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Lotus grazing management for weaner production

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ABSTRACT

A 5 year state-wide project was undertaken by NSW Agriculture in conjunction with MLA, farmer community groups, and agri-business to investigate and demonstrate the potential of Lotus (*L. uliginosus, L. corniculatus*) based pastures to increase grazing production in the high rainfall zone. The R&D program was based on methodology that combined field research to develop management practices for Lotus persistence, with technology transfer to promote increased use of Lotus. The field research comprised a core experiment replicated in 4 target regions (north coast, south coast, northern tablelands, and southern tablelands) with factorial combinations of grazing strategies, grazing intensity levels, Lotus cultivars, and companion grass types to develop practices for increased persistence of Lotus. Seventeen co-learning sites were established on farms adjacent to the experimental sites to assess adaptation of target Lotus cultivars, and to demonstrate a comparison of best bet “strategic grazing” with “traditional grazing” for Lotus persistence.

Results from the core experiment provided large and valuable data-sets for Lotus establishment, botanical presence, and persistence mechanisms in the target environments. GL Maku established best under coastal conditions and BFT Goldie established best under tablelands conditions. Nodulation of GL Sharnae and BFT Goldie were less effective than nodulation of GL Maku, but nodulation effects had no apparent influence on seedling vigour. The population density of all Lotus cultivars declined substantially under the impact of severe drought conditions, although both BFT Goldie and GL Maku remained botanically stable at Glen Innes with GL Maku retaining 20 – 40% presence and BFT Goldie retaining 30 – 50% presence, depending on time of year. In general, there was little effect of grazing strategy on Lotus presence, rhizome activity, seedbank development or seedling recruitment. Of the 17 on-farm co-learning sites, 9 of 10 sites in northern NSW and 3 of 7 sites in southern NSW established successfully and yielded useful information. All 5 failed sites were unsuccessful due to establishment failure associated with severe drought conditions at, or following planting. An overview of environmental conditions, establishment procedures, management protocols and results at each co-learning site is documented as case study reports of the adaptation of Lotus to the climatic, edaphic and management conditions across the high rainfall zone.

The project achieved significant outcomes including:-

(i) Improved definition of the Lotus zone – GL for high rainfall coastal districts and niche tablelands sites; BFT as a new mainstream perennial legume for northern NSW. Of the Lotus species and cultivars studied (GL Maku, GL Sharnae, BFT Goldie, BFT ‘Spanish’) and the environments where trials were located (north coast, south coast, northern tablelands/slopes, southern tablelands/Monaro), BFT showed best potential for providing a perennial legume where it is most needed – the north-west slopes and northern tablelands of NSW. GL was found to be outstanding in vigour and persistence in niche environments on the northern tablelands.

(ii) Greater farmer awareness of the unique and valuable properties of Lotus – bloat safety, drought tolerance, and adaptation to low fertility acidic soils.

(iii) Increase in the knowledge-base of Lotus technology – establishment requirements, management practices for persistence, and cultivar testing results.

The project also identified new directions for research opportunities for agri-business, and initiatives for farmer community groups. These include the need to popularise Lotus use, the need for development of a broad adaptation GL cultivar and a short day length BFT cultivar, and opportunities for the pasture seeds industry. It is concluded that there is potential to expand the Lotus zone in NSW to 3.5 m ha by 2010 and this goal is worthy both to achieve improved productivity of cattle and sheep enterprises in the high rainfall zone, but also to address environmental issues. Lotus offers potential to rehabilitate pastures in decline, lift the productivity of marginal grazing lands, and to increase pasture biomass and water use on acidic soils in dryland salinity recharge areas.

EXECUTIVE SUMMARY

OBJECTIVES

The broad objective of DAN 082 was to develop and promote Lotus technology in New South Wales. Specific objectives were as follows:-

Experimental objective:

To determine if grazing intensity and strategic spelling affects expression of the adaptive characteristics of Greater lotus and birdsfoot trefoil and to examine whether the level of grass competition interacts with the response to grazing intensity and strategic spelling.

Industry objective:

(a) To define grazing management strategies that enable Greater lotus and birdsfoot trefoil to maintain at least 30% of total pasture dry matter in a mixed grass/ legume pasture, for at least 4 years in beef breeding system

(b) To demonstrate the use, management and economic benefit of Greater lotus and birdsfoot trefoil cultivars to grow out steers in conjunction with graziers, seed companies, extension officers and other stakeholders through a series of co-learning sites.

METHODOLOGY

These project objectives required a methodology that combines field research to develop sound grazing management practices for Lotus persistence, with technology transfer work to promote increased use of Lotus based pastures. The R&D process implemented to achieve this comprised a research phase (the core experiment with sites in each target region – north coast, south coast, northern tablelands, southern tablelands), combined with an extension phase (co-learning groups and on-farm demonstrations in each of the regions involving farmers, project workers and industry stakeholders).

The core experiment was established at 4 sites (Casino, north coast; Nowra, south coast; Glen Innes, northern tablelands; Canberra, southern tablelands) to examine the effects of grazing intensity and strategic spelling on the persistence of Lotus in relation to the adaptive characteristics of each Lotus species and cultivar. Treatments at each core site were factorial combinations of grazing strategies (continuous grazing, rotational grazing, autumn spelling, summer spelling), grazing intensity (low biomass, high biomass), Lotus cultivars (GL Maku, GL Sharnae, BFT Goldie, BFT 'Spanish') and companion grass type (volunteer, introduced). A standard protocol was implemented to ensure uniform management practices and measurement procedures across the 4 experiment sites. The treatments were imposed for 24 – 40 months depending on site) and measurements made of Lotus establishment, botanical change, rhizome/seedbank development and seedling recruitment to determine whether the grazing treatments affected Lotus persistence.

The experimental and co-learning phases were linked where practicable by paired comparisons at the co-learning sites of key treatments from the core experiment. Seventeen co-learning sites were established on farms; 6 on the northern tablelands/slopes, 4 on the north coast, 4 on the southern tablelands, and 3 on the south coast. Activities at the co-learning sites were designed to assess adaptation of the target Lotus cultivar for the district and to compare "traditional" grazing management with "strategic" grazing management for effects on Lotus persistence. For GL co-learning sites (ie. coastal), the comparison was of *continuous grazing* versus *autumn spelling* as autumn spelling was considered to be the "best bet" treatment to promote rhizome extension, and hence Lotus persistence. For BFT co-learning sites (ie. hinterland), the comparison was of *continuous grazing* versus *summer spelling* as summer spelling was considered to be the "best bet" treatment to promote prolific flowering/podding for seedbank development and seedling recruitment, and hence Lotus persistence.

HIGHLIGHT RESULTS AND CONCLUSIONS

The core experiment

The results from the core experiment provide large and valuable data-sets for seedling establishment, botanical presence, rhizome/seedbank development, and seedling recruitment to enable assessment of the adaptation of GL and BFT in the NSW high rainfall zone, and to assess the significance of strategic grazing for Lotus persistence.

Lotus seedling establishment - All 4 sites experienced severe drought conditions in 1994 – 1995, accordingly the results were obtained under the influence of very dry conditions at establishment. As a consequence, all sites required reseeding following sparse Lotus populations achieved from initial plantings. Ultimately all sites achieved satisfactory Lotus populations prior to commencement of grazing treatments; 96 – 127, 56 – 108, and 64 – 134 seedlings /m^2 for GL Maku, GL Sharnae and BFT Goldie across the 4 sites; seedling density of BFT 'Spanish' (which was planted only at Canberra) was 126 seedlings/m^2. GL Maku established best under coastal conditions and BFT Goldie established best under tablelands conditions. Nodulation was generally effective at all sites, but it is noteworthy that there was a consistent difference between cultivars in the effectiveness of nodulation, nodulation of GL Sharnae was less effective than nodulation of GL Maku at Casino and Nowra, and nodulation of BFT Goldie was less effective than nodulation of GL Maku at Nowra and Canberra. However, these nodulation effects had no apparent influence on seedling vigour.

Lotus botanical presence - The pattern of Lotus botanical presence during the study at each site is described below:-

At Glen Innes:-

- The botanical presence of GL Maku was markedly seasonal with high Lotus presence (~ 40%) in spring and relatively lower presence (~ 20%) in winter; GL Maku remained botanically stable between these limits for the duration of the study, regardless of biomass level.

- GL Sharnae remained at a relatively low (10 – 20%) but stable level.

- BFT Goldie presence was sharply seasonal showing very high presence (40 – 50%) in spring and summer and relatively lower presence (~ 30%) in winter. BFT Goldie maintained greater botanical presence than GL Maku or Sharnae for the duration of the study.

At Casino:-

- GL Maku presence was initially very high (~ 60%) but rapidly declined to a low (~ 10%) level within 1 year of the imposition of grazing treatments, and remained between relatively low limits (5 – 20%) for the duration of the study.

- GL Sharnae presence was high (~ 40%) but rapidly declined to trace levels (5 – 10%).

- BFT Goldie initially had lowest botanical presence (~ 20%) at the commencement of grazing treatments and declined to similar levels as the GL cultivars.

At Nowra:-

- GL Maku was initially present at a moderately high level (~ 40%) and GL Sharnae at a relatively lower level (~ 20%). Both GL cultivars declined in botanical presence to trace population levels (<5%) and there was no evidence of seasonal influence on botanical presence.

- BFT Goldie presence was initially moderately high (*ca.* 35%) but gradually declined over 2 years to low levels (< 10%). BFT Goldie expressed a measure of seasonality with minor biotic expansion each summer declining to a minimum each winter.

At Canberra:-

- All 4 Lotus cultivars were initially present at very high levels – both GL cultivars showed 50 – 60% presence and both BFT cultivars showed 70 – 80% presence.

- Under low biomass and adverse seasonal conditions, all Lotus cultivars declined gradually over 2 years to only trace levels.

- A similar rate of botanical decline was evident under high biomass conditions, except with both GL cultivars the rate of decline was especially rapid under rotational grazing. The BFT cultivars showed a weakly pronounced seasonality with a slight expansion of biotic presence in spring-summer, declining to a minimum in winter.

In general, there was little effect of grazing management treatment on Lotus persistence except for the Glen Innes site where autumn rest enhanced GL Maku presence but by contrast, autumn rest depressed BFT Goldie presence.

Rhizome/seedbank development and seedling recruitment – With GL, rhizome activity provides the mechanisms for regeneration and hence persistence. The data show that rhizome extension was significantly different between GL cultivars with GL Maku>GL Sharnae at both northern sites, particularly in the first year when GL populations were substantial. By contrast, that seedbank development of GL Sharnae was exceptionally high at all sites. Rhizome activity at both southern sites was negligible. With BFT the mechanism for regeneration and persistence is flowering/podding and accretion of seed into the soil seedbank for subsequent seedling recruitment. Seedbank numbers were substantial for BFT 'Spanish' at Canberra (the only site where 'Spanish' was used), but seedbank numbers for BFT Goldie were low at all sites. In general, there were no effects of grazing treatments on rhizome activity or seedbank development; likewise there was no effect of grazing treatment on BFT seedling recruitment. At the northern sites, the level of seedling recruitment was very low (1.5 and 3.4 seedlings/m^2 at Glen Innes and Casino, respectively) and there was no seedling recruitment evident at either southern site.

The co-learning demonstrations

Of the 17 co-learning sites, 9 out of 10 sites in northern NSW and 3 out of 7 sites in southern NSW established successfully and yielded useful information. All 5 failed sites were unsuccessful due to establishment failure associated with severe drought conditions that prevailed in 1994 – 1995 when planting occurred. An overview of the highlights at each site is provided in the following.

Northern tablelands/slopes

- “Dursley”, Swan Vale via Inverell - Establishing BFT into native pasture by direct-drilling into an herbicide treated sward was very successful; the resulting Lotus establishment of 50 - 60 seedlings/square metre was an excellent initial population. Close and continuous selective grazing by sheep in the “traditional” management system virtually eliminated the Lotus population within 3 years of planting. However, the combination of reduced grazing pressure and summer spelling in the ‘”strategic” management treatment resulted in the persistence of Lotus at a substantial level (40% of sward content) 5 years after planting due to improved longevity of original plants and enhanced seedling recruitment.

- “Springsure”, Red Range via Glen Innes - GL proved well adapted to conditions at “Springsure” which comprise moist valley-floor granite soil, vigorous grass competition from introduced perennial grasses, and grazing by sheep and cattle. Lotus consistently was the dominant pasture legume and persistence was unaffected by grazing management. Lotus expressed adaptive characteristics to both close grazing by sheep (leaf plasticity - leaf size decreased under close grazing) and lax grazing by cattle (rhizome activity - rhizomes invaded the litter layer under rank grass growth and thick mulch conditions).

- “Coomerang”, Oakwood via Inverell – The initial population of BFT at Coomerang was low for 3 reasons - low seeding rate, severely dry conditions for 3 months following planting, and severe weed competition. Under these conditions, Lotus established remarkably successfully to achieve a population density of ~ 20 plants/square metre in the spring following autumn-planting. Results to hand are based on less than 3 years experience so conclusions on the adaptation of Lotus at “Coomerang” are tentative. However, early results are promising because i) under the adverse conditions that applied in the establishment year, lotus seedlings established more successfully than introduced grasses, ii) Lotus flowered strongly in the second summer, and iii) The present lotus population is expanding through seedling recruitment.

- “Hawthorn Dale”, Nullamanna via Inverell - Under the good soil moisture conditions that prevailed during planting at “Hawthorn Dale”, direct-drill technology was very successful - a Lotus seeding population of 27 plants/square metre developed within 60 days and a dense Lotus stand developed in the first year. Because the site is only in its second year, conclusions are premature. However, adaptation of BFT in this environment appears promising because: i) an intensive flowering event was observed in the first summer, ii) lotus dominance was achieved in the first year, and iii) prolific seedling recruitment has been observed.

- "Carrawarra", Gum Flat via Inverell - Establishment failure at "Carrawarra" was attributed to the inappropriateness of spring planting where the combination of soil moisture stress and grass competition on warming soils led to establishment failure. At "Carrawarra", there was no real test of lotus adaptation - future development work with BFT should include consideration of the south-west Inverell district because of the apparent suitability of environmental conditions and the potential value of BFT for improving the utilisation of native pasture. Planting should occur in late February/early March and special consideration will need to be given to managing medic and subclover competition in the first spring following planting.

- "Hill Top", Bingara - Experience with BFT at "Hill Top" was limited to only 18 months, so conclusions are tentative. However, results suggest promise for the adaptation of BFT in the Bingara district: i) The achievement of a viable "critical mass" of seedlings (15 - 20 plants/square metre) despite sub-optimal timeliness with planting and adverse conditions (soil washing, weed competition) following planting, ii) Intensive flowering in the first summer, iii) Acceptable Lotus presence (33% sward biomass) in the second year following planting, iv) Favourable local environmental conditions for BFT including increased day length, low incidence of overcast days and an increased heat factor.

North coast

- Melinga via Taree – GL showed successful adaptation at Melinga which is characterised by i) high rainfall, ii) carpet grass/paspalum as companion grass, and iii) cattle grazing; Greater lotus maintained significant presence through adverse seasonal conditions and expanded in population density in favourable seasons. From observations between the trial site where the companion grass was carpet grass and an adjacent paddock where the companion grass was setaria, it was apparent that Greater lotus co-exists better with carpet grass than with setaria. Where Greater lotus commenced from isolated seedlings (from contaminated seed) in the BFT block, it expanded to become a minor but significant sward component with potential to achieve co-dominant status with carpet grass within 3 - 5 years post-planting. BFT by comparison declined dramatically to have only trace presence - presumably due to inability to withstand rhizomatous grass competition from carpet grass.

- Waukivory, via Gloucester - The Gloucester environment is transitional in terms of zones of adaptation for BFT and GL. Both lotus species appeared to be adapted to climatic and grazing components of the environment at the Waukivory site but the limiting factor for both GL and BFT in the Gloucester district in the longer term will be grass competition from kikuyu. BFT was adapted better than GL to heat and dry, but with improvement to soil N fertility following BFT presence, kikuyu under coastal conditions is expected to invade and suppress the non-rhizomatous lotus. By contrast, GL, being rhizomatous is expected to co-exist with kikuyu (and carpet grass) and show long term persistence.

- "Queensbury, Booral - Conditions at Queensbury are characterised by high rainfall, low pH, carpet grass as the dominant grass, and close grazing by cattle.

Best establishment was achieved by Maku lotus in conjunction with starter fertiliser (superphosphate + potash). Surface broadcasting into a closely slashed sward was just as successful as preparing a seed-bed. Maku lotus established, expanded in population density, and persisted at high sward content whereas Goldie lotus declined to zero presence. The superior performance of Maku lotus at Queensbury is attributed to the importance or rhizomes in conferring a capacity to compete effectively with a highly competitive rhizomatous grass (carpet grass).

- "The Croft", Booral – As for 'Queensbury', GL is successfully adapted in the Booral district where environmental conditions are characterised by low soil pH, low soil phosphate fertility, vigorous rhizomatous grass (carpet grass) competition and cattle grazing.

Southern tablelands

- "Woodburn", Bombala - The drought conditions that prevailed at "Woodburn" for 3 years following planting impeded the establishment of Lotus and other sown species, other than perennial ryegrass. Accordingly, results were obtained in the context of severe and protracted drought compounded by close grazing that unavoidably accompanied ongoing drought. Results were inconclusive for the comparison of "strategic" versus "cell grazing" because these treatments were abandoned with onset of drought. Also, conclusions with respect to the relative adaptability of BFT and white clover are made in the context of severe drought, close grazing and strong grass competition. In the establishment year, the high seeding rate of perennial ryegrass resulted in suppression of the original Lotus population, and in subsequent years the lack of presence of perennial grasses (tall fescue, phalaris) and invasion by annual grasses progressively led to demise of lotus and white clover to only remnant status. Under these adverse conditions, BFT expressed slightly better adaptive characteristics than white clover; Lotus showed better longevity of first generation plants, maintained green leaf better under severe moisture stress conditions, and flowered strongly in summer to recruit small populations of new seedlings. This result warrants further research to better define the place of BFT on the Monaro.

- "Stillwater", Yarra via Goulburn - Except for favourable moist niche sites, rainfall conditions in the Goulburn district places it outside the likely zone of adaptation of GL. Future species evaluation work with perennial legumes should include investigation of BFT - especially small leafed rhizomatous types (eg. cv. Steadfast) suited to lower rainfall and close grazing by sheep.

- "The Glen", Goulburn - The trial was unable to assess the adaptation or grazing management requirements of BFT because of establishment failure.

- "Moonbucca", Rylestone - The investigation was unable to address the aims because of establishment failure.

South coast

- "Bundanon", Nowra - Hinterland districts of the NSW south coast lie within the expected zone of adaptation of BFT. Experience at the "Bundanon" site illustrates that conditions were suitable for establishment and seedling recruitment but that intensive management conditions that are characteristic of small holdings like

"Bundanon" are prohibitive for the persistence of BFT. Even with adherence to management protocols to maintain lotus based swards within desirable pasture biomass limits, BFT on the couth coast will inevitably be overwhelmed by competition from local rhizomatous grasses (carpet grass on low fertility soils, kikuyu on high fertility soils) until a rhizomatous BFT like cv. Steadfast variety is commercially available.

- "Elmgrove", Towamba via Bega - The investigation was unable to address the main aims because of establishment failure.

- "Willeroo", Rocky Hall via Bega - The investigation was unable to address the main aims because of establishment failure.

RECOMMENDATIONS

DAN 082 has been a successful partnership between NSW Agriculture, MLA, and farmer community groups to determine the potential of Lotus based pastures to contribute to grazing production in the high rainfall pastoral zone in New South Wales. Some 21 study sites formed the bases for investigation and demonstration of Lotus technology. Project outcomes included:-

greater industry awareness of the unique and valuable properties of Lotus pastures, increase in the knowledge-base of Lotus technology, and improved definition of the potential Lotus zone.

DAN 082 also identified certain issues and limitations which require resolution through future research directions, agri-business opportunities, and community group initiatives. These include:-

- *The need to popularise Lotus use* – It is concluded that the Lotus zone in NSW can be expanded to 3.5 m ha by 2010 and this will require i) a media campaign to build on the awareness profile created by DAN 082, ii) training seed company personnel on Lotus technology, and iii) farmer community group activities to achieve a 'critical mass' of farmer experience with the development and management of Lotus based pastures.

- *Cultivar development and testing* – Expansion of the Lotus zone requires development of a short day length BFT cultivar with enhanced flowering/podding prolificacy for better persistence in northern NSW, and a broad adaptation GL cultivar for adaptation beyond favourable niche sites. This Lotus improvement work is relatively short term and already underway at Glen Innes – the need is for agency or commercial/partner resourcing to complete cultivar development and to support merit testing.

- *Commercialisation of Lotus technology* – The target of 3.5 m ha of Lotus based pastures by 2010 will require adequate availability of both GL and BFT seed at a reasonable price – a desk-top analysis is required to investigate the feasibility of the seeds industry implementing the necessary actions to support this requirement.

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1. BACKGROUND

Two Lotus species are commercially available in Australia – *Lotus uliginosus* (Greater lotus; GL) for very high rainfall coastal districts and favourable moist niche sites in elevated Tablelands environments, and *Lotus corniculatus* (birdsfoot trefoil; BFT) for tablelands and slopes environments.

1.1 Characteristics of Greater lotus and birdsfoot trefoil

1.1.1 Greater lotus

GL is a long-lived rhizomatous perennial legume that is native to Europe and North Africa. Two varieties are commercially available in Australia; Grasslands Maku (tetraploid, large leaf, thick stem, erect growth habit) and Grasslands Sunrise (diploid, small leaf, dense foliage, prostrate growth habit). Both cultivars are derived from mass selection within populations of summer-active New Zealand ecotypes followed by hybridisation of selections with winter-active introductions from Portugal. One breeding program that involved backcrossing this material to the New Zealand and Portuguese parents produced the diploid cultivar G. Sunrise. A second breeding program was based on colchicine-induced tetraploids of the New Zealand ecotypes hybridised with induced tetraploids from the Portuguese collection to produce the tetraploid cultivar G. Maku (Blumenthal *et al.* 1993). A third cultivar bred by NSW Agriculture, cv. Sharnae, was based on selection and polycrossing of accessions collected from the Algarve region of Portugal in 1974 (Anon 1980); Sharnae possesses early flowering phenology and increased warm season performance but has not been successfully commercialised.

In general, GL is an alternative niche legume with warm season growth for wet acidic soils of low fertility with applications for cattle and sheep grazing. In New South Wales, GL is adapted to the very high rainfall coastal districts (north coast and south coast) and favoured moist sites on the northern tablelands. Characteristics of GL include:-

- Vigorous summer growing perennial that spreads by rhizomes and is compatible with introduced temperate or subtropical grasses
- Of special application for wet conditions and on low fertility acid soils – dry matter production exceeds that of white clover and red clover under low fertility conditions – tolerates low soil pH (4.5 – 5.5 pH in $CaCl_2$), high levels of aluminium and manganese, and waterlogged sites
- Non-bloating (due to presence of condensed tannins) and palatable – incorporating GL in a pasture mix can help reduce the incidence of bloat
- Reputedly resistant to predation by insects and soil-living pests due to tannin content
- Where adapted, GL can provide a reliable legume base in pasture for improved animal production (McLaughlin and Clark 1989).

Some limitations of GL cultivars include:-

- Seed is costly and the high price of seed (typically $30/kg) has been an obstacle to widespread use

- Establishment can be slow (especially in cold environments) and problematical because of the lag between sowing and rhizome establishment and susceptibility to moisture stress in the first spring after sowing

- Regrowth after grazing is slow and grazing management needs to accommodate the need for long periods between grazings

- Under certain conditions (eg. low soil fertility, long spells between grazings), condensed tannins in lotus foliage may increase to levels high enough to restrict feed intake (Anon 1995).

1.1.2 Birdsfoot trefoil

BFT is a tetraploid taprooted perennial legume native to Europe, North Africa and parts of Asia. Some 25 cultivars have been developed in the United States and Canada where it is an important legume for pasture, hay, and silage. It is a long day length plant with most American cultivars requiring 14 – 18 h day length for prolific flowering. Mature plants have multi-tillers arising from a single well developed crown and possess a well developed tap-root with numerous lateral branches. Plants generally are short-lived, so intensive flowering and seedling recruitment (or high rhizome density in rhizomatous cultivars) is essential for long term persistence of the population (Beuselinck *et al.* 1994). BFT is winter-hardy and has greater tolerance to acidic, infertile, and poorly drained or saline soils than lucerne or white clover. BFT has nutritive value equal to or greater than lucerne and does not cause bloat in cattle. The characteristics of a range of prominent overseas BFT cultivars are listed below:-

- *Grasslands Goldie:* An erect early flowering variety selected in New Zealand from South American, Mediterranean and European accessions for productivity and persistence. Considered to be suited to moderately well drained light to medium textured soils where pH and fertility are too low for lucerne, or marginal for white clover due to lack of moisture or fertility.

- *AU Dewey:* Developed and released in Alabama, USA where selection was applied across Yugoslavian accessions for rhizomatous nature, prostrate growth habit, vigour and adaptation. Characterised by prostrate habit, high natural reseeding ability, high seedling vigour and high yield potential.

- *Norcen:* Broad-leaf intermediate type. Diverse genetic background provides broad adaptation in to different environments.

- *Steadfast:* The first cultivar developed that has rhizomes. Steadfast was developed in Missouri, USA from crosses between wild rhizomatous accessions collected in Morocco with Norcen and AU Dewey. Steadfast is semi-erect with small to medium stems. It contains a larger number of early flowering genotypes than Norcen or Dewey and is readily distinguished from other cultivars by its rhizomes.

- *Dawn:* Semi-erect, fine stem, small leaf and late maturing. Selected for resistance to root-rot and leaf and stem diseases. Missouri selection with wide adaptation to much of the humid zone of the central and southern US. Less winter-hardy and produces less seed than Norcen.

An Australian Lotus breeding program based with CSIRO at Canberra has been underway since 1990. The breeding strategy for GL involves single crosses between the diploid New Zealand breeding lines (Sunrise and G4704) and 3 Portuguese accessions (including Sharnae); breeding objectives are early flowering for improved seed set, and lower condensed tannin level. The breeding strategy for BFT involves polycrossing among tall productive hay types and prostrate winter-active Spanish accessions; breeding objectives are improved drought and acid soil tolerance, and improved grazing tolerance and persistence (W.M Kelman *pers. comm.*).

1.2 Origins, global distribution, and contemporary use

The lotus genus comprises a diverse group of annuals and perennials totalling 100 – 120 species. *Lotus corniculatus* (birdsfoot trefoil; BFT) and *Lotus corniculatus* (Greater lotus; GL) share similar centres of origin in southern Europe and North Africa and are closely related (Grant and Small 1996). Of the Lotus species, BFT and GL are the most important agronomically with significant use of BFT in the USA, Canada, South America (Uruguay, Argentina, Brazil), Europe (Italy, Austria, France, Germany, Poland, Hungary) and New Zealand. Significant use of GL is restricted to New Zealand, Australia and the USA (Blumenthal and McGraw 1999).

GL was introduced to New Zealand between 1860 – 1870 and developed widespread distribution by the 1940's in high rainfall areas. It was recommended for use in either moist summer-rainfall low fertility hill country, or acidic waterlogged peat-lands (Sheath 1981). Following the release of Grasslands Maku in 1975, GL was promoted for grazing use in marginal lands including wet North Island hill country and acidic low fertility soils of the South island tussocky country where it was found to be best suited to high altitude sunny aspects in drier inland areas. Recently, GL has been used for understory forage production in plantation forests (Blumenthal and McGraw 1999). In Australia, Grasslands Maku is used on wet infertile and acidic soils on beef and dairy farms in coastal districts (Harris *et al.* 1993).

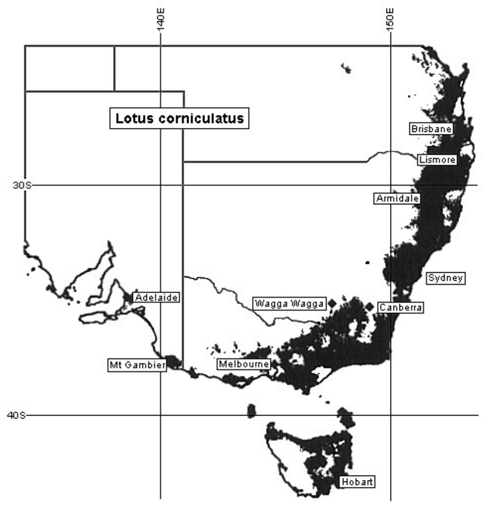
BFT was introduced to both Australia and New Zealand in the early 1900's but did not spread widely because specific rhizobia for BFT was not present in the soil. In New Zealand where soil fertility is low to moderate in dry regions, BFT has been found to be the most persistent legume and often the only remaining productive legume when grazing pressure is lax in old trials after fertility has been depleted (Scott and Charleton 1983).

1.3 Lotus in Australia

GL – The current area of GL in Australia is estimated to be 100,000 ha (Blumenthal and McGraw 1999), 100 ha in 1984 and 5,500 ha in 1990, following release of the first commercial cultivar (Grasslands Maku) in 1975 (Harris *et al.* 1993., Kelman and Blumenthal 1992). The potential zone of adaptation for GL was proposed by Hill *et al.* (1996) to occupy a substantial area in high rainfall coastal districts and favoured moist sites on the northern tablelands where AAR > 1,000 mm (Figure 2.1). The expansion of GL into this potential lotus zone is limited by the narrow adaptive characteristics of G. Maku and the high price of seed.

BFT – Experience with BFT in Australia is limited to species evaluation trials (Kelman and Oram 1989, Kelman and Blumenthal 1993, Blumenthal *et al.* 1999, Kelman *et al.* 1997, Lolicato and Rogers 1997, Kelman 1996, Hill *et al.* 1996) and commercial applications are limited to agency and seed company demonstrations. On the basis of widespread adaptation in northern hemisphere homoclimes and competitiveness with introduced perennial grasses, the potential zone of adaptation for BFT has been estimated (Hill *et al.* 1996) to be comparable but larger than the white clover zone (Figure 1).

a)



b)

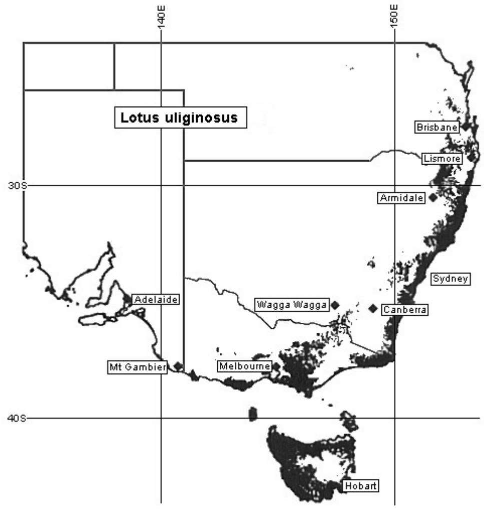


Figure 1. The potential zone of adaptation of birdsfoot trefoil (*Lotus corniculatus*) and b) Greater lotus (*Lotus uliginosus*) from Hill *et al.* (1996).

1.4 Adaptive characteristics

Lotus is best adapted to humid-temperate environments. In Australia and New Zealand, GL is sown in areas receiving > 900 mm AAR with some summer incidence. BFT tends to be more tolerant of droughty soils than GL. However, BFT is not as well adapted to high temperature (Nelson & Smith 1969) or drought (Hoveland 1994) as lucerne. GL is better adapted to high temperature than white clover (Mitchell 1956) or BFT (Duarsa *et al.* 1993) with growth rates and number of growing stems continuing to increase up to a 26 - 22^{o}C day-night temperature regime. BFT had better growth at 27 - 13^{o}C than 31 - 21^{o}C temperature regime (Long *et al.* 1989). GL is less frost tolerant than white clover (Schiller & Ayres 1993) and can be subject to out-of-season frosts on the South Island of New Zealand (Fraser *et al.* 1988).

Despite better growth at relatively high temperature in controlled environments and frost susceptibility, Lotus is considered to be a cool-season plant and is grown primarily in colder climates; however Lotus will grow in warm environments if given adequate moisture. There are two major reasons why Lotus is not usually grown below about 30^{o} N or S lat. First, BFT and GL are long-day plants requiring at least 14 h of day length to flower (Forde & Thomas 1966; Grant & Marten 1985; McKee 1963). At lower latitudes the plants will not set seed and persist. Second, warm temperatures tend to promote foliar and crown-rotting diseases that restrict production and decrease stand persistence (Beuselinck *et al.* 1984). The climatic adaptation of commercially produced Lotus is expanding, particularly in the USA, Uruguay, New Zealand, and Australia as plants are selected for earlier flowering and better stand persistence.

Adaptation to moisture stress

On the basis of soil moisture, adaptation of BFT is often compared with and GL is often compared to white clover. BFT has greater flooding tolerance (Barta 1984, 1986, 1987) but less drought tolerance (Peterson *et al.* 1992) than lucerne. Following inundation for up to 20 d, Heinrichs (Heinrichs 1970) rated the flooding tolerance of BFT to be superior to eight other legume species, including white clover, strawberry clover and red clover, and lucerne on the basis of yellowing of leaves, decay of roots, crude protein percentage, and dry matter yield of roots and leaves. Furthermore, BFT tolerates waterlogging equally well at root zone temperatures of 13, 19 or 25^{o}C; whereas tolerance improved in both lucerne and sainfoin at lower root zone temperature (Heinrichs 1972). In a study by Shiferaw *et al.* (1992), waterlogging tolerance of Maku GL was indicated by thickening of submerged stems and suberisation of roots. Sharnae and G4704 GL were not as tolerant of waterlogging as Maku. In this study, only American jointvetch (cv. Glenn) was more tolerant than GL cv. Maku after inundation to 3 cm for up to 14 d. BFT has greater salt tolerance than a range of legumes including GL (Ayers 1948). The tetraploid GL cv. Maku was more prevalent on seasonally dry north facing slopes in New Zealand North Island hill country with the diploid cv. Sunrise (formerly G4703) more prevalent on moister south and east facing slopes suggesting greater drought tolerance in the tetraploid (Hopkins *et al.* 1993).

Adaptation to acid soils

The acid soil and high Aluminium tolerance of GL has been well documented (Duck 1981; Langer 1973; Seaney & Henson 1970). BFT is not as tolerant as GL, but generally it is more so than lucerne (Baliger *et al.* 1988; Charlton 1983). BFT seedlings did not respond to lime in a soil with pH 5.0 in Pennsylvania (McKee 1961). There was little yield response to lime in BFT with surface soil pH 5.4 and subsoil 4.7 when 50 to 100 kg P ha^{-1} was applied in the Transvaal of South Africa (Barnes 1987). BFT also is less sensitive than other cool season legumes to Mn toxicity associated with acid soils (Russelle & McGraw 1986).

Blamey *et al.* (1990) found, in a solution culture experiment, that whilst the GL cultivar Maku increased in dry matter production with increasing aluminium concentrations, accessions of BFT (including the cultivar Maitland) declined over the same aluminium levels. Hybrids between BFT and GL showed tolerance levels intermediate between the parents. Edmeades *et al.* (1991), in attempting to separate the effects of pH and aluminium in solution culture, found that low pH alone adversely affected Hunter River lucerne, but had no effect on Maku GL or Maitland BFT. With high aluminium, however, they found that Maitland was one of the most sensitive cultivars (even more so than lucerne or white clover). Maku was more tolerant than a wide range of pasture species. Schachtman and Kelman (1991) compared the growth of 19 accessions from nine Lotus species with strawberry clover, white clover and lucerne. GL, including Maku, and a Californian rangeland annual Lotus species (*L. unifoliatus* Benth.) were found to be the most aluminium tolerant. Except for the cultivar AU Dewey (which was classed as moderately tolerant) BFT was generally moderately susceptible. The exceptional acid soil tolerance of GL and the moderate tolerance of BFT has been documented further in both limed pots (Alison & Hoveland 1989a; Barnard & Folder 1988) soil in the field (Floate *et al.* 1985; Kelman & Oram 1989; Lowther *et al.* 1987; McIntosh *et al.* 1984).

Adaptation to low fertility soils

BFT and GL are suitable for infertile acid soils (Charlton 1983; Duke 1981; Langer 1973). Although adapted to poorer soils, BFT needs adequate amounts of P and K for satisfactory growth (Seaney & Henson 1970). Generally, in naturally infertile soils, Lotus sp. will respond well to small fertility increases, but on highly fertile agricultural soils they are prone to be overwhelmed by more productive species such as white clover (Scott & Lowther 1980). Scott & Charlton (1983), after 10 years of observations on BFT sites in New Zealand, suggested its likely role to be in a low-input system. Lowther (1991) recommended a similar role for GL after comparing it with red and white clovers under grazing during 6 years. Most soils in Uruguay have a low P content (< 5 ppm Bray). Compared with white clover, red clover, and lucerne, BFT is able to perform relatively better with only low inputs of P fertiliser (Asuaga 1994).

Brock (1973), in mown swards during a 3 year period, found that with high inputs of P, white clover yielded 10% more herbage dry matter than GL; but with low P, GL yielded 30% more than the clover. In a pot experiment, Gibson *et al.* (1975) found that the Maku GL had greater responses to small applications of P than white clover. Maku was shown by Keen Kahn Kiang (1981), in a field with moderately acid soil (pH 5.3) to have higher yields than white or Caucasian clovers. This was attributed to greater uptake of P from the soil by a more laterally extensive root system and more efficient P use. Similar results were achieved by plants growing in a low-P solution culture experiment.

In a pot experiment, Hart *et al.* (1981) found Maku GL to have the lowest tissue P concentrations, and on the basis of growth per absorbed P it was the most efficient user of P compared to red, white and suckling clover. Davis (1991) applied 9 rates of P to 7 different pasture legumes in the field, and Maku did not produce more than white clover at low levels of P. In the third and subsequent years, until the end of the experiment at year 5, Maitland BFT, produced more than Maku GL, white, red, Caucasian, and alsike clovers, at low levels of P. Floate *et al.* (1985) reported that generally the P requirement of Maku was similar to a mixture of white and red clovers, except that occasionally the clover mix gave comparatively greater yields with higher P inputs. These soils were S deficient and they reported that this could be overcome by the S contained in the recommended rates of superphosphate (250 kg ha^{-1} initially followed by 125 kg ha^{-1} annually).

Although an efficient user of P, Maku GL is a poorer scavenger for K than a wide range of pasture species including kikuyu grass - the major species in dairy pastures in sub-tropical eastern Australia (Pinkerton & Randall 1993). BFT has given relatively poor response to K fertiliser (Foy & Barber 1961); this low response to K has occurred even in soils with low exchangeable K levels (Russelle *et al.* 1991).

1.5 Mechanisms of persistence

Seed set and seedbank formation

BFT and GL are long-day plants. BFT cultivars generally have a critical day length for flowering of 14 to 14.5 hours with blooming being retarded at day lengths less than 15 hours. Full bloom does not occur in most varieties at latitudes lower than 30^{o} S or N (McKee 1963). In a German variety of GL, day length of 14.5 to 15 hours is required for inflorescence initiation (Forde & Thomas 1966). Reseeding in swards is limited in latitudes that fail to meet the critical photoperiod requirement for flowering.

Persistence of BFT cultivars in northern USA relies on allowing swards to set seed early in the stands life so that a seedbank can form for subsequent seedling recruitment (Taylor *et al.* 1973; Templeton *et al.* 1967). Individual plants may live only 2 or 3 years because they are highly susceptible to crown- and root-rots. Crown- and root-rot is caused by a complex of organisms that may vary in different environments. This disease is more severe in warmer climates. Stand losses were 90% after 2 years in Missouri regardless of harvest management (Beuselinck *et al.* 1984). BFT plants have the potential to produce large numbers of hard seed. If managed properly, stands can be maintained through natural reseeding. Seed quality in BFT is influenced by temperature (Beuselinck & McGraw 1988). Seed developed at higher temperatures is smaller and of poorer quality than seed developed at lower temperature. At lower latitudes, management of early season growth for seed production by delaying grazing or harvest would produce a greater quantity of high quality seed than delaying seed production until later in the season. In lower latitudes, varieties need to be selected with a shorter critical day length for flowering if seedbanks are to be developed. Plants with shorter critical photoperiods also would flower earlier when temperatures are cooler leading to greater reproductive success.

A survey of soil seedbanks in farmers' fields in eastern Australia revealed that the size of the seedbank was positively correlated with latitude and negatively correlated with January mean maximum temperature (Blumenthal & Harris 1993). Seedbanks can contribute to the persistence of Maku GL only at high latitudes (> 32^{o}S) with seedbanks as large as 6000 seeds m^{-2}. An advantage of GL cv. Sharnae is that it is earlier flowering than Maku and can set seed and form a seedbank at lower latitudes in eastern Australia.

In New Zealand, GL seedbanks were largest (up to 5720 weeds m^{-2}) in high summer rainfall hill pastures particularly in wet areas (Charlton 1975; Suckling & Charlton 1978). GL also was present in gumland clays (Hyde & Suckling 1953). In South Island tussock grassland, natural reseeding is likely to occur in GL only if pastures are rested for the entire growing season. Once reseeding takes place, viable seed is readily spread by grazing animals to germinate in dung pats (Lowther *et al.* 1992).

Breakdown of hard seed in Maku, CPI 67676, 67677, and 67678 GL is much slower than either Tamar or Haifa white clover (Kelman & Blumenthal 1992). Rates of breakdown in 67676 were more rapid than in the other GL lines. Even when Maku is able to set seed, slow break down of hardseed limits the ability to recruit seedlings to increase sward density. Indications are that the rate of hardseed breakdown in BFT also is slow with field germination being greatest in the spring following one full winter in the field (Brown 1955, as cited in Seaney & Henson 1970). The actual mechanisms of hardseed breakdown are yet to be investigated.

