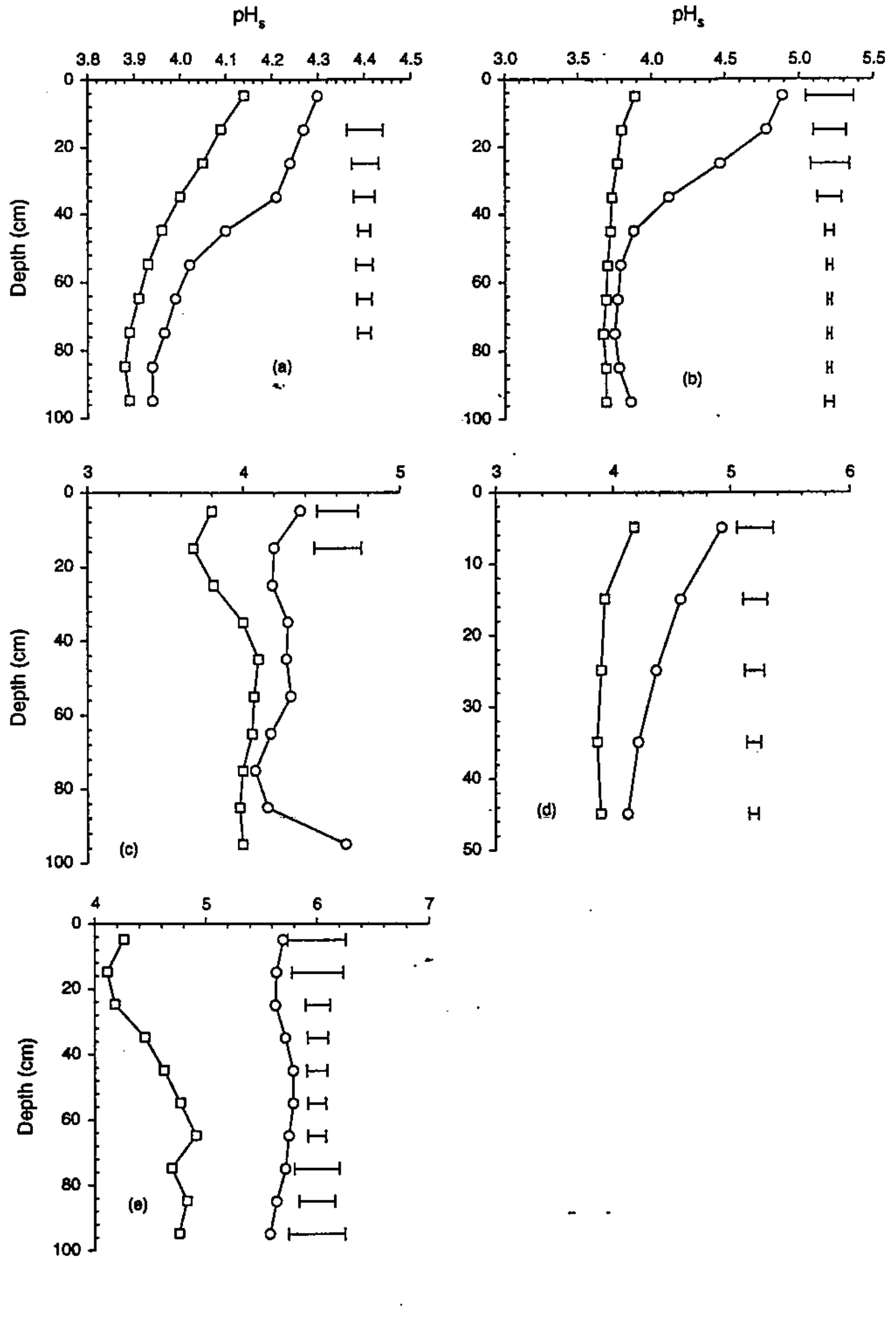

Figure 1. Soil pH$_s$ (0.01 *M* $CaCl_2$) profiles for sites sampled during survey of Northeast Thailand *Stylosanthes* production systems. (a) M3, (b) Chodyai, (c) Notun and (d) Khon Kaen University, (e) Sakon. *Styolsanthes* (□) production systems and a reference site (O). Horizontal bars represent the LSD ($p<0.05$) for that specific depth interval.

Discussion

Acidification rate

The results from this study clearly demonstrate that with the introduction of a *Stylosanthes* production system there has been significant measurable declines in soil pH over a relatively short period of time and confirms previously reported observation for extensive legume based pasture systems in northern Australia (Noble *et al.*, 1997). Whilst soil acidification rates can be estimated as absolute changes or relative to some control soil, the former is often used due to the lack of comprehensive data sets. Using the first method, acid addition rates are calculated from analyses of soils before and after a period of acidification. This requires comparable measurements usually separated by many years. However, relative rates of acidification can be derived from survey data (e.g. fence-line contrasts of developed and undeveloped sites) such as in this study and are more often reported, because of the paucity of suitable data from long-term studies. Because it is likely that acidification occurs in the controls but at a slower rate than on the *Stylosanthes* sites, it can be argued that the rates of acidification presented in Table 2 are conservative. Previous studies by Noble *et al.*, (1997) have shown this to be the case for northern Australian sites surveyed. In addition, the values for pH buffering capacity could be questioned since the methods available do not properly estimate the slow reactions due to the dissolution of aluminium and silica (Ridley *et al.*, 1990a). In previous studies this aspect has not been taken into consideration (Ridley *et al.*, 1990a; Dolling and Porter, 1994; Dolling, 1995). If these slow reactions are indeed significant, actual pH buffering capacity values would be higher than shown in Table 3 and consequently the calculated rates of acidification conservative. In deed, the dissolution of solid phase Al and Fe have been reported on these soils (Brinkman and Dieleman, 1977), thereby acting as a potential sink for protons.

When estimating the pH buffering capacity of a soil it is assumed that there is a linear relationship between pH and acid added. This relationship is only true in the pH range 4.5 to 6.0 and where the neutralisation of exchangeable Al is of minor importance. However, under the prevailing circumstance this may not be the case. A plot of acid/base addition versus pH is given in Figure 2 for selected depth intervals for the Chodyai site (site 2). It is evident from the shape of the curves that as the pH drops below 4 linearity decreases. This would result in an under estimation of the acid addition if a linear relationship was assumed. In the current study we have assumed linearity and consequently the estimation of net acid addition should be treated with caution.

Previous studies of acidification under legume based pastures in temperate Australia have found that the pH_{BC} is raised following the introduction of a legume component in the sward (Ridley *et al.*, 1990a; Dolling and Porter, 1994). However, this has been shown to be not the case in *Stylosanthes* based pasture systems of northern Australia where there has been no significant changes in soil organic carbon after the introduction of *Stylosanthes* (Noble *et al.*, 1997). This is probably a direct result of temperature and rainfall which are conducive to increased mineralisation. In Northeast Thailand where periodic cultivation is undertaken and where the entire crop is removed, the probability of organic carbon increasing under *Stylosanthes* is extremely low.

Net acidification rates under *Stylosanthes* based pasture production systems in Northeast Thailand are similar to those reported for the semi-arid tropics of northern Australia by Noble *et al.* (1997) and by Moody and Aitken (1997) for pastures in the humid tropics. Noble *et al.* (1997) reported rates of 0.2 to 10.6 kmol H^+/ha.year for northern Australian production systems, with the extreme rate being measured on an irrigated commercial seed production system. Moody and Aitken (1997) reported rates of between 1.0 to 11.0 kmol H^+/ha. year for production systems ranging from grazed grass/legume pastures through to fertilised hay production systems. Similarly, Ridley *et al.* (1990) working in temperate Australia reported acidification rates of 2 kmol H^+/ha. year under grazed annual grass/legume pastures and 1.36 kmol H^+/ha. year under comparable pastures based on the perennial grass phalaris instead of annuals. In the current study the acidification rates are comparable to those reported by Noble *et al.* (1997).

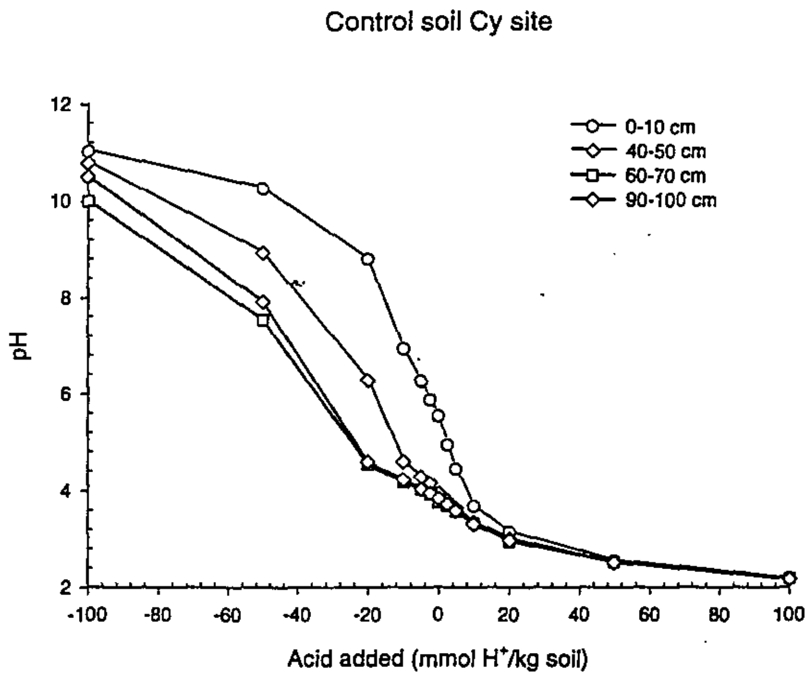

Figure 2. pH buffer curves for the Chodyai site (site 7) for selected depth intervals.