Morphology and grazing management

In BFT, branches develop from stems, and stems develop from a crown. These stems are indeterminate and bear flowers in stalked auxiliary clusters towards the tips. Unlike lucerne, BFT elongation of basal buds from the crown does not occur until after defoliation. Lucerne is able to elongate buds when existing shoots are mature and has a more rapid rate of basal bud elongation (Keoghan & Tossell 1974). BFT maintains low root total nonstructural carbohydrates (TNC) compared to lucerne and lacks the cyclic use and restoration of TNC found in lucerne (Greub & Wedin 1971; Nelson & Smith 1968; Smith 1962). Despite this, Alison and Hoveland (1989b) found a correlation between spring yields and the mean TNC levels in the preceding 2 years. This correlation suggests a cumulative effect of TNC levels on BFT yields and management should be designed to maintain higher TNC levels. Raising the stubble height to 10 rather than 3 cm increases TNC levels. This is particularly important in more erect varieties such as AU Dewey and GA1 (Alison & Hoveland 1989b). Herbage yield increases with length of time between harvests (Alison & Hoveland 1989b; Hoveland & Fales 1985; Smith & Nelson 1967). BFT yield can be greater if cut at a lower stubble height (eg. 2.5 vs 7.5 cm); however, stand life is reduced (Duell & Gasman) 1957). Continuous grazing of BFT stands limits persistence by reducing TNC levels and preventing seed set (Templeton *et al.* 1967; Van Keuren & Davis 1968; Van Keuren *et al.* 1969). In Uruguay, rotational grazing is recommended for BFT with the pasture reaching a height of 20 to 25 cm before grazing takes place (Asuga 1994).

In GL, crown development is weak and plants rely on rhizomes to provide regrowth sites, carbohydrate storage, and colonisation potential (Sheath 1975). At Palmerston North in New Zealand (40^{o}S), spring and early summer growth is dominated by aerial shoots. During late summer and autumn, growth is dominated by underground organs (Sheath 1980a). In Scotland, both aerial shoot and rhizome production reach a peak in autumn (Wedderburn & Gynne 1981). In south-east Queensland (29^{o}S) peak rhizome production may occur in spring not autumn; however, this observation may reflect soil moisture conditions at the time (Voss & Jones 1986). Under good moisture conditions at Nowra NSW (34^{o}S), rhizome development commenced in mid-summer and continued to increase into autumn. A controlled environment study suggests that temperature has a greater effect on rhizome development than day length (Blumenthal & Harris 1993).

Cutting height strongly influenced rhizome shoot numbers and cutting interval increased their dominance in the canopy (Sheath 1980b). Regrowth was slow for 2 to 3 weeks after cutting and DM yield increased as the regrowth period was extended. Higher cutting improved shoot regrowth but resulted in greater dry matter losses and little improvement in net productivity. Rhizome shoots were the major source of potential shoot production; however, the full realisation of the potential through the manipulation of defoliation strategies was difficult (Sheath 1980b). One the South Island of New Zealand, defoliation as early as the start of January reduced the amounts of rhizomes present in April; early February or March defoliation virtually eliminated rhizome growth (Wedderburn & Lowther 1985); in sparse swards it is recommended that grazing be avoided over late summer and autumn.

A cutting interval of 4 weeks with a cutting height of 2 cm virtually eliminated a Maku lotus sward at Nowra. Longer intervals or higher stubble heights were necessary to maintain Maku in the sward (Harris *et al.* 1997). It appears that GL is better suited to longer rotations and lenient grazing heights with strategic rest periods to increase sward density.

Competition with other species

The competitive ability of GL and BFT are dependent on factors already considered above: adaptation to climate and edaphic factors, and the genetic potential for growth. Grazing management has an influence on competitive ability of Lotus with associated species. Other factors important to the competitiveness of Lotus are N-fixing ability, tannin levels, alleopathy, and growth habit.

Within the temperature and soil moisture conditions to which Lotus is adapted, Lotus is more competitive in acid, low P soils. In Northern Ireland, Maku GL was able to compete with tall fescue, red fescue, and perennial ryegrass when grown on an acid peat soil (Laidlaw 1981). Yields in mown swards of GL grown alone were higher than i) white clover, ii) red clover, iii) 50:50 Lotus/white clover or iv) 50:50 lotus/red clover mixtures when grown on acid, low fertility tussock grassland soil in the South Island of New Zealand (Lowther 1980). When grown in growth cabinets in turfs from a similar infertile soil, Maku GL was more competitive than white clover cv. Grasslands Huia, probably due to the greater tolerance of Maku to high levels of Al in the soil solution, rather than above ground competition (Scott & Lowther 1980).

Even when grown in climates and soils to which GL is well adapted, cutting or grazing frequency can have a marked effect on GL competitiveness. Infrequent grazing favoured GL yield over Nui perennial ryegrass compared with frequency grazing when Nui was over-drilled into an existing GL stand on the Canterbury plain of the South Island of New Zealand (Vartha 1983). When Maku and Sharnae GL were established in a sward of kikuyu on the sub-tropical north coast of NSW, in Australia, cutting the sward when the lower leaves of GL commenced senescence favoured GL growth compared with the more frequent fortnightly cutting treatment (Fulkerson & Slack 1996). In a paddock sown to Maku GL on the warm-temperate south coast of NSW, less frequent cutting (every 12 weeks) favoured GL growth compared with more frequent cutting (4 – week interval) that resulted in the ingress of a naturalised small leafed white clover ecotype (Harris *et al.* 1997). When used for grazing, BFT is most often grown with companion grasses (Seaney & Henson 1970). Although grasses have poorer forage quality than BFT, they can contribute to higher herbage yields, fill in vacant areas that develop in stands that allow weed invasion, and decrease the severity of frost heaving (Marten & Jordan 1979; Sheaffer *et al.* 1984). Research and industry experience has shown tall fescue to be the most compatible grass to be sown with BFT in the USA. Tall fescue is slow to establish compared with other improved grasses, as is BFT compared with the improved legumes (Hoveland 1994). Although substances in tall fescue can inhibit BFT germination (Luu *et al.* 1989) problems with BFT germination in the field when sown with or into tall fescue have not been observed. The more erect bunch-type habit of tall fescue provides space for BFT to capture light. BFT does not supply tall fescue with all its N needs and thus reduced the danger of N levels building up to such an extent that fescue is able to out-compete BFT (Hoveland & Richardson 1992). The yield and quality of forage can be greater in BFT- tall fescue mixed swards than in tall fescue only swards with no effect of the habit of the BFT cultivar (Beuselinck *et al.* 1992). Yield and stand life of BFT are generally favoured by less frequent cutting interval; however, when grown in mixture with AU Triumph tall fescue, BFT is more competitive under frequent (3 week) compared with infrequent cutting (6 week) – this effect was most pronounced under conditions of moisture stress (Hill & Hoveland 1993). In contrast to its growth with tall fescue, BFT is not compatible with Bermuda grass ([*Cynodon dactylon* (L.) Pers]; when Bermuda grass invades BFT, productivity declines and the stand disappears (Hoveland 1994).

2. PROJECT OBJECTIVES

2.1 Industry objectives

By June 1999,

(a) To define grazing management strategies that enable Greater lotus and Birdsfoot trefoil to maintain at least 30% of total pasture dry matter in a mixed grass/legume pasture, for at least 4 years in beef breeding system

(b) To demonstrate the use, management and economic benefit of Greater lotus and Birdsfoot trefoil cultivars to grow out steers in conjunction with graziers, seed companies, extension officers and other stakeholders thought a series of co-learning sites.

2.2 Experimental objectives

The central hypothesis tested by the experiment was that grazing management affects the persistence of lotus, and that the type of companion grass moderates the effects of grazing management. Accordingly, experimental design was devised with respect to the following experimental objective:-

> To determine if grazing intensity and strategic spelling affects expression of the adaptive characteristics of Greater lotus and Birdsfoot lotus, and to examine whether the level of grass competition interacts with the response to grazing intensity and strategic spelling.

2.3 Milestones

Key milestone activities for both the research phase and co-learning phase are listed on the timeline below:-

Completion date	Core experiment activity	Completion date	Co-learning activity
		29/07/94	Meet with stakeholders to determine co-learning strategy
31/08/94	Finalise protocol and select core sites		
		30/12/94	Meet at 10 locations across the state to develop co-learning groups
31/05/95	All sites established with adequate population of lotus		
		30/06/95	Establish 10 co-learning sites
		30/03/95	Co-learning groups report, (i) activities for last 12 months; (ii) what learnt; (iii) if sites should continue; (iv) plan for next 12 months.
31/01/95	Treatments and monitoring commenced		
30/06/96	Update on results for 1995/96	30/06/96	Co-learning groups report, (i) activities for last 12 months; (ii) what learnt; (iii) if sites should continue; (iv) plan for next 12 months.
30/06/97	Update on results for 1996/97	30/06/97	Co-learning groups report, (i) activities for last 12 months; (ii) what learnt; (iii) if sites should continue; (iv) plan for next 12 months.

Completion date	Core experiment activity	Completion date	Co-learning activity
30/06/98	Update on results for 1997/98	30/06/98	Co-learning groups report, (i) activities for last 12 months; (ii) what learnt; (iii) if sites should continue; (iv) plan for next 12 months.
		30/06/99	Co-learning groups report on what benefits they have gained from being a member of the co-learning groups, what they have done as a result of this; and what recommendations they would make on running of similar co-learning sites

3. METHODOLOGY

3.1 The core experiment/co-learning paradigm

At the outset of planning for this project in the early 1990's, the development and extension of Lotus technology presented a dilemma. For Greater Lotus, the potential zone of adaptation (high rainfall coastal districts) was small, knowledge (both scientific and farmer experience) was extensive, but adoption was low (< 50,000 ha). By contrast, for birdsfoot trefoil, the potential zone of adaptation (tablelands and slopes) was large, knowledge was slight, and there was no commercial usage. Although both legumes belong to the genus *Lotus*, *L. uliginosus* and *L. corniculatus* are different species with different morphological characteristics and strongly contrasting mechanisms of adaptation. Moreover, both Lotus species were perceived to require specialised management for persistence. However in the target zones for both, intermittent set-stocking is traditionally practiced.

The "terms of reference" for the project was to provide a "fast-track" R&D process to i) determine the relative zones of adaptation for Greater lotus and birdsfoot trefoil, ii) develop management strategies for Lotus persistence, and iii) promote increased adoption of Lotus technology. That is, a single project had to develop new findings on species adaptation and management and simultaneously promote technology transfer – with an imperative for both to be done within the 5 year timeframe of the project. The R&D process developed to achieve this comprised a dual research phase (the core experiment with sites in each target region - North Coast, South Coast, Northern Tablelands, Southern Tablelands), and an extension phase (co-learning groups and on-farm demonstrations in each of the regions involving farmers, project workers and industry stakeholders).

The core experiment was established at 4 sites (Casino, north coast; Nowra, south coast; Glen Innes, northern tablelands; Canberra, southern tablelands) to examine the effects of grazing intensity and strategic spelling on the persistence of Lotus in relation to the adaptive characteristics of each lotus species. Co-learning methodology was employed at 17 sites (North Coast, 4; South Coast, 3; Northern Tablelands, 6; Southern Tablelands, 4) in satellite juxtaposition to the core experiment sites. The location of the core experiment sites and co-learning sites is presented in Figure 2).

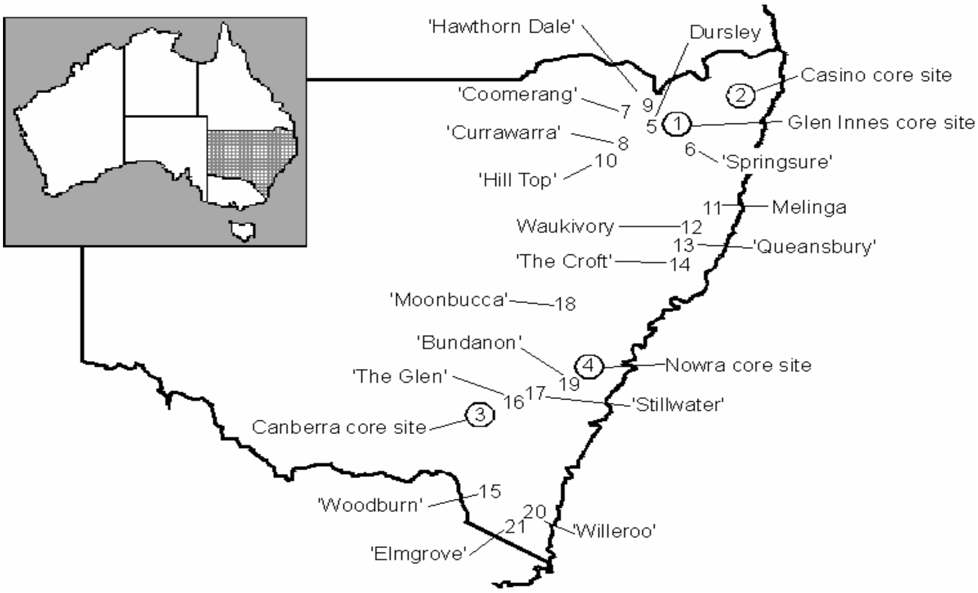


Figure 2: Location of the 4 core experiment sites and 17 co-learning sites.

The research and co-learning phases were linked where practicable by paired-comparison of key treatments from the core experiment at the co-learning sites. For Greater lotus co-learning sites (ie. Coastal districts), the paired-comparison was of T2 and T6 (ie. "continuous grazing/high biomass" versus "autumn spell/high biomass"). For Birdsfoot lotus co-learning sites (ie. Hinterland districts), the paired-comparison was of T2 and T4 (ie. "continuous grazing/high biomass" versus "summer spell/high biomass"). From research in Australia and New Zealand, autumn spelling is considered to be an important management requirement for persistence of Greater lotus. From US research, summer spelling is considered to be an important requirement for persistence of Birdsfoot lotus. The anticipated outcomes from this dual R&D process were expected to be:-

- *From the research phase* - grazing management guidelines for lotus persistence
- *From the co-learning phase* - rapid adoption of project outcomes.

In the development and implementation of the co-learning phase, significant milestone events were as follows:-

(a) A facilitator with expertise in extension methodology (Peter Ampt/University of Sydney) led an initial planning meeting with project workers and industry stakeholders in May 1994 to secure support and commitment for the project to proceed. At this meeting, participants were provided with a definition of co-learning and how it contrasts with the traditional linear research-extension model, how stakeholders and farmers might participate, and the strengths and weaknesses of co-learning. The appropriateness and potential usefulness of co-learning in addressing the project's terms of reference were discussed.

(b) With support from 11 advisory officers, the facilitator undertook a series of meetings across New South Wales to establish co-learning groups. Groups were brought together in different ways, either within existing Landcare or industry groups or by open or selective invitations to the rural community. Between August and November 1994, 11 meetings (Eden, Bombala, Rylestone, Maitland, Taree, Grafton, Casino, Glen Innes, Inverell) were held. A member of the research team or an advisory officer were present at each meeting. The following issues were addressed: Does lotus have potential in your area? Is strategic grazing management logically feasible? What is expected of you? Why are you involved? Who will be responsible? Who else should be involved? Are lines of communication suitable? What are the costs and benefits?

All groups except 1 group agreed to establish a co-learning site on a paddock scale basis to compare "traditional management" with "strategic management". The "traditional" treatment was defined by each group and this generally took the form of intermittent grazing or set-stocking. The "strategic" treatment was defined by the researchers and this took the form of lenient grazing (ie. high biomass) combined with strategic spelling, depending on lotus cultivar. The division of responsibility for conduct of activities was determined independently by each group. Thirteen groups were established by this process and an additional 4 groups were established subsequently in collaboration with the GWYMAC Landcare Co-ordinator (Dick Walker) at Inverell.

(c) An external audit of the co-learning methodology operating at the outset of the project was undertaken by Dr Jeff Coutts (Rural Extension Centre, Gatton Campus, University of Queensland) in April 1996.

(d) Field-work at the 4 core sites was undertaken between 1995 - 1999 (results are reported in 2.4.1.).

(e) Field-work at the 17 co-learning sites proceeded during 1995 - 1999 (results are presented in 2.4.2.).

(f) An external audit of the outcomes from the co-learning phase was undertaken by Dr Jeff Coutts and Dr Kate Roberts (Rural Extension Centre, Gatton Campus, University of Queensland) in October-November 1999. This evaluation focussed on:-

(i) How was co-learning understood and enacted in the context of the project?

(ii) How did co-learning impact on the outcomes of the project?

(iii) What were the strengths and weaknesses of the lotus co-learning model?

(iv) What lessons were learned of benefit to future co-learning projects?

3.2 The core experiment - design and protocols

3.2.1 Location

The grazing experiment was replicated at 4 sites (Glen Innes, Casino, Canberra, Nowra) to sample the 4 regions (Northern Tablelands, North Coast, Southern Tablelands, South Coast) in the high rainfall zone (Figure 2):

Northern tablelands - The northern tablelands site was located at Glen Innes Agricultural Research & Advisory Station, 7 km north-west of Glen Innes (29°42’S, 151°42’E). The climate is characterised by high rainfall (849 mm AAR) with marked summer incidence, a long frosting interval and cold winter conditions (Table 1). The soil is a self-mulching heavy clay-loam derived from basalt. At the outset of the experiment, the soil was low in available P status and was acid in pH reaction (Table 5).

North coast - The north coast site was located on the property of LE & LD Lynch at McKee’s Hill about 15 km north east of Casino (28°53’S,153°01’E). Climate data are presented in Table 2. The soil is a grey-brown alluvial medium clay derived from basalt with medium P status and acid reaction (Table 5).

Southern tablelands -The southern tablelands site was located on the CSIRO Ginninderra Field Station, Canberra. Climate data is presented in Table 3. The soil is a poorly structured grey-brown clay loam with acid pH reaction and high P status (Table 5).

South coast - The south coast site was located on Warrick Mottram’s property at Numbaa, east of Nowra (34°57’S). The paddock is on an alluvial soil on the edge of the Shoalhaven river flood plain and was previously under long term pasture. Climate at the site is characterised by relatively high rainfall (1135 mm AAR) with slight summer incidence (Table 4). Potential pasture growth is markedly seasonal; soil moisture limits growth in summer and low temperature limits growth in winter. The soil is a dark brown clay-loam with strongly acid pH reaction and high available P status (Table 5).

Table 1: Climate summary for Glen Innes (Glen Innes Agricultural Research and Advisory Station)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean daily max temp (°C)	25.0	24.4	22.8	19.8	16.2	12.9	12.2	13.7	16.4	19.6	22.0	24.4	
Mean daily min temp (°C)	13.5	13.4	11.5	8.0	4.9	1.7	0.6	1.2	4.0	7.1	9.7	12.1	
Mean monthly rainfall (mm)	108.0	92.4	69.5	40.9	50.4	54.3	57.6	49.0	55.0	77.8	85.2	108.9	
Mean daily evaporation (mm)	5.5	4.9	4.3	3.2	2.1	1.6	1.7	2.4	3.5	4.3	5.2	5.6	848.9
Number of frosts	nil	nil	0.3	3.5	11.9	19.3	22.3	21.9	14.5	5.1	1.3	0.6	100.8

Table 2: Climate summary for Casino (Casino Airport)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean daily max temp (°C)	31.4	30.5	29.1	27.0	23.8	21.5	21.2	22.8	25.5	27.9	29.9	31.2	
Mean daily min temp (°C)	18.8	18.8	22.7	14.0	10.6	7.9	6.6	7.3	10.1	13.2	15.9	17.7	
Mean monthly rainfall (mm)	138.0	157.7	150.7	97.3	80.7	67.9	59.3	42.5	42.6	70.2	88.3	114.8	1108
Mean daily evaporation (mm)	5.8	5	4.4	3.6	2.7	2.5	2.9	3.6	4.6	5.1	5.6	6.1	
Number of Frosts	0	0	0	0	0	0.6	1.6	0.6	0	0	0	0	2.8

Table 3: Climate summary for Canberra (CSIRO Ginninderra Field Station)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean daily max temp (°C)	27.7	26.9	24.3	19.7	15.2	12.0	11.1	12.8	15.9	19.1	22.5	25.9	
Mean daily min temp (°C)	12.9	12.9	10.7	6.7	3.1	0.8	-0.2	0.9	2.9	5.9	8.5	11.1	
Mean monthly rainfall (mm)	58	57	56	53	49	37	40	47	50	67	63	53	632.3

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean daily evaporation (mm)	8.1	7.1	5.5	3.6	2.2	1.6	1.7	2.6	3.7	5.1	6.4	8.1	
Number of frosts	0	0	0.4	5	13.5	18.3	21.1	18.7	13.7	6.5	2	0.3	99.7

Table 4: Climate summary for Nowra (HMAS Albatross Navy Base)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean daily max temp (^oC)	25.8	25.7	24.4	22.1	19.0	16.3	15.8	17.1	19.3	21.4	23.2	25.1	
Mean daily min temp (^oC)	16.0	16.2	14.7	12.1	9.7	7.6	6.2	6.7	8.2	10.6	12.5	14.5	
Mean monthly rainfall (mm)	95.8	125.7	130.4	100.6	92.3	107.9	56.2	69.3	65.0	114.3	102.4	75.5	1135.5
Mean daily evaporation (mm)	6.3	5.7	4.7	7.0	3.1	2.9	3.1	4.1	5.0	5.7	6.0	6.9	
Number of frosts	0	0	0	0	0.2	0.9	2.1	1.8	0.5	0	0	0	5.5

Table 5: Soil nutrient status at the 4 core sites prior to treatments

	Glen Innes †	Casino ‡	Canberra †	Nowra †
pH (1:5 Ca Cl_2)	4.6	4.9	4.8	4.2
Phosphorus (mg/kg Colwell)	-	43	115	112
Phosphorus (mg/kg Bray1)	9	-	-	-
Conductivity (d S/m)	0.06	0.08	0.06	0.4
Cation exchange capacity	-	27.2	-	-
Potassium (meq/100 g)	0.1	0.3	0.6	0.9
Calcium (meq/100 g)	7.8	12.1	4.2	5.3
Magnesium (meq/100g)	8.8	13.8	1.5	3.6
Sodium (meq/100g)	0.24	09.8	0.13	0.85
Aluminium (meq/100g)	-	0.10	-	-
Aluminium saturation (%)	-	0.4	-	-
Sulphur (mg/kg, KCl)	6	-	-	-
Nitrate nitrogen (mg/kg)	2	-	-	-
Total nitrogen (%)	1.5	-	-	-

† 0 - 10 cm profile ‡ 0 - 7.5 cm profile

3.2.2 Design and treatments

The experiment investigated the significance of alternative grazing treatments for different lotus/grass mixes to determine sound grazing management strategies for lotus. Treatments at each site were factorial combinations of 7 grazing treatments and 8 lotus/grass mixes as below:-

	GRAZING TREATMENTS	**x**	*CULTIVAR MIXES*
T1:	Continuous grazing/low biomass		Maku lotus/phalaris
T2:	Continuous grazing/high biomass		Maku lotus/danthonia
T3:	Summer spell/low biomass		Sharnae lotus/phalaris
T4:	Summer spell/high biomass		Sharnae lotus/danthonia
T5:	Autumn spell/low biomass		Goldie lotus/phalaris
T6:	Autumn spell/high biomass		Goldie lotus/danthonia
T7	Rotational grazing/high biomass		[t] Spanish lotus/phalaris
			[t] Spanish lotus/danthonia

The plot layout at each site is presented in Appendices 1 - 4.

[t] The Spanish lotus cultivar treatments was included at the Canberra site only

A standard protocol was adopted to ensure uniform management practices and measurement techniques across the 4 experiment sites. A diary of management events is presented in Appendices 5 - 8, the grazing schedule is presented in Appendices 9 - 12, and the measurements schedule is presented in Appendices 13 – 16.

3.2.3 Site preparations

Glen Innes site - The paddock was cover cropped with Italian ryegrass (*Lolium multiflorum* cv. Concord) in the year prior to planting, treated with herbicide (glyphosate) in September 1994 and planted under direct drill culture in October, 1994. Sowing rates were 3 kg/ha for Greater lotus (cvv. Maku, Sharnae), 10 kg/ha for Birdsfoot lotus (cv. Goldie), 1.5 kg/ha for *Danthonia richardsonii* (cv. Taranna) and 10 kg/ha for tall fescue (*Fescue arundinacea* cv. Demeter) and phalaris (*Phalaris acquatica* cv. Sirosa) combined. Due to establishment failure associated with severe drought, the plots were replanted in March 1995 and the seedbank was fortified by serial oversowings in October 1995, March 1996 and April 1996 (Table 6). Grazing treatments were imposed from March 1997 - June 1999.

Casino site - The paddock was treated with glyphosphate herbicide (6 L/ha) in February 1995 for control of couch grass. Plots were planted by manual broadcasting, hand raking and rolling in March 1995. Sowing rates were 3 kg/ha for Maku, 6 kg/ha for Sharnae, 10 kg/ha for Goldie, 3 kg/ha for Narok setaria and 3 kg/ha for paspalum/carpet grass mixture. Single molybdenated superphosphate was applied at 250 kg/ha prior to sowing and 150 kg/ha each spring in subsequent years. Sown species established from this initial planting very slowly due to drought conditions in 1995; botanical estimations undertaken in December 1995 show Goldie>Sharnae>Maku, broadleaf weed invasion and poor populations of sown grasses (Table 3). The carpet grass and paspalum failed to establish so these plots are subsequently referred to as “volunteer grass” plots. Infection of lotus with rhizoctonia was observed in February 1996 leading to extensive demise of the lotus populations. Plots were resown with lotus in March 1996 - manual broadcasting, hand raking and rolling following seedbed preparation with glyphosate to eliminate couch grass. The lotus cultivars established well due to very wet conditions in May - seedling density results are presented in Table 7.

Canberra site - The experiment site was located on a paddock following a crop of linseed (1994). Due to dry conditions the site was irrigated to wet the sub-soil and harrowed to produce a seedbed. The experiment was sown with a cone-seeder on March 23 and 24, 1995 using 3 kg/ha Maku, 6 kg/ha Sharnae, 10 kg/ha Goldie and 10 kg/ha “Spanish prostrate”. All legume seed was inoculated with recommended innoculum and treated with Mo-trioxide. Coopex (permethrim, 250 g/kg) was added to the pedunculatus seed. Phalaris (cv. Holdfast) was sown at 3 kg/ha. 125 kg/ha Starter 15 fertiliser was applied at sowing with 20 kg/ha Mesurol (methiocarb, 20 g/kg) slug bait. Seed and fertiliser were dropped onto a prepared seedbed and rolled with a rubber tyred roller. After sowing, drought conditions prevailed and irrigation continued until arrival of winter rain. Herbicide applications during establishment included 2 l/ha Sprayseed (paraquat/diquat, 100 g/l) on 1 April 1995 for wild oat control, Bromoxynil on 31 May, 1995 for control of broadleaf weeds, and glyphosate (1.2 l/ha) with wick-wiper for annual grass control on 9 June 1995. Seedling counts on 31 May, 1995 and 27 July, 1995 showed unsatisfactory populations of sown species so the lotus cultivars were oversown on 11 October 1995 following herbicide application of 3 l/ha 2,4 DB and 50 ml/ha Lemat (omethoate, 580 g/l) on 28 September 1995. Seedling density results are presented in Table 8. During the period until grazing treatments commenced (12 March,

1996) the site was maintained with occasional irrigation and forage harvesting to prevent grass smother of lotus seedlings.

Nowra site - The site was selected in late 1994, weeds were suppressed by application of 6 L/ha glyphosate and 1 L/ha dicamba in January 1995 followed by rotary hoeing in February 1995. The plots were planted on 5 April, 1995 using a cone seeder; seed was dropped on the surface, raked and rolled. Sowing rates were 3 kg/ha for Maku, 6 kg/ha for Sharnae (due to low germination %), 10 kg/ha for Goldie, 10 kg/ha for Kangaroo Valley perennial ryegrass and 1 kg/ha for kikuyu; 150 kg/ha Pasture 13 fertiliser (P:6.5% K:12.2% and Ca:14.7%) + 50 kg/ha urea was applied at planting. On 29/5/95, the trial site was sprayed with Tribunal to control corn spurry (*Spergula arvensis*) and again on 28/9/95 with 2.8 L/ha 24DB to control broad leaf weeds. Seedling establishment (from plant counts undertaken on 2/8/95) was sub-optimal so plots were oversown with lotus cultivars on 29/9/95 and again on 28/11/95 (Table 9). Irrigation was applied on three occasions for lotus seedling survival during very dry conditions in December/January, and following uniformity forage cut on 12/2/96; grazing treatments commenced in March 1996.

3.2.4 Measurements

The purpose in measuring seedling density, nodulation and seedling frequency following the initial plantings was to ascertain the success of lotus establishment at each site. The purpose in measuring the pasture parameters, rhizome and seedbank characters, and seedling recruitment was to determine whether the grazing treatments affected the Lotus populations.

(a) *Seedling density*

The success of establishment of sown species was estimated by counting seedlings (SL, lotus; NSL, non sown legumes; SG, sown grass; NSG, non sown grass; BLW, broad leaf weeds) from 2 treatment cells (T1, continuous grazing/low biomass; T2, continuous grazing/high biomass) in each of 3 replicate blocks at each site prior to implementation of grazing treatments. Seedlings were counted at 15 random sites in each plot using alternate 10 x 10 cm grids in a 40 x 40 cm weldmesh quadrat frame; data was expressed as seedlings/m^2. Data was obtained at Glen Innes on 2 occasions (16/8/95, 6/8/96), at Casino on 1 occasion (August 1996), at Canberra on 3 occasions (31/5/95, 27/7/95, November 1995) and at Nowra on 2 occasions (2/8/95, 21/3/96).

(b) *Nodulation*

Nodulation relates to how well the root-rhizobial association developed for each lotus cultivar at each site. The purpose of measuring modulation was to check the efficacy of the inoculum, especially for Goldie because of concern expressed about commercial *L. corniculatus* inoculum. Juvenile plants were sampled from each treatment cell using a soil corer and measurements made of plant number, nodule number, nodule weight, root weight and shoot weight. These components were used to calculate i) number of nodules per plant, ii) number of nodules per gram of root, iii) weight of nodules per gram of root and iv) shoot/root ratio. Nodulation measurements were made at all 4 sites but only in sufficient detail at Casino, Nowra and Canberra to allow analysis of data.

(c) *Seedling frequency*

Lotus frequency, a measure of basal cover of lotus was determined at Glen Innes and Casino sites to determine the success of seedling establishment. Frequency was estimated using a quadrat frame with a series of 10 x 10 cm cells placed at 10 observation sites on each plot - presence or absence of lotus in each cell was recorded providing a minimum of 50 estimates per plot.

(d) *Pasture observations*

The plots were sampled at approximately 3-monthly intervals to 7determine total pasture biomass, green and senesced fractions, and botanical components for each season. Measurement occasions (Appendices 13 – 16) corresponded with 3 weeks regrowth following a synchronised grazing of all treatments at each site (Appendices 9 – 12). Nutritive value was assessed by forage sampling and assay from all lotus/grass sub-plots in treatments 5 and 6 on 2 occasions each year to represent winter and spring forage. The pasture data was obtained by sampling at 10 fixed points by placing a 30 cm x 30 cm quadrat frame along a transect positioned diagonally in each lotus/grass sub-plot. The same transects and sampling points were revisited on each measurement occasion using a taut cord with affixed tags numbered 1 through 10 to identify the sampling points. Therefore, each reported value (mean, standard error) was derived from 10 estimates per sub-plot from the same sampling sites across measurement occasions.

Total pasture biomass and % green were estimated using calibrated “double sampling” procedures (Morley *et al.* 1964) and regression analysis. Species composition (%) was estimated using Botanal procedures (Hargreaves and Kerr 1978). Nutritive value assay was undertaken on green and senesced fractions; *in vitro* digestibility (% OM basis) was determined by a 2 – step procedure as described by Ayres (1991); nitrogen content (N, g N/kg DM) was determined using the Kjeldahl procedure (AOAC, 1980) using a Kjeltec Auto 1030 (Tecador AB, Sweden); organic matter (OM, %) was determined by ashing at 580^{o}C for 16 h. in a muffle furnace.

(e) *Rhizome density and seedbank development*

Rhizome density (rhizome number, rhizome segments/m^2; rhizome length, m/m^2; rhizome weight, g /m^2) and Lotus seedbank (number of seeds/m2) were measured from soil cores taken from the high biomass treatments (T2: continuous grazing/high biomass; T4: summer spell/high biomass; T6: autumn spell/high biomass, T7: rotational grazing/high biomass) in winter in the 3 years 1997, 1998 and 1999. Sampling was undertaken at Glen Innes in July 1998, June 1998 and July 1999; at Casino in August 1997, August 1998 and August 1999; at Canberra in August 1997, July 1998 and June 1999; and at Nowra in June 1997, June 1998 and June 1999. Soil sampling was undertaken with a 5 cm diameter soil corer to a depth of 5 cm. Sampling frequency was 20 cores per lotus/grass sub-plot along a diagonal transect opposite to the transect used for the pasture measurements. Samples were processed in accordance with the methods of Lock and Butler (1977) and Jones and Bunch (1988) – seed Appendix 21.

(f) *Seedling recruitment*

Seedling recruitment refers to the germination and establishment of new generations of Lotus arising from the Lotus soil seedbank – this is the principal mechanism for regeneration with BFT which is free-seeding but not with GL which regenerates mainly from rhizome extension. Seedling recruitment measurements were undertaken from BFT 'Goldie' sub-plots from treatment 2 (high biomass/continuous grazing) and treatment 4 (high biomass/summer spell) at all 4 sites on termination of the experiment in spring (1999). BFT seedlings were counted from 10 sites using a 30 x 30 cm quadrate frame along the fixed diagonal transect used to measure the pasture parameters. Results were expressed as seedlings per m^2 and data analysis enabled comparison of T2 with T4 to determine whether significant seedling recruitment occurred where rest from grazing during flowering – podding in summer facilitated Lotus seedbank development.

3.2.5 Analysis of the data

The experimental design was a split-plot with *grazing treatments* as main plots and *lotus/grass* combinations as sub-plots. There were 3 reps for main plots and variation amongst quadrat sites served as sampling error. For all parameters measured, means and standard errors were calculated using analysis of variance carried out using Genstat 5 (Genstat 5 Committee, 1993). For the Botanal data for sown legume (Lotus), repeated measurements over time were fitted to splines. The fit, however, was generally imprecise and provided no useful additional information on treatment effects with time, so this analysis was abandoned and graphs were generated based on treatment effects at each measurement occasion with LSD's presented diagrammatically.

3.2.6 Co-learning demonstrations- design and protocols

Seventeen co-learning demonstration sites were established on farms in New South Wales - 6 on the northern tablelands/slopes, 4 on the North Coast, 4 on the southern tablelands and 3 on the south coast (Figure 2). The demonstrations were designed to assess adaptation of the appropriate lotus species (Greater lotus, Birdsfoot lotus) for the district, and where appropriate to compare "traditional" grazing management with "strategic" grazing management for effects on the persistence of lotus based pastures.

Adaptation was assessed at each study site by i) monitoring the pattern of seedling establishment in the year of planting and the persistence of lotus over a sequence of years, and by ii) a consideration of how successfully lotus was able to express its adaptive characteristics in each environment under consideration. Environmental conditions at each site including soil type, vegetation type and grazing system were described and measurements were made of soil nutrient status, monthly rainfall, seedling density, and seasonal (autumn/spring) botanical composition.

For Greater lotus, "strategic" grazing comprises spelling in autumn for 6 - 8 weeks to promote rhizome development while at other times maintaining total pasture biomass between relatively high limits (2500 - 3500 kg DM/ha). The "traditional" treatment aimed to simulate close continuous grazing by maintaining pasture biomass between 1500 - 2500 kg DM/ha limits.

For Birdsfoot lotus, the "traditional" grazing system represented local grazing management practice, ie. "intermittent" grazing. The "strategic" grazing system utilized grazing management guidelines developed for Birdsfoot lotus in the U.S. The guidelines include:-

- Initiate grazing when apical tip dominance inhibits tillering from the crown - this applies during spring and autumn when the plant is in vegetative mode

- Cease grazing when plant height is reduced to 3-5 cm
- Spell in summer from early flowering (mid December) to pod shatter (January - February) to promote seed-bank development and seedling recruitment.

4. RESULTS

4.1 The core experiment

4.1.1 Site conditions

Monthly rainfall data for the 4 sites is presented in Figure 3. All sites experienced severe drought conditions in 1995, the year when first attempts were made to establish the plots. At Glen Innes, drought recovery occurred in 1996 and rainfall conditions remained generally favourable during 1997 - 1999. At Canberra, rainfall conditions were favourable in 1996 but reverted to below average rainfall conditions for the remainder of the study. Similar unfavourable rainfall conditions generally persisted at Nowra and Casino with below average rainfall in most seasons to 1999. Generally, a severe 2 year drought was experienced in NSW 1994 - 1995 and this extended into a 5 year drought in southern NSW.

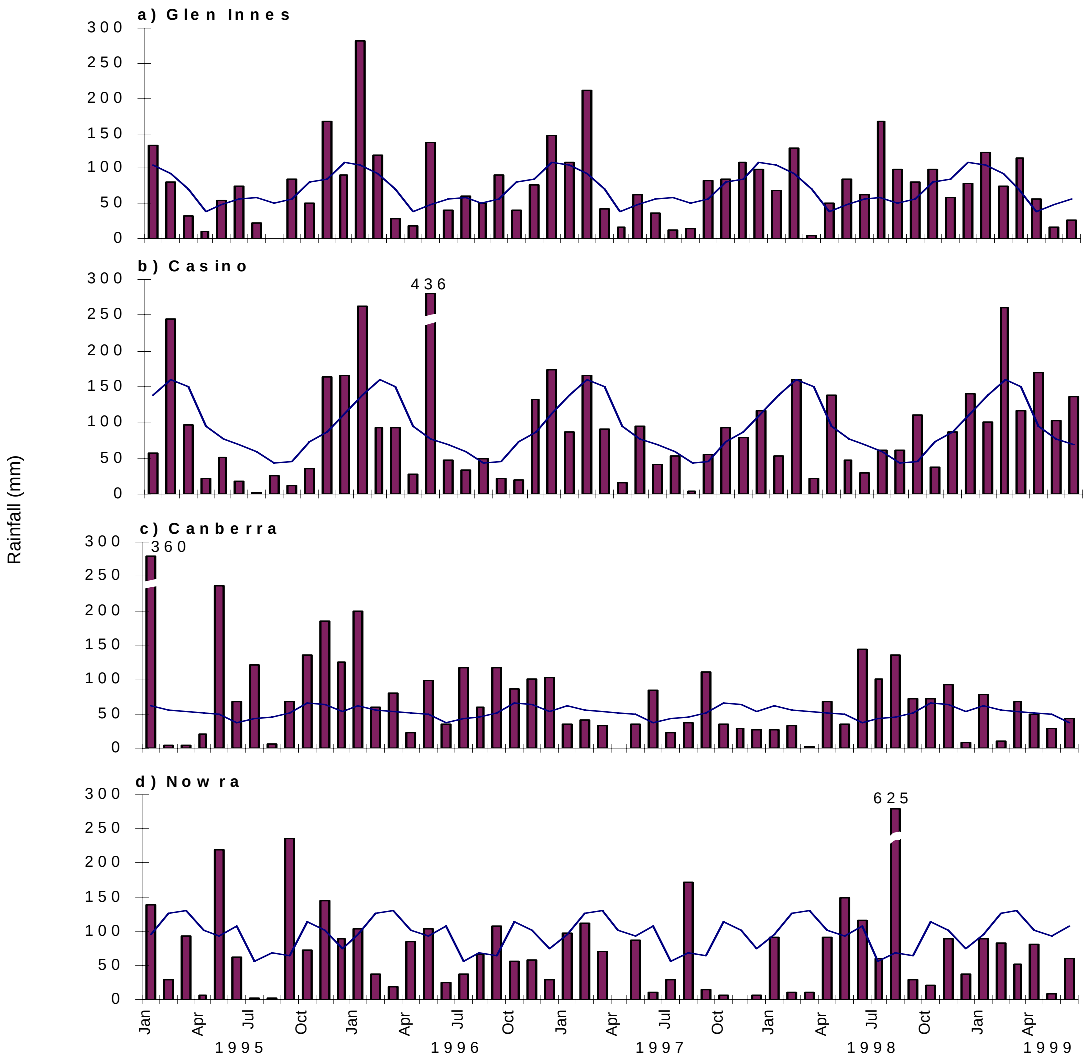


Figure 3: Monthly rainfall at the 4 grazing experiment sites; a) Glen Innes, b) Casino, c) Canberra, d) Nowra; ▮ recorded rainfall, —— long term mean rainfall.

4.1.2 Seedling establishment

Seedling density for lotus cultivars, sown grasses and weeds is presented in Tables 6, 7, 8 and 9 for Glen Innes, Casino, Canberra and Nowra, respectively. All 4 sites experienced drought conditions at the initial planting and lotus seedling populations for all cultivars were so sparse that re-seeding lotus by hand-broadcasting on either 1 follow-up occasion (Canberra, Casino), 2 occasions (Nowra) or by serial plantings (Glen Innes) was necessary. Ultimately, all sites achieved substantial lotus populations prior to commencement of grazing treatments; 96 - 127, 56 - 108 and 60 - 134 seedlings/m^2 for Maku, Sharnae, Goldie respectively across the 4 sites. The seedling density of Spanish at Canberra was 126 seedlings/m^2.

The significance of *lotus cultivar* and *grass type* treatments for seedling density is highlighted in Table 10. The final lotus seedling populations were greatest for cv. Maku at the coastal sites (127, 91 and 123 seedlings/m^2 for Maku, Sharnae and Goldie at Nowra; 102, 56 and 60 seedlings/m^2 for Maku, Sharnae and Goldie at Casino). Lotus seedling density was greater in association with volunteer grass at 2 sites (136 cf. 102 seedlings/m^2 at Canberra, 123 cf 104 seedlings/m^2 at Nowra).