Acidification processes and agricultural systems

The rate of acidification following the introduction of *Stylosanthes* can be assumed to be a function of (i) soil (ii) climate and (iii) the population density of *Stylosanthes*. The systems that were sampled in this study were predominantly seed production systems and would therefore represent an extreme situation with respect to plant population density. These production systems are characterised by the entire removal of the crop to some location in the field where threshing of the seed is undertaken and subsequent burning of the trash. The removal of all above ground biomass at harvest would represent a net export of alkalinity from the site. In this respect the ash alkalinity of a number *Stylosanthes* accessions have been determined (see section below) and found to range from 81.1 to 130.4 $cmol_c\ kg^{-1}$ which is equivalent to 40.6 to 65.2 kg $CaCO_3$ per tonne of *Stylosanthes* dry matter. This would represent a significant addition to the proton pool over time. In contrast to these monoculture systems Noble *et al.* (1997) have reported that on soil with a high inherent buffering capacity and an equitable distribution of legume and grass in the pasture, no significant acidification has occurred over a 20 year period.

In evaluating the various components that contribute to net acidification, it is difficult in the current study to directly apportion absolute values to the various components due to a lack of records or measurements. However, it is pertinent to discuss the potential contributors to this process. Net acidification due to product export, namely the harvesting of the crop for seed, may be largest contributor to acidification. Depending on the size of the crop harvested and the ash alkalinity of the material one would assume that the net contribution due to product removal could be substantial. Using the previously quoted ranges of ash alkalinity as measured on a set of samples from Lansdown, northern Australia, a mean value of 91.5 $cmol_c$ H^+/kg on dry matter basis could be expected for the varieties grown in Northeast Thailand. This would effective equates to 0.91 kmol H^+/ha.year per ton of material removed. With the entire removal of the crop, the opportunity for nitrogen mineralisation of plant material is minimised therefore the potential for nitrate leaching and its associated acidification is reduced. Whilst no attempt was made to evaluate the mineral nitrogen status of the soils sampled there is evidence from northern Australia where there has been significantly elevated nitrate levels in a profile dominated by *Stylosanthes* in comparison to an adjacent *Urochloa mosambicensis* (Sabi grass) dominated pasture (Noble *et al.*, 1997). In these northern Australian pasture systems there is evidence to suggest that nitrate leaching may be the dominant mechanism of acid input since the quantity of acid added in product export (beef cattle) is negligible. In these extensive beef systems it is speculated that with the onset of the first rains significant mineralisation of organic nitrogen could occur and in the absence of an actively growing pasture sward leaching of nitrate could follow. Similar effects could be expected under the monoculture production systems of Northeast Thailand.

Minimising the risk of acidification

The extent of acidification over a relative short period of time should be of concern on these light textured soils. These soil have an inherently low buffering capacity and are therefore predisposed to rapid acidification. From a practical perspective the remediation of acidity using conventional surface applications of lime over extensive areas of northern Australia and parts of Northeast Thailand may be both ineffectual, due to the extremely slow vertical movement of surface applied lime (Coventry, 1992), and uneconomic. In addition, the problem of over liming resulting in potential micronutrient deficiencies is a distinct possibility on these light textured soils. Consequently, management strategies to minimise the impact of these production systems need to formulated. Within the extensive grazing systems of northern Australia a series of strategies that focus on reducing *Stylosanthes* dominance in the sward and promoting a more balanced grass/legume population is being promoted.
These strategies include:

1. In situations where legume dominance has occurred, the use of fire in the early spring followed by reduced grazing pressure will promote the growth of perennial grass species such as *Heteropogen contortus* in the pasture thereby reducing legume dominance. Since *Stylosanthes* is relatively intolerant of fire this strategy will result in re-establishment by seed of the grass species and allow a competitive advantage for the regeneration of the grass component.
2. Grazing management which favours seed production by perennial grasses during the summer through spelling and reduced grazing pressure. In addition, minimising the spread of legume seed by grazing animals.
3. The establishment of pasture species that are tolerant of grazing pressure would reduce the risk of legume dominance occurring in a sward. Species such as *Urochloa mosambicensis* and *Bothriochloa pertusa* have been identified as possible species that may fill this niche (McIvor *et al.*, 1996). In addition, these species which have a vigorous growth habit and therefore a high demand for nitrogen, have the ability to capture nitrate before it is leached. This would significantly reduce the risk of nitrate leaching and associated acidification.
4. In legume dominant swards the addition of phosphorus may assist in maintaining perennial grasses in the pasture. Conversely, the planting of *Stylosanthes* could be confined to soils that have a high inherent phosphorus status so that grasses can better compete with the legume.
5. Given that the management of oversown pastures can be extremely difficult it is suggested that planting small areas to legume and managing these areas intensively may reduce the risk of widespread accelerated acidification. Typically these areas would be confined to soils having a high pH buffering capacity or to areas with an inherently high P status.

Whilst these options may not be relevant under current production systems in Thailand, they do offer an insight into potential ways of managing the problem.

The positive impacts of legume introduction on the soil resource base may be evident in the increase in the inherent fertility of the soil through the fixation of nitrogen and its subsequent transfer to the soil (this may need to be substantiated). The results of this study clearly show that the impact of *Stylosanthes* introduction on accelerated soil acidification is more pronounced on soils having a low buffering capacity. If this acid is not neutralised, ultimately the pH falls to a level where the soil resource is degraded and becomes less productive. Key management strategies that promote the maintenance of an equitable grass/legume composition will slow down the rate of acidification by capturing greater amounts nitrogen. However, these changes which may have negative impacts on production in the long-term have to be viewed in the context of the short to medium term benefits of legume establishment in native pastures.

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Management Of Native Pastures Oversown With Stylo

MRC Project: NAP3.221 **Project Duration:** 1/7/93-30/6/2001 **Report Date:** 1/7/98

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Project Objectives:

Identify and communicate practical methods of maintaining a balance of grass and legume in oversown native pastures by:

(1) testing management options (fire, grazing) for maintaining native perennial grasses in pastures oversown with *Stylosanthes* species;
(2) developing methods for introducing and managing exotic grasses into stylo-dominant pastures;
(3) assessing the economic benefits of different management systems;
(4) communicating and promoting management practices that encourage stability and productivity of oversown pastures

Summary:

To help identify effective management options for managing the grass-legume balance in stylo-based pastures, a field experiment was established near Dimbulah during 1993-94 using an existing stylo-dominant pasture (Seca and Verano). Combinations of various stocking rates, wet-season spelling, fire and seeding with exotic grasses, are being evaluated. In addition, commercial stylo-based pastures in the Einasleigh and Burdekin regions are being monitored to document the extent of stylo dominance and the success of introduced grasses.

The experimental site was heavily stylo-dominant (>90% of pasture as stylo) and was initially very resistant to change regardless of management. However, a combination of fire and spelling is now producing a significant recovery in native grasses, as a consequence of less competition from stylo plants and greater generation of new grass seedlings. Opportunities to effectively burn these pastures have been few, due to lack of fine fuel. However, even patchy fires have reduced the amount of Seca, in favour of grass.

Sowing exotic grasses into cultivated portions of each paddock was successful, after the second attempt, and these grasses (predominantly Sabi grass) now contribute up to 50% of pasture in the sown portions. Fire and light grazing pressure have favoured the sown grasses over stylo.

Commercial stands of stylo that were sown during the 1980's now contain up to 90% Seca, so will be resistant to attempts to increase the grass component . Stylo pastures sown during the 1990's were slow to establish, due to poor seasons, but now contain up to 30% legume. Where grass seed (usually sabi grass) has been included in the seed mix, it has usually taken 5 years or more to produce a significant sown grass component in the stand.

Results and achievements

Background to project

There is concern over the long-term stability of native pastures oversown with stylo, due mainly to observations of stylo dominating pastures to the exclusion of perennial native grasses. This in turn increases the risk of weed invasion, accelerated erosion, increased variability in animal production, and soil acidification.

Native perennial grasses are displaced by stylo because of (1) increased grazing pressure on grasses and (2) competition from stylo plants. Varying the overall grazing pressure and wet-season spelling are two options for favouring native grasses. Fire kills at least some stylo plants and intermittent burning therefore offers a potentially potent way of managing the balance of native grass and stylo. An alternative strategy is to sow seed of introduced grass species that may compete and persist better under current management. A field experiment was set up to compare the relative effectiveness of combinations of these options for restoring and maintaining the grass component in an existing stylo-dominant pasture. We are also monitoring the composition and vigour of a wide sample of commercial stylo pastures to document the extent of stylo dominance and the success of introduced grasses.

Methodology

The field experiment commenced in 1993 on Mr Neil Davis's property on Eureka Creek, west of Dimbulah. The 15-ha area is part of a paddock that was sown to Seca and Verano in 1982. By 1993, the pasture was dominated by the stylos with little grass cover remaining. Different combinations of grazing pressure, spelling during the early wet, fire, and sowing with introduced grass, have been implemented to form a suite of treatment plots with 2 reps of each (see Table 1).

Table 1. Grazing, fire, and sowing treatments at the experimental site.

Treatment number	Grazing pressure (stocking rate)	Fire	Early wet spell[2]	Exotic grasses[1]
1	low (5.25 ha/hd)	yes	no	10% of area
2	low	no	yes	10% of area
3	medium (3.5 ha/hd)	no	no	10% of area
4	medium	no	yes	10% of area
5	medium	yes	no	10% of area
6	medium	yes	yes	10% of area
7	high (1.75 ha/hd)	no	yes	10% of area

[1] mix of Indian couch (*Bothriochloa pertusa*), buffel (*Cenchrus ciliaris*), and Sabi grass (*Urochloa mosambicensis*)

[2] spelling from the break in the wet until the black speargrass plants commence flowering

Results

Rainfall

Wet season rainfall at the experimental site for 1997-98 was above average, for the first time since the trial began (Table 1).

Table 2. Seasonal rainfall by year at the experimental site

	1993/94	1994/95	1995/96	1996/97	1997/98	Long-term average
Wet season	330	551	552	529	781	723
Dry season	5	62	141	70		73

Maintaining perennial native grasses in stylo pastures
(These results pertain to the area of each paddock not sown with grasses)

The experimental site had very little native perennial grass remaining when the experiment commenced, so our results relate more to the restoration of native grasses rather than to maintaining an already healthy contribution of grasses. Standing crop (SC, the amount of standing pasture) in all pastures contained about 90% stylo at the start of the experiment (1993-94 growing season), with Verano contributing most to SC (50-60%, see Fig. 1).

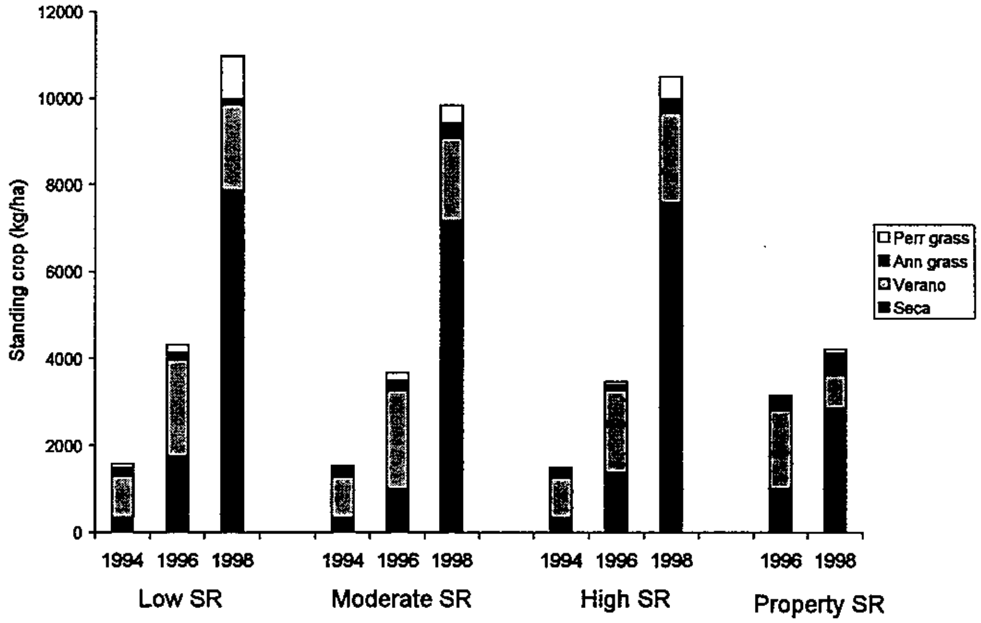

Fig. 1. Changes in standing crop and composition between 1994 and 1998 for pastures grazed at either low, moderate, high, or "property" stocking rates.

Stocking rate has had little effect on the grass-stylo balance in these pastures (Fig.1). Total standing crop has steadily increased at all stocking rates, with a small boost to native grasses under the lightest stocking pressure. Interestingly, even the highest stocking rate is clearly much lighter than the grazing pressure outside the trial area under normal commercial management (Fig. 1).

Fire has been the key to initiating changes to the grass-stylo balance in this experiment. Only patchy, infrequent fires have been possible due to lack of fine fuel, but this has still been sufficient to increase the amount of perennial grass in the pasture to 18% of SC, compared to only 7% in the absence of fire (Fig. 2). While this is only a small absolute increase, the amount of grass has likely reached the critical mass required to accelerate the rate of recovery. This is also reflected in the data on frequency of perennial grasses (a measure of abundance and distribution through the paddock). Fire has also changed the structure of the pasture sward, with less "woody" stylo thickets and more patchiness in pasture composition. Spelling, on the other hand, has had relatively little effect on native grass recovery.

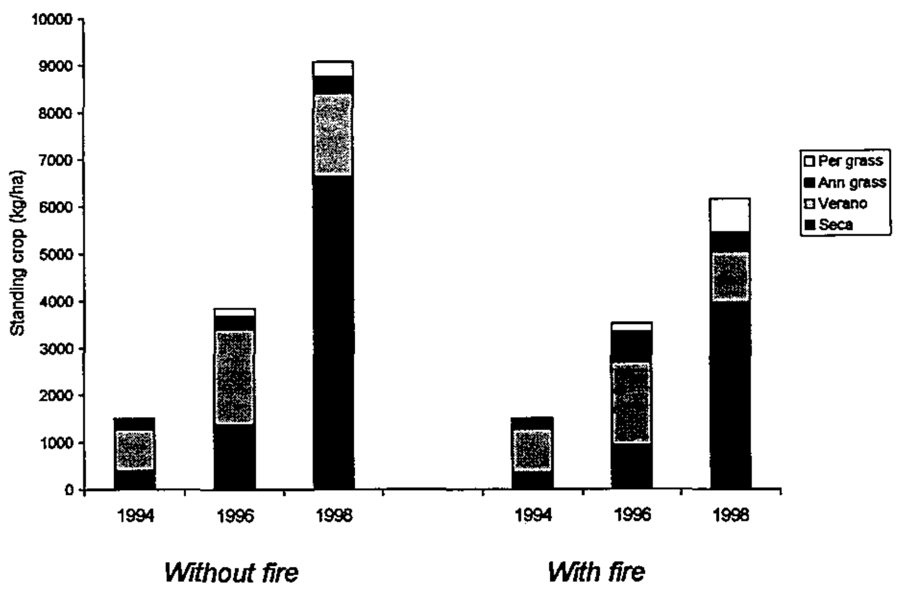

Fig. 2. Effect of fire on the standing crop and composition of pastures between 1994 and 1998

Establishing sown grass into stylo-dominant pastures
(These results pertain only to the sown portion of each paddock)

Establishment was satisfactory for all 3 grass species (after a second sowing), but Sabi quickly became the dominant sown grass, contributing up to 40% of SC by the end of the 94-95 season. As expected the pre-sowing cultivation reduced stylo yield and density dramatically but Verano recovered quickly such that it was the dominant pasture species (43-70% of SC) in the cultivated portion of paddocks by the end of the 1994-95 season (Fig.3). Seca, by comparison, contributed less than 2-4% of SC at this time. Interestingly, Seca has regained its dominance in the sown area of each paddock, but the over-all balance of Seca, Verano and sown grasses varies depending on management.

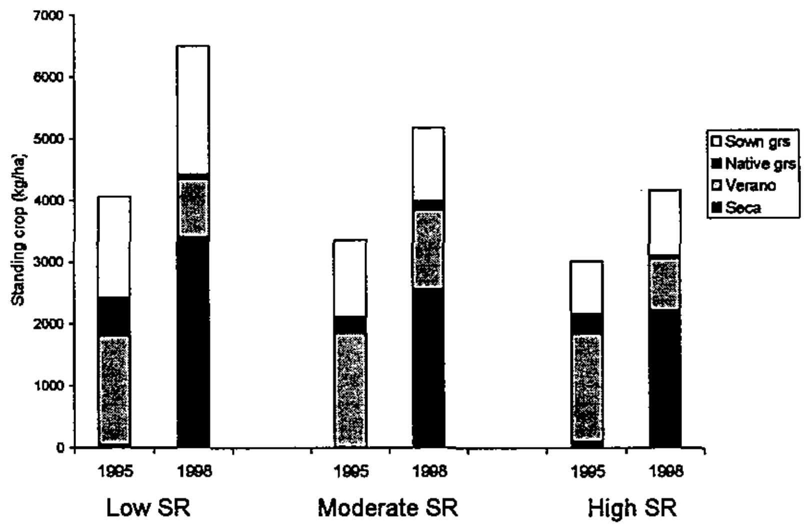

Fig. 3. The effect of stocking rate on the balance of grass and stylo in the sown portion of each paddock

Stocking rate affected total standing crop, but has had little effect on the balance of grass and stylo (Fig. 3). Light stocking has only given the sown grasses a slight advantage over stylo, compared to heavier stocking rates, and has not retarded the resurgence of Seca. All combinations of spelling and fire are being tested under the moderate stocking rate, so comparison of the current compositions of these paddocks (Fig. 4) shows the potential for fire and/or spelling to influence the balance of sown grass and stylo. In the absence of either fire or spelling, stylo dominates the sown areas (>70% of SC). In contrast, a combination of fire and spelling has produced a 50:50 balance of grass and stylo (Fig. 4).

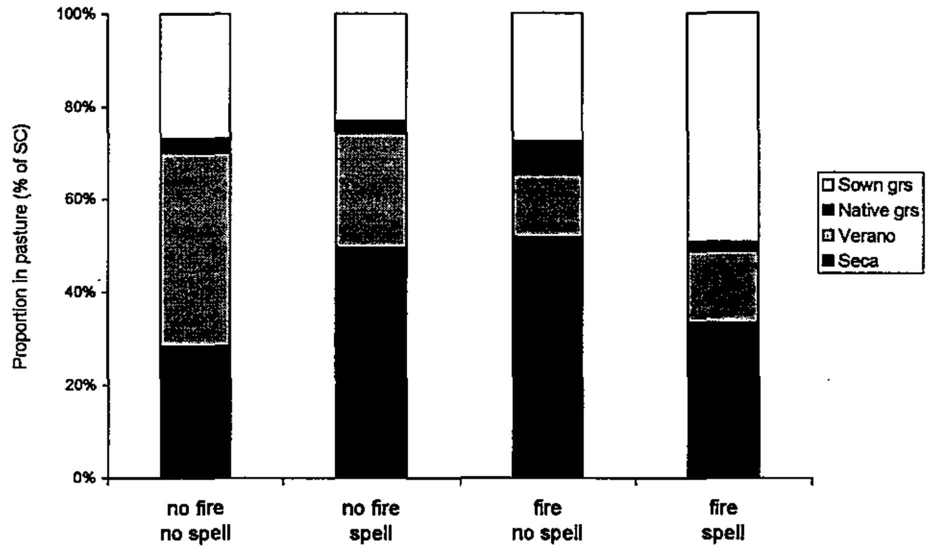

Fig. 4. The effect of fire and/or spelling on the current balance (% of SC) of grass and stylo in the sown portions of paddocks grazed at a moderate stocking rate.