The frequency measurements of lotus at Casino and Glen Innes (shortly prior to implementation of grazing treatments) illustrates the significance of the differences in establishment success of *cv.* Maku and *cv.* Goldie in the 2 contrasting environments. At Casino (coastal site), lotus frequency was 74, 41 and 35% for Maku, Sharnae and Goldie respectively; at Glen Innes, lotus frequency was 61, 56 and 81% for Maku, Sharnae and Goldie, respectively; *cv.* Maku clearly established and spread best under coastal conditions and *cv.* Goldie established best under tablelands conditions.

The presence of sown grass seedlings dominated the sown grass plots at all sites except Casino (Table 7) where poor establishment of setaria occurred due to drought conditions; at Casino, both sown grass and volunteer grass plots had similarly low levels of setaria (2 - 4 seedlings/m^2).

The density of weed seedlings was unaffected by the presence of either lotus or sown grass seedlings other than at Canberra where the population of weed seedlings in the presence of volunteer grass was 31 seedlings/m^{-2} in association with sown grass.

Table 6: Seedling establishment at Glen Innes prior to implementation of grazing treatments. Seedling density (plants/m2) in August 1995 (Occasion 1) following planting with a cone-seeder in March 1995; seedling density in August 1996 following serial broadcasting (lotus seed only) during spring 1995 - autumn 1996.

		Occasion 1			**Occasion 2**		
		SL†	**SG‡**	**W¥**	**SL†**	**SG‡**	**W¥**
Maku	Sown grass	14	12	51	119	-	-
	Volunteer grass	17	3	68	74	-	-
Sharnae	Sown grass	6	10	63	113	-	-
	Volunteer grass	4	2	56	104	-	-
Goldie	Sown grass	35	17	52	99	-	-
	Volunteer grass	29	2	51	86	-	-
	l.s.d (P< .05)	6.6	5.1	13.8	28.5	-	-

† *Sown legume seedlings* (lotus) ‡ *Sown grass seedlings* (tall fescue/phalaris)
¥ *Broadleaf weeds* - Not measured

Table 7: Seedling establishment at Casino prior to implementation of grazing treatments. Seedling density (plants/m2) in August 1996 following broadcast planting in March 1996.

		SL†	**SG‡**	**W¥**
Maku	Sown grass	104	2	129
	Volunteer grass	100	3	100
Sharnae	Sown grass	58	2	134
	Volunteer grass	53	3	121

		SL†	SG‡	W¥
Goldie	Sown grass	55	4	102
	Volunteer grass	65	2	114
	l.s.d (P< .05)	52.9	3.6	52.7

† *Sown legume seedlings* (lotus) ‡ *Sown grass seedlings* (setaria)
¥ *Broadleaf weeds*

Table 8: Seedling establishment at Canberra prior to implementation of grazing treatments. Seedling density (plants/m2) in May 1995 (Occasion 1) and July 1995 (Occasion 2) following planting with a coneseeder in March 1995; seedling density in November 1995 following broadcast planting by hand (lotus seed only) in October 1995.

		Occasion 1			Occasion 2			Occasion 3		
		SL†	SG‡	W¥	SL†	SG‡	W¥	SL†	SG‡	W¥
Maku	Sown grass	54	67	289	52	60	-	109	54	11
	Volunteer grass	39	2	256	40	0	-	94	0	32
Sharnae	Sown grass	69	61	213	65	77	-	77	56	17
	Volunteer grass	68	0	205	36	0	-	140	0	20
Goldie	Sown grass	119	74	242	100	76	-	116	60	23
	Volunteer grass	98	0	194	93	0	-	152	2	53
Spanish	Sown grass	74	64	271	59	88	-	107	65	17
	Volunteer grass	67	4	224	49	0	-	145	0	18
	l.s.d (P< .05)	27.0	16.6	84.7	22.4	15.4	-	55.7	23.4	25.7

† *Sown legume seedlings* (lotus) ‡ *Sown grass seedlings* (phalaris)
¥ *Broadleaf weeds*

Table 9: Seedling establishment at Nowra prior to implementation of grazing treatments. Seedling density (plants/m^2) in August 1995 (Occasion 1) following planting with a cone-seeder in April 1995; seedling density in March 1996 (Occasion 2) following broadcast-planting (lotus seed only) in September 1995 and November 1995.

		Occasion 1			Occasion 2		
		SL†	SG‡	W¥	SL†	SG‡	W¥
Maku	Sown grass	58	147	107	112	179	42
	Volunteer grass	82	7	192	141	9	38
Sharnae	Sown grass	66	151	132	90	169	39
	Volunteer grass	59	9	137	92	11	71

		Occasion 1			Occasion 2		
		SL[†]	SG[‡]	W[¥]	SL[†]	SG[‡]	W[¥]
Goldie	Sown grass	85	151	168	112	150	21
	Volunteer grass	121	7	224	134	4	37
	l.s.d (P< .05)	27.4	24.0	79.2	29.3	38.9	39.1

[†] *Sown legume seedlings* (lotus) [‡] *Sown grass seedlings* (phalaris)
[¥] *Broadleaf weeds*

Table 10: Summary of the factors (lotus cultivar[†] , grass type[‡] , grazing treatment[¥]) that significantly (P < 0.05) affected seedling density at the 4 sites; Glen Innes, Casino, Canberra and Nowra.

Site	Occasion	Sown Legume	Sown grass	Weeds
Glen Innes	1	lotus	grass	ns
Glen Innes	2	***grass***	-	-
Casino	1	***lotus*** grazing	ns	ns
Canberra	1	lotus	grass	ns
Canberra	2	lotus, grass	grass	ns
Canberra	3	***grass***	grass	grass
Nowra	1	lotus, grass	grass	grass
Nowra	2	**lotus, *grass***	grass	ns

[†] *Lotus cultivar:* Maku, Sharnae, Goldie (Spanish at Canberra site) [‡] *Grass type:* Introduced grass species, volunteer grass
[¥] G*razing treatment:* Continuous grazing/low biomass, continuous grazing/high biomass

4.1.3 Modulation of lotus seedlings

Results for the effectiveness of nodulation of lotus cultivars at Casino, Nowra and Canberra are presented in Table 11. For all nodulation parameters measured (nodules/plant, nodules/g. root, nodule weight/g. root), there was no effect of the nominal grazing treatments on nodulation - ie. nodulation was uniform across the trial site. However, at each site, there was a significant difference between cultivars in effectiveness of nodulation; i) at Casino, nodulation of Sharnae was relatively low compared with Maku in terms of nodules/plant, ii) at Nowra, nodulation of both Sharnae and Goldie were relatively lower than Maku in terms of nodules/plant, and iii) at Canberra, nodulation of Goldie was relatively lower than all *L. uliginosus* cultivars in terms of nodules/g. root. There was no apparent effect of low nodulation on shoot/root ratio.

Table 11: The effectiveness of nodulation of lotus inoculated with commercial inoculum. Data for all lotus cultivars (*Lotus uliginosus,* cvv. Maku, Sharnae, "Spanish"; *Lotus corniculatus* cv. Goldie), all treatments and reps, at 3 core sites a) Casino, b) Nowra, c) Canberra.

	Number of nodules/ plant	Number of nodules/ g. root	Nodule weight/ g .root (g.)	Shoot/root ratio
a) *Casino*				
Maku	111[a]	55[a]	0.015[a]	-
Sharnae	20[b]	35[a]	0.005[a]	-
Goldie	89[a]	37[a]	0.010[a]	-
LSD	66	41	0.009[a]	-
b) *Nowra*				
Maku	34[a]	614[a]	0.199[a]	0.909[a]
Sharnae	19[b]	537[a]	0.188[a]	0.995[a]
Goldie	16[b]	486[a]	0.150[a]	0.917[a]

	Number of nodules/ plant	Number of nodules/ g. root	Nodule weight/ g .root (g.)	Shoot/root ratio
LSD	12	275	0.068	0.347[a]
c) *Canberra*				
Maku	59[a]	392[a]	0.134[a]	0.755[a]
Sharnae	38[a]	489[a]	0.136[a]	0.657[a]
Goldie	46[a]	157[b]	0.056[a]	0.786[a]
"Spanish"	37[a]	360[a]	0.187[a]	0.813[a]
LSD	22	186	0.117	0.353

4.1.4 Botanical composition

(a) *Species diversity*

Species diversity was extensive at all 4 sites (Table 12). The total number of species recorded across sites ranged from 27 – 31, (Glen Innes, 30; Casino, 31; Nowra, 28; Canberra, 27) with most diversity due to large numbers of volunteer grass and weed species.

Table 12: Plant species identified at the core sites (Glen Innes, Casino, Nowra, Canberra) during the grazing study.

	Sown legume	**Volunteer legume**	**Sown grass**	**Volunteer grass**	Weeds
Glen Innes	Goldie Lotus (*L. corniculatus*)	White clover (*T. repens*)	Phalaris (*P. aquatica*)	Poa (*Poa* spp.)	Kidney weed (*D. repens*)
	Maku Lotus (*L. uliginosus)*	Medic (*Medicago* spp.)	Tall fescue (*F. arundinacea*)	Vulpia (*Vulpia* spp.)	Flat weed (*H. radicata)*
	Sharnae Lotus (*L. uliginosus)*	Sub clover (*T. subterraneum)*	Perennial ryegrass (*L. perenne*)	Danthonia (*D. richardsonni*)	Cobblers peg (*B. pilosa*)
		Red clover (*T. pratense*)		Annual ryegrass (*L. rigidum*)	Plantain (*Plantago* spp.)
				Cocksfoot (*D. glomerata*)	Oxalis (yellow) (*Oxalis* spp.)
				Paspalum (*P. dilatatum*)	Onion weed (*A. fistulosus*)
				Digitaria (*Digitaria* spp.)	Capeweed (*A. calendula*)
				Setaria (*Setaria* spp.)	Dandelion (*T. officinale*)
				Button grass (*D. radulans*)	Spear thistle (*C. vulgare*)
				Red grass (*B. macra*)	Scotch thistle (*O. acanthium*)
				Chloris (*Chloris* spp.)	
Casino	Goldie Lotus (*L. corniculatus*)	White clover (*T. repens*)	Setaria (*S. sphacelata*)	Tall fescue (*F. arundinacea*)	Carrot weed (*A. australis*)
	Maku Lotus (*L. uliginosus)*	Medic (*Medicago* spp.)		Rhodes grass (*C. gayana*)	Kidney weed (*D. repens*)
	Sharnae Lotus (*L.*	Vetch ((*Vicia*		Sporobolus	Fleabain (*C.*

	Sown legume	**Volunteer legume**	**Sown grass**	**Volunteer grass**	Weeds
	uliginosus)	*spp.*)		(*Sporobolus* spp.)	*canadensis*)
		Glycine (*G. javanica*)		Ryegrass (*Lolium* spp.)	Scotch thistle (*O. acanthium*)
				Digitaria (*Digitaria* spp.)	Cobblers peg (*B. pilosa*)
				Couch (*C. dactylon*)	Stagger weed (*S. arvensis*)
				Carpet grass (*A. affinis*)	Marshmallow weed ((*Malva* spp.)
				Millet (*Panicum* spp.)	Dock (*Rumex* spp.)
				Chloris (*Chloris* spp.)	Verbina (*V. bonariensis*)
				Paspalum (*P. dilatatum*)	Plantain (*Plantago* spp.)
					Fireweed (*S. madagascariensis*)
					Oxalis (yellow) (*Oxalis* spp.)
					Juncus (*Juncus* spp.)
Nowra	Goldie Lotus (*L. corniculatus*)	White clover (*T. repens*)	Perennial ryegrass (*L. perenne*)	Setaria (*S. verticillata*)	Creeping oxalis (*O. corniculata*)
	Maku Lotus (*L. uliginosus)*	Sub clover (*T. subterraneum*)	Kikuyu (*P. clandestinum*)	Paspalum (*P. dilatatum*)	Dandelion (*T. officinale*)
	Sharnae Lotus (*L. uliginosus)*	Red clover (*T. pratense*)		Prairie grass (*B. catharticus*)	Thistle (*C. vulgare*)
				Wintergrass (*P. annua*)	Paddy's lucerne (*S. rhombifolia*)
				Yorkshire fog (*H. lanatus*)	Fireweed (*S. madagascariensis*)
				Carpet grass (*A. affinis*)	Curled dock (*R. crispus*)
				Couch (*C. dactylon*)	Plantain (*P. lanceolata*)
				Summer grass (*D. sanguinalis*)	Catsear (*H. radicata*)
				Great Brome (*B. diandrus*)	Sand wireweed (*P. arenastrum*)
					Mouse-eared chickweed (*S. media*)
					Red flowered mallow (*M. caroliniana*)
Canberra	Goldie Lotus (*L. corniculatus*)	White clover (*T. repens*)	Phalaris (*P. arundinacea*)	Danthonia (*Danthonia* spp.)	Plantain (*P. lanceolata*)
	'Spanish' Lotus (*L. corniculatus*)	Suckling clover (*T. dubium*)		Ryegrass (*L. perenne, L. rigidum*)	Wild oats (*A. fatua*)
	Maku Lotus (*L. uliginosus)*	Red clover (*T. pratense*)		Tall fescue (*Festuca* spp.)	Capeweed (*A. calendula*)

	Sown legume	**Volunteer legume**	**Sown grass**	**Volunteer grass**	Weeds
	Sharnae Lotus (*L. uliginosus)*	Medic (*M. polymorpha*)		Couch (*C. dactylon*)	Marshmallow (*M. parviflora*)
				Yorkshire Fog (*H. lanatus*)	Sorrel (*R. acetosella*)
				Brome (*B. catharticus*)	Dock (*R. brownii*)
				Vulpia (*V. myuros*)	Dandelion (*T. officinale*)
				Wintergrass (*Poa annua*)	Horehound (*M. vulgare*)
					Wireweed (*P. aviculare*)
					Creeping oxalis (*O. corniculata*)
					Thistle (*C. vulgare*)

(b) *Effects of treatments on Lotus*

The Botanal results (means, LSD) for sown legume (Lotus) for all sites on all measurement occasions is presented in the Appendix (Glen Innes, Appendix 17; Casino, Appendix 18; Canberra, Appendix 19; Nowra, Appendix 20). These data were analysed to determine whether the main treatments (grazing treatments 1 – 7), or sub-plot secondary treatments (Lotus cultivar, companion grass) influenced lotus content in the sward. The expectation (hypothesis under test) was that:-

(i) *Autumn rest* compared with *continuous grazing* promotes increased GL (Maku, Sharnae) presence
(ii) *Summer rest*, *rotational grazing* promotes increased BFT (Goldie, 'Spanish') presence
(iii) Grazing intensity (*high biomass* cf. *low biomass*) interacts with grazing treatment.

Tables 13, 14, 15 and 16 highlight which factors (*grazing treatments*, *Lotus cultivar*, *companion grass*) significantly affected the Lotus content of pasture at the 4 sites.

Table 13: The effects of treatments (*grazing treatment, Lotus cultivar, companion grass*) on Lotus presence at the Glen Innes core site over 10 successive measurement occasions from April 1997 through June 1999.

Occasion	**Treat**	**Lotus**	**Grass**	**Treat x Lotus**	**Treat x Grass**	**Lotus x Grass**	**Treat x Lotus x Grass**
1 (April '97)	n.s.	***	***	n.s.	n.s.	***	n.s.
2 (June '97)	n.s.	***	***	n.s.	n.s.	***	n.s.
3 (Aug '97)	n.s.	***	***	n.s.	n.s.	***	n.s.
4 (Nov '97)	n.s.	***	***	***	n.s.	**	n.s.
5 (Apr '98)	n.s.	***	***	n.s.	n.s.	***	n.s.
6 (Jun '98)	n.s.	***	***	**	n.s.	**	n.s.
7 (Sep '98)	n.s.	***	***	***	n.s.	***	n.s.
8 (Dec '98)	n.s.	***	***	***	n.s.	**	n.s.
9 (Apr '99)	n.s.	***	n.s.	*	n.s.	n.s.	n.s.
10 (Jun '99)	n.s.	***	***	**	n.s.	*	n.s.

Table 14: The effects of treatments (*grazing treatment, Lotus cultivar, companion grass*) on Lotus presence at the Casino site over 8 measurement occasions from September 1997 through August 1999.

Occasion	**Treat**	**Lotus**	**Grass**	**Treat x Lotus**	**Treat x Grass**	**Lotus x Grass**	**Treat x Lotus x Grass**
1 (Sep '97)	n.s.	***	**	n.s.	n.s.	n.s.	n.s.
2 (Nov '97)	n.s.	***	n.s.	*	n.s.	n.s.	n.s.
3 (Feb '98)	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.
4 (May '98)	n.s.	**	-	n.s.	n.s.	n.s.	n.s.
5 (Aug '98)	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.
6 (Oct '98)	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
7 (Apr '99)	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.
8 (Aug '99)	n.s.	***	n.s.	n.s.	n.s.	n.s.	n.s.

Table 15: The effects of treatments (*grazing treatment, Lotus cultivar, companion grass)* on Lotus presence at the Canberra site over 14 measurement occasions from March 1996 through June 1999.

Occasion	**Treat**	**Lotus**	**Grass**	**Treat x Lotus**	**Treat x Grass**	**Lotus x Grass**	**Treat x Lotus x Grass**
1 (Mar '96)	n.s.	***	***	n.s.	n.s.	n.s.	n.s.
2 (Jun '96)	n.s.	***	***	n.s.	*	n.s.	n.s.
3 (Sept '96)	n.s.	***	n.s.	n.s.	*	n.s.	n.s.
4 (Dec '96)	n.s.	***	n.s.	*	**	n.s.	n.s.
5 (Mar '97)	n.s.	***	*.	n.s.	n.s.	n.s.	n.s.
6 (Jul '97)	n.s.	***	**	n.s.	n.s.	n.s.	n.s.
7 (Nov '97)	n.s.	***	*	n.s.	n.s.	n.s.	n.s.
8 (Dec '97)	n.s.	***	***	n.s.	n.s.	*	n.s.
9 (Mar '98)	n.s.	***	***	n.s.	n.s.	*	n.s.
10 (Aug '98)	n.s.	**	n.s.	n.s.	n.s.	*	n.s.
11 (Oct '98)	n.s.	***	n.s.	n.s.	n.s.	n.s.	n.s.
12 (Jan '99)	n.s.	***	n.s.	n.s.	n.s.	n.s.	n.s.
13 (Mar '99)	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.
14 (Jun '99)	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.

Table 16: The effects of treatments on (*grazing treatment, Lotus cultivar, companion grass)* on Lotus presence at the Nowra site over 14 measurement occasions from march 1996 through June 1999.

Occasion	Treat	Lotus	Grass	Treat x Lotus	Treat x Grass	Lotus x Grass	Treat x Lotus x Grass
1 (Mar '96)	n.s.	***	*	n.s.	n.s.	n.s.	n.s.
2 (Jul '96)	n.s.	***	*	n.s.	n.s.	n.s.	n.s.
3 (Sep '96)	n.s.	***	n.s.	.*.	n.s.	n.s.	n.s.
4 (Dec '96)	n.s.	***	n.s.	*	n.s.	n.s.	n.s.
5 (Mar '97)	n.s.	***	*.	**	n.s.	**	n.s.
6 (Jun '97)	n.s.	***	***	n.s.	n.s.	**.	n.s.
7 (Oct '97)	n.s.	***	*	*.	n.s.	*.	n.s.
8 (Jan '98)	n.s.	***	**	n.s.	n.s.	**	n.s.
9 (Apr '98)	n.s.	***	*	*	n.s.	n.s.	n.s.
10 (Jun '98)	n.s.	**	*	n.s.	n.s.	*n.s.	n.s.
11 (Sep '98)	n.s.	***	***	*	n.s.	*	n.s.
12 (Dec '98)	n.s.	***	***	n.s.	n.s.	n.s.	n.s.
13 (Mar '99)	n.s.	***	***	n.s.	n.s.	***	n.s.
14 (Jun '99)	n.s.	**	**	n.s.	n.s.	n.s.	n.s.

In general, (i) there was no effect of grazing treatment on Lotus presence, (ii) there were significant differences between Lotus cultivars in Lotus presence, and (iii) with the exception of the Glen Innes site there were few high order interactions in the data. At Glen Innes (Table 13), there was a consistent and significant *Lotus cultivar* x *companion grass* 2-way interaction which was due to a different response by Sharnae to the influence of sown grass cf. volunteer grass. While both Maku and Goldie presence was reduced by sown grass, Sharnae presence was generally low regardless of companion grass. There was a significant *grazing treatment* x *Lotus cultivar* interaction at Glen Innes on occasion 4 and occasions 6 – 10. This was due to a contrasting response by GL Maku and BFT Goldie to autumn rest; Maku presence was enhanced by autumn rest while Goldie presence was depressed by autumn rest. At Nowra, a *Lotus cultivar* x *grass type* interaction was evident in the data on 4 of 14 measurement occasions (Table 16). This was associated with the botanical presence of BFT Goldie being depressed by kikuyu in the early stages of the study (Tables 98, 99, 100) and the botanical presence of GL Maku being enhanced in conjunction with kikuyu in the latter stages of the study (Table 106).

(c) *Longitudinal effects*

Graphs of the time trends of Lotus presence under both low and high biomass conditions, and as affected by grazing treatments are depicted in Figures 4, 5, 6 and 7.

At Glen Innes (Figure 4):-

- The botanical presence of GL Maku was markedly seasonal with high Lotus presence (*ca.* 40%) in spring and relatively lower presence (*ca.* 20%) in winter. GL Maku remained botanically stable between these limits for the duration of the study, regardless of biomass level.

- GL Sharnae remained at a relatively low (10 – 20%) but stable level. GL Sharnae showed a significant response to the autumn rest treatment in 1997 under high biomass conditions in the sown grass subplots.

- The botanical presence of BFT Goldie was sharply seasonal showing very high (40 – 50% presence) in spring and summer and relatively low presence (*ca.* 30%) in winter. BFT Goldie maintained greater botanical presence than GL Maku or Sharnae for the duration of the study.

At Casino (Figure 5):-

- GL Maku initially was very high (~ 60%) in botanical presence but rapidly declined to low (~ 10%) presence within 1 year of the imposition of grazing treatments and remained between relatively low limits (5 – 20%) for the duration of the study.

- GL Sharnae initially was high (~ 40%) in botanical presence but rapidly declined to trace levels (5 – 10%).

- BFT Goldie initially had lowest (~ 20%) botanical presence at the commencement of grazing treatments and declined to similar levels as the GL cultivars except for spring –summer 1998 when BFT Goldie expressed biotic expansion, especially under high biomass conditions.

At Nowra (Figure 6):-

- GL Maku was initially present at a moderately high level (*ca.* 40%) and GL Sharnae at a relatively lower level (*ca.* 20%). Both GL cultivars declined in botanical presence to trace population levels (<5%) and there was no evidence of seasonal influence on botanical presence.

- BFT Goldie presence was initially moderately high (*ca.* 35%) but gradually declined over 2 years to low levels of botanical presence (< 10%) regardless of grazing treatment on biomass level. BFT Goldie at Nowra expressed a measure of seasonality with minor botanical expansion each summer and minimum botanical presence each winter.

At Canberra (Figure 7):-

- All 4 Lotus cultivars were initially present at very high levels – both GL cultivars showed 50 – 60% presence and both BFT cultivars showed 70 – 80% presence.

- Under low biomass conditions, and dry seasons, all cultivars declined gradually (over 2 years) to only trace botanical presence levels.

- A similar rate of botanical decline was evident under high biomass conditions, except with both GL cultivars the rate of decline was especially rapid under rotational grazing. The BFT cultivars showed a weakly pronounced seasonality with a slight expansion of presence in spring-summer and declining to a minimum in winter.

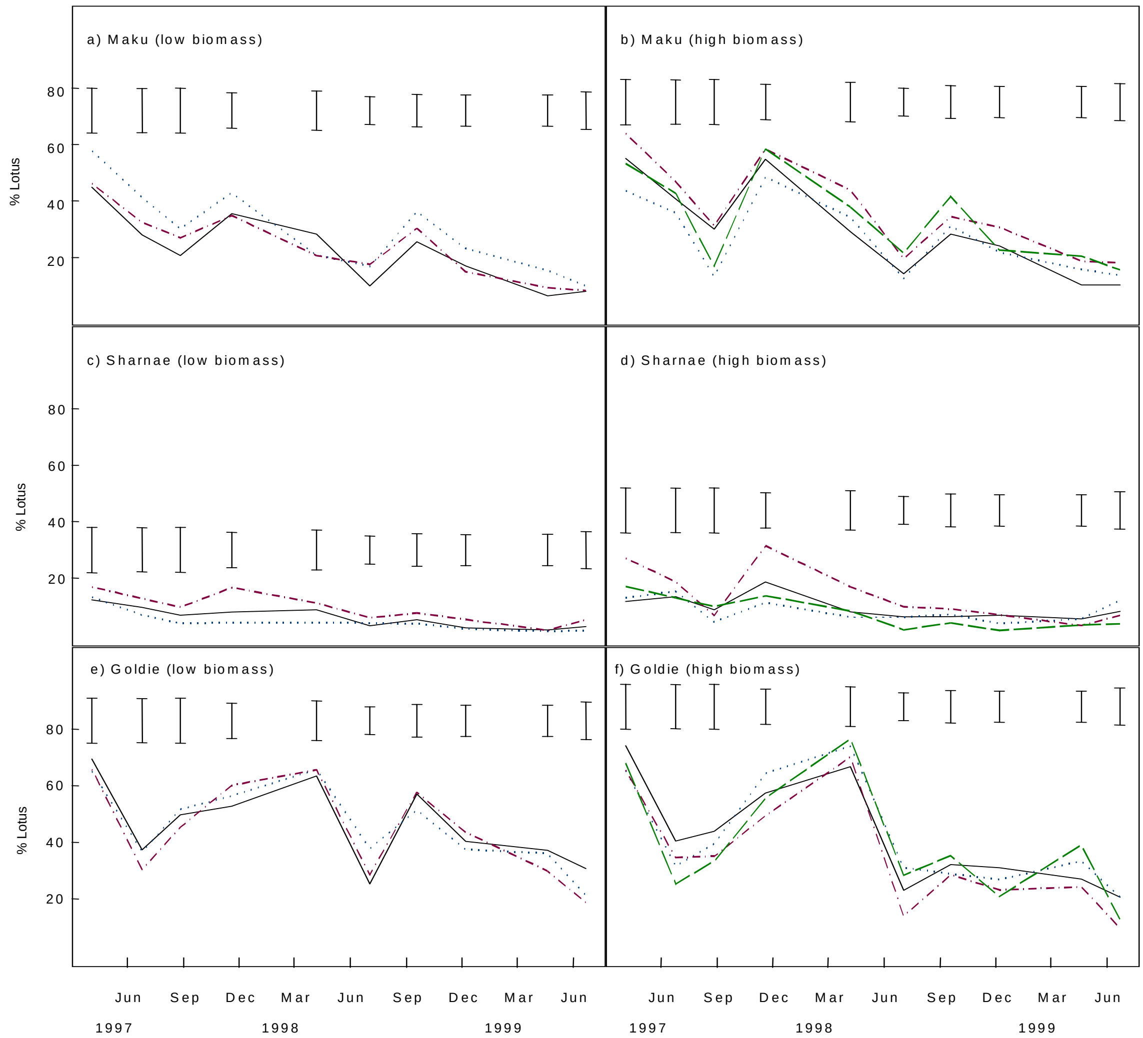


Figure 4: Longitudinal effects of grazing treatments (continuous grazing, —— ; summer rest, · · · ·, autumn rest, – · – · – ; rotational grazing, - - - -) on Lotus (GL Maku, GL Sharnae, BFT Goldie) presence at 2 levels of pasture biomass (low, high); Glen Innes core site. LSD's (<0.05) are denoted by vertical bars.

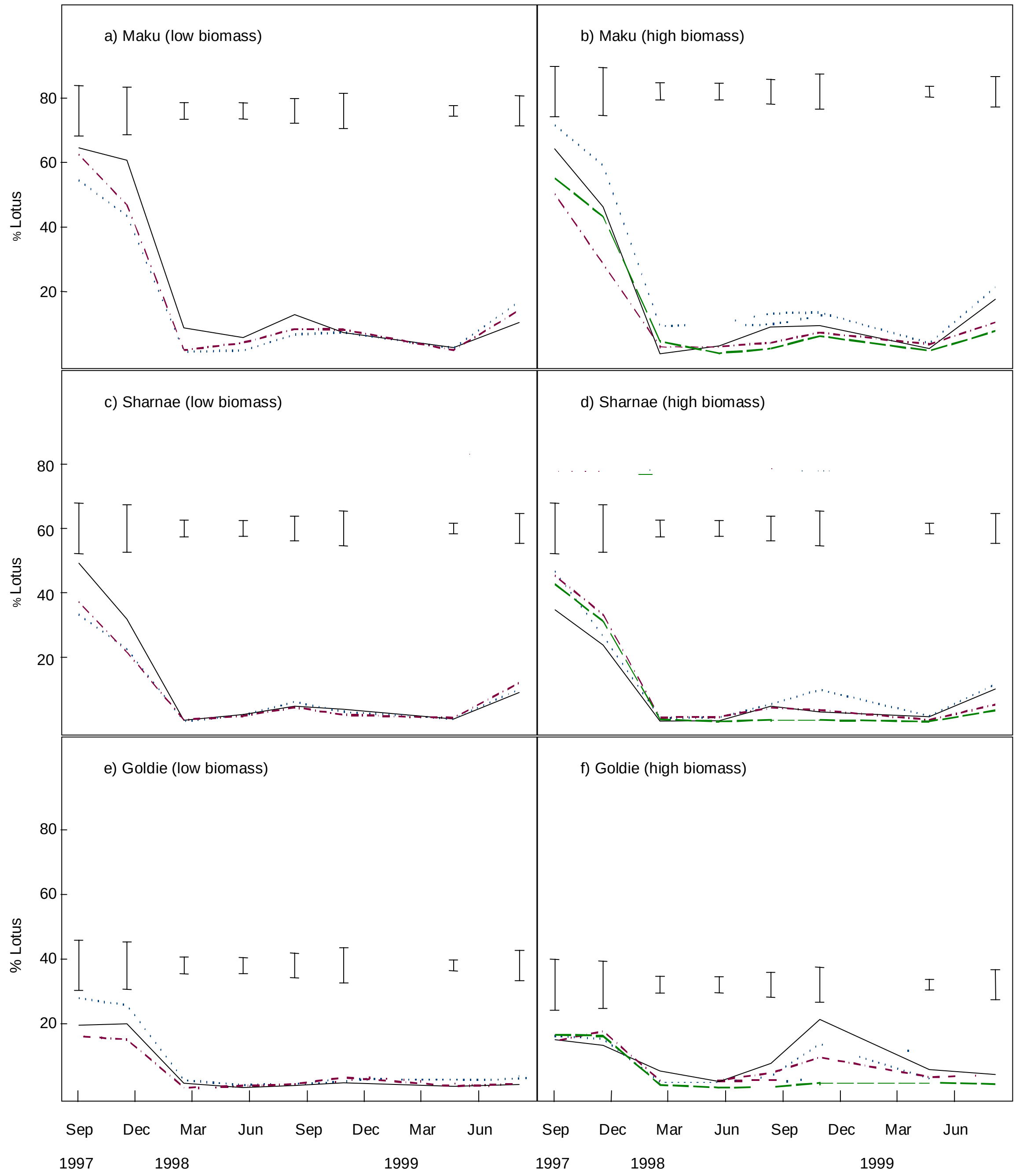


Figure 5: Longitudinal effects of grazing treatments (continuous grazing, —— ; summer rest, · · · ·, autumn rest, – · – · – ; rotational grazing, - - - -) on Lotus (GL Maku, GL Sharnae, BFT Goldie) presence at 2 levels of pasture biomass (low, high); Casino core site. LSD's (<0.05) are denoted by vertical bars.

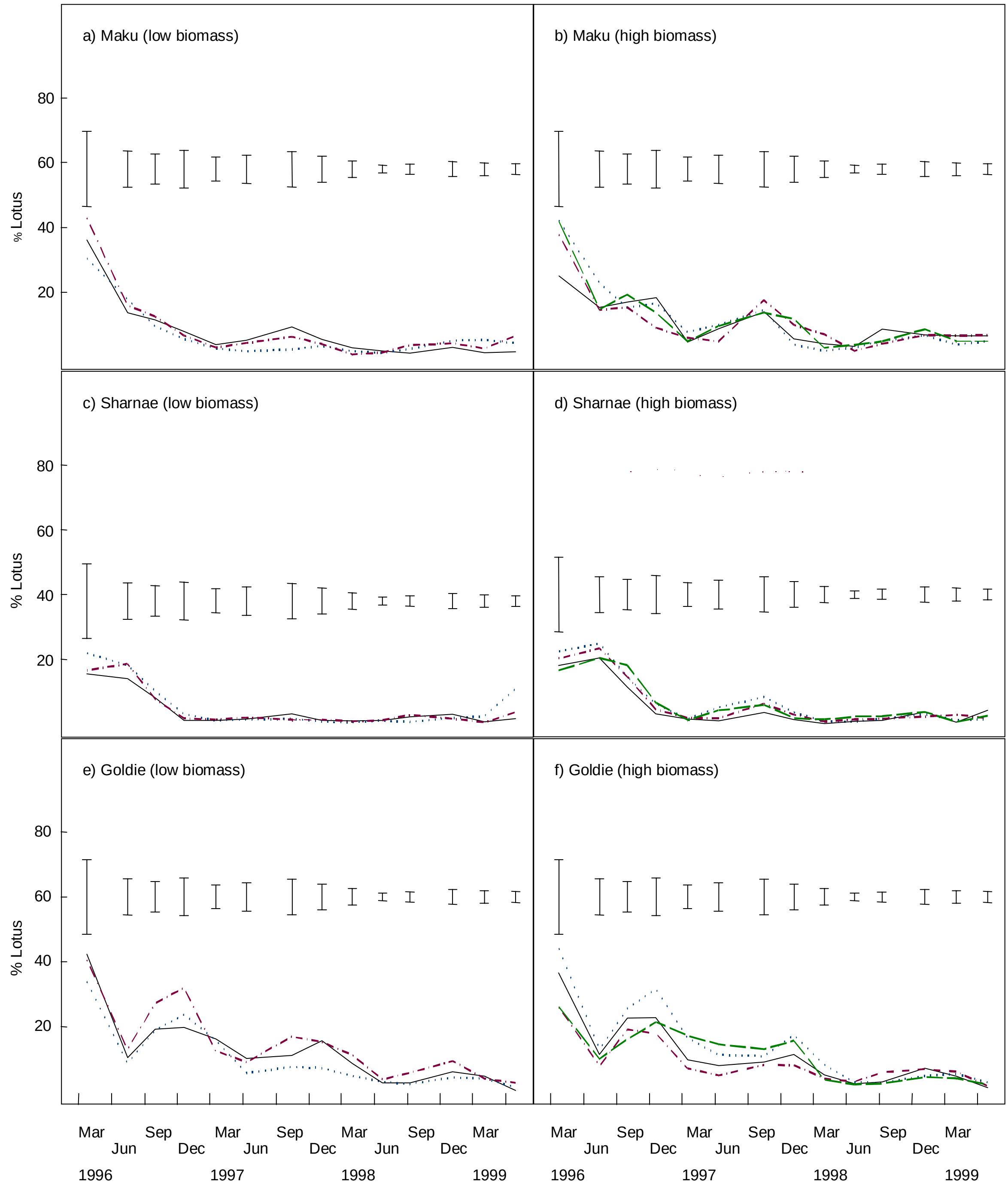


Figure 6: Longitudinal effects of grazing treatments (continuous grazing, ——; summer rest, · · · ·, autumn rest, – · – · –; rotational grazing, - - - -) on Lotus (GL Maku, GL Sharnae, BFT Goldie) presence at 2 levels of pasture biomass (low, high); Nowra core site. LSD's (<0.05) are denoted by vertical bars.

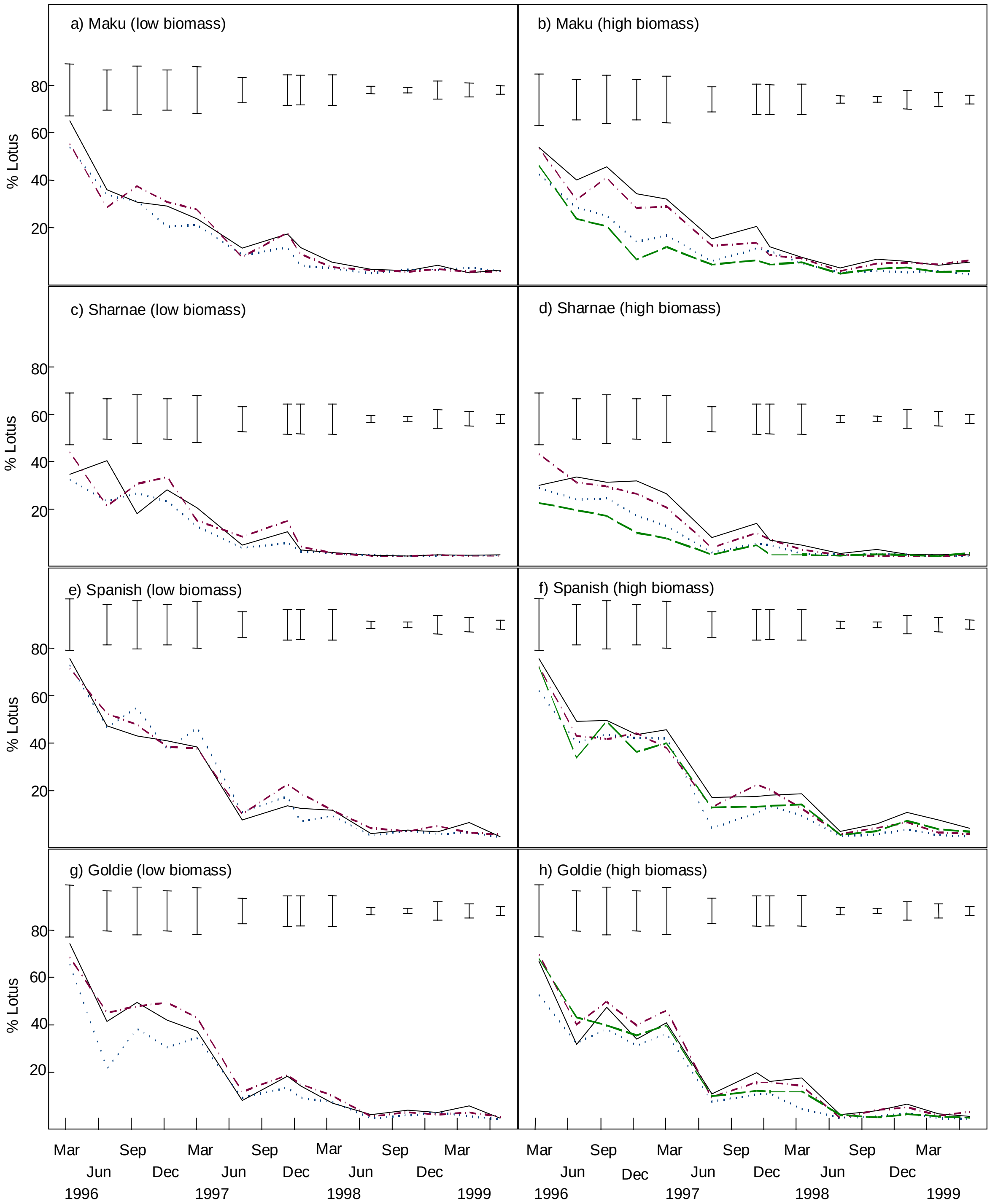


Figure 7: Longitudinal effects of grazing treatments (continuous grazing, ——; summer rest, · · · ·, autumn rest, – · – · –; rotational grazing, - - - -) on Lotus (GL Maku, GL Sharnae, BFT Goldie) presence at 2 levels of pasture biomass (low, high); Canberra core site. LSD's (<0.05) are denoted by vertical bars.

4.1.5 Rhizome extension and seedbank development

The rhizome/seedbank data came from the high biomass sub-plots, ie. treatment 2 (continuous grazing/high biomass), 4 (summer rest/high biomass), 6 (autumn rest/high biomass) and 7 (rotational grazing/high biomass) at each site over 3 successive years (1997, 1998, 1999). It is to be noted that rhizomes only occur in GL (Maku, Sharnae), but all 4 Lotus cultivars under study (GL Maku and Sharnae, BFT Goldie and 'Spanish') have potential to contribute seed into the soil seedbank.

In general, at the 2 northern sites (Glen Innes, Casino), significant differences were detected in the rhizome and seedbank data between Lotus cultivars, but there were no effects of grazing treatment or companion grass (Tables 17, 18). In general, at the southern sites (Nowra, Canberra) the rhizome data contained many zero values and there were few occasions of significant treatment effects (Tables 19, 20).

Table 17: Effects of Lotus and grazing treatments on rhizome and seedbank characters at the Glen Innes core site.

		Treatment	Lotus
	Seed number	n.s.	**
1997	Rhizome number	*	***
	Rhizome length	*	***
	Seed number	n.s.	***
1998	Rhizome length	n.s.	***
	Rhizome number	n.s.	***
	Rhizome weight	n.s.	***
	Seed number	n.s.	***
1999	Rhizome length	n.s.	*
	Rhizome number	n.s.	*
	Rhizome weight	n.s.	*

Table 18: Effects of Lotus and grazing treatments on rhizome and seedbank characters at the Casino core site.

		Treatment	Lotus
	Seed number	n.s.	**
1997	Rhizome number	n.s.	***
	Rhizome length	n.s.	***
1998	Seed number	n.s.	***
1999	Seed number	n.s.	***

Nb: The rhizome data for 1998 and 1999 contained many zeros

Table 19: Effects of Lotus and grazing treatments on rhizome and seedbank characters at the Nowra site.