Grass-stylo balance in commercial stands

The balance of grass and stylo in 18 commercial pastures, located in the Mareeba, Georgetown, and Charters Towers areas, was measured in 1995 and again this year. There is a mix of recently-sown and older sites, and most sowings had included some grass seed. In 1995, the younger pastures (sown 1991-93) had little legume and were generally dominated by native pasture. This year, most of these pastures have 10% to 30% legume but the content of sown grass varies from 5% to 85%. Older pastures (sown 1983-89) were stylo dominant (50 to 70% of SC) in 1995. Stylo has continued to build up at these sites, with standing crop at some sites of 6000-9000 kg/ha, 80 to 90% of this being stylo.

Conclusions:

- Once pasture becomes heavily stylo dominant, it is resistant to simple management options such as spelling and fire. Such options should be applied before stylo exceeds 60% or so of the pasture.
- Simply adjusting stocking rate is not likely to greatly influence the grass-stylo balance. Fire is required to give a competitive edge to grasses, and wet season spelling may also be beneficial.
- Exotic grasses such as Sabi grass may be more competitive with stylo than native grasses, but reliable establishment is problematic.
- Existing commercial stylo pastures should plan to use fire and spelling to manage a healthy mix of stylo and grass. New sowings should include seed of colonising grass species.

Communication Activities

- Twelve producers attended a field day on productivity and management of stylo at "Thalanga", west of Charters Towers, on 20th November 1997.
- The importance of maintaining a healthy mix of grass and stylo was one of the issues covered in several pasture management workshops held in the Charters Towers district.

- A short article reporting the major findings of the project is being prepared for distribution to regional newspapers and newsletters

Planned activities

- Complete and circulate the media article, and prepare a technical note for inclusion in NAP News and the newsletters of the Tropical Grasslands and Aust. Rangelands Societies.
- Hold a field day at the experimental site in April 1999.
- Prepare a paper on stylo-grass management for the International Rangelands Congress in Townsville, July 1999.
- Lobby for, and assist with, the integration of project findings into all pasture extension material and modules (eg FutureProfit).

Publications

Cooksley, D. G. (1996). Maintaining and establishing grass on oversown pastures. *Tropical Grasslands* 30:153.

Quirk, M. F. (1997). Managing stylo pastures. Thalanga Field Day Booklet.

Communication of Stylo Management Practices

Project No: NAP3.220 (PROMIS 2323)

Duration: 01/10/1997 to 01/04/2001

Milestone: Peer Group Report and Meeting by 31/08/98

Principal investigators:
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Workshop Group - A group of about 30 pasture scientists, extension workers, graziers, agri-business and R&D funders.
Producer Consultative Group - A group of producers to oversee and review the project.

Project objectives:

By June 2001 ensure that the majority of producers with stylo-based pasture are made aware of management strategies and practices that can reduce the incidence of acidification and erosion so as to improve long term production and sustainability.

Project summary:

A project aimed at minimising the potentially bad effects of legume (stylo) dominance on soils was commenced in the latter part of 1997. The project was designed in response to a recognition by scientists and graziers that situations existed where stylo could dominate native grass and that this legume dominance could lead to increased soil acidification and soil erosion. In August 1997 an industry workshop identified management guidelines and mechanisms for their promotion.

The identified management guidelines to reduce the risk of legume dominance included: identification and mapping of 'at risk' environments; strategic control of grazing pressure; summer spelling to promote grass seed production; periodic summer burning to reduce stylo and promote grass; use of 'grazing resilient' grasses to compete with stylo; use of fertiliser to promote grass in specific situations; particular strategies for legume seed and hay crops; the use of GRASS CHECK to monitor pasture changes.

To date a Technical Note on soil acidification has been prepared (Andrew Noble - CSIRO) and distributed to Technical Field Staff. The guidelines have been prepared. Awareness articles were published in the NAP and Tropical Grassland Society Newsletters, Cross Country TV, ABC Country Hour, local ABC Breakfast Session (twice) and Landcare Newsletter (Marlborough). Stylo Management has featured in two major Field Days (North Qld) and two Landcare Field Walks (Central Qld). A 3-fold colour brochure is under preparation for mail-out at the beginning of 1998/99 summer season. The mail-address database has been prepared. Similarly the material will be available in electronic form (DPI Notes, Farm Fax, Prime News CD ROM and DPI Web Site) by Spring 1998.

PROGRESS REPORT 1997-98

1) Problem definition:

Pasture scientists and producers have been aware for some time that stylo could dominate native grass pastures in some situations. While high legume content improved animal performance there was a potential problem with soil exposure to erosion where grass cover declined to a low level. A MRC commissioned review (McIvor, Noble and Orr 1998) of the stability of native pasture oversown with legume highlighted the problem of legume dominance and the associated risks. Noble *et al* (1997) emphasised problems with stylo dominance when they showed that unused nitrogen 'fixed' by stylo dominant pasture caused significant soil acidification when leached down the soil profile.

Industry workshops were convened by MRC in Novenber 1996 and June 1997 to review the situation. The 1997 workshop brought together pasture specialists in research and extension together with the practical use and management of stylo-based pasture provided by graziers. The workshop outcomes were:

- stylo-based pasture had a highly beneficial economic effect on beef production
- there was emerging evidence that stylo dominance at the expense of native grass could expose the soil to degradation in particular situations
- there already was a body of knowledge and practical experience available on management practices that would assist in maintaining grass/legume balance in pasture
- in the interest of the long-term production and stability of stylo-based native pasture 'best practice' management guidelines should be widely promoted by a wide range of extension methods.

2) Defining the objectives and methodology

The objective as defined at the workshop was: *by June 2001 ensure that the majority of producers with stylo-based pasture are made aware of management strategies and practices that can reduce the incidence of acidification and erosion so as to improve long term production and sustainability.*

It was agreed that the collective experience of the workshop group would be used to identify and contribute to the preparation of appropriate management strategies and their communication to clients.

The workshop group identified a wide range of extension/promotion activities to assist in achieving the objective. These included the use of all media (written, radio, TV, video, electronic) as well as field days, meetings, conferences etc.

The project will be evaluated for achievement of objectives in the final year.

3) 1997-98 achievements in relation to objectives/milestones

In broad terms the contracted milestone in the 1998/99 year of the project was to ***'prepare a Technical Note on soil acidification and management guidelines for distribution in various forms including a colour brochure and Farm Notes.....by December 1997'.*** The Project Proposal detailed the use of all media types as in indicated in 2).

The achievements to date have been:

(i) Preparation of management guidelines (copy attached).

The workshop group combined to help prepare and edit management strategies for stylo based pasture. These included 500-800 word information sheets on each of the following topics:

a) ***Stylo dominance - a need for management.*** This introductory note outlines the history of stylo and highlights its significance to the Queensland beef industry. With close to 1M ha sown it can have a big effect on animal performance in terms of weight gain, age of turnoff and improved breeding. This sheet also warns readers that stylo can dominate in certain circumstances and that this can lead to undesirable effects on pasture, soil, animal production and ultimately landscape sustainability.

b) ***Stylo dominance - areas at risk.*** The Second Guideline identifies the areas and conditions under which stylo dominance is most likely to occur. The most 'at risk' areas are light textured, infertile soil and where summer grazing pressure is excessive. This situation gives a competitive advantage to stylo over native grass. It is important to recognise and map these areas so that appropriate management systems can be incorporated in the whole property management plan.

c) ***Grazing management to prevent stylo dominance.*** Grazing management, the Third Guideline, identifies grazing pressure as a major factor that can influence grass/legume balance. It explains the powerful effect that continual heavy selective grazing in summer has on grass seeding and its subsequent regeneration and survival. The role of strategic summer spelling is promoted.

d) ***Using fire to manage stylo dominance.*** The Fourth Guideline re-introduces readers to the role that periodic burning can have in native pasture containing stylo. In addition to the traditional reasons for graziers to burn native pasture, it can be used effectively in reducing the stylo population and promoting native grass. Burning needs to be implemented while there is still grass fuel available in the paddock.

e) ***A role for sown grasses.*** In areas where stylo dominance is considered likely or where dominance has already occurred then the inclusion of a sown grass more competitive than the native grasses may be a viable proposition. In the Fifth Guideline a number of grasses have been identified for different environments, the stoloniferous ones being important (*Bothriochloa, Urochloa, Digitaria, Brachiaria*). A region list is provided together with suggestions on how and when to incorporate them.

f) ***Managing seed and hay crops.*** Legume seed and hay crops present special problems as the pure stand of 'N' fixing legume, where most material is removed from the paddock, predisposes to rapid soil acidification. The use of fertiliser and lime may be necessary. Other strategies that include rotational land use with grass crops and pasture to 'soak' up fixed nitrogen are discussed.

g) ***The role for fertiliser.*** A draft of this module will be presented at the review meeting for comment.

(ii) Preparation of colour brochure.