		Treatment	Lotus
	Seed number	n.s.	***
1997	Rhizome number	n.s.	n.s.
	Rhizome length	n.s.	n.s.
	Rhizome weight	n.s.	n.s.
	Seed number	n.s.	***
1998	Rhizome length (omitting T2)	n.s.	n.s.
	Rhizome number	n.s.	n.s.

		Treatment	Lotus
	Rhizome weight	n.s.	n.s.
	Seed number	n.s.	Only Sharnae
1999	Rhizome length	n.s.	n.s.
	Rhizome number	n.s.	n.s.
	Rhizome weight	n.s.	n.s.

Table 20: Effects of Lotus and grazing treatments on rhizome and seedbank characters at the Canberra site.

		Treatment	Lotus
	Seed number	n.s.	***
1997	Rhizome number	n.s.	**
	Rhizome length	n.s.	*
	Seed number	n.s.	*
1998	Rhizome length	n.s.	Only Maku, Volunteer T2, 4, 7 non zero
	Rhizome number	n.s.	
	Rhizome weight	n.s.	
	Seed number	n.s.	** omitting Goldie *
1999	Rhizome length	n.s.	
	Rhizome number	n.s.	
	Rhizome weight	n.s.	

Data is presented in Table 2.4.1.5 (e). To illustrate the differences between Lotus cultivars in seedbank development; at Glen Innes, Sharnae>Maku, Goldie; at Casino, Sharnae>Goldie, Maku; at Nowra, Sharnae>Maku, Goldie; and at Canberra, Spanish>Sharnae>Maku, Goldie.

Table 21: Differences between GL Maku, Sharnae and BFT Goldie, 'Spanish' in seedbank development at the 4 core sites (Glen Innes, Casino, Nowra, Canberra) in 3 successive years.

		GL Maku	GL Sharnae	BFT Goldie	BFT Spanish	LSD
Glen Innes	1997	39	140	97	-	60.6
	1998	67	231	19	-	60.2
	1999	49	176	12	-	70.3
Casino	1997	6	37	23	-	17.9
	1998	14	186	18	-	45.8
	1999	6	44	0	-	18.2
Nowra	1997	70	221	65	-	67.5
	1998	86	199	35	-	78.7
	1999	0	99	0	-	30.2
Canberra	1997	19	60	40	110	41.8
	1998	52	193	17	257	173.6
	1999	3	106	0	302	176.8

Data for rhizome characters are presented in Table 22 to illustrate the rhizome extension activity of the GL cultivars (Maku, Sharnae) at the 4 sites. At the northern sites (Glen Innes, Casino), rhizome activity was substantial in the first year of observations with Maku>Sharnae; in subsequent years, rhizome activity of both cultivars declined to low levels. At the southern sites (Nowra, Canberra), rhizome activity of both cultivars was negligible.

Table 22: Difference between GL cultivars (Maku, Sharnae) in rhizome characters (rhizome number, segments/m^2; rhizome length, m/m^2; rhizome weight, g/m^2) at the 4 core sites (Glen Innes, Casino, Nowra, Canberra) in 3 successive years.

		Rhizome number			Rhizome length			Rhizome weight		
		Maku	Sharnae	LSD	Maku	Sharnae	LSD	Maku	Sharnae	LSD
Glen Innes	1997	894	203	294.3	37.6	7.8	11.33	-	-	-
	1998	177	40	49.3	7.0	1.6	1.97	7.8	0.9	1.89
	1999	65	31	31.5	2.7	1.0	1.31	3.9	1.1	2.06
Casino	1997	1784	997	400.1	90.3	49.1	20.78	-	-	-
	1998	-	-	-	0	0	-	-	-	-
	1999	0	2.4	2.57	0	0.1	0.11	0	0.1	0.08
Nowra	1997	22	14	13.2	1.7	1.3	1.11	1.2	0.5	0.82
	1998	13	16	26.1	0.4	0.4	0.68	0.5	0.4	0.82
	1999	24	13	27.6	1.0	0.5	1.11	1.3	0.5	1.47
Canberra	1997	-	-	-	0.4	0.3	0.33	0.4	0	0.27
	1998	4.3	0	4.30	0.2	0	-	0.2	0	0.17
	1999	16	0	21.39	0.5	0	-	0.8	0	1.18

4.1.6 Seedling recruitment

Very little BFT seedling recruitment was evident. At the northern sites the level of seedling recruitment was low (1.5 seedlings/m^2 at Glen Innes, 3.4 seedlings/m^2 at Casino) and there was no effect of treatments (Tables 23, 24). There was only 1 non-zero observation at each of the southern sites; at the Nowra site the single seedling observation was recorded on 1 rep of the Goldie/sown grass sub-plot of treatment 2 (continuous grazing/high biomass); at the Canberra site the single seedling observation was recorded on 1 rep of the Goldie/sown grass sub-plot of treatment 4 (summer rest/high biomass).

Table 23: Effects of grazing treatment and companion grass on seedling recruitment at the Glen Innes and Casino core sites. Seedling recruitment at the Nowra and Canberra sites was zero.

	Grazing treatment	Companion grass	Grazing treatment x companion grass
Glen Innes	ns	ns	ns
Casino	ns	ns	ns

Table 24: Seedling recruitment (seedlings/m^2) at the Glen Innes and Casino sites.

	Glen Innes		Casino	
	Sown grass	**Volunteer grass**	**Sown grass**	**Volunteer grass**
Continuous grazing/ high biomass	0.7	2.6	2.6	3.7
Summer rest/ high biomass	0.4	2.6	3.0	4.4
LSD (P< 0.05)	4.07		6.88	

4.2 Co-learning demonstrations

4.2.1 Northern tablelands and slopes sites

"Dursley", Swan Vale via Inverell

Aim: The "Dursley" site was established to demonstrate the use and management of *Lotus corniculatus* cv. Grasslands Goldie (birdsfoot trefoil) as a new perennial legume for the North-West Slopes. The trial was designed to contrast "traditional" grazing management with "strategic" grazing management for the persistence birdsfoot trefoil in conjunction with native pasture on a heavy basalt soil.

Trial site: The trial is situated on the property "Dursley" operated formerly by the Newmarch family and currently by John Wilson; "Dursley" is located 25 km east of Inverell (elevation 750 m). The paddock is on a basalt soil and has a native grass pasture base. Site rainfall and soil fertility status are presented in Figure 8 and Table 25, respectively.

Site establishment: The paddock was grazed closely prior to planting to check grass competition; soil moisture conditions were not suitable for planting until late May, 1995. The trial site was sprayed with a low rate of gramoxone (1.5 L/ha) to reduce competition from grass and medics. Goldie lotus seed (inoculated and lime pelleted) was direct drilled with a Connor-Shea combine (coil tyne drill coulter with Baker boot feet) at 5 kg/ha on 24 May, 1995. The paddock was inspected on 29 June, 1995 and germination of lotus seedlings was evident. Seedling establishment results are presented in Table 26.

Site management: Because the plant population was initially sparse and patchy, the trial block was ungrazed for the first 10 months to allow flowering and seed set and to encourage seedling recruitment. Flowering commenced in mid December, 1995 and immature seed pods were observed on 14 January, 1996. The site was inspected on 12 February, 1996 and the stand showed a large variation in flowering maturity (early bud to pod shatter). Subsequent site inspections showed evidence of only minor seedling recruitment through the autumn. The trial block was opened to grazing from March 1996.

Table 25. Soil nutrient status at "Dursley", 1995 and 1999.

	March 1995	August 1999
pH (1:5 $CaCl_2$)	6.0	5.7
Phosphorus (mg/kg	5	4
Bray-1)	-	21
Phosphorus (mg/kg	0.07	-
Colwell)	0.9	0.8
Conductivity (dS/m)	26	21
Potassium (meq/100g)	19	15
Calcium (meq/100g)	0.21	0.2
Magnesium (meq/100g)	2	-
Sodium (meq/100g)	0.75	-
Sulphur (mg/kg, KCl)		
Total nitrogen (%)		

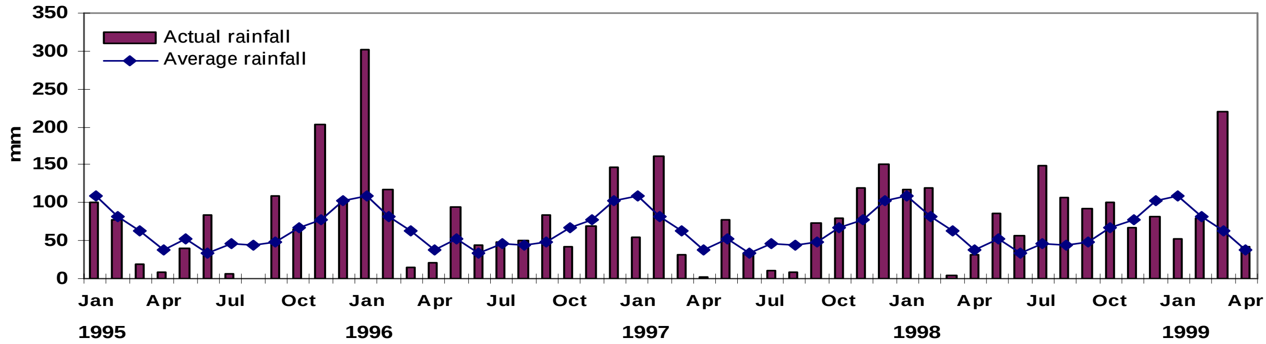


Figure 8. Monthly rainfall at "Dursley, 1995 – 1999.

Table 26. Seedling establishment measured on three occasions at "Dursley".

		Seedling density (plant/square metre)				
Days post-planting	**Grazing treatment**	**Goldie lotus**	**Other legumes†**	**Danthonia**	**Other grasses‡**	**Weeds#**
93	Traditional	13	8	94	12	26
	Strategic	20	4	82	2	30
126	Traditional	20	9	111	20	35
	Strategic	26	10	95	17	36
189	Traditional	53	-	-	-	-
	Strategic	61	-	-	-	-

† medics, lucerne ‡Queensland Bluegrass, Red Grass, Stipa spp., annual ryegrass
\# St Barnabas thistle, mintweed, capeweed

Table 27. Species composition and pasture biomass at "Dursley", 1996 - 1999.

		Goldie lotus (%)	Native grasses† (%)	Other grasses‡ %)	Other legumes¥ (%)	Weeds# (%)	Pasture Biomass (kg DM/ha)	Green (%)
Autumn	Traditional	45	39	0	0	16	4431	65
1996	Strategic	51	39	0	0	10	4156	71

		Goldie lotus (%)	Native grasses† (%)	Other grasses‡ %)	Other legumes¥ (%)	Weeds# (%)	Pasture Biomass (kg DM/ha)	Green (%)
Spring 1996	Traditional	29	52	11	6	2	2616	43
	Strategic	51	35	4	8	1	3169	48
Autumn 1997	Traditional	47	52	0.0	0	1	4164	82
	Strategic	57	42	0.0	0	1	4256	84
Spring 1997	Traditional	9	74	1	8	9	1278	57
	Strategic	22	68	0.0	4	6	1485	43
Autumn 1998	Traditional	0.0	76	3	15	7	2200	38
	Strategic	14	78	0.0	6	2	2469	20
Spring 1998	Traditional	1	37	30	26	7	3960	44
	Strategic	22	40	18	10	10	4656	39
Autumn 1999	Traditional	0.0	96	0.0	3	1	4238	23
	Strategic	12	86	0.0	1	1	3975	24
Spring 1999	Traditional	1	96	0	1	2	2694	32
	Strategic	41	54	0	3	2	2676	42

† Danthonia, Queensland Blue grass & tussocky Poa ‡ Annual ryegrass ¥ Medic & lucerne # thistles (St Barnabas thistle) and mint weed

Results:

- The population of 50 - 60 lotus seedlings/square metre achieved in the spring following autumn-planting was an excellent initial lotus population.

- Immediately prior to commencement of the grazing treatments, there was no difference between the blocks - pasture biomass was about 4,000 kg DM/ha and species composition was 45 - 50% lotus, 40 - 50% native grasses and 15 - 20% broadleaf weeds.

- In the first year following planting, the lotus population in both blocks remained very high (30 - 60% lotus content), although lower lotus content was evident in the “traditional” treatment presumably due to selective grazing by sheep.

- By the third year following planting, lotus in both blocks appeared to be in decline - lotus content declined to zero (trace isolated plants) in the “traditional” system and 15 - 20% in the “strategic” system. With only sparse flowering/podding in the first 3 summers and no evidence of seedling recruitment, the prospect of lotus persistence appeared remote.

- However, above average rainfall conditions in the fourth and fifth years (1998, 1999) following planting led to recovery of lotus plants previously considered demised. Minor seedling recruitment from germination events were observed first in November 1998 and subsequently in December 1998, March 1999, September 1999 and October 1999. In the fifth spring following planting, lotus in the “strategic” system recovered to 40% botanical presence but lotus in the “traditional” system was present at only a trace level.

Conclusions: Establishing birdsfoot trefoil into native pasture by direct-drilling into a herbicide treated sward was very successful; the resulting Lotus establishment of 50 - 60 seedlings/square metre was an excellent initial population. Close and continuous selective grazing by sheep in the "traditional" system virtually eliminated the lotus population within 3 years of planting. However, the combination of reduced grazing pressure and summer spelling in the '"strategic" treatment resulted in the persistence of Lotus at a substantial level (40% of sward content) 5 years after planting due to improved longevity of original plants and enhanced seedling recruitment.

"Springsure", Red Range via Glen Innes

Aim: The "Springsure" site was established to demonstrate the use and management of *Lotus uliginosus* cv. Maku for Northern Tablelands pastures on granite soils. The site was also designed to contrast "traditional" with "strategic" grazing management for the persistence of Maku lotus.

Trial site: The site is on the property "Springsure" operated by Neville Duddy, located 12 km east of Glen Innes. The paddock is a granite soil that has been regularly topdressed (125 kg super per ha p.a.) for the last 15 years. Soil fertility status is presented in Table 28. The nearest Meteorological Bureau rainfall recording station is at Red Range; monthly rainfall for Red Range is presented in Figure 9.

Site preparation: The paddock was planted in early March 1995. The paddock was sprayed with glyphosate at 2.5 L/ha before cultivation (February 1995), ploughed twice (chisel tines, wide tines) and then harrowed and rolled. Seed was broadcast onto the surface and harrowed. The pasture mix comprised: Maku lotus (2 kg/ha), white clover (0.5 kg/ha), tall fescue (5.5 kg/ha), cocksfoot (2.5 kg/ha), phalaris (2 kg/ha) and perennial ryegrass (1 kg/ha). By early June 1995, establishment of Maku lotus was excellent with a good distribution of vigorous plants throughout the paddock; an establishment count done on 29 June, 1995 in the trial block showed a lotus plant population of 62 plants/square metre. The site was subsequently inspected on 6 September, 1995 and lotus showed evidence of strong rhizome development.

Management: The pasture was growing strongly in September 1995 so the trial block was opened up to light grazing by cattle on 6 September, 1995. At the end of October 1995, the paddock was topdressed with 125 kg/ha of molybdenated superphosphate as part of the routine fertiliser program. Most of the cattle were removed through the dry conditions of early November. Strong pasture growth occurred through summer in response to good moisture conditions. Cattle (40 cows/calves) were put back into the paddock in early March 1996 and grazing treatments commenced. Subsequently, grazing has comprised cattle, sheep or mixed species grazing.

Table 28. Soil nutrient status (0-10cm) at "Springsure"; 1994 and 1995.

	September 1994	August 1999
pH (1:5 $CaCl_2$)	5.3	5.0
Phosphorus (mg/kg Bray I)	8	13
Phosphorus (mg/kg Colwell)	-	43
Conductivity (dS/m)	0.07	-
Potassium (meq/100g)	0.3	0.3
Calcium (meq/100g)	5.1	5
Magnesium (meq/100g)	1.1	1
Sodium (meq/100g)	0.06	0.1
Sulphur (mg/kg, KCl)	9	-
Total nitrogen (%)	0.64	-

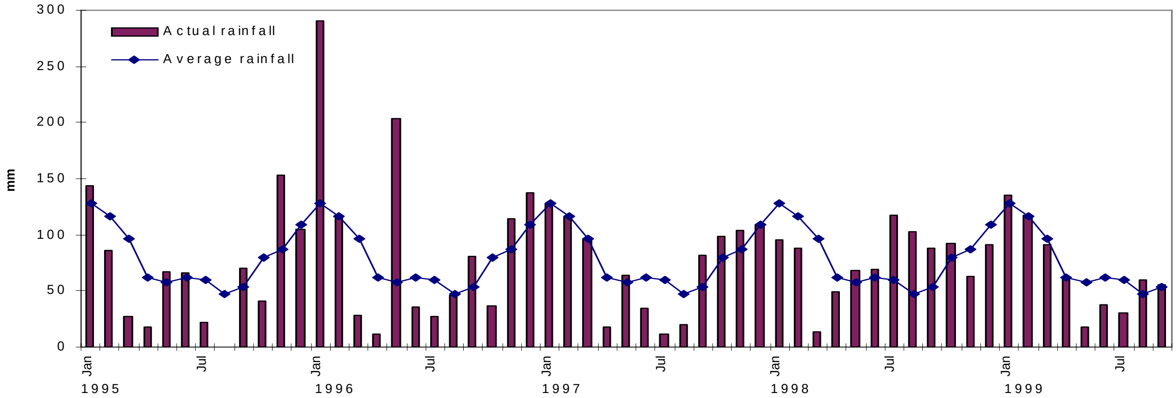


Figure 9: Monthly rainfall at Red Range, 1995 – 1999.

Table 29: Species composition and pasture biomass at "Springsure", 1996 – 1999.

		Lotus (%)	White clover (%)	Introduced grasses	Yorkshire Fog (%)	Other Grasses† (%)	Weeds‡	Total biomass (kg DM/ha)	Green (%)
Autumn 1996	Traditional	13	19	58	10	0	1	4125	76
	Strategic	13	8	66	10	1	2	3799	80
Spring 1996	Traditional	14	28	49	8	0	1	2111	72
	Strategic	15	19	61	4	0	1	4304	78
Autumn 1997	Traditional	32	11	54	2	0	1	2588	82
	Strategic	30	13	54	2	0	1	3284	79
Spring 1997	Traditional	46	15	26	10	1	2	3906	86
	Strategic	60	3	30	6	0	1	5556	86
Autumn 1998	Traditional	24	2	63	1	8	2	2313	41
	Strategic	29	0	59	8	3	1	2754	33
Spring 1998	Traditional	17	4	68	7	3	1	1894	79
	Strategic	23	2	65	7	1	2	3301	73
Autumn 1999	Traditional	11	3	58	26	0	2	1864	79
	Strategic	7	3	70	20	0	0	3301	73
Spring 1999	Traditional	17	12	35	34	1	1	2668	70
	Strategic	17	4	42	36	1	0	4125	59

† Ryegrass, annual setaria, brome grass, crab grass ‡ Flat weed, thistles

Results:

- The Lotus population (62 seedlings/square metre) achieved at the outset of the trial was excellent.

- In March 1996, immediately prior to commencement of the grazing treatments, there was little difference between the 2 blocks; overall pasture biomass was approximately 4000 kg DM/ha and species composition was 12% lotus and 60% sown grasses.

- The grazing treatments successfully maintained strongly contrasting pasture biomass levels - on average total pasture biomass in the "traditional" block was 2500 kg DM/ha compared with 3800 kg DM/ha in the "strategic" block. The introduced grasses, especially tall fescue dominated the sward, however Yorkshire Fog expanded in both blocks apparently in response to the high rainfall conditions experienced in spring/summer of 1998 and 1999.

- There was no apparent effect of grazing treatment on Lotus persistence. Flowering/podding was observed to be greater in the "strategic" block presumably due to reduced incidence of defoliation of flowering buds associated with greater plant height and leaf size has been bigger. Yorkshire Fog in the "traditional" block has been better utilised than in the "strategic" block where it is clumpy, under-utilised and retains high levels of senesced residues.

- There has been little incidence of pests and disease other than localised patchy loss of lotus and tall fescue in November 1997 and again in May 1998 presumed to be due to scarab activity. Complete recovery of Lotus and tall fescue occurred during the excellent mild and moist conditions that prevailed during the 1998 winter/spring.

Conclusions: Greater lotus proved well adapted to conditions at "Springsure" which comprise moist valley floor granite soil, vigorous grass competition from introduced perennial grasses, and grazing by sheep and cattle. Lotus consistently was the dominant pasture legume and persistence was unaffected by grazing management . Lotus expressed adaptive characteristics to both close grazing by sheep (leaf plasticity - leaf size decreased under close grazing) and lax grazing by cattle (rhizome activity - rhizomes invaded the litter layer under rank grass growth and thick mulch conditions).

"Coomerang", Oakwood

Aim: The "Coomerang" site was established to evaluate the adaptation of *Lotus corniculatus* cv. G. Goldie as a new perennial legume for the North-West Slopes. The potential role for lotus in this environment is to provide bloat-safe legume forage on soils too acid for lucerne and to extend the period of active green growth in summer/autumn to improve sheep and cattle nutrition.

Trial site: The trial site is situated on "Coomerang" operated by Des & Myrene Adams and is located 25 km north of Inverell at Oakwood (elevation 600 m). The paddock is on a light red basalt soil . Average annual rainfall is 775 mm (Figure 10); soil fertility status is presented in Table 30. A 1 ha block was fenced to enable "strategic" management with cattle and sheep.

Site preparation: The paddock was cultivated prior to planting as follows; a) deep ripping with narrow points in November 1996, b) scarifying in January 1997, c) disc ploughing twice with a combine in autumn 1997 and d) harrowing in May 1997. The site was fertilised with 125 kg/ha 600S during autumn cultivation. Planting took place on 31 May, 1997 using a conventional combine with grass seed box plus levelling bar and trailing harrows followed by a rubber tyre roller. Planting rate was 3 kg/ha Goldie lotus, 3 kg/ha Sirosa phalaris and 2 kg/ha Demeter tall fescue plus 100 kg/ha single superphosphate.

Table 30. Soil nutrient status at "Coomerang", 1997 and 1999.

	May 1997	August 1999
pH (1:5 $CaCl_2$)	5.3	5.5
Phosphorus (mg/kg Bray-1)	12	11
Phosphorus (mg/kg Colwell)	-	56
Conductivity (dS/m)	0.07	-
Sulphur (mg/kg, KCl)	10	-
Potassium (meq/100 g)	-	2
Calcium (meq/100 g)	-	11
Magnesium (meq/100 g)	-	4
Sodium (meq/100 g)	-	< 0.1

Figure 10: Monthly rainfall at "Coomerang", 1997 – 1999.

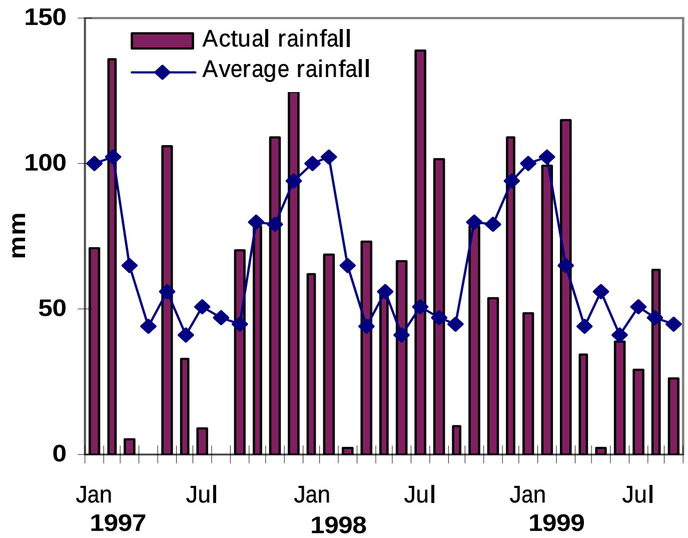


Table 31: Species composition and pasture yield at "Coomerang"; 1998-1999.

	Lotus (%)	Other legumes† (%)	Introduced grasses‡ (%)	Other grasses¥ (%)	Weeds# (%)	Pasture biomass (kg DM/ha)	Green (%)
Autumn 1998	7	2	37	29	25	1694	54
Spring 1998	8	62	2	2	8	3100	26
Autumn 1999	27	6	50	15	2	2750	36
Spring 1999	22	15	50	1	12	2044	57

† medic, sub-clover, lucerne, white clover, red clover ‡ phalaris & fescue
¥ Ryegrass, liverseed grass, brome grass, barley grass # Wireweed, thistle, Pattersons curse

Results:

- Establishment was initially sparse and patchy because conditions were adverse for germination due to low rainfall following planting in May 1997. Best germination occurred in wheel tracks where additional soil compaction conserved moisture. It was also evident that seedling density of Lotus and introduced grasses was best on the headlands where double planting occurred.

- Severe competition from broadleaf weeds and liverseed grass occurred through spring 1997 and it was evident that where liverseed grass was dominant, lotus and introduced grasses were excluded. Lotus seedling density counts were 22, 19, 18 and 21 plants per square metre on 19 August, 22 September, 10 December and 15 January, 1997 respectively. Seedling density stabilised at approximately 20 plants/m^2 in spring 1997 - this represents about half the Lotus population considered desirable and reflects the low lotus seeding rate at planting compounded by patchy establishment due to dry conditions and invading grass competition.

- The Lotus population remained at a low level (lotus < 10% sward biomass) in the 2 years following planting but strong flowering was observed in the second summer (1998/99) and germination events occurred in March 1999 and October 1999. Through seedling recruitment, the Lotus population expanded to 20 - 30% of sward biomass in the third year.

Conclusions: The initial population of birdsfoot trefoil at Coomerang was low for 3 reasons - low seeding rate, severely dry conditions for 3 months following planting, and severe weed competition. Under these conditions, Lotus established remarkably successfully to achieve a population density of *ca.* 20 plants/square metre in the spring following autumn-planting. Results to hand are based on less than 3 years experience so conclusions on the adaptation of lotus at “Coomerang” are tentative. However, early results are promising:-

- Under the adverse conditions that applied in the establishment year, Lotus seedlings established more successfully than introduced grasses

- Lotus flowered strongly in the second summer

- The present Lotus population is expanding through seedling recruitment.

“Hawthorn Dale”, Nullamanna via Inverell

Aim: The “Hawthorn Dale” site was established to investigate the adaptation of Goldie lotus direct drilled into native grass on red basalt soils under cattle grazing. The potential role seen for birdsfoot trefoil in the Nullamanna district is to provide a legume component in pasture to improve the utilisation of low quality native grass. Birdsfoot trefoil is anticipated to be an alternative legume to the mainstream legumes lucerne and subclover. Bloat-safety, low fertiliser requirements, perennial habit and summer growth activity are seen to be attractive characteristics of birdsfoot trefoil provided it is adapted to local climate and grazing conditions.

Trial site: The trial is situated on the property “Hawthorn Dale” operated by John and Doreen Mather and is located 25 km north of Inverell on the Emmaville Road at Nullamanna. The paddock is on a red basalt soil and has a native pasture base. Average annual rainfall is 800 mm.

Management: The paddock was treated with gramoxone (2 L/ha) prior to planting to reduce competition from grass, broadleaf weeds and sub clover. Goldie seed (inoculated/lime pelleted) was planted on 20th May, 1998 using a direct-drill Connor-Shea planter (coil tyne drill coulter with Baker boot feet) at 5 kg/ha. Planting depth was approximately 20 mm; 120 kg/ha Granulock fertiliser was applied at planting.

Table 32. Soil nutrient status at “Hawthorn Dale”.

	August 1997	August 1999
pH (1:5 $CaCl_2$)	6.5	5.6
Phosphorus (mg/kg Bray-1)	14	8
Phosphorus (mg/kg Colwell)	-	54
Conductivity	0.10	-
Sulphur (mg/kg, KCl)	11	-
Potassium (meq/100g)	-	1
Calcium (Meq/100 g)	-	16
Magnesium (meq/100 g)	-	5
Sodium (meq/100 g)	-	< 0.1

Figure 11: Monthly rainfall at “Hawthorn Dale”, 1998 - 1999.

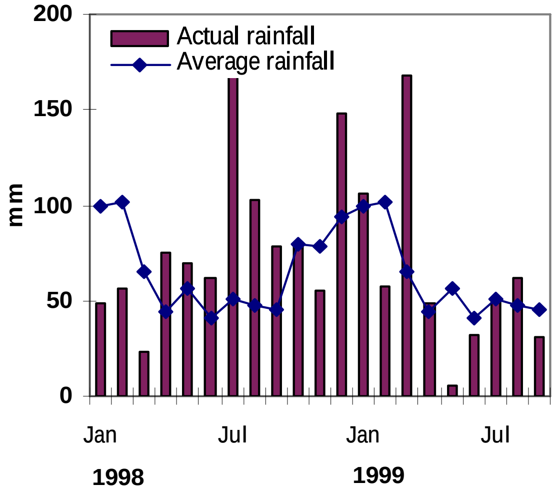


Table 33: Lotus seedling counts(plants/ Square metre) at “Hawthorn Dale”, measured 60, 90 and 120 days post-planting.

60 days	90 days	120 days
27	34	30

Table 34: Species composition at "Hawthorn Dale" 1998-1999.

	Goldie lotus	Other legumes†	Native grass	Other grasses‡	Weeds#	Pasture biomass (kg DM/ha)	Green %
Spring 1998	14	32	19	15	21	2375	54
Autumn 1999	68	1	24	2	5	2863	58
Spring 1999	56	3	29	9	3	2313	66

† White clover, medic, vetch ‡ Ryegrass, paspalum, foxtail, summer grass # Flat weed, thistles

Results:

- Satisfactory establishment of Lotus occurred at "Hawthorn Dale" under good soil moisture conditions at planting supported by above average follow-up rainfall. The initial lotus seedling density was *ca.* 30 plants/square metre and this is presumed to have expanded substantially by germination events in the following spring.

- A dense and vigorous stand of Lotus was achieved in the first year - lotus presence was 60 - 70% sward biomass accompanied by 20 - 30% native grasses.

- Intensive flowering was observed in the first summer following planting and a substantial germination event was recorded in October 1999; in patches where seedlings were evident, the population density of new Lotus seedlings was of the order of 100 seedlings/square metre.

Conclusions: Under the good soil moisture conditions that prevailed during planting at "Hawthorn Dale", direct-drill technology was very successful - a lotus seeding population of 27 plants/square metre developed within 60 days and a dense lotus stand developed in the first year. Because the site is only in its second year, conclusions are premature. However, adaptation of birdsfoot trefoil in this environment appears promising because: i) an intensive flowering event was observed in the first summer, ii) lotus dominance was achieved in the first year, and iii) prolific seedling recruitment has been observed.

"Carrawarra", Gum Flat via Inverell

Aim: The "Carrawarra" site was set up to evaluate the adaptation of birdsfoot trefoil with native pasture on a granite soil under the lower rainfall conditions south-west of Inverell. The potential role for Goldie lotus in this environment is to provide bloat-safe legume forage to improve the utilisation by cattle of low quality native pasture under low fertiliser input conditions.

Trial site: The trial is situated on the property "Carrawarra" operated by Robert Mason and is located 30 km south-west of Inverell (elevation 600 m) near Gumflat. The paddock is on a granite soil and has a native pasture base. Average annual rainfall is 600 mm (Figure 12); soil fertility status is presented in Table 35. The plan at "Carrawarra" was to establish Goldie lotus in an existing stand of native grass by direct-drill planting and then to proceed with a management study comparing “strategic” with “traditional” grazing.

Site preparation: The paddock was sprayed with gramoxone (2 L/ha) prior to planting to reduce competition from grass, broadleaf weeds and sub clover. Goldie seed (inoculated/lime pelleted) was planted on 13 August, 1997 using a direct-drill planter developed by NSW Department of Land and Water Conservation, Gunnedah. The “soil-flow seeder” has a leading disc coulter that cuts a slot through soil and sward, a tine creates a deep zone of tilth and places fertiliser at the base of the trench, and an adjustable delivery tube places seed in a 25 mm zone of tilth; the trench is closed with a press-wheel. Planting was done in two passes (at an obtuse angle) with the seeding rate totalling 8 kg lotus seed per hectare.

Table 35: Soil nutrient status at “Carrawarra”.

	August 1997
pH (1:5 $CaCl_2$)	5.2
Phosphorus (mg/kg Bray-1)	14
Conductivity	0.07
Sulphur (mg/kg, KCl)	9

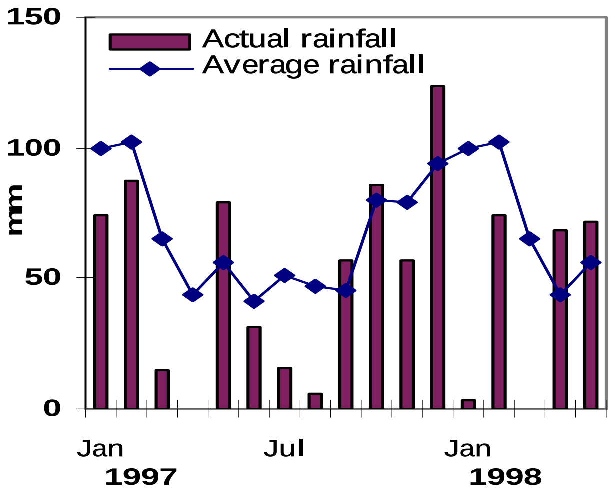


Figure 12: Rainfall at “Carrawarra”, 1997 - 1998.

Table 36: Species composition and pasture biomass at “Carrawarra” .

	Lotus (%)	Native Grasses (%)	Other Grasses† (%)	Other legumes‡ (%)	Weeds# (%)	Pasture biomass (kg DM/ ha)	Green (%)
June 1998	0	32	3	59	6	1750	56
November 1998	1	14	4	77	5	3019	30

† Ryegrass, brome grass ‡ Medic, subclover, red clover, glycine, haresfoot clover, vetch # Flatweed, thistle, kidney weed

Results:

- Soil moisture conditions were adverse at planting on 13 August, 1997 and follow-up rainfall did not occur.

- Seedling counts indicate lotus population densities of 1.1, 1.8 and 1.3 plants per square metre on 31 October, 10 December and 5 February, respectively; this represents only a trace Lotus population. Moreover, conditions during March-April, 1998 were very dry and hot and these juvenile Lotus plants were observed to die from moisture stress.

- Botanical assessment undertaken in June 1998 show zero Lotus presence.

Conclusions: Establishment failure at “Carrawarra” is attributed to the inappropriateness of spring planting where the combination of soil moisture stress and grass competition on warming soils led to establishment failure. At “Carrawarra”, there was no real test of lotus adaptation - future development work with birdsfoot trefoil should include consideration of the south-west Inverell district because of the apparent suitability of environmental conditions and the potential value of birdsfoot trefoil for improving the utilisation of native pasture. Planting should occur in late February/early March and special consideration will need to be given to managing medic and subclover competition in the first spring following planting.

“Hill Top”, Bingara

Aim: The potential role for birdsfoot trefoil in the Bingara district is i) to provide an alternative pasture legume to lucerne and subclover and to offset the pasture quality feedgap which occurs in autumn (February - May) that limits feed conditions for finishing steers before onset of winter. The aim of the “Hill Top” site was to assess the establishment and adaptation of Goldie lotus direct-drilled with Sirosa phalaris.

Trial site: The trial is situated on the property “Hill Top” operated by Phillip and Graham Charters and is located 20 km from Bingara on the Barraba Road. Annual average rainfall is 745 mm and the soil type is a red-brown earth. Rainfall and soil fertility data are presented in Figure 13 and Table 37 respectively.

Site preparation: Following rainfall in May 1998, 2 L/ha gramoxone was applied to eliminate germinating subclover. Planting took place on 25 May, 1998 using a Connor-Shea direct drill seeder (coil tyne drill coulter with Baker boot feet). Planting rate was 5 kg/ha Goldie lotus and 2 kg/ha Sirosa phalaris plus 120 kg/ha Granulock fertiliser. The seed was planted at a depth of 2 cm covered by 5 - 10 mm of soil.

Table 37. Soil nutrient status at “Hill Top”.

	March 1998	August 1999
pH (1:5 $CaCl_2$)	5.3	5.1
Phosphorus (mg/kg Bray-1)	18	21
Phosphorus (mg/kg Colwell)	-	66
Sulphur (mg/kg, KCl)	9	-
Conductivity	0.07	-
Potassium (meq/100 g)	-	0.7

	March 1998	August 1999
Calcium (meq/100 g)	-	8
Magnesium (meq/100 g)	-	1
Sodium (meq/100 g)	-	< 0.1

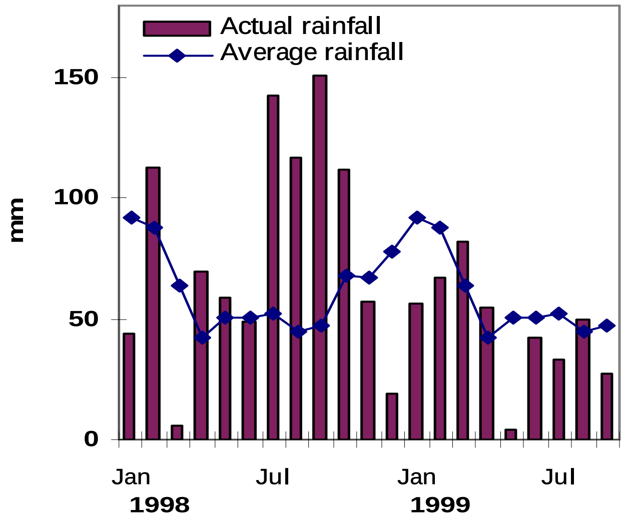


Figure 13: Monthly rainfall at "Hill Top", 1998- 1999.

Table 38: Seedling establishment (seedlings/square metre) of lotus at "Hill Top" measured 60, 90 and 120 days post-planting.

60 days	90 days	120 days
13	20	14

Table 39: Species composition and pasture biomass at "Hill Top".

	Lotus %	Phalaris %	Other grasses[#] %	Sub clover %	Other legumes[†]	Broadleaf Weeds[‡]	Yield (Kg DM/ha)	Green %
December 1998	24	44	11	8	0	12	2883	56
May 1999	13	58	0	3	0	27	2075	24
October 1999	33	56	5	0	6	0	3813	72

[†] Medic, subclover, white clover [‡] Wireweed [#] Ryegrass

Results:

- Direct-drill planting took place under good soil moisture conditions but was late in the autumn compared with district practice.

- Above average rainfall occurred following planting in May 1998 but intensive rainfall events apparently led to some of the seed being buried too deep in the drills for successful establishment. A seedling population of 15 - 20 plants/square metre developed by the spring following autumn - planting. This seedling population was exposed to severe competition from annual ryegrass and wireweed - the Lotus population was assessed as being "sparse and uneven" in September 1998, "low but constant" in October 1998 and then "reasonable" in December 1998.

- The lotus was observed to flower prolifically in the first summer following planting and the presence of juvenile plants was noted in March 1999, May 1999 and October 1999. By spring of the year following planting, the lotus population had expanded such that lotus comprised 33% of sward biomass.

Conclusions: Experience with birdsfoot trefoil at "Hill Top" is limited to only 18 months so conclusions are tentative. However, results to date suggest promise for the adaptation of birdsfoot trefoil in the Bingara district:

(a) The achievement of a viable "critical mass" of seedlings (15 - 20 plants/square metre) despite sub-optimal timeliness with planting and adverse conditions (soil washing, weed competition) following planting.

(b) Intensive flowering in the first summer.

(c) Acceptable Lotus presence (33% sward biomass) in the second year following planting.

(d) Favourable local environmental conditions for birdsfoot trefoil including increased day length, low incidence of overcast days and an increased heat factor.

4.2.2 North coast sites

Melinga via Taree

Taree district is a high rainfall coastal environment - average annual rainfall is 1154 mm with summer/autumn dominance and highly variable spring rainfall. It is a subtropical (C4) grass environment characterised by podzolic acid soils, low pH status (pH typically 4.3 - 4.6) and lack of adapted legumes. The major feed-gap occurs in late winter/early spring and low pasture quality is a limitation, especially on unimproved country. The potential for Lotus in the Taree district is as a low input pioneer legume to improve the utilisation of carpet grass. Uncertainties with Lotus are:-

- Adaptive ability with subtropical grasses like setaria, paspalum, carpet grass

- Persistence - local experience with Maku lotus is good in favourable years but it declines during dry conditions due to lack of regeneration.

Aim: The aim at the Melinga site was to compare the adaptation and persistence of Greater lotus and birdsfoot trefoil for typical North Coast pastures close to the coast. The "strategic" lock-up times were flowering to seed-set for Goldie lotus and an autumn lock-up for Maku lotus. This site provided a comparison of Maku lotus/carpet grass with Goldie lotus/carpet grass - both managed under strategic grazing with cattle.

Trial site: The Melinga site is located 14 km from Taree on the Lansdowne road; the farm is operated by Howard Hammond. The terrain is gently undulating and consists of a shallow podzolic soil over most of the site. Pasture cover comprises carpet grass, a sparse population of paspalum and native grasses. Rainfall data is presented in Figure14 and soil test data is presented in Table 40.

Site establishment: The co-learning site was on a north-facing slope. An area of 10 ha was subdivided into two 5 ha blocks; one for development with cv. Maku and the other for cv. Goldie. The area was initially burned to reduce grass cover then lightly disced twice with a disc seeder. Seed and superphosphate were broadcast on 7 June 1996 and the area was slashed close to the ground. Molybdenated superphosphate was used as a carrier at 150 kg/ha; cv. Goldie was planted at 2.4 kg/ha and Maku was planted at 2.5 kg/ha.

Table 40. Soil nutrient status at Melinga, 1996 – 1998.

		December 1997		December 1998		June 1999	
	March 1996	Maku	Goldie	Maku	Goldie	Maku	Goldie
pH (1:5 $CaCl_2$)	4.9	4.7	4.7	4.5	4.9	4.6	4.8
Phosphorus (mg/kg Colwell)	10	-	-	-	-	46	69
Phosphorus (mg/kg Bray -1)		20	14	10	9	23	30
Sulphur (mg/kg KCl)	-	36	30	7	6	-	-
Potassium (meq/100 g)	0.2	-	-	-	-	0.2	0.3
Calcium (meq/100g)	4.3	-	-	-	-	3	4
Magnesium (meq/100 g)	1.9	-	-	-	-	2	2
Aluminium (meq/100 g)	0.23	-	-	-	-	0.8	0.6
Sodium (meq/100 g)	0.27	-	-	-	-	0.3	0.3
Conductivity (dS/m)	0.04	0.08	0.09	0.05	0.06	-	-

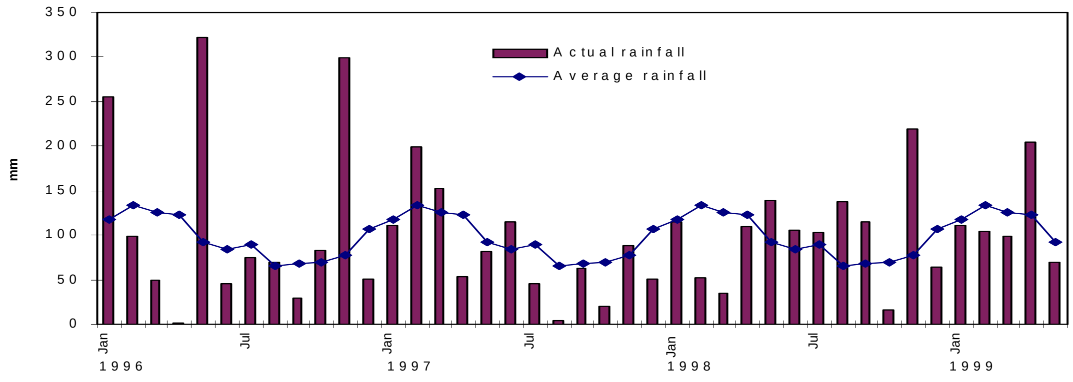


Figure 14. Monthly rainfall at Melinga, 1996 – 1999.

Table 41. Species composition and pasture biomass at Melinga, 1997 – 1999.

		Lotus (%)	Other Legumes † (%)	Carpet grass (%)	Paspalum (%)	Other grasses‡ (%)	Weeds+ (%)	Pasture biomass (kg/DM/ha)	Green (%)
May 1997	Maku	32	0	57	10	0	1	0	0
	Goldie	12	0	73	14	0	1	0	0
Dec 1997	Maku	8	4	58	17	1	13	3753	48
	Goldie	13	8	63	8	2	6	3850	57
May 1998	Maku	19	1	52	18	-	8	3488	67
	Goldie	5	2	68	13	3	8	3025	59
Dec 1998	Maku	14	4	45	34	1	2	4269	95
	Goldie	1	18	61	14	3	3	4119	59
June 1999	Maku	28	2	54	12	1	3	4088	49
	Goldie	0	12	59	21	4	4	3905	31
Nov 1999	Maku	35	3	51	6	4	1	2954	52
	Goldie	1	14	61	21	2	1	3352	35

† Includes white clover, native glycine ‡ Includes native grasses, rhodes grass, vulpia
\+ Includes fireweed, dandelion, lambs tongue, oxalis, plantation

Results:

- Plant counts undertaken in May 1997 show a strong seedling population of cv. Maku lotus (37 plants/square metre) and a smaller population of cv. Goldie lotus (19 plants/square metre). The cv. Goldie population was about half the desirable population density and reflected the low seeding rate.

- Despite severe moisture stress during summer-autumn 1997/98, Maku lotus retained a substantial botanical presence although Maku was observed to wilt and senesce from moisture stress and heat. Goldie presence was significant in 1997 and produced high green biomass - new seedlings were evident but Goldie presence was sparse by autumn 1998.

- With return to favourable seasonal conditions from spring 1998, the Maku lotus population expanded substantially. Although not measured, there was an observable increase in vigour of the companion grasses growing with Maku lotus.

- The Goldie lotus population failed to recover from the dry conditions in 1997 - 1998, flowering was sparse and no seedling recruitment was evident. By 1999, only a trace population of surviving plants were present and these had poor vigour.

Conclusions: Greater lotus showed successful adaptation at Melinga which is characterised by i) high rainfall, ii) carpet grass/paspalum as companion grass, and iii) cattle grazing; Greater lotus maintained significant presence through adverse seasonal conditions and expanded in population density in favourable seasons. From observations between the trial site where the companion grass was carpet grass and an adjacent paddock where the companion grass was setaria, it was apparent that Greater lotus co-exists better with carpet grass than with setaria. Where Greater lotus commenced from isolated seedlings (from contaminated seed) in the birdsfoot trefoil block, it expanded to become a minor but significant sward component with potential to achieve co-dominant status with carpet grass within 3 - 5 years post-planting. Birdsfoot trefoil by comparison declined dramatically to have only trace presence - presumably due to inability to withstand rhizomatous grass competition from carpet grass.

Waukivory via Gloucester

Persistence of sown species in drier parts of the Gloucester/Taree district is a major problem. Several farmers in the district have tried Maku lotus in the past 5 - 10 years. There is a general view that Maku lotus establishes and persists best on low lying areas prone to waterlogging, although there has been some success on drier hilly country. There is a perception that the earlier enthusiasm for widespread use of Maku lotus was misplaced - many failed stands have been reported. Most landholders who have sown Maku lotus lost these stands during the below average rainfall years of the early 1990's. There are few success stories with Maku lotus west of Waukivory. Goldie lotus has not been used at all in commercial sowings.

The potential role for lotus in the Waukivory district is to provide a low-input legume to improve the utilisation of carpet grass and bladey grass. John Clark, the site cooperator at Waukivory has extensive experience with Maku lotus with outstanding results - especially lotus/kikuyu and lotus/cocksfoot on hill country. Experience at Waukivory is that Maku lotus is well adapted and has provided a 3-fold increase in carrying capacity of beef cattle.

Aim: The co-learning site at Waukivory was established to compare the persistence of Greater Lotus (cv. Maku) and birdsfoot trefoil (cv. Goldie) both managed strategically with a summer spell for Goldie and an autumn spell for Maku.

Trial site: John Clarke's property is located 3 km east of Waukivory on the Waukivory-Markwell road. The property is mostly steep hills and brown-earth soils. The site is on a dark grey-brown sandy clay loam. Rainfall and soil test data are presented in Figure 15 and Table 42 respectively.

Site establishment: The 3 ha site was sprayed with 3/L glyphosate per hectare and disced twice. Inoculated Goldie seed (5 kg/ha) and Maku seed (3 kg/ha) were broadcast with molybdenated superphosphate at 250 kg/ha in May 1995. No covering harrows were used due to the open nature of the seedbed and the risk of deep burial.

Site management: Strategic grazing management was applied to the site from January 1996. Electric fencing was used to exclude grazing during full flower to pod shatter in summer in the Goldie block and during autumn (May-June) in the Maku block. The Goldie block was spelled from late November 1996 until pod shatter in early 1997 - strong flowering was observed and some new seedlings were evident in spring 1997. Maku lotus appeared to have been eliminated by an unknown insect during February 1997.

Table 42. Soil nutrient status (0 - 10 cm) at Waukivory.

	May 1995	April 1996	December 1997 Goldie	December 1997 Maku	December 1998 Goldie	December 1998 Maku	June 1999 Goldie	June 1999 Maku
pH (1:5 $CaCl_2$)	5.1	5.1	5.1	5.1	5.0	5.0	5.1	5.3
Phosphorus (mg/kg Colwell)	69	40	-	-	-	-	41	63
Phosphorus (mg/kg Bray -1)	-	-	25	46	24	9	17	25
Sulphur (mg/kg KCl 40)	-	-	9	13	5	8	-	-
Potassium (meq/100 g)	1.0	-	-	-	-	-	0.8	0.7
Calcium (meq/100 g)	11.8	-	-	-	-	-	13	14
Magnesium (meq/100g)	3.3	-	-	-	-	-	4	5
Aluminium (meq/100g)	<0.05	-	-	-	-	-	0.1	<0.1
Sodium (mg/100g)	0.08	-	-	0.09	-	-	0.1	0.2
Conductivity (dS/m)	0.07	-	0.09	-	0.06	0.06	-	-

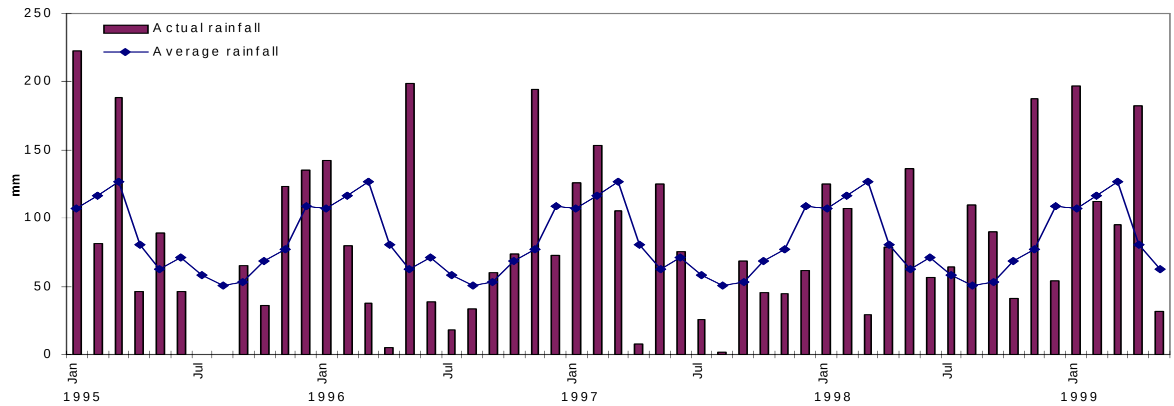


Figure 15. Rainfall at Waukivory, 1995 – 1999.

Table 43. Species composition at Waukivory, 1995 – 1998.

		Lotus (%)	White clover (%)	Ryegrass (%)	Other grasses † (%)	Broadleaf weeds (%)	Other ‡ (%)	Pasture biomass (kg DM/ha)	Green (%)
October 1995	Maku	7	38	28	3	21	3	-	-
	Goldie	3	38	34	0	6	9	-	-
March 1996	Maku	26	50	5	8	11	-	-	-
	Goldie	23	44	8	11	15	-	-	-
October 1996	Maku	14	31	36	10	10	-	-	-
	Goldie	32	25	28	6	10	-	-	-
June 1997	Maku	0	0	21	70	9	-	-	-
	Goldie	4	0	21	73	3	-	-	-
December 1997	Maku	0	0	15	77	7	-	2094	46
	Goldie	11	0	12	66	11	-	2144	48
May 1998	Maku	1	10	3	84	12	-	2588	47
	Goldie	3	0	4	86	7	-	2625	54
Dec 1998	Maku	0	35	2	58	2	3	2525	69
	Goldie	8	12	1	76	0	3	2780	73
June 1999	Maku	3	9	1	85	2	0	3025	65
	Goldie	8	13	0	78	1	0	3480	58
Nov 1999	Maku	5	21	7	65	2	0	4525	68
	Goldie	21	16	11	51	1	0	5075	72

† Perennial and annual invaders including Rhodes grass, setaria, paspalum, kikuyu, Vulpia spp, Digitaria spp ‡ Sedges, turnip

Results:

- Lotus seedling counts undertaken during October 1995 (4 months post-planting) showed 16 Maku plants/square metre and 15 Goldie plants/square metre. Although these seedling densities were less than ideal, they provided reasonable basal populations. Further germination events presumably occurred through spring/summer 1995/96, although these were not measured.

- Lotus presence was substantial for both Maku and Goldie during 1996 - Maku represented 14% and Goldie 32% of pasture biomass in spring. However, Maku presence declined to zero and Goldie to 4% in the following autumn.

- By spring 1997, Maku lotus was observed to be only sparsely present and isolated plants were wilting due to moisture stress. The best population density of Maku was on the hill-top where nitrogen fertility was high, as evidenced by presence of kikuyu. By contrast, Goldie was not wilting and had a significant population density. Goldie seedlings were observed in November 1997 and the Goldie population exceeded the Maku population in autumn 1998 although both were present as only minor sward components.

- Seasonal conditions from autumn 1998 were favourable. Goldie was observed to flower strongly in the summers of 1997/98 and 1998/99 and seedling recruitment was noted in spring 1998 and autumn 1999. Goldie progressively expanded its distribution in conjunction with increased presence of setaria and kikuyu.

- Maku failed to recover from the dry conditions that occurred in summer 1997/98. The decline in Maku presence may have been further compounded by insect predation; by 1999, Maku remained present only in favourable moist galley sites.

Conclusions: The Waukivory environment is transitional in terms of zones of adaptation for birdsfoot trefoil and Greater lotus. Both lotus species appeared to be adapted to climatic and grazing components of the environment but the limiting factor in the longer term will be grass competition from kikuyu. Birdsfoot trefoil was is adapted better than Greater lotus to heat and dry, but with improvement to soil N fertility following birdsfoot trefoil was presence for a few years, kikuyu is expected to invade and suppress the non-rhizomatous lotus. By contrast, Greater lotus, being rhizomatous will effectively co-exist with kikuyu (and carpet grass) for long term persistence.

"The Croft", Booral

In the lower Hunter, there is a need for a pasture legume for low fertility soils that has warm season growth performance, persistence in dry marginal environments, can tolerate water logging and is non-bloating. There has been some local experience with Greater lotus but establishment success has been inconsistent.

Aim: The aim at "The Croft" site was to monitor the persistence of Greater lotus (cv. Maku) in a carpet grass sward.

Trial site: "The Croft" is located 10 km south of Booral on Gunns Gully Road. Soil test data is presented in Table 44 and rainfall data is presented in Figure 16 - average annual rainfall is 1138 mm. The trial site was 4 ha in area.

Site establishment: The site was slashed, agro-ploughed and then planted on 8 April, 1997. Dominant grass species initially were carpet grass>ryegrass>paspalum with a sparse population of broadleaf weeds (verbina, flatweeds). A mixture of Maku lotus (2.5 kg/ha) and Tetila ryegrass (25 kg/ha) was broadcast with molybdenated single superphosphate (125 kg/ha). Potash was applied at three rates: nil (western block), 187.5 kg/ha (central block) and 75 kg/ha (eastern block).

Table 44. Soil nutrient status at "The Croft".

	April 1998		December 1998		June 1999
	Lower flat	Upper flat	+ potash	- potash	
pH (1:5 $CaCl_2$)	4.6	4.6	4.5	4.5	4.6
Phosphorus (mg/kg, Colwell)	10	13	-	-	18
Phosphorus (mg/kg (Bray $^{-1}$)	-	-	7	8	4
Sulphate sulphur (mg/kg, KCl)	7	7	10	6	-
Potassium (meq/100 g)	0.3	0.2	-	-	0.4
Calcium (meq/100 g)	3.3	2.3	-	-	2
Magnesium (meq/100 g)	1.8	1.3	-	-	1
Aluminium (meq/100 g)	0.18	0.24	-	-	0.30
Sodium (meq/100 g)	0.18	0.22	-	-	0.1
Chloride (mg/kg)	18	20	-	-	-
Electrical conductivity (dS/m)	0.04	0.04	0.04	0.04	-
Nitrate nitrogen (mg/kg)	<2	<2	-	-	-

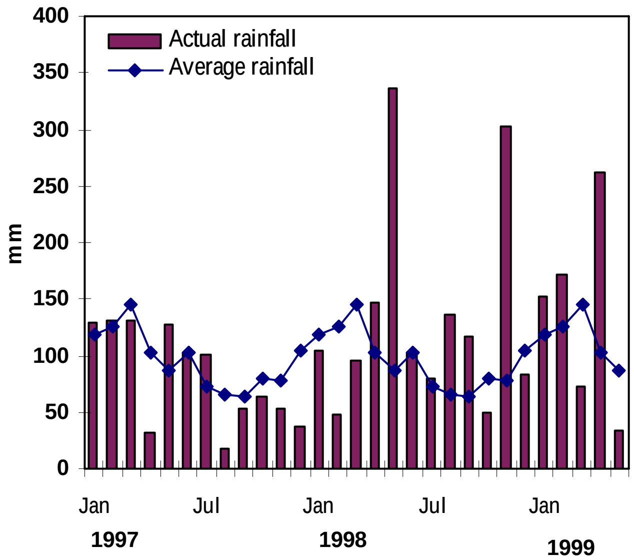


Figure 16. Rainfall at "The Croft", 1997 – 1999.

Table 45. Species composition at "The Croft",1997 – 1999.

		Lotus (%)	White clover (%)	Carpet grass (%)	Weeds (%)	Annual grasses (%)	Perennial grasses (%)	Pasture biomass (kg DM/ha)	Green (%)
Spring 1997	Nil K	15	0	73	5	0	7	3450	59
	Low K	5	11	78	9	1	7	4306	65
	High K	7	0	66	9	3	15	3500	59
Autumn 1998	Nil K	9	0	70	18	0	3	2425	57
	Low K	3	0	77	11	0	9	2550	61
	High K	1	0	86	6	0	7	2738	58
Spring 1998	Nil K	11	1	69	5	0	14	2744	47
	Low K	3	1	79	4	0	13	2900	51
	High K	3	0	91	3	0	3	3210	48
Autumn 1999	Nil K	16	0	75	5	0	4	4550	38
	Low K	3	1	86	3	0	7	4275	32
	High K	6	1	84	5	0	5	4956	33
Spring 1999	Nil K	21	1	64	1	0	13	4363	35
	Low K	4	1	81	2	0	12	3723	31
	High K	5	1	74	1	0	19	5225	22

Results:

- Establishment counts were not undertaken but it was observed that a good establishment of Maku lotus was achieved in the western block (nil potash) but only a sparse and patchy establishment occurred in the other 2 blocks.
- In the 2 years following establishment, the lotus population remained relatively low and stable - the western block had the best lotus presence as did low lying wetter sites in the paddock.
- With the very wet conditions experienced in 1998 and 1999, the lotus population expanded to achieve significant presence in conjunction with carpet grass - especially on the western block where the original establishment was best; lotus is persisting without specialised management.

Conclusions: Greater lotus is successfully adapted in the Booral district where environmental conditions are characterised by low soil pH, low soil phosphate fertility, vigorous rhizomatous grass (carpet grass) competition and cattle grazing.

"Queensbury", Booral

There has been some local experience with Maku lotus in the lower Hunter district but establishment success has been inconsistent.

Aim: The aim at the "Queensbury" site was:-

- To investigate the best establishment method for lotus establishment in unimproved carpet grass pasture - ie. is cultivation necessary?

- To investigate fertiliser requirements
- To compare the persistence of Greater lotus (cv. Maku) with birdsfoot trefoil (cv. Goldie).

Trial site: The "Queensbury" site is located on the Buckets Way 5 km south of Booral and is operated by Paul and Karen Hutchinson. Soil test data is provided in Table 46 and rainfall data is provided in Figure 17; annual average rainfall is 1138 mm.

Site establishment: The "Queensbury" site was established on a lower slope hill paddock on 19 May 1995;- site area was 1.6 ha split into 4 x 0.4 ha blocks:-

1. 1 kg Maku lotus + super + potash
2. 1 kg Goldie lotus + super + potash
3. 1 kg Maku unfertilised
4. 1 kg Goldie unfertilised.

A comparison was initially made of "cultivated seed-bed" versus "agro-ploughed" versus "slashing only". The fertiliser rates where applied were 120 kg molybdenated superphosphate and 120 kg potash/ha. A small block of Sharnae lotus was established for comparison with cv. Maku.

Site management: The site was open to grazing by cattle.

Table 46. Soil nutrient status at "Queensbury".

	February 1995		December 1998		June 1999	
	Lower	Upper	Maku - fertiliser	Maku + fertiliser	Maku - fertiliser	Maku + fertiliser
pH (1:5 $CaCl_2$)	4.8		4.8	4.5	4.7	4.6
Phosphorus (mg/kg, Colwell)	6		-	-	14	22
Phosphorus (mg/kg) (Bray $^{-1}$)	-		9	7	4	6
Sulphur (mg/kg) KCl 405)	-		4	7	-	-
Potassium (meq/100 g)	0.2		-	-	0.2	0.2
Calcium (meq/100 g)	2.5		-	-	2	2
Magnesium (meq/100 g)	1.6		-	-	1	1
Aluminium (meq/100 g, KCl)	0.20		-	-	0.1	0.3
Sodium (meq/100 g)	0.14		-	-	0.2	0.1
Electrical conductivity dS/M	0.03		0.04	0.04	-	-
Total nitrogen (%)	0.30		-	-	-	-

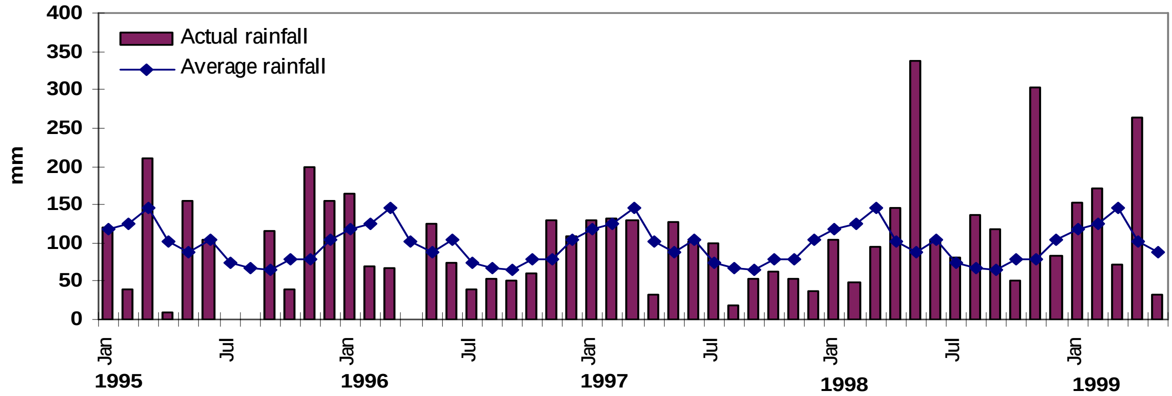


Figure 17. Rainfall at "Queensbury", 1995 – 1999.

Table 47. Lotus establishment at "Queensbury" as affected by cultivar, fertiliser, aspect and seedbed preparation .

		Seedling density (plants/square metre)	Botanical composition (%)
Variety	Maku	106	20
	Goldie	41	2
	Sharnae	38	†
Fertiliser	Plus	100	22
	Minus	47	1
Aspect	Upper slope	77	12
	Lower slope	70	11
Seedbed	Broadcast	79	14
	Agro-plough	72	12
	Cultivated	69	7

Table 48. Species composition at "Queensbury", 1997 – 1999.

			Lotus (%)	Other legume (%)	Carpet grass (%)	Weeds (%)	Annual grasses (%)	Perennial grasses (%)	Pasture biomass (kg DM/ha)	Green %
Spring 1997	Maku	Fertilised	20	0	64	9	0	7	1690	62
		Unfertilised	5	0	70	5	1	19	2988	54
	Goldie	Fertilised	8	2	56	9	0	25	2063	50
		Unfertilised	3	1	67	9	0	21	3950	50
Autumn 1998	Maku	Fertilised	5	2	58	19	0	17	1938	67
		Unfertilised	1	0	65	13	0	21	2125	51
	Goldie	Fertilised	1	3	69	17	0	9	2100	57
		Unfertilised	1	1	75	14	0	9	2625	42
Spring 1998	Maku	Fertilised	7	1	72	6	0	14	2680	73
		Unfertilised	3	0	71	6	0	20	3025	63
	Goldie	Fertilised	0	5	75	7	0	13	3179	66
		Unfertilised	0	0	76	4	0	20	3388	53
Autumn 1999	Maku	Fertilised	22	1	65	6	0	6	3731	40
		Unfertilised	1	0	63	7	0	29	4175	36
	Goldie	Fertilised	0	2	68	10	0	20	4049	35
		Unfertilised	0	0	28	8	0	67	4188	34
Spring 1999	Maku	Fertilised	38	0	46	1	0	15	2650	63
		Unfertilised	3	2	64	4	0	27	2680	77
	Goldie	Fertilised	2	7	62	3	0	26	2844	66
		Unfertilised	0	2	52	4	0	42	2781	71

Results:

- Establishment was best in conjunction with phosphate fertiliser and without cultivation; there were 106 plants/square metre of Maku and 41 plants/square metre of Goldie resulting in 20 and 2% of total sward biomass, respectively. Surface broadcasting was just as successful as planting into a prepared seedbed.

- The site was closely grazed by cattle and a strong grazing preference for lotus was observed.

- Following severe moisture stress during the 1997/98 summer-autumn, the presence of all lotus cultivars declined; reasonable lotus presence persisted on the lower moister slope but Goldie was sparse and Sharnae had only trace presence.

- With the above average rainfall conditions that prevailed in 1998 and 1999, Maku lotus presence expanded on the *plus fertiliser* block - this appeared to be related to the greater basal population of Maku lotus at establishment rather than a current response to fertiliser.

Conclusions: Conditions at Queensbury are characterised by high rainfall, low pH, carpet grass as the dominant grass, and close grazing by cattle. Best establishment was achieved by Maku lotus in conjunction with starter fertiliser (superphosphate + potash). Surface broadcasting into a closely slashed sward was just as successful as preparing a seed-bed. Maku lotus established, expanded in population density, and persisted at a high sward content whereas Goldie lotus declined to zero presence. The superior performance of Maku at Queensbury is attributed to the importance or rhizomes in conferring a capacity to compete effectively with a highly competitive rhizomatous grass (carpet grass).

4.2.3 Southern tablelands sites

"Woodburn", Bombala

Aim: On the Monaro, the feed-year comprises autumn growth following the "autumn-break" in May, relative dormancy from June - mid September, a flush of growth in spring and a seasonal feed-gap from mid December - January. February typically is associated with storm rains. In this context the potential role for lotus is to provide green feed in summer for weaner lambs.

The aims of the site at "Woodburn" were twofold:-

i) To assess the adaptation and agronomic performance of *Lotus corniculatus* cv Goldie and Tahora white clover for the Monaro region,

ii) To compare "strategic grazing" *vs* "cell grazing" for Goldie persistence.

Trial site: The co-learning site is located at "Woodburn", Mila 15 km south-west of Bombala. The soil is a sandy clay loam with friable clay loam ridges and clay loam gullies. Soil test results are presented in Table 49 and a climate summary is presented in Figure 18. Average annual rainfall at "Woodburn" is 640 mm.

Site establishment: The pasture was planted in October 1995 under direct-drill culture following glyphosate treatment at 1.5 L/ha. The seeding rate was 5 kg/ha Goldie lotus, 6 kg/ha perennial ryegrass, 2 kg/ha phalaris and 3 kg/ha tall fescue. Fertiliser was applied at planting as a 1:1 mixture of "Starterphos" plus molybdenated superphosphate totalling 50 kg/ha.

Management: The pasture area was originally subdivided by electric fencing to facilitate implementation of "cell grazing" *vs* "strategic grazing" with sheep (merino ewes/1st cross lambs). Cell grazing at "Woodburn" was planned to be based on a schedule comprising intensive grazing for short durations (~ 5 days) down to approximately 800 kg DM/ha followed by 50 - 80 days spell, depending on time of the year and seasonal conditions. Strategic grazing comprised a form of rotational grazing in which stock were periodically removed before the crown of the lotus plant is damaged to allow recovery from defoliation, and the pasture was spelled during flowering and seed production (mid December - late January) to allow the lotus to flower, set seed and regenerate from seed - preferably most years but every three years at a minimum. However, with the onset of severe and protracted drought conditions, the implementation of contrasting management practices was not possible and the study reverted to a comparison of the persistence of Goldie lotus in the lotus paddock and Tahora white clover in an adjacent white clover paddock.

Table 49. Soil nutrient status at "Woodburn".

	February 1996	July 1999	
		Lotus	White clover
pH (1:5 $CaCl_2$)	4.7	4.9	4.9
Phosphorus (mg/kg Bray)	-	14	13
Phosphorus (mg/kg Colwell)	33	31	29
Potassium (meq/100 g)	0.3	0.5	0.4
Calcium (meq/100 g)	3.4	3	3
Magnesium (meq/100 g)	1.1	1	1
Aluminium (meq/100 g)	0.18	0.2	0.2
Sodium (meq/100 g)	0.08	<0.1	<0.1
Electrical conductivity (d S/m)	0.06	-	-
CEC	-	5	4

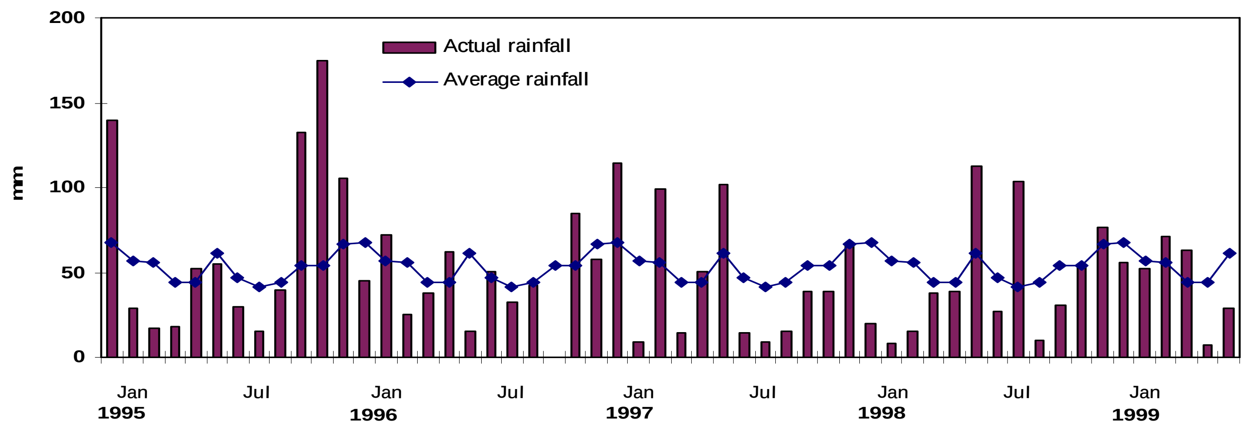


Figure 18. Monthly rainfall at "Woodburn", 1995 - 1998.

Table 50. Species composition at "Woodburn", summer 1996 - autumn 1998.

	Grazing treatment	Lotus (%)	White clover (%)	Ryegrass (%)	Fescue (%)	Phalaris (%)	Weeds (%)	Annual grass (%)	Other† (%)	Pasture biomass (kg Dm/ha)	Green (%)
February 1996	White clover	0	3	43	4	7	30	10	3	-	
	Lotus	2	0	25	4	1	44	21	4	-	
November 1996	White clover	0	21	42	2	1	17	13	4	-	
	Lotus	4	1	43	3	1	25	13	5	-	
November 1997	White clover	0	10	51	8	1	18	8	3	1464	29
	Lotus	14	1	50	4	2	14	4	10	2455	32
May 1998	White clover	0	0	23	1	15	22	18	19	216	79
	Lotus	1	0	14	2	13	13	21	36	830	86
December 1998	White clover	1	1	23	6	2	9	3	56	2041	27
	Lotus	3	0	25	1	3	4	3	61	3338	21
July 1999	White clover	0	0.3	53	2	7	3	3	32	1475	40
	Lotus	0.4	0	53	7	7	2	11	20	2147	32

† Other: sub clover, Danthonia, Poa, medics

Results:

- Goldie lotus established satisfactorily with a population density of 33 plants per square metre. Perennial ryegrass was too competitive in the establishment year restricting Goldie lotus to 2% sward biomass in autumn 1996 and 4% sward biomass in spring 1996.

- By spring 1997, the Lotus population had expanded despite very dry conditions. There was a substantial population density in valley floor micro-sites and where moisture and fertility conditions were best. There was a sparse stand of lotus on ridges where soils are skeletal, stony and lack a litter layer or Ao horizon. There was evidence of juvenile Lotus plants, probably from original seed rather than seedling recruitment. Following continuation of severe drought conditions over summer/autumn 1998, Goldie lotus presence remained low in terms of sward botanical composition but lotus plant density was significant (>5 plants per square metre) in some parts of the block - some new seedlings were evident.

- Tahora white clover achieved a high sward contents (31%) in the year following planting (1996), declined to 10% sward biomass in spring 1997 under drought conditions and was totally eliminated from the sward by autumn 1998.

Conclusions: The drought conditions that prevailed at "Woodburn" for 3 years following planting impeded the establishment of lotus and other sown species, other than perennial ryegrass. Accordingly, results were obtained in the context of severe and protracted drought compounded by close grazing that unavoidably accompanies ongoing drought. Results were inconclusive for the comparison of "strategic" versus "cell grazing" because these treatments were abandoned with onset of drought. Also, conclusions with respect to the relative adaptability of birdsfoot trefoil and white clover are made in the context of severe drought, close grazing and strong grass competition. In the establishment year, the high seeding rate of perennial ryegrass resulted in suppression of the original lotus population, and in subsequent years the lack of presence of perennial grasses (tall fescue, phalaris) and invasion by annual grasses progressively led to demise of lotus and white clover to only remnant status. Under these adverse conditions, birdsfoot trefoil expressed slightly better adaptive characteristics than white clover; lotus showed better longevity of 1st generation plants, maintained green leaf better under severe moisture stress conditions, and flowered strongly in summer to recruit small populations of new seedlings. This result warrants further research to better define the place of birdsfoot trefoil in the Monaro district.

The Glen", Goulburn

Aim: Pastures on more fertile soils of the Goulburn district are grazed close and frequently and it is generally considered that species that require strategic spelling pose major management problems. However, low fertility hill country is regularly spelled to maintain groundcover, so a species like *Lotus corniculatus* that requires specialised management is considered to be worth investigating. No useful legume is presently persisting well on this hill country so if *L. corniculatus* were to be adapted to this pasture environment, it would have a useful application. Specific aims for the co-learning site at "The Glen" were:

1. To investigate the suitability of *L. corniculatus* cv. Goldie in a low fertility southern tablelands high rainfall environment,
2. To compare grazing management systems to see if *L. corniculatus* can be maintained by strategic grazing.

Trial site: The site was located on "The Glen", approximately 20 km south of Goulburn on the Currawong Road. The property is operated by Chris Fischer. Climatic data is presented in Figure 19; average annual rainfall is 682 mm. The soil is a shale derived clay loam, topography is "hill country" and the site has a northerly aspect; soil test data are presented in Table 51.

Site preparation: A 65 x 200 m block was sown in early August 1997. The site is within a paddock of scrub regrowth re-cleared with a bulldozer. The aim of pasture development on the "The Glen" is to introduce improved pasture based on subclover, perennial grasses and white clover. The project offered an opportunity to test the adaptation of Goldie lotus. Establishment was delayed for two years (1995, 1996) due to dry conditions. Finally, planting was undertaken in August 1997 although soil moisture conditions at sowing were unfavourable and follow-up rain was inadequate. The seeding rate was 3 kg/ha tall fescue, 1.5 kg/ha Currie cocksfoot, 8 kg/ha subclover (4 varieties early to late), 0.25 kg/ha white clover and 8 kg/ha Goldie lotus. Fertiliser included 60 kg/ha lime-super and 60 kg/ha DAP.

Management: It was originally intended that the 2 ha block would include a fenced exclosure to facilitate a comparison of "conventional" grazing with "strategic" spelling. It was proposed that "conventional" grazing would comprise continuous grazing to 750 - 1000 kg DM/ha without summer spelling and "strategic" grazing would include rotational grazing in which stock are withdrawn at approximately 1200 kg DM/ha in summer and 1000 kg DM/ha in winter to allow pasture to regenerate. Also, the pasture would be spelled during flowering - seed production (mid December - late January) to allow birdsfoot trefoil to regenerate from seed.

Table 51. Soil nutrient status at "The Glen".

	November 1997
pH (1:5 $CaCl_2$)	4.4
Phosphorus (mg/kg, Colwell)	9
Conductivity (d s/m)	0.07
Potassium (meq/100 g)	0.6
Calcium (meq/100 g)	3.4
Magnesium (meq/100 g)	1.6
Sodium (meq/100 g)	0.07
Sulphur (mg/kg, KCl)	13
Nitrate nitrogen (mg/kg)	37
Aluminium (meq/100 g)	0.35
Chloride (mg/kg)	27

Figure 19. Rainfall at "The Glen", 1992 - 1998.

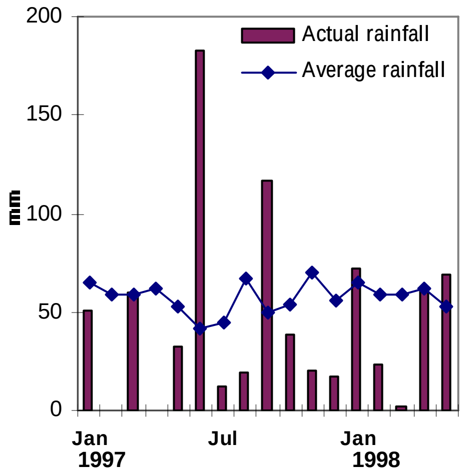


Table 52. Species composition at "The Glen".

	Goldie lotus (%)	Subclover (%)	Sown grass (%)	Native grass (%)	Annual grasses (%)	Weeds (%)
Spring 1997	1	31	8	28	15	16
Autumn 1998	0	1	2	38	49	10

NB. Total *biomass* and *& green* in Autumn 1998 were 722 kg DM/ha and 70%, respectively.

Results:

- Rainfall conditions following planting were adverse for establishment and survival of sown species - the population density of Goldie lotus three months post-planting was 5 plants per square metre.

- The site was subjected to severely dry conditions until rainfall in February 1998. In autumn 1998, the sward was dominated by vulpia and microlaena with minor presence of cocksfoot, subclover and broadleaf weeds. A trace presence of Goldie lotus occurred only in niche sites (moist hollows) or where there was an accumulation of a litter layer.

- The site did not have an adequate lotus population to warrant proceeding with a management study and re-sowing at the present site did not occur because it was considered that moisture deficit conditions would be severe until a litter layer developed.

Conclusions: The trial was unable to assess the adaptation or grazing management requirements of birdsfoot trefoil because of establishment failure.

"Stillwater", Yarra via Goulburn

Aim: Wet sites in the southern tablelands are subject to invasion by Yorkshire fog. Robert Lance, "Stillwater" has been in the forefront advocating control of Yorkshire fog by strategic grazing - this is facilitated by using intensive grazing to keep Yorkshire fog plants vegetative and palatable. A potential application for *Lotus uliginosus* in this region is to ingress into the Yorkshire fog community to improve sward palatability for increased utilisation of Yorkshire fog. The specific aim at "Stillwater" is to determine the adaptation and persistence of *Lotus uliginosus* cv. Maku under "conventional" and "strategic" grazing under wet fertile southern tablelands conditions.

Trial site: "Stillwater" is located at Yarra via Collector and is operated by Robert Lance. The soil is a wet valley floor brown clay-loam, average annual rainfall is 682 mm. Site rainfall and soil fertility status are provided in Figure 20 and Table 53.

Site establishment: The pasture was sown into a prepared seed-bed using a band-seeder on 26 May, 1996. The species mix comprised 1 kg/ha Tahora white clover, 1 kg/ha Palestine Strawberry clover, 2 kg/ha Trikkala subterranean clover, 4 kg/ha Maku lotus, 1 kg/ha paspalum, 1 kg/ha Victorian ryegrass, 3 kg/ha Australian phalaris and 6 kg/ha Demeter fescue. All legumes were inoculated, molybdenum coated and lime pelleted. Single superphosphate was applied at sowing at the rate of 250 kg/ha. It rained within two weeks of sowing and large parts of the paddock remained water logged until December 1996. No grazing was possible until the paddock dried out. Low levels of red-legged earth mite were present throughout winter and spring. Spraying for insect control would have been desirable but wet conditions prevented this.

Management: The original intention was to impose contrasting management treatments ("conventional" and "strategic" grazing) on adjacent blocks. However, the limited area of lotus that persisted suggests that this be managed using strategic grazing - ie treated as a single block by grazing to 1500 kg DM/ha lower biomass limit and spelling in autumn.

Table 53. Soil nutrient status at "Stillwater".

	1996	1999
pH (1:5 $CaCl_2$)	4.7	4.8
Phosphorus (mg/kg Bray)	18	34
Phosphorus (mg/kg Colwell)	49	70
Potassium (meq/100 g)	0.3	0.3
Calcium (meq/100 g)	3.0	3.0
Magnesium (meq/100 g)	2.8	1
Aluminium (meq/100 g)	0.18	0.2
Sodium (meq/100 g)	2.22	0.5
Electrical conductivity (d S/m)	-	
CEC	-	6

Figure 20. Rainfall at "Stillwater", 1992 – 1998.

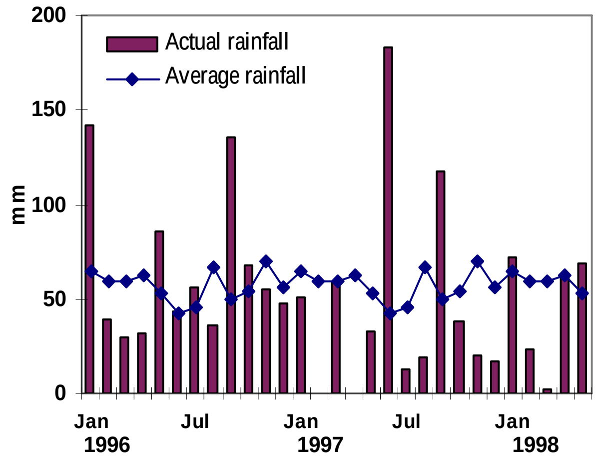


Table 54. Species composition at "Stillwater", 1996 – 1999.