This has not yet been completed. The text material, colour photos and general style have been decided. The delay has been due to a backlog of jobs at the Toowoomba Office where it is being prepared. This milestone was re-negotiated with Barry Walker so that its printing and mail-out would occur at the beginning of next growing season. A database of mail-out addresses has been prepared. This includes all graziers with over 250 ha of land, >500 mm annual rainfall and north of 26° latitude.

(iii) Promotion of management guidelines.

Significant progress has been achieved. The following activities have been conducted.

a) ***Preparation and distribution of a Technical Note on Soil Acidification by legumes.*** The purpose was to inform Technical Staff of recent scientific developments. This was prepared by Andrew Noble (CSIRO Land and Water). About 70 copies were distributed by the Project Leader in October 1997.

b) *Awareness articles on stylo dominance problems* **(see Publications).** The first client announcement of potential problems with stylo dominance and the project aims to counter these was via articles in NAP News and the Tropical Grassland Societies Newsletter T G S News and Views (October and December 1997).

c) ***Radio.*** One ABC Country Hour interview and two Breakfast Session interviews dealing with stylo management were conducted by the Project Leader in October and November 1997.

d) ***TV and Video.*** A segment on stylo dominance, soil acidification and management options was aired in late October 1997. Copies of this are held at major Information Centres.

e) ***Field Days.*** Two major Field Days have been held in north Queensland where the ramifications of stylo dominance have been presented. A Field Day at "Thalanga", Charters Towers, was hosted by the proactive Dalrymple Landcare Committee with financial support from DPI and MRC. Presentations and discussions involved graziers, DPI, CSIRO and the Seed Industry and covered the full range of benefits and problems associated with stylo sown in native pasture. Practical demonstrations of grass planting were also carried out. An excellent booklet was compiled (Rolfe and Dahl,1997) for distribution which contained all the presentations plus the project Management Guidelines.

A second Field Day (March 1998) hosted by MRC and the Tropical Grassland Society at "Strathbogie", Gumlu where the owner, Jim Bloomfield, was presented with the MRC-TGS Pasture Award. Over 80 people attended. Andrew Noble facilitated a session on stylo and soil acidification. A poster on stylo dominance was on display and the Management Guidelines were distributed.

f) ***Landcare Field Walks.*** Col Middleton and David Orr were involved in Field Walks with both the Marlborough and Ulam/Raglan Landcare Groups in October and November 1997. The former was held at a PDS site that addresses some of the management principles highlighted in our Guidelines.

g) ***Technical papers, conferences etc.*** A poster paper by Raymond Jones and Andrew Noble on the potential of soil acidification by leucaena was presented at an International Leucaena Workshop in Hanoi in February 1998. David Orr (Orr *et al* 1997) presented a Poster Paper highlighting management needs of Seca stylo pasture to the Australian Rangelands Society Conference (Gatton) in Dec 1997. Andrew Noble and Col Middleton prepared and presented Posters and Poster Papers at the National Soil Acidification Conference at Coolum last week. These highlighted the problem of legume dominance and demonstrated the cooperative effort between graziers, scientist and extension workers, agri-business and funders in promoting sustainable management practices.

h) ***Other promotion.*** The Guidelines were made available to FARMLINE for its Fact Sheets. Marlborough Landcare featured stylo management in one issue late 1997. Harry Bishop had an article on the need for grass maintenance in stylo pasture in The Queensland Farmer, October 1997.

4) Plans for 1998-99

In the 9 months since the project commenced the major objective has concentrated on preparation of stylo-based pasture management guidelines combined with an awareness program aimed at all sections of the industry from pasture scientists and technicians to the grazier. The second year will concentrate on extending the guidelines to all graziers within stylo growing areas of northern Australia using a variety of methods. The main thrust of the program will commence in the spring. Activities planned include:

- In cooperation with Andrew Noble attend the International Soil Acidification Conference at the Sunshine Coast in July 1998 and present two Poster Papers outlining the problem and our method of managing potential problems caused by pasture legumes.
- Present 1997/98 Progress Report for Peer Group review in July 1998 and incorporate accepted changes.
- Complete the Colour Brochure with management guidelines and have this mailed out to all graziers in the stylo growing areas in the early spring of 1998. Additional copies (number depending on cost) will be made available to MRC, Information Centres, seed outlets etc.
- Get the prepared guidelines onto DPI Notes (by August 1998) CD ROM and the DPI Home Page (by Dec 1998)
- Make the Guidelines available to appropriate Government and Industry Agencies and Agri-business outlets for use by Dec 1998.
- Proactively promote through retail outlets, the booklet on *Stylo for better beef* as this booklet contains most of the management guidelines in question.
- Continue to promote the value of GRASS CHECK in all published material.
- Hold at least one major Field Day on stylo management in each of the Burnett, Central and Northern areas of Queensland during the 1998/99 growing season.

The Workshop Group will continue to be involved in the preparation of all management guidelines.

5) Linkages to other projects

Several other MRC funded projects have significant direct relevance to this project. Close contact is maintained with the relevant Project Leaders so that any valuable management guidelines that emerge can be incorporated in the management promotion guidelines. Linked projects include:

(i) *Sustainability of stylo-based pasture systems in northern Australia: Managing soil acidity* (Andrew Noble - CSIRO)

(ii) *Effect of stocking rate, legumes, supplements and fire on animal production and stability of native pasture* (Bill Burrows - DPI) that researches grazing pressure and fire effects on soil/pasture/animal in native pasture with/without stylo.

(iii) *Management of native pasture oversown with stylo* (Deryk Cooksley - DPI) that researches some management practices (fire, summer spelling, sowing grasses, and grazing pressure) aimed at maintaining grass/legume balance in stylo based pasture.

(iv) *Producer Demonstration Sites* (Col Middleton - DPI). Sites at Mackay/Proserpine (Harry Bishop) and Marlborough (David Orr) that demonstrate pasture management practices in stylo based pasture.

6) Publications

Anon (1997) - Burning. spelling proves effective in stylo control. *NAP News* 6:5.

Anon (1997) - Stylo management. FARMLINE Fact Sheet. Kondinin Group.

Bishop, Harry (1997) - Seca stylo needs grass companion. *Queensland Farmer*, Oct 1997.

McIvor, JG, Noble, AD and Orr, DM. (1998) – Review of Stability and Productivity of Native Pastures Oversown with Tropical Legumes. NAP Occasional Publication No 1, MRC, Sydney.

McIvor, JG, Noble, AD and Orr, DM. (1997) - Strategic management key to balancing legume/grass mix. *NAP News* 6:5.

Middleton, CH *et al* (1997) - Better grasses for stylos. *TGS News and Views* 13(6):7

Middleton, CH and Noble, AD (1998) - Soil acidification under legume based pasture systems of northern Australia: Promotion of management strategies to minimise acidification. *Proceedings of the National Soil Acidification Conference*, Coolum, July 1998 (in press).

Middleton, CH et al (1998) – Stylo Management Guidelines. DPI Note, Agdex 131/21 DPI Qld July 1998.

Noble, Andrew (1997) - Soil acidification. A potential threat to legume based pasture systems. Technical Note. CSIRO Land and Water, Townsville, 1997.

Noble, Andrew (1997) - Legumes fix N - don't waste it. *TGS News and Views* 13(5):2

Noble, AD, Cannon, M and Muller, D (1997) - Evidence of accelerated soil acidification under *Stylosanthes* dominated pastures. *Australian Journal of Soil Research* 35:1309-1322.

Noble, AD and Rogers G (1997) - An assessment of pH_{Ca} differences associated with *Stylosanthes* dominance on two sites on the property Thalanga, north Queensland. Paper prepared for November 1997 Field Day.

Noble, AD (1998) - Soil acidification under legume based pasture systems of northern Australia: The problem. *Proceedings of the National Soil Acidification Conference*, Coolum, July 1998 (in press).

Orr, DM, Burrows, WH, Rutherford, MT and Myles, DJ (1997) - Seca stylo pastures require special management. *Proc. 10th Conference of Aust. Rangelands Soc.*, UQ (Gatton), Dec 1997.

Partridge, Ian (1997) - Stylos - the good, the bad and the cure. *TGS News and Views* 13(5):1-4.

Rolfe, Joe and Dahl, Tania (1997) - Stylos - management balance and production. *ed.* J Rolfe and TDahl. Thalanga Field Day Booklet.

Managing Tropical Woodlands to Control Exotic Woody Weeds (NAP3.206)

1. Project Outline

Project Title: Managing Tropical Woodlands to Control Exotic Woody Weeds
MLA Project number: NAP3.206
Project duration: 1 July 1996 – 30 June 1999

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Project Objectives:
1. Quantify, for land management purposes (i.e. seasons, plant size), the amount of time that elapses between germination of a woody weed cohort and seed production by that cohort.
2. Determine biologically and economically efficient burning frequencies from the relationship between individual woody weed plant size and density and forage production.
3. Develop management practices (fuel loads, environmental conditions, seasons etc) for the frequency and intensity of burning to control a suite of exotic woody weeds by limiting seed production and direct mortality of juvenile and adult plants.
4. Develop a computer based decision support package for use by research and extension officers to assist property managers to evaluate ecological and economic priorities for prickly acacia control at the paddock scale.
5. Integrate ecological data (seed production, seedling establishment, growth rates, time to flowering, burning mortality etc) into economic analysis for decision support of rubbervine management at the paddock scale.

Project Summary:

This project (NAP3.206.701) is focusing on long-term, large scale solutions to problems involving exotic woody weeds in northern Australia. It is gathering information relevant to the question of how often low-input intervention to contain woody weeds is necessary. It is developing tools relevant to decision-making for paddock and property scales, and emphasising techniques that are applicable to the containment and control of woody weed problems in rangeland situations.