	Grazing treatment	Lotus (%)	Perennial ryegrass (%)	Fescue (%)	Phalaris (%)	Other grasses† (%)	White clover (%)	Other legumes‡ (%)	Yorkshire fog (%)	Rush (%)	Weeds (%)
Spring 1996	Traditional	10	28	0	6	3	3	2	26	11	13
	Strategic	0	0	0	0	0	0	0	0	0	0
Autumn 1997	Traditional	1	37	15	5	0	6	0	35	0	2
	Strategic	1	31	31	3	0	4	0	32	0	0
Spring 1997	Traditional	0	5	38	2	2	11	8	33	0	2
	Strategic	0	0	42	0	0	16	3	37	0	0
Autumn 1998	Traditional	0	49	28	1	4	8	4	0	0	6
	Strategic	1	34	43	0	13	4	0	0	0	4
Spring 1998	Traditional	9	10	44	2	2	0	16	0	6	10
	Strategic	8	9	53	4	0	0	15	0	8	4
Autumn 1999	Traditional	1	24	50	3	12	1	1	0	0	10
	Strategic	0.3	20	62	1	5	1	2	0	0	7

† Other grasses: kikuyu, vulpia, Danthonia ‡ Other legumes: subclover, strawberry clover, caucasian clover

NB. Total *biomass* and *% green* in Autumn 1998 were 1080 kg DM/ha and 85%, respectively.

Results:

- Maku lotus established satisfactorily with 140 lotus seedlings per square metre recorded in August 1996. The lotus population continued to develop well under low grazing pressure through spring 1996.

- Two years post-planting, both blocks had vigorous populations of tall fescue, perennial ryegrass and white clover. These sown grass populations were dominant and Yorkshire fog presence was low. The “traditional” block had nil presence of lotus and the “strategic” block had trace Lotus presence, although these difference were not attributed to management because the blocks were managed under common grazing.

- Under adverse rainfall conditions in the 2 years (1997, 1998) following planting, lotus declined to assume only trace presence (*ca.* 1 plant/square metre) except 1 sector in the paddock that maintained 5 - 10% botanical presence. Failure to persist in most of the paddock may have been compounded by lax grazing/hay making which resulted in the accumulation of large residues (> 10,000 kg DM/ha) of standing forage in spring prior to hay cuts. Despite these conditions, of the perennial legumes planted, Greater lotus showed the most reliable persistence.

Conclusions: Except for favourable moist niche sites, rainfall conditions in the Goulburn district place it outside the likely zone of adaptation of Greater lotus. Future species evaluation work with perennial legumes should include investigation of birdsfoot trefoil - especially small leafed rhizomatous types (eg. cv. Steadfast) suited to lower rainfall and close grazing by sheep.

“Moonbucca”, Rylestone

Aim: Interest in Lotus in the Rylestone district revolved around concern about rising water tables, salinity and soil acidity and the potential that lotus might have as a deep-rooted perennial legume for both wet saline conditions and on light sandy soils. The consultative group which discussed these issues in November 1994 representing two Landcare groups (Caperty Valley Landcare group, Windmill Creek Landcare group) as well as individual landholders shortlisted the following activities for lotus co-learning:-

i) A Maku/Sharnae/Goldie cultivar evaluation site on a 5 ha paddock on “Eurella”, Rylestone
ii) A 10 ha Goldie site with two grazing management treatments on unimproved pasture on “Rawdon”, Rylestone
iii) Maku and Goldie in an evaluation of salt tolerant species (Caperty Valley Landcare group)
iv) Testing Goldie on light sandy areas and Maku in wet saline conditions (Windmill Creek Landcare group).

Trial site: The co-learning site chose was located on “Moonbucca”, Rylestone - property operated by J Mann. The site was located on a sandy-loam soil planted eight years previously to phalaris/clovers - remnants of phalaris were still present. Soil test data are presented in Table 55.

Site preparation: Paddock preparation included the application of 1.5 L/ha 24D Amine plus 7 gram/ha Ally in late July 1995 for control of sorrel and skeleton weed. This was followed by application of 1 L/ha Roundup one week prior to planting for control of annual ryegrass and vulpia. A mixture of Goldie lotus and Consol lovegrass was direct-drilled on 21 September, 1995. Planting was undertaken in two passes - the first pass disc drilled Goldie lotus (4 kg seed/ha) with 75 kg/ha 0.04% molybdenated superphosphate - the second pass broadcast 1 kg/ha Goldie lotus and 1 kg/ha Consol lovegrass with 75 kg/ha 0.04% molybdenated superphosphate. Neither pass utilised harrows. The lotus seed was inoculated, lime pelleted and treated with Apron. Soil moisture at planting was excellent - planting followed 50 mm rainfall.

Management: Lotus seedlings were observed in early October 1995. However, dry conditions set in and a second attempt to establish Goldie lotus/Consol lovegrass was undertaken using similar cultural practices on 3 August, 1996. Again, lotus seedlings were observed to have germinated in late September 1996 but inspection of the paddock on 18 November 1996 indicated poor establishment due to the combination of moisture stress and weed competition.

Table 55. Soil nutrient status at "Moonbucca", Rylestone.

	June 1995
pH (1:5 $CaCl_2$)	5.4
Phosphorus (mg/kg, Colwell)	20
Sulphur (mg/kg, KCl)	1
Potassium (meq/100 g)	6.25
Calcium (meq/100 g)	6.3
Magnesium (meq/100 g)	2.5
Aluminium (meq/100 g)	0
CEC	1.6
Ca:Mg	2.5

Results:

- No measurement of seedling establishment was undertaken. However establishment of lotus was reported to be unsuccessful - germination was sparse. It was concluded that establishment failure following both plantings was due to moisture stress and weed competition.

Conclusions: The investigation was unable to address the aims because of establishment failure.

4.2.4 South coast sites

"Bundanon", Nowra

Aim: Previously productive improved pastures in the Nowra district have suffered pasture decline in recent years - improved pastures have become dominated by carpet grass and harbour noxious weeds. The reason for this decline is considered to be due to reduced management in conjunction with subdivision and the proliferation of hobby farms. In this context, lotus is seen to have potential to improve pasture productivity with minimal inputs of. Greater lotus (*Lotus uliginosus* cv. Maku) has already been successfully used on favourable high rainfall coastal sites. The consultative committee considered that the project should address the use of birdsfoot trefoil (*Lotus corniculatus* cv. Goldie) as a reduced input alternative to lucerne on alluvial river flat country; key variables for consideration were i) the effects of low phosphate, ii) sod seeding, and iii) lime application for Goldie lotus compared with lucerne.

Trial site: The co-learning site was located on "Bundanon" owned by the Boyd Trust and managed by Simon Hale; the soil is a fine sandy loam. Climate data are presented in Figure 21 - average annual rainfall is 1136 mm. Soil fertility status is presented in Table 56.

Site establishment: The site was initially planted on 5 May, 1995 on three blocks - block 1: 5 kg/ha Goldie lotus, block 2: 6 kg/ha Aquarius lucerne, block 3: 12 kg/ha Trifecta lucerne. Planting was undertaken with a "Begg Direct Drill" and the fertiliser rate was 100 kg/ha "Starterphos". This planting failed due to the combination of drought and slugs. A second planting was undertaken on 9 May, 1996 on five blocks as follows:-

Block 1: 5 kg/ha Goldie lotus
Block 2: 10 kg/ha Goldie lotus
Block 3: 6 kg/ha Pioneer L69 lucerne
Block 4: 6 kg/ha Pioneer L59 lucerne
Block 5: 12 kg/ha L69/L59 lucerne (3 kg/ha L69, 9 kg/ha L59).

Seed and fertiliser (100 kg/ha "Pasture 13") were broadcast onto ploughed ground and harrowed. Slug and snail bait insecticide was applied at planting.

Management: Initially, the site was managed as a hay crop, ie. largely ungrazed during the establishment year and allowed to accumulate very high biomass. This resulted in dominance by indigenous white clover and broadleaf weeds. The blocks were subsequently managed as grazed pasture using beef cattle.

Table 56. Soil fertility at Bundanon.

	March 1998
pH (1:5 CaCl2)	4.9
Phosphorus (Colwell) mg/kg	54
Potassium meq/100g	1.2
Calcium meq/100g	4.4
Magnesium meq/100g	1.6
Aluminium (KCl) meq/100g	0.12
Sodium meq/100g	0.07
Chloride mg/kg	58
Conductivity dS/m	0.17
Nitrate nitrogen mg/kg	53
Sulfate sulphur (KCl 40) mg/kg	15

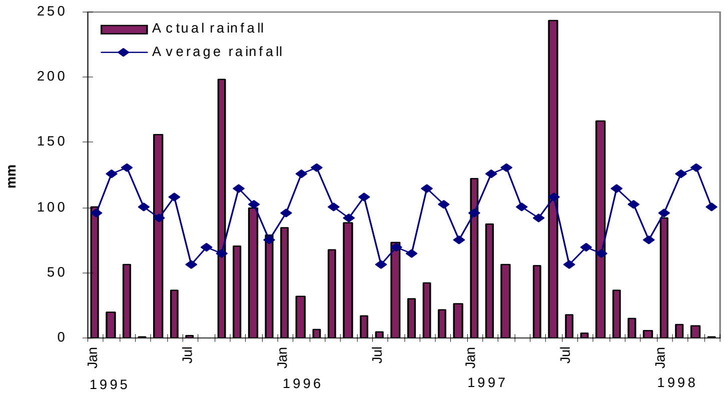


Figure 21. Rainfall at Bundanon, 1994 – 1998.

Table 57. Seedling establishment at "Bundanon".

Block	Seedling density (plants/square metre)					
	Lotus	Lucerne	White clover	Grasses†	Weeds	Sedges
5 kg lotus	73	0	101	7	97	38
10 kg lotus	126	0	31	2	146	6
L69 lucerne	0	81	60	3	110	2
L52 lucerne	0	155	34	1	81	4
L69/L52	0	188	12	0	83	0

† Annual grasses, kikuyu

Table 58. Species composition at Bundanon, 1996 – 1998.

	Grazing treatment	Lotus (%)	Lucerne (%)	White clover (%)	Perennial grasses† (%)	Annual grass (%)	Broadleaf weed (%)	Pasture biomass (kg DM/ha)	Green (%)
Spring 1996	5 kg lotus	8	0	55	0	0	37	-	-
	10 kg lotus	24	0	17	0	2	58	-	-
	L69 (6 kg)	0	27	23	0	0	48	-	-
	L52 (8 kg)	0	25	18	0	3	56	-	-
	L 69 + L52 (12 kg)	0	29	10	0	0	61	-	-
Autumn 1997	5 kg lotus	3	0	25	0	3	69	-	-
	10 kg lotus	7	0	21	0	11	62	-	-
	L69 (6 kg)	0	35	19	0	15	31	-	-
	L52 (8 kg)	0	48	22	0	11	19	-	-
	L 69 + L52 (12 kg)	0	41	11	0	22	26	-	-
Spring 1997	5 kg lotus	10	0	15	63	0	12	960	39
	10 kg lotus	5	0	9	72	0	14	1181	39
	L69 (6 kg)	-	89	0	3	0	9	837	83
	L52 (8 kg)	-	94	1	0	0	4	1432	83
	L 69 + L52 (12 kg)	-	91	4	0	0	6	2524	83
Autumn 1998	5 kg lotus	0	0	6	41	0	54	1647	79
	10 kg lotus	0	0	6	20	0	80	3118	79
	L69 (6 kg)	0	7	1	16	3	74	374	85
	L52 (8 kg)	0	23	2	5	2	69	3564	85
	L 69 + L52 (12 kg)	0	43	0	3	2	53	3546	85

† Kikuyu

Results:

- The autumn 1996 sowing that involved shallow depth of planting and the application of slug and snail bait was successful. There was a greater seedling density (126 plants/square metre) and sward content of Lotus (24%) when sown at 10 kg/ha compared with 5 kg/ha (73 plants/square metre, 8%; respectively). Summer spelling promoted prolific flowering of Lotus.

- Despite an excellent establishment of Goldie lotus, satisfactory Lotus presence for two years following establishment, and evidence of seedling recruitment in spring 1997, the Lotus population declined to zero by autumn 1998. Lack of a companion grass to assist formation of a pasture sward, management as a hay crop in 1996 and 1997, extensive shading, and the combined effects of severe moisture stress and close grazing during 1998 summer/autumn were contributing factors to lotus decline.

Conclusions: Hinterland districts of the NSW South Coast lie within the expected zone of adaptation of birdsfoot trefoil. Experience at the "Bundanon" site illustrates that conditions were suitable for establishment, and seedling recruitment but that intensive management conditions that are characteristic of small holdings like "Bundanon" are prohibitive for persistence of birdsfoot trefoil. Even with adherence to management protocols to maintain Lotus based swards within desirable pasture biomass limits, birdsfoot trefoil in this environment will inevitably be overwhelmed by competition from local rhizomatous grasses (carpet grass on low fertility soils, kikuyu on high fertility soils) until a rhizomatous birdsfoot trefoil like cv. Steadfast variety is available.

"Willeroo", Rocky Hall via Bega

Aim: The Bega valley comprises approximately 800,000 ha and 20 per cent is cleared agricultural land. The dairy industry generates approximately $50m GVP and the beef industry generates $5m; there are some 30,000 sheep. Average annual rainfall is 914 at Bega on the coast, 762 mm at Towamba on the edge of the escarpment and 620 mm at Kameruka in the central Bega valley. Microlaena is widespread and dominant and serrated tussock and lovegrass are serious invasive weeds. The feed-year comprises a winter feed-gap due to low temperate and a summer quality feed-gap due to moisture stress - the Bega valley is a summer rainfall environment but heat and high evaporation occurs from November - February. In this context, the potential role for lotus is:-

- Need a legume that persists through hot/dry summers - subclover and white clover have limitations over summer - lucerne does not fit the production system and is not adapted to low pH.
- Need a legume adapted to summer rainfall/summer moisture stress - the hope from *L. corniculatus* is that the deep rooting habit will confer tolerance to summer moisture stress and provide "green pick" over summer.
- Need a low input legume suitable to complement native pastures for beef cattle. The ideal role for *L. corniculatus* is as a low input legume - ie adapted to acid low P granite soils - established by broadcasting into native pasture - for improved utilisation of tussock and lovegrass infested hill country.

A consultative group representing Towamba Landcare Group considered there was sufficient potential for *L. corniculatus* in the Bega Valley to warrant lotus co-learning trials. The group agreed to set up two co-learning sites - *site 1* comprising a 12.6 ha area on "Elmgrove" and *site 2* comprising a 5 ha area on "Willeroo" - both sites to involve newly planted pasture based on Goldie lotus/phalaris/subclover and to compare "conventional" grazing with "strategic" grazing. Planting was not undertaken in 1995 or 1996 due to prolonged dry conditions.

Trial site: "Willeroo" operated by Ian Baker is in the Bega Valley near Burragate - average annual rainfall is 756 mm. The co-learning site is on a gently sloping and north facing course grey-brown sandy loan granite soil that was previously old phalaris pasture. Rainfall and soil test data are presented in Table 59 and Figure 22, respectively.

Site establishment: The paddock was sprayed with Glyphosate (3 L/ha) prior to planting to reduce grass competition, particularly from couch. Goldie was sown on 12th March, 1997 at 3 kg/ha along with 3 kg phalaris, 2 kg Kangaroo Valley ryegrass, 1 Kg Haifa white clover and 4 Kg Karridale sub clover. The soil moisture was good and sowing successful. Planting was done with a direct drill fitted with caldow points. 125 kg/ha of Starter 15 was applied at sowing.

Table 59. Soil nutrient status at "Willeroo".

	March 1995
pH (1:5 CaCl2)	4.8
Phosphorus (Colwell) mg/kg	26
Potassium meq/100g	0.4
Calcium meq/100g	4.0
Magnesium meq/100g	0.9
aluminium (KCl) meq/100g)	0.11
sodium meq/100g	0.05
Conductivity dS/m	0.06
Total Nitrogen	0.10

Figure 22. Rainfall at "Willeroo", 1995 – 1998.

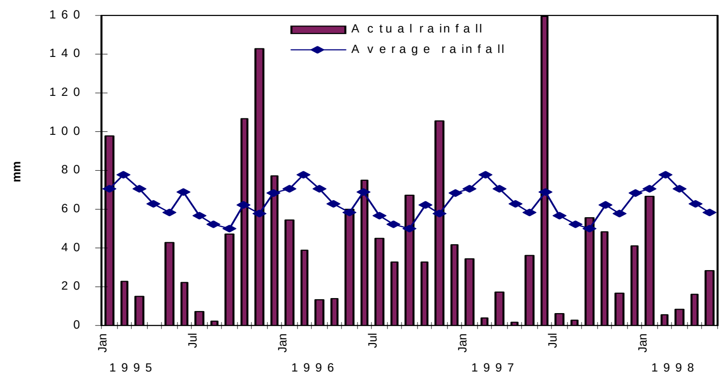


Table 60. Species composition at "Willeroo", autumn 1998.

Sown† grass	White clover (%)	Goldie lotus (%)	Sub clover (%)	Ball clover (%)	Annual‡ grass (%)	Native+ grass (%)	Couch (%)	Weeds (%)	Yield (kg DM/ha)	Green (%)
12	0	0	1	11	25	1	23	28	973	78

† Phalaris, perennial ryegrass ‡ Vulpia + Danthonia

Results:

- After four years of below average rainfall (and four successive dry autumns that were unsuitable for planting the trial site) the block was sown in March 1997 on reasonable surface moisture but poor subsoil moisture. Germination was considered to be successful but virtually no rainfall occurred in July-August and few seedlings other than phalaris survived.

- Inspection of the site in December showed that due to very dry conditions following planting, there was a zero population of lotus seedlings. It is probable that there was one germination event due to planting on moist soil, but that resultant seedlings expired due to moisture stress. There was a sparse population of phalaris but in only some rows suggesting either a compression effect from tractor tyres or variable planting depth due to equipment settings. A small number of aged lotus seedlings were found in moist micro-sites representing remnants of the generation of seedlings that presumably germinated shortly after planting. A seedling count was not undertaken but seedling population at 25/11/97 was deemed to be zero.

    - Inspection of the site in May 1998 confirmed the poor survival of sown grasses and nil survival of lotus - Botanal measurements showed trace populations of phalaris, otherwise ball clover, capeweed, couch and vulpia.

Conclusions: The investigation was unable to address the main aims because of establishment failure.

"Elmgrove", Towamba via Bega

Trial site: "Elmgrove" is located in the Bega Valley near Towamba and is operated by William Wentworth. Average annual rainfall is 875 mm and the site is on a steep north facing grey-brown coarse granite sandy loam. The site was originally a native pasture area with virtually no history of superphosphate. The paddock had extensive areas of serrated tussock and patches of kikuyu in high fertility camp sites. Rainfall and soil fertility status are described in Figure 23 and Table 61 respectively.

Site establishment: Prior to sowing the site was sprayed with glyphosate (3 L/ha) to control serrated tussock. The area was sod-sown with a direct drill machine fitted with caldow baker books, in the first week of May 1997. The seed mix consisted of 3 kg/ha lotus, 1 kg/ha Haifa white clover, 2 kg/ha Karridale sub clover, 2 kg/ha Goulburn sub clover, 1 kg/ha Sirosa phalaris, 1 kg/ ha Australian phalaris and 2 gk/ha Currie cocksfoot. The area was topdressed with 100 kg/ha 0.04% molybdenum superphosphate in March 1996, and at sowing 100 kg/ha Starter 15 was applied.

Table 61. Soil nutrient status at "Elmgrove".

	March 1995
pH (1:5 CaCl2)	5.1
Phosphorus (Colwell) mg/kg	7
Potassium meq/100g	0.3
Calcium meq/100g	5.1
Magnesium meq/100g	1.4
aluminium (KCl) meq/100g)	<0.05
sodium meq/100g	0.10
Conductivity dS/m	0.04
Total Nitrogen	0.28

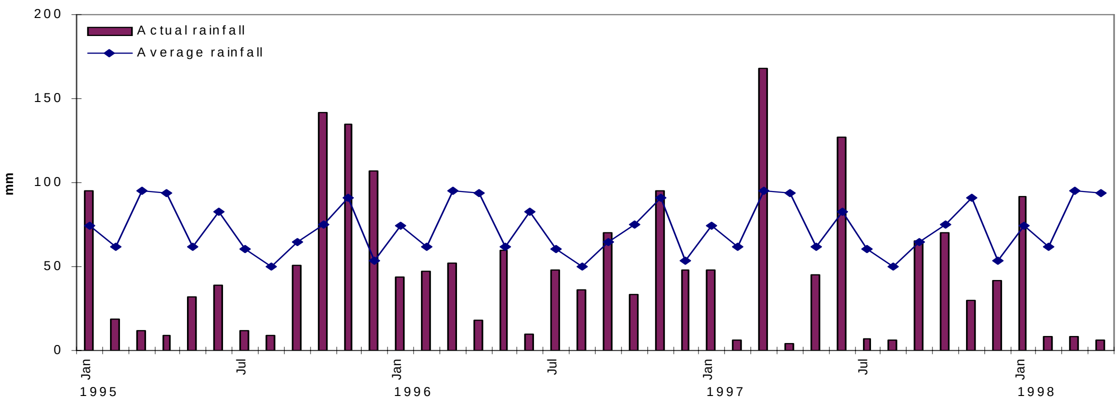


Figure 23. Rainfall at "Elmgrove", 1995 – 1998.

Table 62. Species composition at "Elmgrove" 1998.

		White clover (%)	Goldie lotus (%)	Other† legumes (%)	Sown‡ grass (%)	Native+ grass (%)	Kikuyu (%)	Annual* grass (%)	Weeds (%)	Yield (kg/DM/ha)	Green (%)
Autumn 1998		1	0	5	6	9	1	50	28	-	-
Spring 1998	Ridge	0	0	11	7	2	0	63	17	2450	10
	Gully	24	3	0	2	0	0	16	55	4125	37

† medic ‡ phalaris + * vulpia

Results:

- On inspection in November it was evident that in favourable patches (moist gullys due to springs or run-off) there was strong establishment of phalaris and white clover but with only a sparse population of lotus from a germination event soon after planting. A trace lotus population was observed soon after planting but these seedlings expired due to moisture stress. In most of the paddock, establishment of phalaris and white clover also failed and the sward is dominated by Vulpia, Brome grass and some Yorkshire fog. A seedling count was not done, but the seedling population at 25/11/97 was deemed to be less than 1 plant per square metre.

- On inspection in May 1998, the sward was dominated by Vulpia, capeweed and subclover and a small developing population of phalaris, cocksfoot and ryegrass - only a trace distribution of Goldie lotus was evident.

Conclusions: The investigation was unable to address the main aims because of establishment failure.

5. ACHIEVEMENT OF OBJECTIVES

Activities undertaken within DAN 082 completed all milestones and accomplished significant achievements against the industry objectives and experimental objectives as follows.

Experimental objective:

"To determine if grazing intensity and strategic spelling affects expression of the adaptive characteristics of Greater lotus and birdsfoot trefoil, and to examine whether the level of grass competition interacts with the response to grazing intensity and strategic spelling".

This objective was addressed through conduct of a grazing management field experiment with sites in 4 regions - northern tablelands (Glen Innes site), north coast (Casino site), southern tablelands (Canberra site) and south coast (Nowra site). The experiment comprised fully replicated treatments representing grazing strategy and grazing intensity factors, and a range of lotus cultivar x grass type combinations. The study at each site was run according to the same management protocols (Appendices 9 – 16). The extremely severe drought conditions that prevailed for 20 months in 1994 – 1995 interfered with establishment of the plots and delayed commencement of the experiment, especially at the northern sites (Appendices 5 – 8). Data was subsequently collected for 40 months at Nowra and Canberra, 30 months at Glen Innes, and 24 months at Casino. The results provided large and valuable data-sets for seedling establishment, botanical presence, rhizome density/seed bank development, and seedling recruitment to help assess the adaptation and grazing management requirements of GL and BFT in the NSW high rainfall zone. These results are reported in 2.4.

Industry objective:

1. "To define grazing management strategies that enable Greater lotus and birdsfoot trefoil to maintain at least 20% of total pasture dry matter in a mixed grass/legume pasture, for at least 4 years in a beef breeding system."
2. "To demonstrate the use, management and economic benefit of Greater lotus and birdsfoot trefoil cultivars to grow out steers in conjunction with graziers, seed companies, extension officers and other stakeholders throughout a series of co-learning sites."

These industry objectives were addressed by the experimental and co-learning phases of DAN 082. A pair of the experimental treatments (continuous grazing "control" versus strategic grazing) were implemented at a number of the on-farm co-learning sites. In all, there were 17 co-learning sites with 11 community groups and the work was supported (in kind) by Heritage Seeds, Pacific Seeds, and Incitec and assisted by 8 NSW Agriculture District Agronomists. The R&D model used in DAN 082 was evaluated at the beginning and end of the project by the Rural Extension Centre, Gatton Campus, University of Queensland.

The technical objective of maintaining 30% Lotus content in pasture was achieved at the northern tablelands site where BFT was identified by DAN 082 to be a valuable new perennial legume for northern NSW. This result was repeated at 4 out of 5 of the northern tablelands co-learning sites. A comparable result was achieved at 4 out of 4 of the north coast co-learning sites with GL. However, at neither of the southern core sites nor any of the southern co-learning sites did either Lotus species retain other than low or trace levels of botanical presence.

6. INDUSTRY IMPLICATIONS

DAN 082 has been a successful partnership between NSW Agriculture, Meat and Livestock Australia, agri-business and farmer community groups in the high rainfall zone to determine the potential of Lotus to contribute to grazing production in NSW, and to develop sound grazing management practices for Lotus based pastures. Using on-farm and group-based co-learning, DAN 082 benefited substantially from industry inputs and the exchange of ideas and experiences between science and practice – some 21 study sites oversighted by 8 formal community groups and a further 6 neighbourhood groups formed the bases for investigation and demonstration of Lotus technology in New South Wales. Project outcomes for industry are set to flow from:-

(a) *Greater awareness of the unique and valuable properties of Lotus* – Lotus, is a perennial pasture legume adapted to low fertility acidic soils. GL is suitable for pasture development for cattle and sheep grazing in very high rainfall (> 1000 mm AAR) coastal districts and wet/waterlogged sites or sites with favoured moisture conditions in tablelands environments. BFT is suitable for dryland hinterland (coast, tablelands, slopes) environments with reliable summer rainfall and AAR > 650 mm, BFT is taprooted and possesses a degree of drought tolerance. Both Lotus species provide non-bloating high protein forage for grazing livestock, and have potential to rehabilitate degraded grasslands, BFT has potential application to arrest acidification and salinisation of groundwater recharge zones.

(b) *Increase in the knowledge-base of Lotus technology* – DAN 082 generated research results and experience including the following:-

- Determination of the seed-bed requirements conducive to successful establishment of Lotus based pastures

- Identified the significance of key management factors (grazing intensity, companion grass type, strategic grazing) for long term persistence of Lotus

- Tested available cultivars (GL Maku, GL Sharnae, BFT Goldie, BFT 'Spanish') in a wide range of environments and identified the limits to GL and BFT zonation

- Documented a diversity of experiences relevant to the successful culture and management of Lotus based pastures including, soil type effects on establishment and agronomic performance, seasonal effects on growth and agronomic performance, geographic location effects on regeneration mechanisms, sheep and cattle impacts on regrowth and longevity, and pest/disease incidence.

(c) *Evidence for a far wider diversity of applications for Lotus than previously considered possible* – Prior to DAN 082, Lotus use in Australia was restricted to commercial plantings of GL (principally cv. Maku) in very high rainfall coastal districts – the planted area of Lotus based pasture was assessed in the mid-1990's to be ~50,000 ha – principally for cattle grazing on wet sites on the north coast of NSW. At this time there had been no commercial plantings of BFT in Australia and experience was limited to plot studies on the southern tablelands and Monaro. DAN 082 not only implemented demonstration of both GL and BFT in a wide range of environments (coast, tablelands and slopes in northern NSW; coast, tablelands and Monaro in southern NSW) and a diversity of applications (low rainfall sites, sheep and cattle grazing, companion legume to native and naturalised grasses as well as introduced grasses), but encouraged and promoted a significant incidence of commercial plantings in traditionally non-Lotus areas. The planted area of GL increased 100% to 100,000 ha during the course of DAN 082, and in 2000 some 2 t BFT Goldie seed was imported and forward-sold to retailers.

(d) *Expansion of the Lotus zone* – DAN 082 has confirmed that GL is a valuable pasture legume for high rainfall coastal pastures and favourable niche sites on the northern tablelands. More significantly, DAN 082 has shown that BFT has promising potential for acidic soils on the tablelands and slopes, especially in northern NSW. Climatic modelling and homoclime considerations undertaken by CSIRO in conjunction with the national survey of Australian pastures proposed that the potential zone of adaptation of GL plus BFT in Australia combine to total some 17 m ha. Experience from DAN 082 tentatively indicates that the GL zone in NSW has potential to ultimately expand to occupy up to 4 m ha (far north coast, 1 m ha; northern tablelands, 1 m ha; north coast/central coast and Hunter, 1 m ha; south coast/southern tablelands, 1 m ha), and the BFT zone has potential to exceed 5 m ha (northern tablelands, 1 m ha; north-west slopes, 3 m ha; far south coast hinterland and Monaro, 1 m ha). The history of pasture development in Australian temperate environments is strongly indicative that the level of industry adoption of improved pasture technology is of the order of 25 – 50%; ~ 50% when farm scale and infrastructure are favourable (eg. BFT on the north-west slopes) and ~ 25% when less favourable (eg. GL on the NSW coast). Accordingly, it is proposed that a realistic goal for the Lotus zone in NSW by 2010 is 1 m ha of GL based pastures in high rainfall coastal, escarpment and eastern fall tablelands environments, and 2.5 m ha of BFT based pastures in tablelands and slopes environments where AAR is 650 – 1,000 mm. This would place Australia on a similar level of Lotus use with homoclimes in subcontinental South America (1.8 m ha), USA (1.2 m ha) and eastern Europe (1.5 m ha).

One important outcome from DAN 082 is the evidence and experience to show the potential of Lotus, especially BFT, to become a mainstream pasture legume for low fertility acidic soils in northern NSW. If achieved, this will be a fortuitous coincidence of finding a new pasture plant where it is most needed – a tap-rooted perennial legume to rehabilitate degraded grasslands.

7. RECOMMENDATIONS

DAN 082 has been a 5 year state-wide R&D project with new technology for the grazing industries that has involved experimental work to expand the Lotus technology knowledge base, and joint action between researchers, farmers and agribusiness using co-learning methodology. The project has been a major undertaking by NSW Agriculture with significant achievements. However, DAN 082 has also exposed certain limitations that are restricting technology adoption and expansion of the Lotus zone. Conversely, these limitations when framed as issues for resolution through a combination of future R&D directions, agri-business opportunities, and farmer community group initiatives can be viewed as opportunities for further exploitation of DAN 082 achievements. These are as follows:-

- *Popularisation of Lotus use* – The target of fostering expansion of the Lotus zone to 3.5 m ha by 2010 will require the combination of (i) a media campaign to build on the current low level of awareness of Lotus, (ii) training seeds industry agronomists and retail staff on Lotus agronomy, and (iii) farmer community group activities to achieve a “critical mass” of industry experience with Lotus. Adoption of new technologies and practices is driven far more by group actions than by advertising, so it is strongly recommended that emphasis by placed on co-learning activities supported by programs like MLA PIRD.

- *Commercialisation of Lotus seed* – The target of fostering expansion of the Lotus zone to 3.5 m ha by 2010 will require adequate availability of both GL and BFT seed at a price that is competitive with other pasture legumes like lucerne and white clover (ie. < $10/kg). In the course of activities associated with Dan 082, it has been evident that the combination of low availability and high price of Lotus seed in Australia has significantly impeded Lotus use – this applies to both GL (variously $25 - $35/kg) and BFT (variously $15 - $25/kg). The target of 1 m ha GL and 2.5 m ha BFT implies the need to support initial establishment and annual replanting of the order of 100,000 ha GL and 250,000 ha BFT and a potential annual seed market of 100 t GL and 500 t BFT. It is noteworthy that, the average area of Lotus sown annually in Uruguay is 225,000 ha, USA 125,000 ha, and Austria 100,000; the world seed market is sustaining annual replanting totalling at least 2 m ha. These levels of annual planting are of the order required in Australia to achieve timely expansion of the Lotus zone and it would appear that seed stocks are available on the world market to support the requirement for Australia. It is proposed that a desk-top analysis be undertaken to investigate the feasibility of the seeds industry supporting Australian requirements.

- *Cultivar development and testing* – The target of fostering expansion of the Lotus zone to 3.5 m ha by 2010 will require further plant improvement work and cultivar testing for both GL and BFT, as follows:-

i) The need for a short daylength BFT cultivar. Persistence of BFT depends on prolific flowering and podding for seedbank development and seedling recruitment. Evidence has come from DAN 082 that the BFT cultivar commercially available in Australia, Grasslands Goldie, although agronomically promising, flowers only sparsely and recruits few seedlings under northern NSW daylength conditions. Flowering in BFT requires 14 – 18 hours daylength for prolific flowering. Daylength on the summer solstice in northern NSW is approximately 14 hours, so there is a requirement for a short daylength type. Consequently, there is a need to screen a world-sourced set of *L. corniculatus* germplasm for a line that will flower prolifically on acidic soils under short daylength conditions and hence recruit seedlings for long term stand persistence. Reselection for flowering/podding prolificacy is also being undertaken with cv. Grasslands Goldie.

ii) The need for broad adaptation in GL. A significant advance for the grazing industries located on acidic soils will come from the development of a broad adaptation GL cultivar that will persist beyond favourable niche sites. There is a need with respect to GL to screen a set *L. uliginosus* lines for broad adaptation characteristics on acidic soils in northern NSW.

Plant improvement projects i) and ii) are already underway at Glen Innes and it is anticipated that promising lines will be isolated by 2002. There is however, a need to secure agency or commercial partner funding to complete cultivar development (seed increase, seed production testing, PBR examination), merit testing, and commercialisation. APPEC merit testing is not available for Lotus species, therefore it is recommended that agency funds be sought to conduct coordinated field trials across the Lotus zone for merit testing lines from i) and ii), advanced breeding lines from CSIRO's Lotus program, and cultivars from world sources.

8. INTELLECTUAL PROPERTY

DAN 082 project technology is implicit in milestone reports, the final report, and scientific publications arising from DAN 082 project activities. Documentation or use of DAN 082 project technology is subject to the Agreement Between MRC and NSW Agriculture, DAN 082. However, information in relation to the properties of Lotus cultivars, the adaptive characteristics of Lotus, and the grazing management requirements of Lotus is normally freely available between world-wide agencies. No DAN 082 project technology is subject to royalties, licensing or patents, or confidentiality arrangements beyond the terms of the DAN 082 Agreement.

9. COMMUNICATIONS

Communication of DAN 082 activities with farmers, agri-business, and the scientific community has occurred through a combination of planned media events and ongoing liaison using NSW Agriculture's network of agency linkages. In addition to milestone reports to MLA, the work of DAN 082 has been reported annually to stakeholders, collaborators and co-learning cooperators with site reports. Rural community awareness of project activities has occurred through media reports and field day events, eg;

- MLA "Meat for Profit" display
- Agquip display
- Feature articles in the rural press

- Poster papers in NSW Grasslands Conference, Australian Agronomy Conference, and the International Grasslands Conference.

Numerous field days have been held at the co-learning and core sites. These have been either on an occasional basis (southern sites) or on a regular autumn and spring 'farm-walk' basis (northern sites). There have also been numerous inspections of the core experiments and co-learning demonstrations by seed company agronomists, farmer groups, students, and researchers from other agencies including international visitors.

Publications arising from DAN 082 are listed below:-

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Blumenthal, M.J. and McGraw, R.L. (1999). Agronomic use and management of Lotus. In "*Trefoil: the Science and Technology of Lotus*". Eds. P.R. Beuselinck, C.S. Hoveland and C.J. Nelson *(American Society of Agronomy and Crop Sciences Society of America*) 266 pp.

Ayres, J.F. and Blumenthal, M.J. (2000). Lotus grazing management for weaner production. Final Report on DAN 082 (1994/95 – 1998/99) for Meat and Livestock Australia.

(A series of scientific papers will be submitted for publication in the *Australian Journal of Experimental Agriculture* and the *Journal of Agricultural Extension & Education*.)

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- Robert Lance (Collector Landcare Group), "Stillwater", Yarra via Goulburn
- Chris Fisher, "The Glen" Currawong Road via Goulburn
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- Des Adams (Bannockburn Landcare Group), "Coomerang", Oakwood via Inverell
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- Graham Charters, "Hill Top", Bingara
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- Howard Hammond, Melinga via Taree
- Paul & Karen Hutchinson, "Queensbury", Booral via Stroud
- Will Wentworth, "Elmgrove", Towamba via Bega

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- Colin Ferguson, “Kimo”, Junee Rd, Gundagai, NSW
- Don Lean, “Inglebar”, Jackadgery, NSW
- Charles Litchfield, “Coroo”, PO Box 5, Cooma, NSW
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- Incitec Fertilisers (Martin Williams, Orange)

In terms of i) the prominent linkage between the experimental phase (the core grazing experiments) and the on-farm phase (the co-learning demonstrations) plus ii) the extensive scale of operations, DAN 082 has pioneered co-learning as a new instrument for agriculture R&D in Australia. This concept was brought to fruition by Dr Martin Blumenthal, NSW Agriculture. Acknowledgment is due to Professor Ray Ison, Milton Keynes Open University, United Kingdom and Professor Craig Pearson, University of Queensland for their contribution of ideas to co-learning methodology.

Dr Jeff Coutts, Rural Extension Centre, University of Queensland, undertook a review of DAN 082 co-learning methodology at the outset of the project and again at the conclusion of the project in conjunction with Dr Kate Roberts. This systematic evaluation of DAN 082 co-learning methodology is being documented for publication and will develop recommendations and form a basis for the further development of co-learning methodology.

DAN 082 has been a major research undertaking and has involved close and fruitful collaboration between a large and diverse number of team members from NSW Agriculture. The team has included 3 researchers (Dr Martin Blumenthal, Dr John Ayres, Dr Zvi Hochman), 4 Technical Officers (Leah Lane, Emma Wilson, John O’Connor, Jim Hindmarsh), Biometrician (Helen Nicol), 2 consultant researchers (Terry Launders, Gordon Stovold), and 8 District Agronomists (Linda Ayres, Neil Griffith, Gerry Hennessy, Jeff Lowien, Lester McCormick, Bob McGufficke, Peter Simpson, and Harry Kemp).

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- Helen Nicol for statistical analyses
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12. APPENDICES

Appendix 1a. Plot layout showing grazing treatments at the Glen Innes core experiment.

Rep 3	T3	T5	T2	T4	T7	T6	T1
Rep 2	T2	T1	T4	T3	T6	T5	T7
Rep 1	T7	T3	T6	T5	T2	T1	T4

T1: continuous grazing / low biomass
T2: continuous grazing / high biomass
T3: summer spell / low biomass
T4: summer spell / high biomass
T5: autumn spell / low biomass
T6: autumn spell / high biomass
T7: rotational grazing / high biomass

Appendix 1b. Plot layout showing cultivar treatments at the Glen Innes core experiment.

	SS	GV	MS	MV	MV	MS	SS	GS	GV	SV	GS	MV	GS	MV
Rep 3	SV	GS	GV	SS	GV	SS	SV	MV	MS	GS	SV	GV	MS	SV
	MV	MS	SV	GS	GS	SV	GV	MS	MV	SS	SS	MS	GV	SS
	SV	MV	SS	MS	GV	GS	GS	MS	SS	MS	GS	SV	SV	MV
Rep 2	SS	GS	MV	SV	SS	MV	MV	GV	GS	MV	MS	MV	SS	MS
	MS	GV	GS	GV	MS	SV	SV	SS	GV	SV	SS	GV	GV	GS
	SS	SV	GV	MS	MS	MV	GV	MV	SV	GV	MS	GV	SV	MS
Rep 1	GS	GV	GS	MV	SV	SS	SS	SV	MS	GS	SS	SV	MV	GS
	MV	MS	SS	SV	GS	GV	MS	GS	SS	MV	GS	MV	GV	SS

MV = Maku lotus / volunteer grass
MS = Maku lotus / sown grass
SV = Sharnae lotus / volunteer grass
SS = Sharnae lotus / sown grass
GV = Goldie lotus / volunteer grass
GS = Goldie lotus / sown grass

Appendix 2a. Plot layout showing grazing treatments at the Casino core experiment.

Rep 3	T4	T2	T3	T6	T5	T7	T1
Rep 2	T6	T2	T7	T3	T4	T1	T5
Rep 1	T2	T5	T3	T1	T6	T4	T7

T1: continuous grazing / low biomass
T2: continuous grazing / high biomass
T3: summer spell / low biomass
T4: summer spell / high biomass
T5: autumn spell / low biomass
T6: autumn spell / high biomass
T7: rotation grazing / high biomass

Appendix 2b: Plot layout showing cultivar treatments at the Casino core experiment.

	GS	SS	GV	MV	MS	MV	GV	SV	SV	MV	MV	GV	SV	MV
Rep 3	SV	GV	SV	MS	SS	GS	MS	GS	GV	MS	SS	SV	MS	GV
	MS	MV	GS	SS	SV	GV	SS	MV	SS	GS	GS	MS	SS	GS
	MS	SV	GS	SS	SV	MV	SS	GS	GV	GS	MV	SS	GS	MV
Rep 2	SS	GV	MS	MV	MS	SS	GV	SV	SV	SS	MS	SV	MS	SS
	GS	MV	SV	GV	GV	GS	MS	MV	MV	MS	GV	GS	GV	SV
	SS	MV	MS	MV	SS	GS	SV	MS	MV	SS	MS	GS	MS	SV
Rep 1	MS	GS	GS	SV	SV	MS	GV	MV	GS	MS	SS	GV	MV	GV
	SV	GV	SS	GV	MV	GV	GS	SS	GV	SV	MV	SV	SS	GS

MV = Maku lotus / volunteer grass
MS = Maku lotus / setaria
SV = Sharnae lotus / volunteer grass
SS = Sharnae lotus / setaria
GV = Goldie lotus / volunteer grass
GS = Goldie lotus / setaria

Appendix 3a. Plot layout showing grazing treatments at the Canberra core experiment.