Project Report:

<u>Time to reproduction</u>

Cryptostegia grandiflora Rubbervine

Since 1995 we have monitored the survival of seedlings from five natural cohorts of rubbervine at Lansdown (Figure 1). These emerged in February 1995, August 1995, January 1996, February 1997 and January 1998. No marked seedlings of the February 1995 cohort survived beyond 100 days. All marked seedlings of the August 1995 cohort were dead within 50 days of emergence. All marked seedlings of the January 1996 and February 1997 cohorts were dead within 400 days of emergence. Seedlings of the February 1998 cohort have been followed for 150 days up to which time there has been approximately 20% survival. Their survivorship curve is similar to that of the February 1998 cohort to a similar age.

The oldest surviving seedlings from these monitored cohorts are only approximately 150 days. None are over 20 cm high and so are well short of the one metre height at which a significant proportion of established plants are reproductive. Growth data from monitored established rubbervine at Lansdown suggest that, on average, a 50cm plant may take three years to reach a height of one metre.

Taken together then, these data suggest that typically it may take 5-10 years for a plant, growing under natural conditions in a relatively benign environment such as that of Lansdown, to reach reproductive maturity. This is not inconsistent with the fact that, when cultivated under favourable conditions, plants can reach reproductive maturity within twelve months.

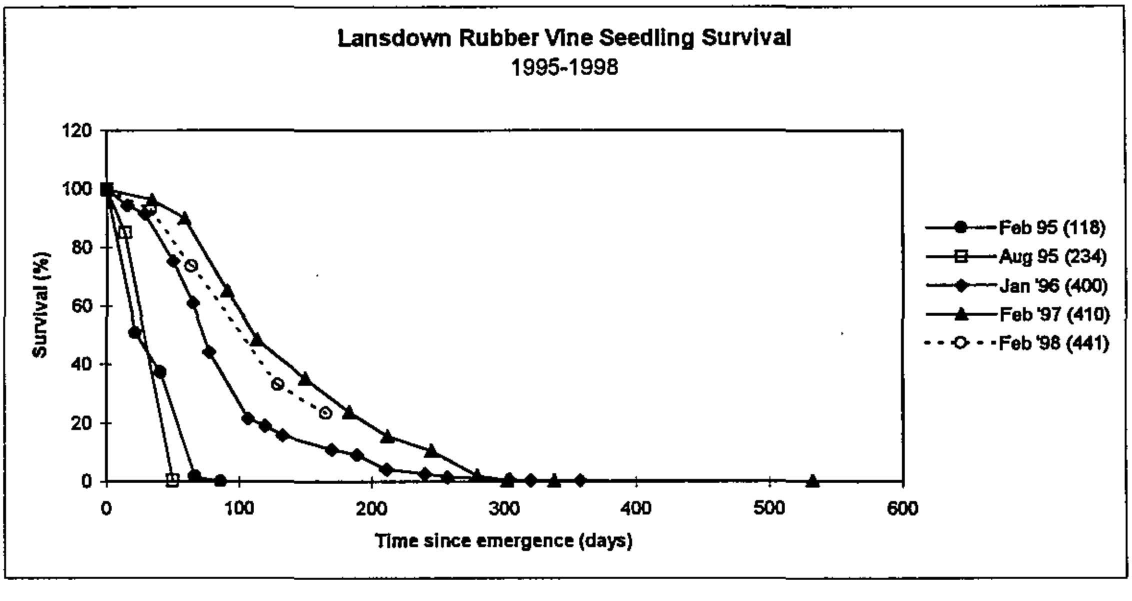


Figure 1. Survival (%) of five cohorts of rubbervine from time of emergence. The five cohorts emergence at the Lansdown Research Station between February 1995 and February 1998. Bracketed figures are sample sizes.

Ziziphus mauritiana Chinee apple

Four cohorts of chinee apple seedlings have been monitored at Lansdown (Figure 2). Emergence times were the same as for rubbervine. Survivorship of chinee apple has been greater than for rubbervine at the same site. All marked seedlings of the February 1995 and January 1996 cohorts died within 350 days of emergence. By contrast with chinee apple plants at the same site, about 20% of marked chinee apple of the February 1997 cohort have survived to about 550 days old. About 80% of the marked plants from the January 1998 cohort are still alive after 200 days.

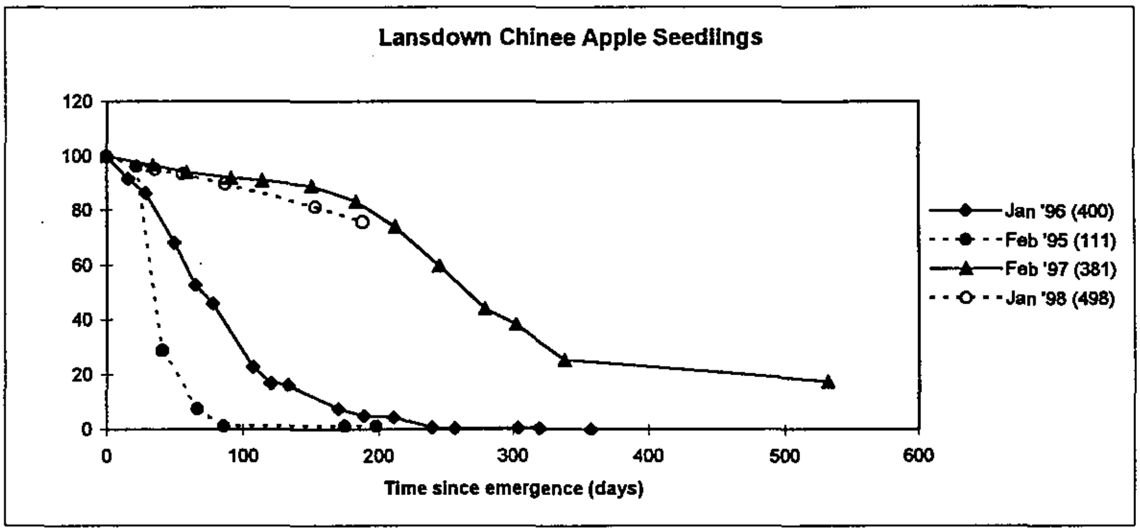


Figure 2. Survival (%) of four cohorts of chinee apple from time of emergence. The four cohorts emergence at the Lansdown Research Station between February 1995 and January 1998. Bracketed figures are sample sizes.

Acacia nilotica Prickly acacia

Numerous cohorts of prickly acacia have been monitored for up to two and a half years at both coastal and inland sites and in riparian, bore drain and upland landscape positions (Figure 3). Growth and survival of prickly acacia varied greatly between sites and landscape positions but also with seasonal circumstances. Along bore drains, non-climatic factors apparently have important effects on seedling survival. These factors include grazing and trampling by cattle and activities associated with the maintenance of the bore drain. On the other hand, seedlings growing in close proximity to bore drains grow far more rapidly than those in uplands and so reach reproductive sizes much sooner. Bore drain since emergence in February 1997 had reached up to 150cm height within twelve months, suggesting that prickly acacia growing in this part of the landscape could reach reproductive size within two years of germination.

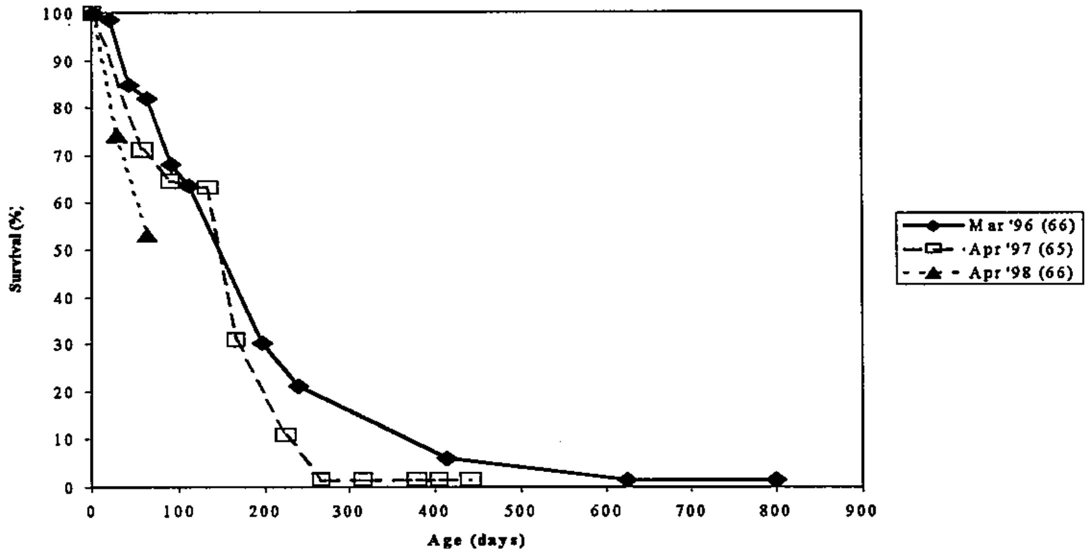


Figure 3. Survival (%) of three cohorts of prickly acacia at Garomna Station, near Julia Creek. The three cohorts emerged in March 1996, April 1997 and April 1998.

Prosopis spp. Mesquite

Eleven natural cohorts of mesquite seedlings have been monitored in permanent transects at Hughenden since October 1995. Three of these cohorts emerged in the 1995/96 wet season, three in the 1996/97 wet season, and five in the 1997/98 wet season. These cohorts have exhibited varied survivability and growth rates.

Only one of the cohorts (December 1995) has had 100% mortality to date, with this taking more than 12 months to occur. Complete data sets are only available as yet for the cohorts emerging in the 1995/96 wet season. Survival rates at six months after emergence for the October 1995, December 1995 and January 1996 cohorts were 18%, 4.25%, and 20% respectively. After 12 months the survival rates for the three cohorts were (in order) 3.91%, 0.36%, and 7.9%.

Approximately 14 000 seedlings have been recorded to date. Of these about 2 400 are over 30 months old. None of these have become reproductive, and only one seedling has even approached the size of a reproductive plant. The results so far suggest that it may take greater than 3 years for a plant to become reproductive under average rainfall years.

It remains to quantify the temporal patterns of recruitment in the main exotic shrub species of northern Australia. It is clear at this stage that seedlings of each species can reach very high densities. At least for chinee apple, prickly acacia and mesquite, large numbers of seedlings emerge from the dung of cattle that have been feeding on the fruits. This notwithstanding, in general, the highest seedling densities occur close to the canopies of large reproductive adults. In all examples monitored seedling mortality is very high during the first dry season following germination. This does not preclude the possibility that certain years occur when a comparatively high proportion of seedlings survive through to a second wet season.

Effective fire frequencies

Nine 1.2 ha plots at Lansdown Research Station have been subjected to one of four fire regimes since 1994. The responses of rubbervine and chinee apple to these fire regimes have been monitored in terms of survival, growth, and reproductive output. The regimes imposed were as follows:

Plot 2	Fire regime
4, 5	Unburnt
9	Burnt once - 1996
1, 2, 6	Burnt twice - 1994 and 1996
3, 7, 8	Burnt four times - 1994, 1995, 1996, 1997

The two species that are the targets of this experiment respond very differently to fire.

Chinee apple sprouts vigorously after fire, small (< 1 m high) plants from the base, larger plants from the base or canopy or both (Figure 4). Very few chinee apple are killed by fire, mortality being very largely restricted to small plants (Figure 5). We have obtained no evidence that late dry season fires decrease the reproductive output of chinee apple though combustion of litter appears to destroy a large proportion of seeds that are on the soil surface.

Rubbervine is also capable of sprouting after fire, though the proportion of fires that do sprout is considerably lower than it is in chinee apple. The majority of rubbervine that sprout after fire do so by producing sprouts at the base rather that in the canopy. Mortality rates for rubbervine in the Lansdown experiment were high but there was a strong effect of plant size (Figure 6). Fires also reduced seed production as evidenced by counts of pods and seedlings.

Experimental results from Lansdown were supported by those obtained from a commercial scale fire conducted at Wrotham Park on the southern part of Cape York Peninsula in a collaborative effort involving station management and staff from Queensland Department of Natural Resources and CSIRO Tropical Agriculture. A prescribed fire was applied to approximately 16 square kilometres of riverine lowlands that were severely infested with rubbervine, some parts at very high density. While the results of this work are yet to be fully assessed it is apparent that mortality rates were similar to those recorded under experimental conditions at Lansdown, probably of the order of 50%. The outcome of this extensive prescribed burn were adequate to prompt managers of the property to burn additional areas in the same season and plan for further use of fire in 1998.

Overall, results of this work on the role of fire as a management tool for exotic shrub weeds indicates considerable potential. The inter-species differences and the effects of plant size are important. A burning program is likely to be far more valuable for rubbervine than for other species. The size-dependence of responses to fire highlight the value of early intervention against any weed species but in the case of rubbervine it appears that, provided a fire of sufficient intensity can be obtained, it will be effective. Knowledge of how fire can be used under different ecological circumstances and of the effects of fires other than late dry season fires would be very useful for applying results to a wider range of situations.

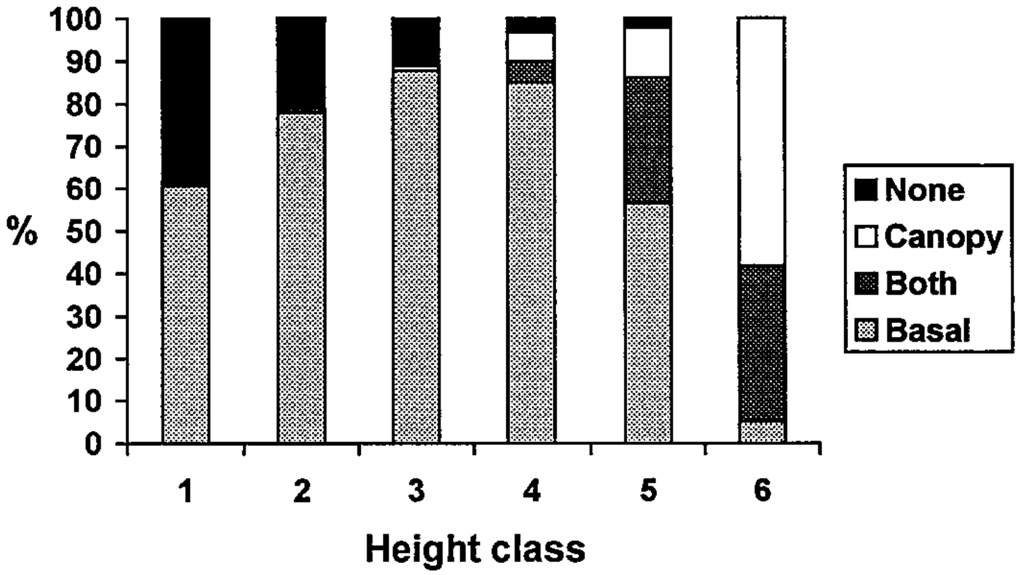
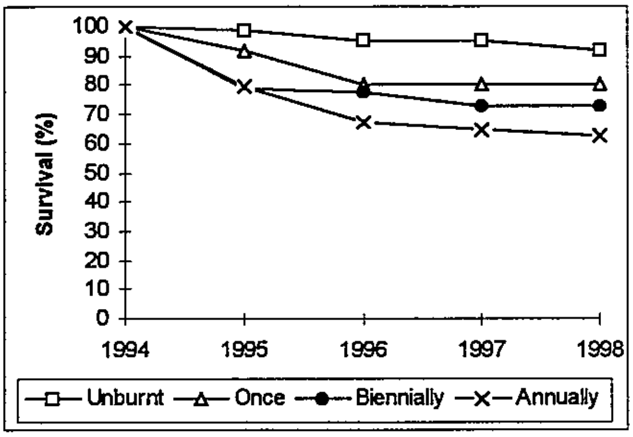


Figure 4. Sprouting positions of chinee apple of six height classes following fire in 1995. Plants are classified as sprouting from the base, from the canopy or from both positions. The six height classes are 0-49cm, 50-0.99cm, 100-149cm, 150-199cm, 200-300cm and >300cm.

The susceptibility of the most widespread mesquite species (*Prosopis pallida)* to fire has been determined over the past two years. Following a single fire, measurements have been undertaken on both fire induced mortality of the original infestation and post fire recruitment of seedlings, with comparisons made against unburnt controls. Apart from an initial 93% kill of original plants, there are significantly fewer new seedlings in burnt plots. This can be attributed to two factors; fire induced mortality of some seeds in the seed bank, and the large reduction in reproductive trees following fire. Consequently 21 months after the fire, burnt plots have a total density of 256 plants per hectare, of which 116 are original plants, 27 are 1996/97 seedlings and 113 are 1997/98 seedlings. In contrast, unburnt controls have a total of 2209 plants per hectare, of which 1464 are original plants, 86 are 1996/97 seedlings and 659 are 1997/98 seedlings.

The seven percent of original plants remaining alive in burnt plots were either not burnt or received minimal damage. If a fire were to carry evenly across a whole paddock and be of sufficient intensity even better kills could be expected. However, landholders would need to control grazing in order to ensure sufficient fuel loads.

(a)



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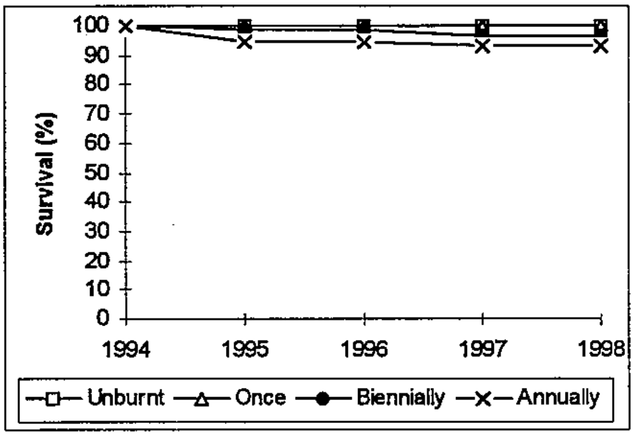

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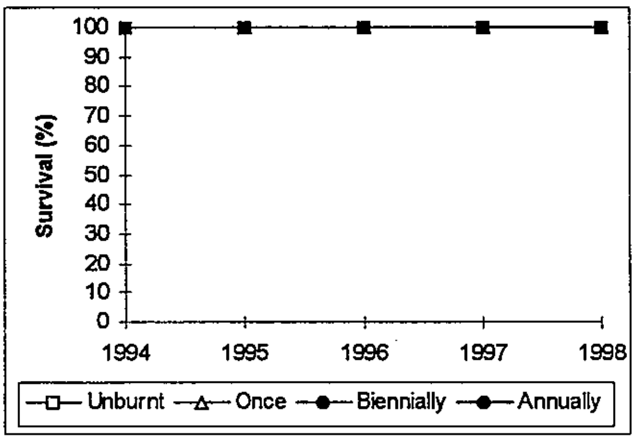
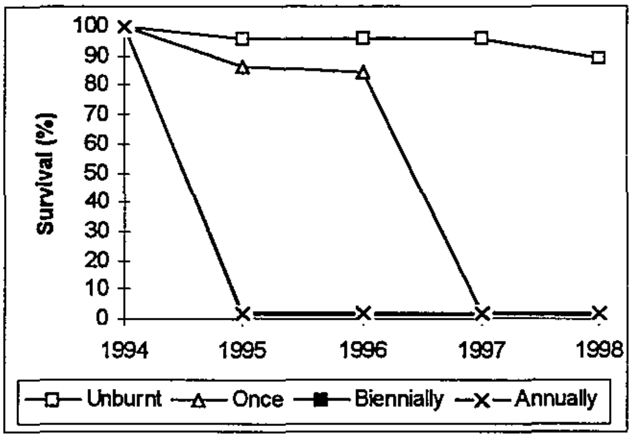


Figure 5. Percentage survival of unburnt, once burnt, annually burnt and biennially burnt (a) small (0-99cm height), (b) medium (100-199cm) and (c) large (≥200cm) chinee apple.