Rep 3	T7	T1	T4	T3	T6	T2	T5
							Lane
Rep 2	T4	T6	T5	T2	T7	T3	T1
							Lane
Rep 1	T2	T7	T1	T5	T3	T4	T6

T1: Continuous grazing / low biomass
T2: Continuous grazing / high biomass
T3: Summer spell / low biomass
T4: Summer spell / high biomass
T5: Autumn spell / low biomass
T6: Autumn spell / high biomass
T7: Rotational grazing / high biomass

Appendix 3b. Plot Layout showing cultivar treatments at the Canberra core experiment.

	GN	PN	PP	SP	PP	PN	PN	GN	SP	SN	MN	GN	MN	SP
Rep 3	SP	GP	GP	MP	SP	MN	PP	SN	MP	MN	SN	SP	GP	MP
	MP	GN	GN	SN	MP	GN	GP	SP	GP	GN	GP	PN	PN	PP
	PP	PM	PM	MN	GP	SN	MP	MN	PN	PP	MP	PP	SN	GN
	SP	SN	SN	MN	GN	MP	MP	PN	GP	PN	SP	GN	MN	GP
Rep 2	PP	GP	GP	PN	PN	MN	SN	PP	MN	GN	PP	GP	PN	SP
	GP	PP	PP	MP	GP	SP	GN	MN	PP	SP	MP	MN	SN	MP
	MP	GN	GN	SP	SN	PP	SP	GP	MP	SN	SN	PN	GN	PP
	SP	GP	GP	MN	PP	SN	MP	GN	PN	SP	GP	MP	MN	MP
Rep 1	MP	MP	MP	PN	GP	MP	GP	SP	SN	GP	PN	GN	SP	PN
	PP	SP	SP	SN	MN	PN	SN	PP	PP	MP	SP	SN	GP	GN
	PN	PP	PP	GN	GN	SP	MN	PN	MN	GN	MN	PP	PP	SN

MN = Maku / danthonia
MP = Maku / phalaris
SN = Sharnae / danthonia
SP = Sharnae / phalaris
GN = Goldie / danthonia
GP = Goldie / phalaris
PN = “Spanish” / danthonia
PP = “Spanish” / phalaris

Appendix 4a. Plot layout showing grazing treatments at the Nowra core experiment.

Rep 3	T3	T7	T6	T2	T4	T5	T1
	Lane						
Rep 2	T4	T1	T2	T7	T6	T3	T5
	Lane						
Rep 1	T5	T3	T6	T1	T7	T2	T4

T1: Continuous grazing/low biomass
T2: Continuous grazing/high biomass
T3: Summer spell/low biomass
T4: Summer spell/high biomass
T5: Autumn spell/low biomass
T6: Autumn spell/high biomass
T7: Rotational grazing/high biomass

Appendix 4b. Plot layout showing cultivar treatments at the Nowra core experiment.

	GR	MR	GR	GK	MR	SR	SR	GK	SK	MK	SR	MR	GK	GR
Rep 3	SE	MK	MK	MR	SK	MK	SK	GR	MR	GR	GK	SK	MK	MR
	GK	SK	SK	MK	GK	GR	MK	MR	SR	GK	GR	MK	SR	SK
	SK	MK	GK	GK	GK	GR	GR	MK	MR	GR	MK	GK	SR	GR
Rep 2	SR	GK	SK	GR	MR	MK	GK	MR	MK	GK	SK	GR	SK	MK
	MR	GR	SR	SK	SK	SR	SK	SR	SR	SK	MR	SR	MR	GK
	MR	SR	MR	GK	GK	MK	SR	GR	MK	GK	MR	SK	MR	GK
Rep 1	GR	GK	SK	GR	GR	SR	MK	GK	SK	GR	GR	MK	SR	GR
	MK	SK	MK	SR	SK	MR	SK	MR	MR	SR	SR	GK	SK	MK

MK= Maku / kikuyu
MR = Maku / ryegrass
SK = Sharnae / kikuyu
SR = Sharnae / ryegrass
GK = Goldie / kikuyu
GR = Goldie / ryegrass

Appendix 5. Diary of events - Glen Innes core experiment.

Date	Site Preparation	Project Developments	Fertiliser	Measurements
Sept 1994	Pegged out plots. Sprayed Roundup (15/9/94 & 29/9/94)		Soil samples (19/9/94)	
Oct	Planted (5/10/94) Fencing (31/10/94)		125 kg/ha Starter 15 (5/10/94)	
Nov		No germination		
Dec		Meeting in Sydney to discuss project (7/12/94)		
Mar 1995	Resprayed plots Roundup/24D (10/3/95) Replanted (31/3/95)		125 kg/ha Starter 15 (31/3/95)	
May		Germination early May, seedlings observed end of May		
June				Ratings on plot establishment (19/6/95)
Aug				110 day establishment counts (16/8/95)
Sept		Site grazed with sheep (28/9/95)		
Oct	Site reseeded 9/10/95		250 kg/ha Single Super (24/10/95)	
Nov	Site mown to remove ryegrass (8/11/95)	Meeting at ARAS (15/11/95)		
Dec	Irrigation through December.	Inspected site (28/12/95) - some new seedlings from resowing.		
Jan 1996	Mowed to remove weed seedheads (16/1/96)			
Feb	Sprayed 1.5 L/ha 24DB for weeds			Plant count to assess lotus (8/2/96)
Mar	Reseeded (12/3/96)		250 kg/ha Single Super (20/3/96)	
April	Reseeded (15/4/96) Irrigation from 18/4/96			
June		Good population of lotus from inspection (4/6/96)		
July 1996	Fencing (10/7/96)			
Aug			Fertilised 250 kg/ha super (27/8/96)	
Oct	Internal fencing completed (7/10/96) Buffers mown (11/10/96) Buffers sprayed Roundup/ dicamba (14/10/96)			
Dec		UNE visitors (19/12/96)		Too dry for nodulation cores ∴ postponed
Jan 1997				
Feb				Nodulation cores
March				*Grazing 1(13/3/97)*
April		Field day 16/4/97		Botanal 1 (4/4/97) Grazing 2 (8/4/97) Grazing 3 (24/4/97)
May				Grazing 4 (15/5/97)
June				Grazing 5 (5/6/97) Botanal 2 (24/6/97)
July				Grazing 7 (17/7/97) - close treatments only
Aug.			Soil Samples taken	Rhizome & seedbank cores Botanal 3 & forage sample (27/8/97) Grazing 9 (28/8/97) - close treatments only
Sep		Field Day - Paul Beuselinck visit (15/9/97)	250 kg/ha Super	Grazing 10 (18/9/97)

Glen Innes diary continued …

Date	Site Preparation	Project Developments	Fertiliser	Measurements
Oct				Grazing 11 (9/19/97) Grazing 12 (30/10/97)
Nov				Botanal 4 & forage sample (18/11/97) Grazing 13 (20/11/97)
Dec 1997				Grazing 14 (11/12/97)
Jan 1998				Grazing 15 (8/1/98) Grazing 16 (29/1/98)
Feb.				Grazing 17 (19/2/98)
April				Botanal 5 (7/4/98)
May		Pathology samples (20/5/98)		Grazing 21 (14/5/98) - close treatments only
June				Grazing 22 (4/6/98) - close treatments only
July 1998				Botanal 6 (3/7/98) Grazing 24 (16/7/98) Close treatments only
Aug.			Soil samples (14/8/98)	Grazing 25 (6/8/98) not done due to insufficient growth Rhizome & seedbank cores (14/8/98) Grazing 26 (27/8/98) not done due to insufficient growth
Sep				Botanal 7 and forage sample (18/9/98) Grazing 27 (16/9/98)
Oct				Grazing 28 (8/10/98) Grazing 29 (29/10/98)
Nov			Field Day (25/11/98)	Grazing 30 (19/11/98)
Dec 1997				Botanal 8 and forage samples (7/12/98) Grazing 31 (10/12/98)
Jan 1999		Filming for media release (7/1/99)	200 kg/ha super 5/1/99	Grazing 32 (7/1/99) Grazing 33 (21/2/99)
Feb.				Grazing 34 (11/2/99)
March				Grazing 35 (4/3/99) Mowing (11/3/99) Grazing 36 (25/3/99) close treatments only
April				Botanal 9 (20/4/99) Grazing 37 (21/4/99)
May				Grazing 38 (6/5/99)
June			Soil samples (1/7/99)	Grazing 39 (3/6/99) not taken due to insufficient growth Botanal 10 (22/6/99) Grazing 40 (17/6/99) not done due to insufficient growth Rhizome & seedbank cores (1/7/99)

Appendix 6. Diary of events - Casino core experiment.

Date	Site Preparation	Project Development	Fertiliser	Measurements
Feb 1995	Site cultivated (4/2/95) Spray with Roundup ® 6L/ha			
March			Soil samples (17/3/95) Super @ 225kg/ha	
April	Pegged out plots (5/6/95)			
May	Rep 1 sown (22/5/95) Rep 2 sown (25/5/95) Rep 3 sown (26/5/95)			
Aug	21/8/95 Sprayed plots with Buticide			
Sep	6/9/95 Fenced perimeter of site			
Dec				6/12/95 Root nodulation count 9/12/95 Botanical composition
April 1996	28/4/96 Sprayed with Roundup ® 6L/ha 29/4/96 Planted Rep 1			
May	27/5/96 Sprayed with Roundup ® 6L/ha 6/6/96 Re-planted Rep 1			
Aug				Establishment counts (21/8/96)
Oct	Set up met station			
Dec		Site grazed (31/12/96)		
Jan 1997	Site mown (8/1/97) Plots resown(9/1/97)			
Feb		Field day (13/2/97)		
Mar		Virus like symptoms of lotus identified (20/3/97)		
Apr		Plots grazed (1/4/97)		Lotus presence (23/4/97)
Jun	Plots fenced			
Aug	Mowed off after graze 12/8		Super @ 225 kg/ha	Grazing 1 6/8/97
Sep				Botanal 1 (2/9/97) Grazing 2 3/9 Grazing 3 18/9
Oct				Grazing 4 14/10 Nodulation Cores Grazing 5 30/10
Nov				Grazing 6 24/11 Botanal 2 (18/11)
Dec 1997				Grazing 7 18/12
Jan 1998				Grazing 8 3/1 Grazing 9 29/1
Feb		Lotus plants for disease analysis 19/2		Botanal 3 (17/2) Grazing 10 20/2
Mar		Soil samples for Lotus disease analysis 11/3		Grazing 11 13/3
Apr				Grazing 12 2/4 Grazing 13 24/4
May				Botanal 4 22/5 grazing 14 22/5
Jun	Mowing off setaria 22/6			Grazing 15 11/6
July				Grazing 17 no grazing
Aug				Rhizome & seedbank (11/8/98) Botanal & yield/green (12/8/98) Grazing 18 (12/8/98)
Sep				Grazing 18 (4/9/98) Grazing 20 (17/9/98)

Casino diary continued ….

Date	Site Preparation	Project Development	Fertiliser	Measurements
Oct				Grazing 21 (15/10/98) Botanal & yield/green (29/10/98)
Nov				Grazing 22 (6/11/98) Grazing 23 (24/11/98)
Dec			Super @ 22k kg/ ha Potash @ 50 kg/ha	Grazing 24 (16/12/98)
Jan 1999				Grazing 25 (5/1/99) Grazing 26 (26/1/99)
Feb				Grazing 27 (17/2/99)
Mar	Mowing setaria (25/3 & 26/43/99)			Grazing 28 (15/3/99)
Apr				Botanal & yield/green (22/4/99) Grazing 29 (23/4/99)
May				Grazing 30 (10/5/99)
Jun 1999	Annual soil samples (17/8/99)			Grazing 31 (1/6/99) Rhizome & seedbank (5/8/99) Botanal & yield/green (5/8/99)

Appendix 7. Diary of events - Canberra core experiment.

Date	Site Preparation	Project Developments	Fertiliser	Measurements
Jan 1995	Linseed crop			
Feb	Scarified to level area			
March	Trial sown 23 & 24/3/95 Irrigation- due to dry Autumn		125 kg/ha Starter 15	
April	Sprayed wild oats with spray seed on 1/4/95 Irrigation-due to dry Autumn			
May	Weed control for broadleaf & Broxynil 31/5/95, Irrigation.			First count 31/5/95 & 1/6/95
June	Wick wiped 9/6/95-Sprayed	Winter rains-irrigation stopped. Roundup-worked on wild oats not on Vulpia.		
July 1995				Second count 27/7/95
Aug.		Grazing in late August. Selective grazing of lotus evident.		
Sep	Fence Posts put in (13/9/95) Spray 3 1/ha 2,4,DB + 50 ml/ha Lemat (28/9/95)			
Oct		Rain fell delaying oversowing till (11/10/95.)		
Nov	Wick wiping late Nov, annual medic thinned by hand.			Third count - (29/11/95) "Forage harvested" (18/11/95)-good growing conditions.
Dec		Late Dec irrigation needed approx 35mm.		"Forage harvest" (5/12/95
Jan 1996			Soil samples taken 31/1/96	
Feb	Site visit 22/2/96 - ready for graze	Irrigated early Feb. with 35 mm.		Nodule counts.
Mar	Gates & Fencing installed and finished (4/3/96). TRAMAT sprayed (11/3/96).	Grazing begins (12/3/96)		Botanal 1 (12/3/96)
May		Grazing only Autumn spell plots (14/5/96), other plots not grazed due to dry spell.		
June				Botanal 2 (18 - 21 June)
July		G.T.s were mown 18/7/96		
Aug.		No Grazing 6/8/96 or 27/8/96		Feed quality cuts for forage sampling 8/8/96
Sep				Botanal 3 (12/9/96)
Nov		Levelled plots with mower 27/11/96		Feed quality cuts for forage sampling 18/11/96
Dec		Grazing of 10/12/96 start of summer spell. Field day 12/12/96.		Botanal 4 10/12/96
Jan 1997		21/1/97 - end of summer spell		
Mar		25/3/97 - start of autumn spell		Botanal 5 4/3/97
Apr		15/4/97 - 27/5/97: Grazing suspended due to dry		
May		6/5/97: Autumn spell due to end (not imposed on other plots)		
Jun		17/6/97: Grazing and mowing		
July 1997		29/7/97: Grazing/mowing		Botanal 6 8/7/97
Aug		19/8/97 - too low to graze		Soil sampling
Sep		9/9/97 - Grazing/mowing 18/9/97: Beuselinck visit		

Canberra diary continued ….

Date	Site Preparation	Project Developments	Fertiliser	Measurements
Oct		21/10/97: Grazed/mown		
Nov				Botanal 7 11/11/97
Dec		23/12/97 - summer spell starts		IVD: 2/12/97 Botanal 8 18/12/97
Feb 1998		2/2/98 - Summer spell extended 29/2 - Grazed/mown		
Mar		17/3/98 - not grazed, start of autumn spell		Botanal 9 17/3/97
Apr		7/4/97 - not grazed 28/4/98 - autumn spell extended		
May		19/5/98 - autumn spell ends		
Jun		9/6/98 - low biomass only grazed		
July		21/7/98 - not grazed due to insufficient growth		Botanal 10 Forage samples Rhizome and seed bank samples 22/7/98
Aug		11/8/98 grazed		
Sep		1/9/98 grazed 22/9/98 grazed/mown		
Oct		13/10/98 grazed		Botanal 11 Forage sample 14/10/98
Nov		3/11/98 grazed 26/11/98 grazed/mown		
Dec		15/12/98 grazed		
Jan 1999		5/1/99 grazed 26/1/99 grazed		Botanal 12 6/1/99
Feb		16/2/99 not grazed due to insufficient growth		
Mar		9/3/99 grazed 30/3/99 grazed		Botanal 13 23/3/99
Apr		20/4/99 grazed		
Jun		1/6/99 grazed		Botanal 14 Rhizome and seed bank samples 30/6/99

Appendix 8. Diary of events - Nowra core experiment.

Date	Site Preparation	Project Developments	Fertiliser	Measurements
Jan 1995	Sprayed Roundup. No sowing due to dry weather	.		
Feb.	Rotary-hoed 22-2-95	Soil tests taken 22/2/95		
April	Trial sown- raked & rolled 5/4/95			
May	Sprayed with Tribunal to control spurry- good result.	Rain mid May, start of most plants growth.		
Aug				Plant counts 2/8/95
Sep	Sprayed 28/9/95 Oversown with lotus 29/9/95			
Nov	Area cut in mid Nov. “Top up” sowing on 28/11/95			
Dec	Mid Dec hand watering to mid Jan.			
Jan 1996				Area inspected in mid Jan - lotus assessed
Feb	Area cut for forage (12/2/96)			Cores for nodule counts (15/2/96) Area inspected in mid Feb - lotus assessed
Mar		Grazing begins (26/3/96)		Botanal 1 prior to grazing (24/3/96) Establishment counts (21-22/3/96)
May		No grazing due to dry spell (8/5/96)		
Jun				Forage sample (30/6/96)
July		Grazing, little growth had occurred (30/7/96). Sample for IVD		Botanals 2 (15/7/96)
Aug	Whole trial sprayed with TRAMAT (13/8/96)	Plots mown (1/8/96) No grazing lotus too short (21/8/96)		
Sep				Botanal 3 (30/9/96)
Nov				Forage sampling (12/11/96)
Dec				Botanal 4 (17/12/96) T1, T5 grazed
Mar 1997				Botanal 5 (17/3/97)
May		Plots mown for uniform height after grazing (22/5/97)		
Jun		Plots mown for uniform height after grazing		Rhizome and seedbank coring (19/6/97) Botanal 6 (11/6/97)
July 1997		Plots mown		Forage sampling (23/797)
Aug		Pots mown (cattle not available)		Soil test
Sep		Beuselinck visit (19/9/97)		
Oct				Botanal 7 (15/10/97
Nov		Plots mown		Forage sampling (28/11/97)
Jan 1998		Grazed low plots only		Botanal 8 (7/1/98)
Feb		Summer spell extended		
Apr		Low plots mown		Botanal 9 (1/4/98)
May		Summer spell extended		

Nowra diary continued …

Date	Site Preparation	Project Developments	Fertiliser	Measurements
Jun				Botanal 10 (24/6/98)
July 1998		Plots mown 15/7/98		
Aug		Plots mown 10/8/98 Plots mown 28/8/98		
Sep		Plots mown 18/9/98		Botanal 11 8/9/98
Oct		Plots grazed/mown 7/10/98 Ungrazed due to insufficient growth 28/10/98		
Nov		Plots mown 20/11/98		
Dec		Plots mown 9/12/98 Plots mown 22/12/98		Botanal 21 21/12/98
Jan 1999		Plots mown 20/1/99		
Feb		Plots mown 12/2/99		
Mar		Plots mown 4/3/99 Grazed by horse 29/3/99		Botanal 13 22/3/99
Apr		Grazed my horse/mown 19/4/99		
May		Plots mown 5/5/99 Plots mown 26/5/99		
Jun		Plots mown 18/6/99		Botanal 14 29/6/99 Rhizome & seedbank samples 29/6/99

Appendix 9. Grazing schedule for the core experiment at Glen Innes.

	Continuous	Summer Rest	Autumn Rest	Rotational
13/03/97	graze	graze	graze	graze
3/04/97	graze	graze	spell	spell
24/04/97	graze	graze	spell	graze
15/05/97	graze	graze	spell	spell
5/06/97	graze	graze	graze	graze
26/06/97	graze	graze	graze	spell
17/07/97	graze	graze	graze	spell
7/08/97	graze	graze	graze	graze
28/08/97	graze	graze	graze	spell
18/09/97	graze	graze	graze	graze
9/10/97	graze	graze	graze	spell
30/10/97	graze	graze	graze	graze
20/11/97	graze	graze	graze	spell
11/12/97	graze	graze	graze	graze
7/01/98	graze	spell	graze	spell
29/01/98	graze	spell	graze	graze
19/02/98	graze	spell	graze	spell
12/03/98	graze	graze	graze	graze
2/04/98	graze	graze	spell	spell
23/04/98	graze	graze	spell	graze
14/05/98	graze	graze	spell	spell
4/06/98	graze	graze	graze	graze
25/06/98	graze	graze	graze	spell
16/07/98	graze	graze	graze	graze
6/08/98	graze	graze	graze	spell
27/08/98	graze	graze	graze	graze
17/09/98	graze	graze	graze	spell
8/10/98	graze	graze	graze	graze
29/10/98	graze	graze	graze	spell
19/11/98	graze	graze	graze	graze
10/12/98	graze	graze	graze	spell
31/12/98	graze	spell	graze	graze
21/1/99	graze	spell	graze	spell
11/2/99	graze	spell	graze	graze
4/3/99	graze	graze	graze	spell
25/3/99	graze	graze	graze	graze
15/4/99	graze	graze	spell	spell
6/5/99	graze	graze	spell	graze
27/5/99	graze	graze	spell	spell
17/6/99	graze	graze	graze	graze

Appendix 10. Grazing schedule for the core experiment at Casino.

	Continuous	Summer Rest	Autumn Rest	Rotational
7/08/97	graze	graze	graze	graze
28/08/97	graze	graze	graze	spell
18/09/97	graze	graze	graze	graze
9/10/97	graze	graze	graze	spell
30/10/97	graze	graze	graze	graze
20/11/97	graze	spell	graze	spell
11/12/97	graze	spell	graze	graze
7/01/98	graze	spell	graze	spell
29/01/98	graze	graze	graze	graze
19/02/98	graze	graze	graze	spell
12/03/98	graze	graze	graze	graze
2/04/98	graze	graze	graze	spell
23/04/98	graze	graze	graze	graze
14/05/98	graze	graze	spell	spell
4/06/98	graze	graze	spell	graze
25/06/98	graze	graze	spell	spell
16/07/98	graze	graze	graze	graze
6/08/98	graze	graze	graze	spell
27/08/98	graze	graze	graze	graze
17/09/98	graze	graze	graze	spell
8/10/98	graze	graze	graze	graze
29/10/98	graze	graze	graze	spell
19/11/98	graze	spell	graze	graze
10/12/98	graze	spell	graze	spell
31/12/98	graze	spell	graze	graze
21/1/99	graze	graze	graze	spell
11/2/99	graze	graze	graze	graze
4/3/99	graze	graze	graze	spell
25/3/99	graze	graze	graze	graze
15/4/99	graze	graze	graze	spell
16/5/99	graze	graze	spell	graze
27/5/99	graze	graze	spell	spell
17/6/99	graze	graze	spell	graze
8/7/99	graze	graze	graze	spell
29/7/99	graze	graze	graze	graze

Appendix 11. Grazing schedule for the core experiment at Canberra.

	Continuous	Summer Rest	Autumn Rest	Rotational
12/3/96	graze	graze	graze	graze
2/4/96	graze	graze	spell	spell
23/4/96	graze	graze	spell	graze
14/5/96	graze	graze	graze	spell
4/6/96	graze	graze	graze	graze
25/6/96	graze	graze	graze	spell
16/7/96	graze	graze	graze	graze
6/8/96	graze	graze	graze	spell
27/8/96	graze	graze	graze	graze
17/9/96	graze	graze	graze	spell
8/10/96	graze	graze	graze	graze
29/10/96	graze	graze	graze	spell
19/11/96	graze	graze	graze	graze
10/12/96	graze	spell	graze	spell
31/12/96	graze	spell	graze	graze
21/1/97	graze	graze	graze	spell
11/2/97	graze	graze	graze	graze
4/3/97	graze	graze	graze	spell
25/3/97	graze	graze	spell	graze
15/4/97	graze	graze	spell	spell
6/5/97	graze	graze	graze	graze
27/5/97	graze	graze	graze	spell
17/6/97	graze	graze	graze	graze
8/7/97	graze	graze	graze	spell
29/7/97	graze	graze	graze	graze
19/8/97	graze	graze	graze	spell
9/9/97	graze	graze	graze	graze
30/9/97	graze	graze	graze	spell
21/10/97	graze	graze	graze	graze
11/11/97	graze	graze	graze	spell
2/12/97	graze	graze	graze	graze
23/12/97	graze	spell	graze	spell
13/1/98	graze	spell	graze	graze
3/2/98	graze	spell	graze	spell
24/2/98	graze	graze	graze	graze
17/3/98	graze	graze	spell	spell
7/4/98	graze	graze	spell	graze
28/4/98	graze	graze	spell	spell
19/5/98	graze	graze	graze	graze
9/6/98	graze	graze	graze	spell
30/6/98	graze	graze	graze	graze
21/7/98	graze	graze	graze	spell
11/8/98	graze	graze	graze	graze
1/9/98	graze	graze	graze	spell
22/9/98	graze	graze	graze	graze
13/10/98	graze	graze	graze	spell
3/11/98	graze	graze	graze	graze
24/11/98	graze	graze	graze	spell
15/12/98	graze	graze	graze	graze
5/1/99	graze	spell	graze	spell
26/1/99	graze	spell	graze	graze
16/2/99	graze	spell	graze	spell
9/3/99	graze	graze	graze	graze
30/3/99	graze	graze	spell	spell
20/4/99	graze	graze	spell	graze
11/5/99	graze	graze	spell	spell
1/6/99	graze	graze	graze	graze

Caberra grazing schedule continued …

	Continuous	Summer Rest	Autumn Rest	Rotational
27/3/96	graze	graze	graze	graze
17/4/96	graze	graze	spell	spell
8/5/96	graze	graze	spell	graze
29/5/96	graze	graze	graze	spell
19/6/96	graze	graze	graze	graze
10/7/96	graze	graze	graze	spell
31/7/96	graze	graze	graze	graze
21/8/96	graze	graze	graze	spell
11/9/96	graze	graze	graze	graze
2/10/96	graze	graze	graze	spell
23/10/96	graze	graze	graze	graze
13/11/96	graze	graze	graze	spell
4/12/96	graze	graze	graze	graze
25/12/96	graze	spell	graze	spell
15/1/97	graze	spell	graze	graze
5/2/97	graze	graze	graze	spell
26/2/97	graze	graze	graze	graze
19/3/97	graze	graze	graze	spell
9/4/97	graze	graze	spell	graze
30/4/97	graze	graze	spell	spell
21/5/97	graze	graze	graze	graze
11/6/97	graze	graze	graze	spell
2/7/97	graze	graze	graze	graze
23/7/97	graze	graze	graze	spell
13/8/97	graze	graze	graze	graze
3/9/97	graze	graze	graze	spell
24/9/97	graze	graze	graze	graze
15/10/97	graze	graze	graze	spell
5/11/97	graze	graze	graze	graze
26/11/97	graze	graze	graze	spell
17/12/97	graze	graze	graze	graze
7/1/98	graze	spell	graze	spell
28/1/98	graze	spell	graze	graze
18/2/98	graze	spell	graze	spell
11/3/98	graze	graze	graze	graze
1/4/98	graze	graze	spell	spell
22/4/98	graze	graze	spell	graze
13/5/98	graze	graze	spell	spell
3/6/98	graze	graze	graze	graze
24/6/98	graze	graze	graze	spell
15/7/98	graze	graze	graze	graze
5/8/98	graze	graze	graze	spell
26/8/98	graze	graze	graze	graze
16/9/98	graze	graze	graze	spell
7/10/98	graze	graze	graze	graze
28/10/98	graze	graze	graze	spell
18/11/98	graze	graze	graze	graze
9/12/98	graze	graze	graze	spell
30/12/98	graze	spell	graze	Graze
20/1/99	graze	spell	graze	Spell
10/2/99	graze	spell	graze	graze
3/3/99	graze	graze	graze	graze
24/3/99	graze	graze	spell	graze
14/4/99	graze	graze	spell	spell
5/5/99	graze	graze	spell	graze
26/5/99	graze	graze	graze	spell
16/6/97	graze	graze	graze	graze

Appendix 12. Grazing schedule for the core experiment at Nowra.

	Continuous	Summer Rest	Autumn Rest	42 day R
27/3/96	graze	graze	graze	graze
17/4/96	graze	graze	spell	spell
8/5/96	graze	graze	spell	graze
29/5/96	graze	graze	graze	spell
19/6/96	graze	graze	graze	graze
10/7/96	graze	graze	graze	spell
31/7/96	graze	graze	graze	graze
21/8/96	graze	graze	graze	spell
11/9/96	graze	graze	graze	graze
2/10/96	graze	graze	graze	spell
23/10/96	graze	graze	graze	graze
13/11/96	graze	graze	graze	spell
4/12/96	graze	graze	graze	graze
25/12/96	graze	spell	graze	spell
15/1/97	graze	spell	graze	graze
5/2/97	graze	graze	graze	spell
26/2/97	graze	graze	graze	graze
19/3/97	graze	graze	graze	spell
9/4/97	graze	graze	spell	graze
30/4/97	graze	graze	spell	spell
21/5/97	graze	graze	graze	graze
11/6/97	graze	graze	graze	spell
2/7/97	graze	graze	graze	graze
23/7/97	graze	graze	graze	spell
13/8/97	graze	graze	graze	graze
3/9/97	graze	graze	graze	spell
24/9/97	graze	graze	graze	graze
15/10/97	graze	graze	graze	spell
5/11/97	graze	graze	graze	graze
26/11/97	graze	graze	graze	spell
17/12/97	graze	graze	graze	graze
7/1/98	graze	spell	graze	spell
28/1/98	graze	spell	graze	graze
18/2/98	graze	spell	graze	spell
11/3/98	graze	graze	graze	graze
1/4/98	graze	graze	spell	spell
22/4/98	graze	graze	spell	graze
13/5/98	graze	graze	spell	spell
3/6/98	graze	graze	graze	graze
24/6/98	graze	graze	graze	spell
15/7/98	graze	graze	graze	graze
5/8/98	graze	graze	graze	spell
26/8/98	graze	graze	graze	graze
16/9/98	graze	graze	graze	spell
7/10/98	graze	graze	graze	graze
28/10/98	graze	graze	graze	spell
18/11/98	graze	graze	graze	graze
9/12/98	graze	graze	graze	spell
30/12/98	graze	spell	graze	graze

Nowra grazing schedule continued …

	Continuous	Summer Rest	Autumn Rest	42 day R
20/1/99	graze	spell	graze	spell
10/2/99	graze	spell	graze	graze
3/3/99	graze	graze	graze	spell
24/3/99	graze	graze	spell	graze
14/4/99	graze	graze	spell	spell
5/5/99	graze	graze	spell	graze
26/5/99	graze	graze	graze	spell
16/6/99	graze	graze	graze	graze

Appendix 13. Measurement schedule for the core experiment at Glen Innes.

Month	Site maintenance	Measurements
January 1997		
February		
March	Grazing 1 - 13/3/97	
April	Grazing 2 - 7/4/97 Grazing 3 - 24/4/97	Pre-treatment Botanal 1 - 3/4/97
May	Grazing 4 - 15/5/97	
June	Grazing 5 - 5/6/97, Grazing 6 - 26/6/97	Autumn Botanal 2 - 24/6/97
July	Grazing 7 - 17/7/97	Rhizome and seedbank cores (Year 1)
August	Soil sample trial site in first week of August Grazing 8 - 7/8/97 Grazing 9 - 28/8/97	Winter Botanal 3 & forage samples - 26/8/97
September	Fertilise trial site first week of September Grazing 10 - 18/9/97	
October	Grazing 11 - 9/10/97, Grazing 12 - 30/10/97	
November	Grazing 13 - 20/11/97	Spring Botanal 4 & forage samples - 18/11/97
December	Grazing 14 - 11/12/97	
January 1998	Grazing 15 - 7/1/98 Grazing 16 - 29/1/98	
February	Grazing 17 - 19/2/98	
March	Grazing 18 - 12/3/98	
April	Grazing 19 - 2/4/98 Grazing 20 - 23/4/98	Summer Botanal 5 - 7/4/98
May	Grazing 21 - 14/5/98	
June	Grazing 22 - 4/6/98 Grazing 23 - 25/6/98	Autumn Botanal 6 - 23/6/98 Rhizome and seed bank cores (Year 2)
July	Grazing 24 - 16/7/98	
August	Soil sample trial site in first week of August Grazing 25 - 6/8/98 Grazing 26 - 27/8/98	Biomass - 6/8/98
September	Fertilise trial site first week of September Grazing 27 - 17/9/98	Winter Botanal 7 & forage samples - 15/9/98
October	Grazing 28 - 8/10/98 Grazing 29 - 29/10/98	Biomass - 29/10/98
November	Grazing 30 - 19/11/98	
December	Grazing 31 - 10/12/98 Grazing 32 - 31/12/98	Spring Botanal 8 & forage samples - 8/12/98
January 1999	Grazing 33 - 2/1/99	
February	Grazing 34 - 11/2/99	
March	Grazing 35 - 4/3/99 Grazing 36 - 25/3/99	
April	Grazing 37 - 15/4/99	Summer Botanal 9 - 14/4/99
May	Grazing 38 - 6/5/99 Grazing 39 - 27/5/99	
June	Grazing 40 - 17/6/99	Autumn Botanal 10 - 30/6/99 Rhizome and seed bank cores (Year 3)

Appendix 14. Measurement schedule for the core experiment at Casino.

Month	Site maintenance	Measurements
August	Soil sample 1st week in August Grazing 1- 7/8/97, Grazing 2- 28/8/97	Pre-treatment Botanal 1, forage samples - 2/8/97 Rhizome and seed bank cores (Year 1)
September	Fertilise 1st week in September Grazing 3 - 18/9/97	
October	Grazing 4 - 9/10/97 Grazing 5 - 30/10/97	
November	Grazing 6 - 20/11/97	Spring Botanal 2 and forage samples- 18/11/97
December	Grazing 7 - 11/12/97	
January 1998	Grazing 8 - 7/1/98 Grazing 9 - 29/1/98	
February	Grazing 10 - 19/2/98	Summer Botanal 3 - 17/2/98
March	Grazing 11- 12/3/98	
April	Grazing 12 - 2/4/98 Grazing 13 - 23/4/98	
May	Grazing 14 - 14/5/98	Autumn Botanal 4 - 12/5/98
June	Grazing 15 - 4/6/98 Grazing 16 - 25/6/98	
July	Grazing 17 - 16/7/98	
August	Soil sample 1st week in August Grazing 18 - 6/8/98, Grazing 19- 27/8/98	Winter Botanal 5 and forage sampling - 4/8/98 Rhizome and seed bank cores (Year 2)
September	Fertilise 1st week in September Grazing 20 - 17/9/98	
October	Grazing 21 - 8/10/98 Grazing 22 - 29/10/98	Spring Botanal 6 and forage sampling - 27/10/98
November	Grazing 23 - 19/11/98	
December	Grazing 24 - 10/12/98 Grazing 25 - 31/12/98	
January 1999	Grazing 26 - 21/1/99	
February	Grazing 27 - 11/2/99	
March	Grazing 28 - 4/3/99	Summer Botanal 7 - 2/3/99
April	Grazing 29 - 15/4/99	Autumn Botanal 8 - 14/4/99
May	Grazing 30 - 16/5/99 Grazing 31 - 27/5/99	
June	Grazing 32 - 17/6/99	
July	Grazing 33 - 8/7/99 Grazing 34 - 29/7/99	
August	Soil sample 1st week in August	Winter Botanal 9 and forage sampling - 16/8/99 Rhizome and seedbank cores (Year 3)

Appendix 15. Measurement schedule for the core experiment at Canberra.

Month	Site maintenance	Measurements
March	Grazing 1 - 12/3/96	Pre treatment Botanal 1 - 12/3/96
April	Grazing 2 - 2/4/96 Grazing 3 - 23/4/96	
May	Grazing 4 - 14/5/96	
June	Grazing 5 - 4/6/96 Grazing 6 - 25/6/96	Botanal 2 - 18/6/96 - 25/6/96
July	Grazing 7 - 16/7/96	
August	Grazing 8 - 6/8/96 Grazing 9 - 27/8/96	Forage sampling - 6/8/96
September	Grazing 10 - 17/9/96	Botanal 3 - 17/9/96
October	Grazing 11 - 8/10/96 Grazing 12 - 29/10/96	
November	Grazing 13 - 19/11/96	Forage sampling - 18/11/96
December	Grazing 14 - 10/12/96 Grazing 15 - 21/12/96	Botanal 4 - 10/12/96
January 1997	Grazing 16 - 21/1/97	
February	Grazing 17 - 11/2/97	
March	Grazing 18 - 4/3/97 Grazing 19 - 25/3/97	Botanal 5 - 4/3/97
April	Grazing 20 - 15/4/97	
May	Grazing 21 - 6/5/97 Grazing 22 - 27/5/97	
June	Grazing 23 - 17/6/97	
July	Grazing 24 - 8/7/97 Grazing 25 - 29/7/97 Soil sample	Botanal 6 - 8/7/97 Rhizome and seedbank coring (Year 1) Forage sampling - 8/7/97
August	Grazing 26 - 19/8/97 Fertilise trial site	
September	Grazing 27 - 9/9/97 Grazing 28 - 30/9/97	Botanal 7 - 11/11/97
October	Grazing 29 - 21/10/97	
November	Grazing 30 - 11/11/97	
December 1997	Grazing 31 - 2/12/97 Grazing 32 - 23/12/97	Botanal 8 - 18/12/97 Forage sampling - 2/12/97
January 1998	Grazing 33 - 13/1/98	
February	Grazing 34 - 3/2/98 Grazing 35 - 24/2/98	
March	Grazing 36 - 17/3/98	Botanal 9 - 17/8/97
April	Grazing 37 - 7/4/98	
	Grazing 38 - 28/4/98	
May	Grazing 39 - 19/5/98	
June	Grazing 40 - 9/6/98	
	Grazing 41 - 30/6/98	
July	Grazing 42 - 21/7/98 Soil sample	Botanal 10, Forage sampling Rhizome and seed bank coring (Year 2)
August	Grazing 43 - 11/8/98 Fertilise trial site	
September	Grazing 44 - 1/9/98 Grazing 45 - 22/9/98	
October	Grazing 46 - 13/10 /98	Botanal 11 Forage sampling
November	Grazing 47 - 3/11/98 Grazing 48 - 24/11/98	
December	Grazing 49 - 15/12/98	
January 1999	Grazing 50 - 5/1/99 Grazing 51 - 26/1/99	Botanal 12
February	Grazing 52 - 16/2/99	
March	Grazing 53 - 9/3/99 Grazing 54 - 30/3/99	Botanal 13
April	Grazing 55 - 20/4/99	
May	Grazing 56 - 11/5/99	
June	Last Grazing 57 - 1/6/99	Botanal 14, Forage sampling Rhizome and seedbank coring (Year 3)

Appendix 16. Measurement schedule for the core experiment at Nowra.

Month	Site maintenance	Measurements
February 1996		Nodulation measurements
March	Grazing 1 - 27/3/96	Pre treatments Botanal 1 (27/3/96)
April	Grazing 2 - 17/4/96	
May	Grazing 3 - 8/5/96 Grazing 4 - 29/5/96	
June	Grazing 5 - 19/6/96	
July	Grazing 6 - 10/7/96 Grazing 7 - 31/7/96	Botanal 2 (10/7/96) Forage sampling (30/7/96)
August	Grazing 8 - 21/8/96	
September	Grazing 9 - 11/9/96	
October	Grazing 10 - 2/10/96 Grazing 11 - 23/10/96	Botanal 3 (2/10/96)
November	Grazing 12 - 13/11/96	Forage sampling (13/11/96)
December	Grazing 13 - 4/12/96 Grazing 14 - 25/12/96	Botanal 4 (19/12/96)
January 1997	Grazing 15 - 15/1/97	
February	Grazing 16 - 5/2/97 Grazing 17 - 26/2/97	
March	Grazing 18 - 19/3/97	Botanal 5 (19/3/97)
April	Grazing 19 - 9/4/97 Grazing 20 - 30/4/97	
May	Grazing 21 - 21/5/97	
June	Grazing 22 - 11/6/97	Botanal 6 (11/6/97) Rhizome and seedbank cores
July	Grazing 23 - 2/7/97 Grazing 24 - 23/7/97	Forage sampling (23/7/97)
August	Grazing 25 - 13/8/97 Soil sample	
September	Grazing 26 - 3/9/97 Fertilise trial site Grazing 27 - 24/9/97	
October	Grazing 28 - 15/10/97	Botanal 7 (15/10/97)
November	Grazing 29 - 5/11/97 Grazing 30 - 26/11/97	Forage sampling (28/11/97)
December	Grazing 31 - 17/12/97	
January 1998	Grazing 32 - 7/1/98	Botanal 8 (7/1/98)
February	Grazing 34 - 18/2/98	
March	Grazing 35 - 11/3/98	
April	Grazing 36 - 1/4/98 Grazing 37 - 22/4/98	Botanal 9 (1/4/98)
May	Grazing 38 - 13/5/98	
June	Grazing 39 - 3/6/98 Grazing 40 - 24/6/98	Botanal 10, Rhizome and seedbank cores Forage sampling
July	Grazing 41 - 15/7/98	
August	Grazing 42 - 5/8/98 Grazing 43 - 26/8/98 Soil sample	
September	Grazing 45 - 16/9/98 Fertiliser trial site	Botanal 11
October	Grazing 46 - 7/10/98 Grazing 47 - 28/10/98	Forage sampling
November	Grazing 48 - 18/11/98	
December	Grazing 49 - 9/12/98 Grazing 50 - 30/12/98	Botanal 12
January 1999	Grazing 51 - 20/1/99	
February	Grazing 52 - 10/2/99	
March	Grazing 53 - 3/3/99 Grazing 54 - 24/3/99	Botanal 13
April	Grazing 55 - 14/4/99	
May	Grazing 56 - 5/5/99 Grazing 57 - 26/5/99	
June	Last grazing 58 - 16/6/99	Rhizome and seedbank cores Forage sampling Botanal 14

Appendix 17. Botanal results for the core experiment at Glen Innes.