(a)



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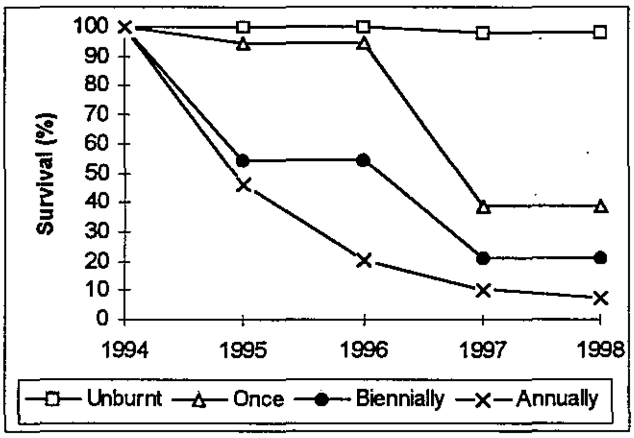

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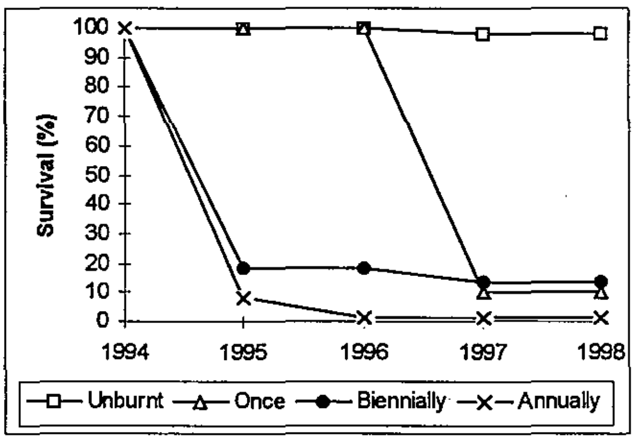

Figure 6. Percentage survival of unburnt, once burnt, annually burnt and biennially burnt (a) small (0-99cm height), (b) medium (100-199cm) and (c) large (≥200cm) rubbervine.

Decision support for management of prickly acacia

We have quantified the spatial patterns that occur in the cattle-aided dispersal of prickly acacia seeds in the Mitchell grass plains. There are effects of distance from water and seed source but also considerable variation between paddocks. It is clear from this work that very large numbers of viable seeds are dispersed considerable distances by cattle and that control of this dispersal mechanism could be a crucial element of a strategy for restoring shrub-invaded Mitchell grasslands.

A simple stochastic model for predicting changes in the distribution and abundance of prickly acacia at the paddock scale has been developed in collaboration with Dr Joe Scanlan (Queensland Department of Natural Resources). At this stage the model is limited to predicting changes in the density of prickly acacia in each cell of an homogenous array representing a hypothetical paddock. The model is based on data derived from a 25 year sequence of aerial photographs from the Mitchell grass plains in the Richmond area. Its current value is restricted to demonstrating comparative time trends of increase under different sequences of wet and dry years. The model was used as a basis for an economic analysis of the costs and benefits of control at various stages in the invasion process (Miller and Scanlan 1997). A more advanced model would make predictions of trend in heterogeneous paddocks and be able to simulate the impacts of different management activities and strategies. Such a model would be more helpful for decision-making.

Economic analysis for the management of rubbervine at the paddock scale

We developed a simple model to analyse the economic implications of using fire to contain rubbervine infestations. The model was based on current ecological knowledge of rubbervine and a number of economic assumptions as follows:

- Pasture and animal production in a hypothetical paddock, typical of the Charters Towers area, were made using GRASP (McKeon *et al.* 1990). Input for the model included historical climatic data for the Charters Towers region.

- The model predicted changes in the abundance of rubbervine and the probability of fire. It was assumed that 2,500 kg/ha of fuel was necessary for an effective fire.

- The effects of two stocking regimes were compared, one a variable stocking rate utilising 40% of annual growth, the other, set stocking at 3.6 ha/adult equivalent.

- Fires were simulated to occur every eight years or, if fuel loads were inadequate, in the first suitable year thereafter. This fire regime was assumed to be adequate to contain rubbervine.

- It was assumed that the paddock was destocked for 12 months prior to burning and for 2 months after burning.

- A discount rate of 8% was used for the analyses.

The most important predictions of the model were:

- Treated (burnt) and untreated (unburnt) scenarios diverged in terms of predicted pasture growth with differences being greater in the latter stages of the 20 year simulation. This is the phase when discounting had its greatest effect so the effect of the differences is minimal.

- The greatest differences between treatments occurred during wet years. This means that years in which the paddock is rested prior to burning are those with the greatest pasture response.

- Pasture production benefits and resultant beef production responses were not sufficient to justify burning to contain rubbervine given the prevailing climatic regime and a discount rate of 8%.

- Results of the analysis were sensitive to destocking practices, the discount rate, capacity to redistribute stock from rested paddocks and rainfall regime.

There are some important limitations to this analysis:

- The model assumes that it is necessary to destock to have an effective prescribed fire for the containment of rubbervine. Current practice belies this assumption. The apparently effective commercial scale fire at Wrotham Park was carried out without destocking. The need to rest a paddock to conserve fuel for burning is certainly dependent upon rainfall and the requirement may vary geographically. Destocking may be more needful in heavily grazed areas such as the Charters Towers region. Neither is paddock resting practised in association with wet season burning of riparian rubbervine.

- The model assumes that it is necessary to burn a whole paddock to gain a benefit in terms of rubbervine containment. This is not necessarily the case, particularly given the heterogeneous distribution of the species, including its concentration in riparian and similar areas.

- The economic model does not consider many of the possible benefits of rubbervine containment. These include maintaining property values, more economic mustering, and environmental benefits.

A more comprehensive presentation of the results of this economic analysis of the use of fire in containing rubbervine can be found in the Proceeding of the 41st Annual Conference of the Australian Agricultural and Resource Economics Society.

Communication Activities:

Evaluation of four producer groups using a focus group approach has commenced in collaboration with Alison Cotteral (James Cook University). This evaluation is documenting current practices including those relevant to the management of exotic shrub weeds. The focus groups will be reassessed over the next three years to determine what impact woody weed and other research has on producer awareness, attitudinal changes and adoption of grazing management principles flowing from the research.

<u>Recent publications</u>

Brown, J.R. and Carter, J. 1998 Spatial and temporal patterns of exotic shrub invasion in an Australian tropical grassland. Landscape Ecology (in press).

Brown, J.R., Scanlan, J. and McIvor, J.G. 1997 Herbaceous competition as a limiting factor in shrub increase: a test with different growth forms. Journal of Vegetation Science (in press).

Grice, A.C. 1997 Fire for the strategic management of rubbervine *Cryptostegia grandiflora*, an invasive shrub. Bushfire '97. Proceedings of the Australian Bushfire Conference. Pp. 239-244, Darwin.

Grice, A.C. and Brown, J.R. 1997 Managed fire to control the impacts on northern Australian plant communities of the invasive shrub *Cryptostegia grandiflora*. In Hale, P and Lamb, D. (editors) Conservation Outside Nature Reserves. Pp. 356-358. Centre for Conservation Biology, University of Queensland .

Grice, A.C., Radford, I.J. and Abbott, B.N. (submitted 1998) Landscape ecology of the invasive *Cryptostegia grandiflora* R. Br.: a qualitative framework and analysis of land resource survey data. Biological Invasions.

Kriticos, D., Brown, J., Radford, I. and Nicholas, M. (submitted 1998) Biological control of invasive perennial plants in rangeland ecosystems: *Acacia nilotica* as a case study. Biological Control.

Miller, E.N. and Scanlan, J.C. 1997 Linking ecology and economics for woody weed management in Queensland's rangelands.

Presentations

Campbell, S. and Grice, A.C. (1998). Fire management for exotic woody plant control. 7th Queensland Fire Research Workshop. July 1998, Cairns, Queensland.

Grice, A.C. Fire for the strategic management of rubbervine *Cryptostegia grandiflora*, an invasive shrub. Bushfire '97. July 1997, Darwin, Northern Territory.

Department of Natural Resources. Rubbervine Management Koolatah Field Day, August 1997.

Nicholas, M. Julia Creek Landcare Meeting. Prickly acacia management based on ecological research. December 1997, Julia Creek, Queensland.

Radford, I. Weed Control Research. Invited presentation at MRC Meat Profit Day, Emerald, April 1998.

Department of Natural Resources "Acacia Management Field Day", May 1998, Acacia Downs, Muttaburra, Queensland.

Other activities

A commercial scale test and demonstration of the value of fire in the management of rubbervine was conducted at Wrotham Park Station on the southern part of Cape York Peninsula. An area of approximately 16 square kilometres that was severely infested with rubbervine was burnt in October 1997. The site is particularly useful as a demonstration because it is along-side the main road from Chillagoe to Kowanyama/Normanton. It is also within the area of the Mitchell River Catchment Group, that will be a focus of future research. This makes is readily accessible and open to viewing by a large amount of local traffic. Monitoring plots were established at the site to document the effects of the fire and photopoints were established.