Table 63. The effect of grazing treatments on sward content of lotus at 2 levels of grass competition; Glen Innes core site – Botanal 1 (4/4/97).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	59.9	79.1	31.3	58.1	9.9	14.9
GRZ	High biomass	61.2	87.3	45.5	67.5	6.0	17.5
SUMM	Low biomass	53.0	77.2	45.1	70.3	13.1	13.3
REST	High biomass	56.1	74.6	32.3	54.6	14.6	11.4
AUT	Low biomass	51.9	79.6	27.8	64.6	13.7	20.1
REST	High biomass	47.6	83.3	61.5	66.3	25.0	28.9
ROT	High biomass	58.2	77.8	41.1	65.4	12.5	21.5
l.s.d (P = 0.5) within column		19.66					
l.s.d. (P = 0.5) across columns		16.73					

Table 64. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 2 (24/6/97).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	29.9	44.8	19.4	36.5	10.6	8.8
GRZ	High biomass	30.4	50.6	22.8	58.6	4.3	22.7
SUMM	Low biomass	22.8	50.6	29.8	52.8	7.7	6.3
REST	High biomass	21.8	41.2	28.2	43.4	10.6	20.0
AUT	Low biomass	26.4	34.4	21.2	43.4	14.4	11.1
REST	High biomass	22.2	46.8	36.3	57.3	17.8	19.5
ROT	High biomass	15.7	34.6	26.8	58.5	12.2	13.8
l.s.d (P = 0.5) within column		19.92					
l.s.d. (P = 0.5) across columns		17.87					

Table 65. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 3 (26/8/97).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	46.3	52.9	13.4	28.0	9.2	4.5
GRZ	High biomass	30.9	56.8	13.9	46.3	2.5	15.4
SUMM	Low biomass	44.2	59.0	16.8	463.7	6.1	2.0
REST	High biomass	27.0	51.7	8.5	17.9	4.0	5.1
AUT	Low biomass	42.2	48.4	19.2	34.6	8.5	11.0
REST	High biomass	24.5	45.5	22.1	40.4	6.5	7.0
ROT	High biomass	21.6	45.1	8.8	25.3	4.9	11.6
l.s.d (P = 0.5) within column		19.49					
l.s.d. (P = 0.5) across columns		16.53					

Table 66. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 4 (18/11/97).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	54.1	51.7	27.3	43.8	9.1	6.9
GRZ	High biomass	45.9	69.1	46.0	63.8	11.3	26.2
SUMM	Low biomass	52.1	60.6	37.7	47.9	5.7	1.3
REST	High biomass	61.4	67.4	48.9	48.0	10.5	12.0
AUT	Low biomass	58.1	62.1	26.7	42.9	17.3	16.0
REST	High biomass	43.6	54.9	53.3	63.3	33.7	29.1
ROT	High biomass	47.9	63.4	49.2	67.5	13.0	14.5
l.s.d (P = 0.5) within column		15.67					
l.s.d. (P = 0.5) across columns		13.71					

Table 67. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 5 (7/4/98).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	45.0	81.7	17.5	39.1	5.3	9.5
GRZ	High biomass	52.2	81.3	15.0	43.4	4.3	12.0
SUMM	Low biomass	45.2	86.1	11.5	30.1	4.5	2.6
REST	High biomass	60.0	87.8	18.8	49.5	3.0	9.5
AUT	Low biomass	49.8	81.5	12.4	28.7	4.1	18.3
REST	High biomass	58.3	81.8	39.6	47.8	9.7	24.2
ROT	High biomass	61.7	91.4	21.6	54.1	7.0	7.1
l.s.d (P = 0.5) within column		19.53					
l.s.d. (P = 0.5) across columns		19.40					

Table 68. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 6 (3/7/98).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	20.1	30.5	6.8	13.3	1.9	4.6
GRZ	High biomass	14.6	31.2	7.5	21.1	3.3	9.4
SUMM	Low biomass	29.6	45.9	6.4	27.3	4.2	2.4
REST	High biomass	21.1	40.8	7.1	17.9	5.1	7.2
AUT	Low biomass	29.5	27.3	11.9	23.2	3.2	8.8
REST	High biomass	12.1	15.7	19.9	19.4	7.7	11.9
ROT	High biomass	16.5	40.1	8.1	34.9	2.3	0
l.s.d (P = 0.5) within column		14.07					
l.s.d. (P = 0.5) across columns		14.22					

Table 69. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 7 (18/9/98).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	50.7	63.4	16.7	34.5	2.3	8.5
GRZ	High biomass	25.8	38.4	14.0	42.6	4.6	8.4
SUMM	Low biomass	42.9	59.8	24.2	48.4	2.6	3.8
REST	High biomass	24.0	33.6	19.8	42.6	5.7	8.5
AUT	Low biomass	49.1	66.3	21.9	38.8	5.5	9.8
REST	High biomass	25.4	31.5	28.0	40.9	4.8	13.5
ROT	High biomass	25.9	44.6	28.0	55.4	3.0	5.3
l.s.d (P = 0.5) within column		15.63					
l.s.d. (P = 0.5) across columns		15.08					

Table 70. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 8 (7/12/98).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	36.7	43.9	10.6	23.6	1.2	2.9
GRZ	High biomass	30.5	31.4	12.4	35.9	5.8	8.0
SUMM	Low biomass	28.8	46.2	13.2	33.2	1.0	2.5
REST	High biomass	25.0	28.5	15.3	28.2	4.3	3.6
AUT	Low biomass	46.5	40.6	15.5	14.2	2.7	6.2
REST	High biomass	25.4	20.9	27.7	33.7	7.0	7.0
ROT	High biomass	17.1	24.4	13.4	31.8	0.3	1.6
l.s.d (P = 0.5) within column		14.93					
l.s.d. (P = 0.5) across columns		14.45					

Table 71. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 9 (20/4/99).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	33.3	40.9	4.3	8.7	0.3	2.0
GRZ	High biomass	25.2	28.8	7.5	13.2	5.6	5.5
SUMM	Low biomass	31.4	40.4	10.2	20.5	2.2	0.3
REST	High biomass	33.5	33.1	11.7	19.7	7.7	3.6
AUT	Low biomass	35.9	23.6	9.4	9.4	1.0	2.2
REST	High biomass	20.1	28.3	21.5	15.9	2.5	3.9
ROT	High biomass	35.4	42.7	17.1	23.8	4.3	2.4
l.s.d (P = 0.5) within column		13.59					
l.s.d. (P = 0.5) across columns		11.58					

Table 72. The effects of grazing treatments on sward content of lotus at two levels of grass competition; Glen Innes core site - Botanal 10 (22/6/99).

		Goldie/ Sown Grass	Goldie/ Volunteer Grass	Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass
CTS	Low biomass	25.7	35.8	3.9	12.0	2.6	3.3
GRZ	High biomass	16.0	25.2	5.0	15.6	8.8	7.8
SUMM	Low biomass	15.9	26.4	9.9	10.1	1.5	1.3
REST	High biomass	12.5	28.7	6.6	20.7	10.4	14.0
AUT	Low biomass	19.6	17.8	5.	11.5	1.7	8.7
REST	High biomass	4.4	14.8	11.2	25.0	7.5	6.0
ROT	High biomass	10.2	15.1	7.1	24.2	2.6	5.0
l.s.d (P = 0.5) within column		16.04					
l.s.d. (P = 0.5) across columns		13.44					

Appendix 18. Botanal results for the core experiment at Casino.

Table 73. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Casino core site - Botanal 1 (2/9/97) - botanical composition prior to beginning of grazing treatments.

		Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass	Goldie/ Sown Grass	Goldie/ Volunteer Grass
CTS	Low biomass	58.4	70.7	44.5	53.9	15.7	23.3
GRZ	High biomass	59.1	69.2	33.6	35.9	21.3	8.5
SUMM	Low biomass	50.9	58.0	25.0	41.6	23.6	31.8
REST	High biomass	61.9	81.0	43.0	5.4	5.1	27.0
AUT	Low biomass	53.3	71.7	33.9	40.6	21.2	10.6
REST	High biomass	46.9	53.6	36.7	54.2	7.1	21.8
ROT	High biomass	44.2	65.9	44.9	40.5	13.2	19.6
l.s.d (P = 0.5) within column		24.19					
l.s.d. (P = 0.5) across columns		23.12					

Table 74. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Casino core site - Botanal 2 (18/11/97).

		Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass	Goldie/ Sown Grass	Goldie/ Volunteer Grass
CTS	Low biomass	57.0	64.6	32.1	31.7	17.0	22.8
GRZ	High biomass	48.6	43.9	25.8	22.0	16.5	9.8
SUMM	Low biomass	45.3	41.5	17.9	27.2	23.0	28.4
REST	High biomass	55.7	62.5	19.9	33.2	10.1	20.0
AUT	Low biomass	46.2	47.4	15.5	27.5	13.0	16.8
REST	High biomass	38.4	18.6	32.3	34.2	7.9	27.2
ROT	High biomass	38.0	48.4	31.0	31.3	15.4	16.8
l.s.d (P = 0.5) within column		20.29					
l.s.d. (P = 0.5) across columns		19.91					

Table 75. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Casino core site - Botanal 3 (17/2/98).

		Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass	Goldie/ Sown Grass	Goldie/ Volunteer Grass
CTS	Low biomass	3.0	14.3	0.3	0.6	1.8	1.2
GRZ	High biomass	1.2	0.3	0.3	0.3	5.5	5.0
SUMM	Low biomass	1.8	0.9	0	0.6	1.3	3.4
REST	High biomass	8.7	9.7	0.6	1.9	2.2	1.3
AUT	Low biomass	1.8	1.9	0.3	1.0	0	0
REST	High biomass	4.3	1.5	0	2.7	1.9	2.5
ROT	High biomass	2.6	6.4	0.9	0.6	0.3	1.6
l.s.d (P = 0.5) within column		7.24					
l.s.d. (P = 0.5) across columns		7.04					

Table 76. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Casino core site - Botanal 4 (22/5/98).

		Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass	Goldie/ Sown Grass	Goldie/ Volunteer Grass
CTS	Low biomass	2.2	9.4	1.6	3.0	0	0
GRZ	High biomass	3.2	3.2	0.6	0.3	1.8	2.2
SUMM	Low biomass	0.9	2.5	2.5	1.6	0.6	1.3
REST	High biomass	2.2	17.7	0.6	2.2	1.6	2.0
AUT	Low biomass	2.2	6.0	0.9	2.7	1.3	0
REST	High biomass	1.8	4.1	0.3	2.9	2.2	2.5
ROT	High biomass	0.3	1.3	0	0.3	0	0
l.s.d (P = 0.5) within column		7.28					
l.s.d. (P = 0.5) across columns		7.18					

Table 77. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Casino core site - Botanal 5 (12/8/98).

		Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass	Goldie/ Sown Grass	Goldie/ Volunteer Grass
CTS	Low biomass	9.9	15.7	5.5	4.4	1.2	0.3
GRZ	High biomass	7.4	10.8	5.6	4.2	7.4	7.8
SUMM	Low biomass	7.1	6.3	6.2	6.3	0.6	2.3
REST	High biomass	7.9	18.4	1.5	9.4	2.6	4.2
AUT	Low biomass	7.8	8.9	3.3	5.8	1.3	1.0
REST	High biomass	3.4	4.6	0.7	8.0	4.3	4.6
ROT	High biomass	1.2	3.3	0.3	0.9	1	0.3
l.s.d (P = 0.5) within column		10.77					
l.s.d. (P = 0.5) across columns		10.73					

Table 78. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Casino core site - Botanal 6 (29/10/98).

		Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass	Goldie/ Sown Grass	Goldie/ Volunteer Grass
CTS	Low biomass	5.5	9.0	4.6	3.4	1.7	1.6
GRZ	High biomass	8.0	10.8	3.3	3.0	24.1	18.4
SUMM	Low biomass	8.1	6.5	4.0	2.3	3.2	2.2
REST	High biomass	7.7	19.1	7.3	12.6	16.9	10.1
AUT	Low biomass	9.6	6.5	1.5	3.0	5.6	0.7
REST	High biomass	6.3	8.3	3.9	3.4	7.0	11.8
ROT	High biomass	4.3	7.9	0.6	0.6	0.9	2.2
l.s.d (P = 0.5) within column		14.00					
l.s.d. (P = 0.5) across columns		12.75					

Table 79. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Casino core site - Botanal 7 (22/4/99).

		Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass	Goldie/ Sown Grass	Goldie/ Volunteer Grass
CTS	Low biomass	2.5	2.9	1.2	0.9	0.6	0.6
GRZ	High biomass	2.7	2.0	1.7	1.6	4.8	6.5
SUMM	Low biomass	2.5	2.3	1.5	0.6	2.0	2.9
REST	High biomass	2.6	5.3	1.2	2.5	2.0	3.6
AUT	Low biomass	2.0	1.5	0.6	1.8	0.6	0.6
REST	High biomass	1.9	5.4	0.3	.9	3.7	3.0
ROT	High biomass	0.6	2.6	0	0.3	2.4	0.6
l.s.d (P = 0.5) within column		4.20					
l.s.d. (P = 0.5) across columns		3.77					

Table 80. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Casino core site – Botanal 8 (5/8/99).

		Maku/ Sown Grass	Maku/ Volunteer Grass	Sharnae/ Sown Grass	Sharnae/ Volunteer Grass	Goldie/ Sown Grass	Goldie/ Volunteer Grass
CTS	Low biomass	12.6	8.2	7.4	10.8	1.0	1.0
GRZ	High biomass	19.1	16.0	8.2	12.2	5.4	3.0
SUMM	Low biomass	17.4	16.4	10.1	10.0	3.9	3.4
REST	High biomass	15.6	26.8	12.1	11.2	2.6	2.3
AUT	Low biomass	18.6	9.8	8.9	15.3	1.6	1.0
REST	High biomass	2.9	17.9	4.3	6.3	4.0	3.8
ROT	High biomass	2.9	12.5	0.6	6.6	1.0	1.2
l.s.d (P = 0.5) within column		12.21					
l.s.d. (P = 0.5) across columns		11.30					

Appendix 19. Botanal results for the core experiment at Canberra.

Table 81. Sward content of lotus (%) at the Canberra core site prior to commencement of grazing treatments; Botanal 1 (12/3/96).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	60.1	69.7	49.4	19.4	77.5	73.9	77.6	70.6
GRZ	High biomass	62.7	45.1	28.5	31.2	80.1	71.2	69.6	63.9
SUMM	Low biomass	57.4	50.2	30.4	31.2	73.6	72.3	64.0	67.2
REST	High biomass	44.6	40.1	40.8	16.7	73.1	51.2	57.7	47.6
AUT	Low biomass	56.3	54.3	41.2	46.9	75.8	67.3	65.0	71.7
REST	High biomass	55.8	50.9	58.0	28.1	74.9	69.3	73.2	65.8
ROT	High biomass	59.3	33.1	30.3	14.5	74.1	70.1	78.2	57.5
l.s.d (P = 0.5) within column		25.87							
l.s.d. (P = 0.5) across columns		20.39							

Table 82. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 2 (25/6/96).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	34.9	37.1	46.7	34.0	45.5	49.3	55.1	27.4
GRZ	High biomass	51.7	28.2	38.0	29.0	59.0	39.5	45.0	18.3
SUMM	Low biomass	39.0	28.4	24.3	22.1	46.2	46.9	26.3	16.6
REST	High biomass	37.0	19.6	26.1	21.8	56.2	23.8	43.2	21.0
AUT	Low biomass	34.5	22.4	2.8	21.7	57.8	46.9	43.2	47.0
REST	High biomass	37.4	25.7	40.0	22.2	52.5	33.2	54.1	25.7
ROT	High biomass	26.7	20.5	28.8	10.2	42.5	25.0	62.5	23.4
l.s.d (P = 0.5) within column		23.35							
l.s.d. (P = 0.5) across columns		22.70							

Table 83. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 3 (17/9/96).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	20.2	40.9	17.9	18.3	42.3	43.7	50.2	48.2
GRZ	High biomass	44.9	46.6	36.9	25.7	55.6	43.5	54.5	40.4
SUMM	Low biomass	23.2	38.9	22.8	30.3	50.5	59.3	36.2	40.2
REST	High biomass	25.1	24.8	25.0	24.1	55.5	31.4	36.9	39.1
AUT	Low biomass	32.6	42.0	23.1	37.9	42.9	52.6	40.2	55.1
REST	High biomass	44.8	37.1	28.3	30.5	44.1	39.3	51.6	47.7
ROT	High biomass	26.0	15.1	23.7	10.0	24.6	43.8	44.3	34.8
l.s.d (P = 0.5) within column		24.63							
l.s.d. (P = 0.5) across columns		20.21							

Table 84. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 4 (10/12/96).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	26.3	31.7	30.6	25.9	40.3	41.5	40.4	43.5
GRZ	High biomass	29.9	38.5	37.1	26.6	39.9	47.2	31.5	36.4
SUMM	Low biomass	10.5	30.1	18.8	27.8	38.2	35.8	30.9	29.6
REST	High biomass	13.8	14.0	11.8	22.3	55.8	28.6	35.3	26.8
AUT	Low biomass	32.9	28.3	33.9	32.9	33.8	42.7	45.4	53.3
REST	High biomass	30.8	25.3	23.3	29.3	48.9	39.1	43.8	35.4
ROT	High biomass	8.0	4.9	15.2	4.4	44.8	43.3	27.5	27.5
l.s.d (P = 0.5) within column		20.20							
l.s.d. (P = 0.5) across columns		15.93							

Table 85. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 5 (4/3/97).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	23.7	23.6	21.7	19.1	32.7	43.9	37.3	37.3
GRZ	High biomass	29.5	34.5	28.7	23.7	51.7	39.6	42.3	39.5
SUMM	Low biomass	20.0	22.0	8.4	16.8	49.3	43.3	33.1	35.6
REST	High biomass	20.6	12.7	11.7	13.5	54.9	28.9	42.7	29.6
AUT	Low biomass	21.3	33.8	12.2	18.0	41.8	33.7	34.0	51.5
REST	High biomass	30.2	27.7	18.4	22.8	42.8	33.1	50.4	41.4
ROT	High biomass	16.9	6.4	10.5	4.3	49.0	30.8	51.1	28.1
l.s.d (P = 0.5) within column		22.67							
l.s.d. (P = 0.5) across columns		16.50							

Table 86. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 6 (8/7/97).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	15.6	7.2	7.0	2.6	8.7	6.2	9.5	6.5
GRZ	High biomass	16.4	14.0	9.7	6.2	20.5	13.7	12.1	9.2
SUMM	Low biomass	9.7	7.0	3.6	3.4	9.8	11.7	7.6	10.7
REST	High biomass	7.8	3.6	2.0	1.3	5.3	3.1	8.4	6.7
AUT	Low biomass	6.1	8.6	10.6	5.9	10.0	9.5	7.9	15.5
REST	High biomass	17.0	7.5	4.2	3.0	17.3	8.3	8.7	9.9
ROT	High biomass	7.6	0.9	1.0	0.1	17.0	8.6	13.7	5.7
l.s.d (P = 0.5) within column		12.43							
l.s.d. (P = 0.5) across columns		9.46							

Table 87. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 7 (11/11/97).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	19.5	15.0	12.7	8.0	15.7	11.5	22.6	13.9
GRZ	High biomass	16.7	24.4	17.1	10.6	17.5	17.3	20.8	18.7
SUMM	Low biomass	9.0	13.7	6.3	5.2	13.8	21.0	12.5	14.2
REST	High biomass	15.1	7.0	5.8	4.7	14.2	6.0	11.0	9.7
AUT	Low biomass	15.2	20.1	18.2	11.7	27.0	18.1	21.3	15.8
REST	High biomass	14.2	12.7	8.8	10.5	31.8	13.0	14.5	16.7
ROT	High biomass	6.7	5.2	6.6	2.7	15.0	11.0	12.3	11.5
l.s.d (P = 0.5) within column		15.40							
l.s.d. (P = 0.5) across columns		12.52							

Table 88. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 8 (18/12/97).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	18.7	4.4	2.5	2.9	18.0	6.9	20.4	8.1
GRZ	High biomass	15.3	8.5	8.5	5.1	20.4	15.3	20.5	11.3
SUMM	Low biomass	5.2	2.5	1.8	2.4	8.7	5.0	9.9	8.3
REST	High biomass	13.9	6.0	5.8	3.7	22.7	4.2	15.7	5.6
AUT	Low biomass	8.9	8.3	6.1	2.2	27.2	10.4	11.1	18.5
REST	High biomass	11.0	5.5	9.2	4.8	32.3	8.4	19.3	11.8
ROT	High biomass	6.0	2.3	0.3	0.9	19.3	7.8	17.0	6.7
l.s.d (P = 0.5) within column		15.47							
l.s.d. (P = 0.5) across columns		12.95							

Table 89. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 9 (17/3/98).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	7.8	2.8	2.0	1.2	16.6	6.6	8.1	5.5
GRZ	High biomass	11.9	2.8	4.2	5.1	15.2	21.9	19.7	15.4
SUMM	Low biomass	2.2	2.8	0	3.0	14.1	4.3	11.3	3.6
REST	High biomass	8.4	0.9	2.1	0	17.0	1.5	5.7	2.9
AUT	Low biomass	0.7	5.6	1.3	1.4	18.2	5.1	8.8	11.0
REST	High biomass	10.1	3.9	3.8	1.7	19.5	5.0	15.0	13.5
ROT	High biomass	9.0	1.5	0	1.4	19.6	8.2	9.7	14.0
l.s.d (P = 0.5) within column		15.15							
l.s.d. (P = 0.5) across columns		11.79							

Table 90. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 10 (10/8/98).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	3.0	1.6	0.3	0.5	3.4	0.3	3.1	1.0
GRZ	High biomass	3.4	2.0	1.4	0.8	2.5	3.1	2.0	2.0
SUMM	Low biomass	1.1	0.2	0	0.9	1.5	0.2	0.3	0.5
REST	High biomass	1.4	0.6	0	0.9	0.6	0.3	1.1	0.1
AUT	Low biomass	0.8	3.0	0	0.3	7.3	0.7	0.5	1.8
REST	High biomass	2.0	1.1	0	1.0	1.4	1.4	0.5	0.8
ROT	High biomass	0.6	0.2	0.1	0.4	1.2	1.2	0.1	3.7
l.s.d (P = 0.5) within column		3.54							
l.s.d. (P = 0.5) across columns		2.70							

Table 91. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 11 (14/10/98).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	2.9	0.6	0	0.3	5.5	1.2	6.0	1.9
GRZ	High biomass	6.1	7.1	4.2	1.5	4.3	7.3	4.0	3.2
SUMM	Low biomass	3.7	0.7	0	0.3	4.5	1.2	1.4	1.9
REST	High biomass	1.7	1.7	0.7	1.2	3.2	0	1.0	1.6
AUT	Low biomass	0	2.6	0	0	4.9	0.6	3.5	2.5
REST	High biomass	7.7	1.7	0	0.6	5.4	2.9	4.0	3.8
ROT	High biomass	2.9	2.0	0	1.8	1.3	4.3	0.3	1.3
l.s.d (P = 0.5) within column		5.73							
l.s.d. (P = 0.5) across columns		4.73							

Table 92. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 12 (6/1/99).

		Maku/ danthonia	Maku/ Phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	4.3	4.0	0.7	0.6	3.9	1.3	3.6	2.3
GRZ	High biomass	7.1	4.6	0.9	0.9	8.5	12.7	4.8	8.2
SUMM	Low biomass	2.0	2.5	0.7	0	1.3	1.9	2.4	3.3
REST	High biomass	1.6	0.6	0	1.2	5.0	1.8	3.3	1.6
AUT	Low biomass	0	4.7	0.7	0.3	9.2	0.7	1.6	2.6
REST	High biomass	7.3	2.7	0	0.3	10.0	3.2	3.8	6.3
ROT	High biomass	4.8	1.2	0	0.9	6.4	8.1	2.5	1.8
l.s.d (P = 0.5) within column		7.09							
l.s.d. (P = 0.5) across columns		5.43							

Table 93. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 13 (23/3/99).

		Maku/ danthonia	Maku/ phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	2.0	0	1.0	0	11.2	1.5	4.6	7.0
GRZ	High biomass	3.8	4.0	1.7	0	4.1	10.9	2.3	2.5
SUMM	Low biomass	3.0	2.6	0	0.7	2.6	2.0	1.0	1.9
REST	High biomass	0	3.3	0	0	1.9	0.6	0.6	0.3
AUT	Low biomass	0	2.6	0	0.3	3.6	0.6	2.5	3.2
REST	High biomass	7.7	1.0	0	0	3.3	1.0	0.3	2.9
ROT	High biomass	1.9	0.3	0	0	2.9	4.3	0.6	1.9
l.s.d (P = 0.5) within column		7.30							
l.s.d. (P = 0.5) across columns		6.04							

Table 94. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Canberra core site - Botanal 14 (30/6/99).

		Maku/ danthonia	Maku/ Phalaris	Sharnae/ danthonia	Sharnae/ phalaris	Goldie/ danthonia	Goldie/ phalaris	Spanish/ danthonia	Spanish/ phalaris
CTS	Low biomass	3.7	0.3	1.3	0.3	0.7	0	1.0	0
GRZ	High biomass	6.8	3.9	1.4	0	3.0	5.0	2.2	0.3
SUMM	Low biomass	0	3.5	0.7	0	0	0.3	0	0
REST	High biomass	0.3	0	0	0.3	1.0	0	0.6	0
AUT	Low biomass	0	3.7	0	0.3	2.3	1.0	0.9	1.3
REST	High biomass	9.9	2.2	0	1.2	2.0	1.8	4.3	1.8
ROT	High biomass	2.0	1.0	1.7	1.0	1.9	3.3	0.3	0.7
l.s.d (P = 0.5) within column		4.88							
l.s.d. (P = 0.5) across columns		4.50							

Appendix 20. Botanal results for the core experiment at Nowra.

Table 95. Sward content of lotus (%) prior to commencement of grazing treatments; Nowra core site - Botanal 1 (24/3/96).

		Maku/ kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	38.8	33.5	14.1	17.1	55.4	29.3
GRZ	High biomass	31.5	18.4	20.6	15.6	41.0	32.2
SUMM	Low biomass	36.4	24.5	23.6	20.1	48.6	19.0
REST	High biomass	42.8	41.5	19.2	25.8	40.1	48.0
AUT	Low biomass	40.2	45.5	13.5	19.6	45.6	35.3
REST	High biomass	37.9	37.6	30.5	9.9	30.2	21.4
ROT	High biomass	36.2	47.5	18.7	14.4	29.8	22.2
l.s.d (P = 0.5) within column		26.86					
l.s.d. (P = 0.5) across columns		20.23					

Table 96. The effect of grazing treatments on the sward content of lotus (%) at two levels of grass competition; Nowra core site - Botanal 2 (15/7/96).

		Maku/ kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	9.1	18.2	12.4	15.5	12.5	8.1
GRZ	High biomass	14.0	16.5	17.1	23.8	10.0	12.7
SUMM	Low biomass	12.8	22.8	16.9	19.3	10.0	7.3
REST	High biomass	17.9	27.5	20.8	28.8	11.5	14.4
AUT	Low biomass	12.1	19.6	11.9	25.1	12.5	13.2
REST	High biomass	11.7	17.2	31.2	15.3	6.7	8.9
ROT	High biomass	13.6	15.8	24.1	16.5	8.8	11.0
l.s.d (P = 0.5) within column		14.01					
l.s.d. (P = 0.5) across columns		12.32					

Table 97. The effect of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 3 (30/9/96).

		Maku/ kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	8.8	14.1	9.0	7.0	19.0	19.0
GRZ	High biomass	21.4	12.6	10.4	12.5	21.8	23.4
SUMM	Low biomass	8.6	10.3	7.4	13.0	18.2	19.4
REST	High biomass	18.9	11.2	13.3	15.7	29.2	21.6
AUT	Low biomass	11.7	12.9	6.4	9.0	22.5	31.7
REST	High biomass	10.9	19.6	19.3	9.8	17.0	20.9
ROT	High biomass	16.3	21.9	24.6	11.5	15.2	16.7
l.s.d (P = 0.5) within column		11.75					
l.s.d. (P = 0.5) across columns		10.31					

Table 98. The effect of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra Core site - Botanal 4 (19/12/96).

		Maku/ kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	7.4	8.36	0.4	1.7	19.7	19.6
GRZ	High biomass	20.2	16.5	3.0	3.3	22.0	23.5
SUMM	Low biomass	7.2	3.6	1.5	4.6	19.1	28.2
REST	High biomass	20.7	12.2	4.9	7.3	32.8	30.2
AUT	Low biomass	5.8	7.2	2.0	1.5	28.8	34.8
REST	High biomass	5.2	12.4	4.3	4.3	17.0	18.6
ROT	High biomass	15.8	11.3	4.2	8.6	13.4	29.1
l.s.d (P = 0.5) within column		14.05					
l.s.d. (P = 0.5) across columns		11.41					

Table 99. The effect of grazing treatments on sward content of lotus at two levels of grass competition; Nowra core site - Botanal 5 (17/3/97).

		Maku/ kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	3.1	4.3	1.3	0.8	13.3	18.9
GRZ	High biomass	4.8	4.4	2.0	0.8	8.7	10.6
SUMM	Low biomass	3.3	1.7	1.0	1.2	14.2	17.1
REST	High biomass	9.0	6.2	1.2	1.8	16.5	16.0
AUT	Low biomass	2.7	3.2	2.1	0.5	9.2	15.5
REST	High biomass	3.0	8.7	3.1	0.5	5.8	8.1
ROT	High biomass	4.3	5.1	1.0	1.2	8.7	25.3
l.s.d (P = 0.5) within column		8.51					
l.s.d. (P = 0.5) across columns		6.25					

Table 100. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 6 (11/6/97).

		Maku/ Kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	1.4	9.1	1.3	1.7	6.8	13.2
GRZ	High biomass	6.4	11.0	1.2	0.8	4.6	11.2
SUMM	Low biomass	3.0	0.4	1.3	1.4	2.8	8.4
REST	High biomass	9.3	10.3	5.2	5.0	7.1	15.2
AUT	Low biomass	2.8	5.7	1.2	2.7	6.3	11.5
REST	High biomass	3.4	5.9	2.4	0.9	3.2	6.4
ROT	High biomass	4.1	14.7	2.9	5.4	6.7	22.0
l.s.d (P = 0.5) within column		10.14					
l.s.d. (P = 0.5) across columns		7.62					

Table 101. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 7 (15/10/97).

		Maku/ Kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	3.9	14.5	3.8	2.4	8.9	13.4
GRZ	High biomass	14.4	13.1	2.1	4.9	4.3	13.8
SUMM	Low biomass	2.8	1.7	1.1	2.1	6.0	8.8
REST	High biomass	20.5	8.3	8.5	8.1	10.6	10.9
AUT	Low biomass	9.3	2.9	1.3	1.4	11.7	21.9
REST	High biomass	12.6	22.3	6.9	5.3	4.9	11.3
ROT	High biomass	10.1	17.1	4.3	7.4	6.5	19.3
l.s.d (P = 0.5) within column		12.75					
l.s.d. (P = 0.5) across columns		9.75					

Table 102. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 8 (7/1/98).

		Maku/ Kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	3.5	7.3	1.3	0.8	11.2	19.8
GRZ	High biomass	6.4	4.6	1.1	1.6	7.0	15.7
SUMM	Low biomass	5.1	1.7	0.7	0.7	7.9	6.3
REST	High biomass	4.0	3.6	3.1	4.0	12.9	21.8
AUT	Low biomass	3.2	4.6	1.9	0.9	9.7	20.4
REST	High biomass	7.1	12.4	3.8	1.7	6.9	8.8
ROT	High biomass	7.4	15.9	2.0	1.3	7.8	23.3
l.s.d (P = 0.5) within column		10.23					
l.s.d. (P = 0.5) across columns		9.20					

Table 103. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 9 (1/4/98).

		Maku/ Kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	1.2	4.3	1.0	1.0	6.6	10.5
GRZ	High biomass	3.4	4.6	0	0.3	4.8	5.2
SUMM	Low biomass	2.2	1.2	0.9	0.1	3.6	5.7
REST	High biomass	2.6	0.9	0.3	1.2	3.8	12.3
AUT	Low biomass	1.0	0.3	0	1.4	4.2	18.1
REST	High biomass	1.9	11.8	1.4	0.1	3.8	3.8
ROT	High biomass	2.2	3.3	1.7	0.9	4.4	2.5
l.s.d (P = 0.5) within column		6.89					
l.s.d. (P = 0.5) across columns		6.64					

Table 104. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 10 (24/6/98).

		Maku/ Kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	2.1	1.4	2.0	0.5	1.7	3.5
GRZ	High biomass	5.3	1.2	0.1	1.5	1.8	2.7
SUMM	Low biomass	1.9	0.4	1.8	0.2	3.7	1.9
REST	High biomass	4.8	0.8	0.8	0.6	1.7	3.5
AUT	Low biomass	2.4	0.1	0.8	1.4	2.4	4.6
REST	High biomass	2.0	1.6	2.6	0.2	4.1	1.6
ROT	High biomass	3.6	3.7	3.6	0.8	2.6	1.4
l.s.d (P = 0.5) within column		3.26					
l.s.d. (P = 0.5) across columns		3.18					

Table 105. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 11(8/9/98).

		Maku/ Kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	2.0	0.3	3.7	1.0	4.1	1.2
GRZ	High biomass	12.9	4.3	1.3	1.0	4.1	1.4
SUMM	Low biomass	4.4	0.3	1.0	0.3	3.8	0.6
REST	High biomass	7.0	2.6	1.6	1.7	3.6	1.5
AUT	Low biomass	6.2	1.0	0.7	5.0	2.6	8.7
REST	High biomass	4.7	3.2	3.2	0	4.8	6.8
ROT	High biomass	6.4	3.2	4.3	0.3	3.9	0.7
l.s.d (P = 0.5) within column		4.68					
l.s.d. (P = 0.5) across columns		4.89					

Table 106. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 12 (21/12/98).

		Maku/ Kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	4.1	2.0	5.1	1.0	6.8	5.1
GRZ	High biomass	11.9	1.6	4.1	3.2	10.2	3.9
SUMM	Low biomass	9.3	0.6	3.4	0.3	4.3	4.1
REST	High biomass	11.8	1.3	4.1	1.9	7.2	2.0
AUT	Low biomass	6.5	1.7	2.4	0.9	7.2	11.3
REST	High biomass	9.3	4.0	4.0	0.3	8.9	4.6
ROT	High biomass	8.6	8.2	6.0	1.3	6.4	2.2
l.s.d (P = 0.5) within column		6.51					
l.s.d. (P = 0.5) across columns		6.46					

Table 107. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 13 (22/3/99).

		Maku/ kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	2.3	0.3	1.0	0.3	4.1	5.3
GRZ	High biomass	12.2	1.0	0	1.0	4.0	5.4
SUMM	Low biomass	10.5	0	3.6	1.0	6.1	1.6
REST	High biomass	7.4	0	2.5	0	7.7	3.0
AUT	Low biomass	3.7	1.3	1.0	0	4.0	3.7
REST	High biomass	10.8	2.2	5.7	0	8.1	3.9
ROT	High biomass	8.4	1.2	1.3	0	5.6	2.3
l.s.d (P = 0.5) within column		5.30					
l.s.d. (P = 0.5) across columns		5.12					

Table 108. The effects of grazing treatments on the sward content of lotus at two levels of grass competition; Nowra core site - Botanal 14 (29/6/99).

		Maku/ Kikuyu	Maku/ ryegrass	Sharnae/ kikuyu	Sharnae/ ryegrass	Goldie/ kikuyu	Goldie/ ryegrass
CTS	Low biomass	1.9	1.2	2.0	1.4	0	0.3
GRZ	High biomass	10.2	2.7	1.9	6.7	1.7	0.3
SUMM	Low biomass	8.2	0	21.3	0.3	1.0	1.3
REST	High biomass	9.3	0.3	2.2	0.6	4.2	1.0
AUT	Low biomass	7.2	5.4	4.8	2.6	2.3	2.7
REST	High biomass	10.5	2.9	3.4	0	1.0	2.0
ROT	High biomass	5.4	4.3	2.6	2.3	1.0	2.9
l.s.d (P = 0.5) within column		9.27					
l.s.d. (P = 0.5) across columns		9.21					

APPENDIX 21. METHODS OF SAMPLING AND MEASURING RHIZOME DENSITY AND SEEDBANK DEVELOPMENT

1. Soil core sampling in the field

Using a 50mm*80mm soil sampler, twenty cores were collected at random from all lax grazing and rotational grazing treatment cells. (While sampling was regarded as random, the transect used for Botanal sampling within each plot was avoided, to maintain the integrity of the pasture profile).

Each plot sample was collected in a labelled plastic bag.

Soil sampling for rhizome density and seedbank was carried out at Canberra in August 1997, July 1998 and June 1999; at Nowra in June 1997, June 1998 and June 1999; at Glen Innes in July 1997, June 1998 and July 1999; at Casino in August 1997, August 1998 and August 1999.

2. Sample storage

Once samples were collected from the field they were transferred to a cool room as soon as possible and stored at a temperature of six degrees Centigrade for a short time prior to processing,

3. Rhizome and soil processing

Sample preparation

Twenty four hours prior to washing, the bags containing the samples were filled with water and allowed to soak. While Jones and Bunch (1988) recommend soaking samples in Calgon (water softener) solution (2g per litre of water) for two hours for gleyed soils and four hours for heavy black earths, soaking for an extended period (without a water softener) greatly improved the separation of vegetative material from the soil and sped up the washing process. The Casino samples being a heavy clay required forty eight hours of soaking. All soaking samples were kept in a dark environment to reduce the risk of seed germination.

Washing samples with water

Each sample was placed into the first (or top sieve) in a series of three 42 cm diameter interlocking sieves. The three interlocking sieves comprised screen sizes of 5mm for the top sieve, 1.0mm for the middle sieve and 0.3mm for the bottom sieve.

Using an adjustable trigger type hose nozzle, each soil core was thoroughly washed at normal town water pressure, effectively separating vegetative material from the soil in the top sieve. At this point any rhizomes in the soil core were clearly identified, collected and placed in a labelled container for further processing. The contents of the top (5mm) sieve being only vegetative material or stones was then discarded.

The resultant fine vegetative material and soil collected in the middle (1.0mm) sieve was rubbed by hand and washed through. This effectively broke up small clods (particularly found in silty and clayey soils). Once completely washed through the contents of this sieve were then placed in a labelled container. The contents of the bottom (0.3mm) sieve was also rubbed by hand and washed through, effectively separating fine clay material from the sample The contents of the bottom sieve were then placed in the abovementioned container.

Several trials were carried out by adding known quantities of lotus seed to soil cores from a site that did not contain lotus. This ensured that the washing process used did not incur seed loss.

The reduced sample was drained of water then placed overnight in a dehydrator set at 40 degrees Centigrade. The rhizomes collected were assessed as primary or secondary, the length of each rhizome was measured and recorded then all rhizomes were also placed in a dehydrator at 40 degrees Centigrade overnight. The total rhizome dry weight for each sample was recorded.

The dehydrated samples were then stored at normal air temperature awaiting the next stage of processing

Separating vegetative material from the soil

Several methods of blowing the dried vegetative material from the sample were experimented with through the duration of the project, but it is the final method used that appears to be the most successful in terms of the quality of separation and the time taken to complete the job.

Materials used for the blowing process

- A small electric air compressor with a flexible hose typically used for spray painting;
- A cardboard shoebox with a hole made at the side for the entry of the compressors' flexible hose and a 10 cm square hole at the top for the air outlet. Only three sides of the top square were cut to allow the cut out square to fold down and act as a baffle.

The idea of the box was to sufficiently reduce the air pressure so as to negate the opportunity for seed in the sample to blow out with the vegetative material. Several trials were carried out to ensure that no seed was removed in this process.

The blowing process

The dried sample was placed in a small (20cm)diameter sieve with a screen size of 0.5mm. The sample was then ground by hand to break up the sample. By gently shaking the sieve over the air outlet most of the dried vegetative material was removed from the sample

4. Isolating the seed

Materials used for the chemical isolation of seed

The chemical solvent used was Perchlorethylene (a chemical traditionally used for dry cleaning). Loch and Butler (1977) described the successful use of Perchlorethylene for the separation of inorganic material from soil. Perchlorethylene is a dangerous chemical and as such, its use requires the wearing of protective clothing and respirator.

Reduction of sample by chemical process

In a well ventilated room with exhaust fans, a large beaker was three quarters filled with Perchlorethylene . The sample was sprinkled into the liquid and stirred, allowing time for the organic material to rise to the top and the heavier soil particles to sink to the bottom. This process was done twice to allow any seed that may be trapped in the settling soil at the bottom of the beaker to move to the top.

The vegetative material at the top of the liquid was removed by carefully pouring the contents through a 0.5mm hand strainer and placed back in the labelled container. The remaining soil at the bottom of the beaker was then discarded and the Perchlorethylene recycled for continuous use.

The samples were then placed in a dehydrator at 40 degrees Centigrade overnight to allow to dry and fumes to dissipate prior to final recovery of individual seeds from the sample.

The chemically treated samples were then stored at normal air temperature awaiting the next stage of processing

At the beginning of the sampling process each plot sample weighed approximately between two and three kilos. Following the described processing the remaining sample weighed approximately nine to twelve grams.

5. Seed measurements

Using an illuminated magnifying lamp, the sample was spread out in a linear fashion over a sheet of white paper. Examples of the seed to be identified were stuck to cards and held nearby as ready reference. Carefully viewing all the material across the paper, the target lotus seed was identified and collected with a pair of tweezers and numbers recorded.

6. Data processing

All data was recorded on a Microsoft Excel spreadsheet for analysis.